DOE/OR/02-1185&D2&

Vol. 1

Feasibility Study for the East Fork Poplar Creek —Sewer Line Beltway

CLEARED FOR PUBLIC RELEASE

ChemRisk Document No. 1841

Vol. 1

DOE/OR/02-1185&D2&V1

1331.940819.007

Feasibility Study for the East Fork Poplar Creek - Sewer Line Beltway

Volume 1

August 1994

prepared by
U.S. Department of Energy, Oak Ridge Operations Office

with technical assistance from
Science Applications International Corporation
under Contract No. DE-AC05-90OR21851

93-008P/071994

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

contributed to the preparation of this document and should not be considered an eligible contractor for its review.

CONTENTS

TABLES vii
FIGURES xi
ACRONYMS xiii
EXECUTIVE SUMMARY xvii

VOLUME 1

1. INTRODUCTION 1-1
   1.1 PURPOSE AND ORGANIZATION OF THE REPORT 1-1
   1.2 SCOPING PROCESS SUMMARY 1-2
   1.3 RELATED FEDERAL PROJECTS 1-4
   1.4 CONSULTATION AND COORDINATION 1-5

2. SITE BACKGROUND INFORMATION 2-1
   2.1 SITE DESCRIPTION 2-1
      2.1.1 Soils and Prime Farmlands 2-1
      2.1.2 Water Quality 2-3
      2.1.3 Climate and Air Quality 2-8
      2.1.4 Land Use 2-9
      2.1.5 Ecological Resources 2-12
      2.1.6 Archaeological, Cultural, and Historical Resources 2-36
      2.1.7 Socioeconomic and Institutional Issues 2-37
   2.2 SITE HISTORY 2-51
   2.3 NATURE AND EXTENT OF CONTAMINATION 2-53
      2.3.1 RI Implementation and Results 2-54
      2.3.2 Data Quality Assessment 2-63
   2.4 CONTAMINANT FATE AND TRANSPORT 2-65
      2.4.1 Fate and Transport Profiles 2-65
      2.4.2 Approach to Fate and Transport Modeling 2-70
      2.4.3 Sediment Transport Modeling 2-70
      2.4.4 Floodplain Erosion/Runoff Modeling 2-73
      2.4.5 Contaminated Soil Deposition 2-78
   2.5 BASELINE RISK ASSESSMENT 2-78
      2.5.1 Human Health Risk Assessment 2-79
      2.5.2 Ecological Risk Assessment 2-87
      2.5.3 Human Health and Ecological Remediation Goal Options 2-104

3. IDENTIFICATION AND SCREENING OF REMEDIAL ACTION TECHNOLOGIES 3-1
   3.1 CRITERIA FOR DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES 3-1
   3.2 EVALUATION OF THE SURFACE WATER, SEDIMENT, AIR, AND DIRECT RADIATION PATHWAYS 3-3
      3.2.1 Surface Water and Sediments 3-3
      3.2.2 Air 3-4
      3.2.3 Direct Radiation 3-4

3.3 REMEDIATION PLANNING EVALUATION OF HUMAN HEALTH AND ECOLOGICAL REMEDIATION GOAL OPTIONS 3-5
3.3.1 Remediation Goal Options for Human Health 3-5
3.3.2 Remediation Goal Options for Ecological Receptors 3-9
3.4 SITE-SPECIFIC REMEDIAL ACTION OBJECTIVES 3-13
3.5 GENERAL RESPONSE ACTIONS 3-13
3.5.1 No Action 3-14
3.5.2 Institutional Actions 3-15
3.5.3 Containment Actions 3-15
3.5.4 Excavation Actions 3-16
3.5.5 Treatment Actions 3-16
3.5.6 Disposal and Beneficial Reuse Actions 3-17
3.6 IDENTIFICATION AND SCREENING OF TECHNOLOGIES 3-21
3.6.1 Identification of Applicable Technologies 3-21
3.6.2 Initial Screening Criteria 3-21
3.6.3 Initial Screening of Technologies and Process Options 3-21
3.7 EVALUATION OF RETAINED TECHNOLOGIES AND SELECTION OF REPRESENTATIVE TECHNOLOGIES AND TECHNOLOGY PROCESS OPTIONS 3-22
3.7.1 Evaluation Criteria 3-22
3.7.2 Evaluation of Technology Process Options 3-23
3.8 REPRESENTATIVE TECHNOLOGY PROCESS OPTIONS FOR SOIL 3-23

4. DEVELOPMENT AND SCREENING OF ALTERNATIVES 4-1
4.1 INTRODUCTION 4-1
4.2 DESCRIPTION OF EFPC RUs 4-2
4.2.1 Surface Water/Sediments RU 4-3
4.2.2 SLB RU (Soil) 4-3
4.2.3 Commercial/DOE RU (Soil) 4-3
4.2.4 Other RU (Soil) 4-4
4.2.5 Residential RU (Soil) 4-5
4.2.6 Agricultural RU (Soil) 4-5
4.3 DEVELOPMENT OF RU ALTERNATIVES 4-5
4.4 SCREENING OF RU ALTERNATIVES 4-6
4.5 SUMMARY OF RU ALTERNATIVES 4-6
4.5.1 Surface Water/Sediments RU Interim Actions 4-6
4.5.2 Commercial/DOE RU (Soil) Alternatives 4-7
4.5.3 Other RU (Soil) Alternatives 4-7
4.5.4 Residential RU (Soil) Alternatives 4-7
4.6 DEVELOPMENT OF SITEWIDE ALTERNATIVES 4-7
4.6.1 Development Criteria for Sitewide Alternatives 4-7
4.6.2 Sitewide Alternative 1 (SWA 1): No Action 4-9
4.6.3 Sitewide Alternative 2 (SWA 2): Interim Institutional Actions for Surface Water/Sediments RU; Containment and Institutional Actions for Commercial/DOE and Other RU Soil; Excavation and Disposal of Residential RU Soil 4-10
4.6.4 Sitewide Alternative 3 (SWA 3): Interim Institutional Actions for Surface Water/Sediments RU; Excavation and Disposal of Commercial/DOE, Other, and Residential RU Soil 4-10

4.6.5 Sitewide Alternative 4 (SWA 4): Interim Institutional Actions for Surface Water/Sediments RU; Containment and Institutional Actions for Commercial/DOE and Other RU Soil; Excavation, Treatment, and Beneficial Reuse of Residential RU Soil 4-10
4.6.6 Sitewide Alternative 5 (SWA 5): Interim Institutional Actions for Surface Water/Sediments RU; Excavation, Treatment, and Beneficial Reuse of Commercial/DOE, Other, and Residential RU Soil 4-11
4.6.7 Sitewide Alternative 6 (SWA 6): Interim Institutional Actions for Surface Water/Sediments RU; Containment and Institutional Actions for Commercial/DOE and Other RU Soil; Containment and Institutional Actions for DOE-Acquired (Previously Residential) RU Soil 4-11
4.6.8 Sitewide Alternative 7 (SWA 7): Interim Institutional Actions for Surface Water/Sediments RU; Institutional Actions for Commercial/DOE and Other RU Soil; Excavation and Disposal of Residential RU Soil 4-12

5. DETAILED ANALYSIS OF SITEWIDE ALTERNATIVES 5-1
5.1 INTRODUCTION 5-1
5.2 DESCRIPTION OF GENERAL RESPONSE ACTIONS 5-3
5.2.1 Institutional Actions 5-3
5.2.2 Containment Actions 5-5
5.2.3 Excavation Actions 5-6
5.2.4 Treatment Actions 5-8
5.2.5 Disposal and Beneficial Reuse Actions 5-10
5.3 INDIVIDUAL ANALYSIS OF SITEWIDE ALTERNATIVES 5-13
5.3.1 Description and Summary of Evaluation of Sitewide Alternative 1 (SWA 1) 5-13
5.3.2 Description and Summary of Evaluation of Sitewide Alternative 2 (SWA 2) 5-29
5.3.3 Description and Summary of Evaluation of Sitewide Alternative 3 (SWA 3) 5-59
5.3.4 Description and Summary of Evaluation of Sitewide Alternative 4 (SWA 4) 5-70
5.3.5 Description and Summary of Evaluation of Sitewide Alternative 5 (SWA 5) 5-83
5.3.6 Description and Summary of Evaluation of Sitewide Alternative 6 (SWA 6) 5-91
5.3.7 Description and Summary of Evaluation of Sitewide Alternative 7 (SWA 7) 5-107
5.4 MONITORING AND MITIGATIVE MEASURES 5-120
5.5 POTENTIAL CUMULATIVE IMPACTS 5-122
5.5.1 Land Use, Archaeological/Cultural Resources 5-123
5.5.2 Geology and Soils 5-123
5.5.3 Water Quality 5-123
5.5.4 Air Quality 5-124
5.5.5 Ecological Resources 5-124
5.5.6 Human Health and Safety 5-125

5.6 IMPACTS OF POTENTIAL LOSS OF INSTITUTIONAL CONTROLS . . 5-126

6. COMPARATIVE ANALYSIS OF SITEWIDE ALTERNATIVES 6-1
6.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT 6-1
6.2 COMPLIANCE WITH ARARS 6-2
6.3 LONG-TERM EFFECTIVENESS AND PERMANENCE 6-3
6.4 SHORT-TERM EFFECTIVENESS AND ENVIRONMENTAL IMPACTS . 6-4
6.5 REDUCTION IN TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT 6-4
6.6 IMPLEMENTABILITY 6-4
6.7 COST 6-5
6.8 CONCLUSION 6-5

7. REFERENCES 7-1

8. LIST OF PREPARERS 8-1

9. LIST OF RECIPIENTS 9-1

VOLUME 2

APPENDIXES

A. GLOSSARY A-1

B. COPIES OF CORRESPONDENCE B-1

C. DOCUMENTATION OF ARARs C-1

D. COST D-1

E. METHODOLOGY FOR SOCIOECONOMICS E-1

F. HUMAN HEALTH RISK ASSESSMENT F-1

G. ECOLOGICAL RISK ASSESSMENT G-1

H. LAND USE MAPS H-1

I. COMMUNITY AND PUBLIC INVOLVEMENT PROGRAM FOR EAST FORK POPLAR CREEK I-1

J. FLOODPLAINS AND WETLANDS ASSESSMENT FOR REMEDIATION OF EFPC J-1

K. FLOODPLAIN STATEMENT OF FINDINGS FOR EFPC K-1

TABLES

2.1 Water quality summary for fish sampling sites in EFPC and Hinds Creek (October 8-10, 1991) 2-115
2.2 Fish sampling summary for sites in EFPC and Hinds Creek (October 7-12, 1991) 2-116
2.3 Summary table listing fish family, scientific and common names, relative abundance, tolerance classification, trophic feeding group, and lithophilic spawner information for fish collected from EFPC and Hinds Creek during October 7-12, 1991 2-117
2.4 Taxonomic and functional feeding group classifications, tolerance values, number of individuals, and relative abundance of benthic macroinvertebrates in EFPC and Hinds Creek, October 22-29, 1991 2-120
2.5 Abundance index of small mammals along EFPC based on calculations of catch per effort 2-123
2.6 Total number of birds counted by sample plot method at Sites 2 through 6 at EFPC and Mill Branch, whose sum total for each site was greater than 25 birds 2-124
2.7 Summary of adult aquatic and terrestrial arthropod sampling 2-125
2.8 Summary of dominant canopy species of terrestrial vegetation at EFPC and Mill Branch 2-126
2.9 Potential jurisdictional wetlands in the EFPC floodplain 2-128
2.10 Distribution of population by age cohort for areas around EFPC and SLB, Oak Ridge, Anderson and Roane counties, and the state of Tennessee 2-129
2.11 Population trends in areas surrounding EFPC and SLB 2-130
2.12 Growth in the number of housing units for regions surrounding EFPC 2-131
2.13 Housing characteristics for regions surrounding EFPC 2-132
2.14 Distribution of employment in EFPC region of influence, 1979, 1980, 1985, and 1990 2-133
2.15 Distribution of real average annual earnings in EFPC region of influence, 1979, 1980, 1985, and 1990 2-134
2.16 Number of business establishments by county and sector in the EFPC region of influence, 1980 and 1990 2-135
2.17 Trends in population and per capita income for EFPC region of influence, 1980 and 1990 2-136
2.18 Potentially affected local transportation routes 2-137
2.19 Average daily traffic counts for potentially affected routes 2-138
2.20 City of Oak Ridge performance standard for noise 2-139
2.21 Typical values of yearly day-night average sound levels 2-140
2.22 Chemicals of potential concern 2-141
2.23 EFPC RI—media sampling by location 2-143
2.24 Average mercury concentration in SLB 2-144
2.25 Sediment material in the streambed by size class 2-145
2.26 Chemical properties used in GLEAMS model simulations for COCs 2-146
2.27 Soil characteristics used in GLEAMS model simulations 2-147
2.28 Soil contaminant concentrations (ppm) used in the GLEAMS model 2-147
2.29 Mercury concentrations in soil at the NOAA and Bruner sites during the Vertical Integration Study 2-148

2.30 Weighted-average mercury in soil at the NOAA and Bruner sites used as input in the GLEAMS model 2-149
2.31 GLEAMS model predictions of contaminant loading into EFPC for Segment 1 after a 5-year 24-h rainfall event (short-term loading) 2-150
2.32 GLEAMS model predictions of contaminant loading into EFPC for Segment 1 after 1 year of normal rainfall conditions (long-term loading) 2-150
2.33 GLEAMS model predictions of contaminant loading into EFPC for Segment 2 after a 5-year 24-h rainfall event (short-term loading) 2-151
2.34 GLEAMS model predictions of contaminant loading into EFPC for Segment 2 after 1 year of normal rainfall conditions (long-term loading) 2-151
2.35 GLEAMS model predictions of contaminant loading into EFPC for Segment 3 after a 5-year 24-h rainfall event (short-term loading) 2-152
2.36 GLEAMS model predictions of contaminant loading into EFPC for Segment 3 after 1 year of normal rainfall conditions (long-term loading) 2-152
2.37 GLEAMS model predictions of contaminant loading into EFPC for Segment 4 after a 5-year 24-h rainfall event (short-term loading) 2-153
2.38 GLEAMS model predictions of contaminant loading into EFPC for Segment 4 after 1 year of normal rainfall conditions (long-term loading) 2-153
2.39 GLEAMS model predictions of contaminant loading into EFPC for Segment 5 after a 5-year 24-h rainfall event (short-term loading) 2-154
2.40 GLEAMS model predictions of contaminant loading into EFPC for Segment 5 after 1 year of normal rainfall conditions (long-term loading) 2-154
2.41 GLEAMS model predictions of contaminant loading into EFPC for Segment 6 after a 5-year 24-h rainfall event (short-term loading) 2-155
2.42 GLEAMS model predictions of contaminant loading into EFPC for Segment 6 after 1 year of normal rainfall conditions (long-term loading) 2-155
2.43 GLEAMS model predictions of contaminant loading into EFPC for Segment 7 after a 5-year 24-h rainfall event (short-term loading) 2-156
2.44 GLEAMS model predictions of contaminant loading into EFPC for Segment 7 after 1 year of normal rainfall conditions (long-term loading) 2-156
2.45 GLEAMS model predictions of contaminant loading into EFPC for Segment 8 after a 5-year 24-h rainfall event (short-term loading) 2-157
2.46 GLEAMS model predictions of contaminant loading into EFPC for Segment 8 after 1 year of normal rainfall conditions (long-term loading) 2-157
2.47 GLEAMS model predictions of contaminant loading into EFPC for Segment 9 after a 5-year 24-h rainfall event (short-term loading) 2-158
2.48 GLEAMS model predictions of contaminant loading into EFPC for Segment 9 after 1 year of normal rainfall conditions (long-term loading) 2-158
2.49 GLEAMS model predictions of contaminant loading of mercury into EFPC at the Bruner site after a 5-year 24-h rainfall event (short-term loading) and after 1 year of normal rainfall conditions (long-term loading) 2-159
2.50 GLEAMS model predictions of contaminant loading of mercury into EFPC at the NOAA site after a 5-year 24-h rainfall event (short-term loading) and after 1 year of normal rainfall conditions (long-term loading) 2-159
2.51 Mercury concentrations at EFPCM 3.3 as a result of runoff from a 20-ha disturbed area at the NOAA site and the Bruner site during a 5-year 24-h rainfall 2-160
2.52 Contaminant concentrations at EFPCM 3.3 as a result of runoff from a 20-ha site on disturbed Hamblen soil in each segment during a 5-year 24-h rainfall 2-160

2.53 Risk measures and equations for risk 2-161
2.54 EFPC ecological risk assessment endpoints 2-162
2.55 Measurements made for the EFPC ecological risk assessment 2-164
2.56 Dominant mode of exposure of indicator organisms to contaminated source media in EFPC 2-165
2.57 Summary table of trends for whole-body concentrations of contaminants in aquatic biota collected from EFPC and Hinds Creek, October 7-29, 1991 2-166
2.58 Summary table of trends for whole-body contaminant concentrations in terrestrial biota collected from EFPC and reference site in late 1991 2-168
2.59 Summary table of media toxicity investigations conducted in EFPC 2-171
2.60 Classification of risk quotients for aquatic exposures by range and location . . . 2-172
2.61 Classification of risk quotients for terrestrial exposures by range and location . . 2-173
2.62 Patterns of measurement endpoints for the three ecological risk assessment segments 2-174
2.63 Comparison of ecological risk assessment results with assessment endpoints . . . 2-175
2.64 EFPC OU contaminants of concern for human health 2-176
2.65 EFPC soil remediation goal options (C_{soil}; mg of total mercury/kg soil) and assumptions 2-177
3.1 Remedial action objectives for EFPC OU soils 3-29
3.2 EFPC OU general response actions, remedial technologies, and process options considered prior to screening 3-30
3.3 Interim actions for surface water and sediments at the EFPC OU 3-32
3.4 Initial screening of process options for soils at EFPC OU 3-33
3.5 Evaluation of process options for the EFPC OU - soils response technologies . . 3-48
3.6 Representative remedial technologies and process options for EFPC OU general response actions 3-53
4.1 Summary of EFPC remedial unit areas by segment 4-15
4.2 Estimated surface areas of EFPC floodplain soil contaminated above the mercury remediation goal options 4-16
4.3 Estimated in situ volumes of EFPC soil contaminated above the mercury remediation goal option levels 4-17
4.4 Screening of representative remedial actions by RU 4-18
4.5 EFPC OU sitewide alternatives 4-19
5.1 Integration of NEPA values with CERCLA evaluation criteria 5-129
5.2 Contamination within each RU 5-130
5.3 Primary, secondary, and tertiary sediment exposure pathways 5-131
5.4 Primary, secondary, and tertiary soil exposure pathways 5-132
5.5 Summary of short-term risks associated with containment activities at EFPC (SWA 2) 5-133
5.6 Summary of short-term risks associated with excavation activities at EFPC (SWA 2) 5-134
5.7 Summary of short-term risks associated with disposal activities at the Y-12 Plant disposal facility (SWA 2) 5-135
5.8 Summary of short-term risks associated with cleanup from a hypothetical accident during off-site transport of contaminated soils from the EFPC floodplain 5-136
5.9 Estimated in situ volumes and surface areas of EFPC soils contaminated above the mercury remediation goal option 5-137
5.10 Estimated ex situ volumes of soil covers for containment of mercury-contaminated soil in the EFPC floodplain for SWAs 2 and 4 5-138

5.11 Contribution of soil erosion to sediment load and mercury concentration at Location LB (EFPCM 3.3) based on the GLEAMS model of a 5-year, 24-h storm event under various remedial alternatives 5-139
5.12 List of lithophilic fish species captured at various locations in Lower EFPC . . . 5-140
5.13 Riparian habitat type, current lengths, remediated lengths, and percentage converted for SWAs 2 through 6, summarized by segment and RU 5-141
5.14 Summary of bottomland hardwood forest habitat (acres) subject to conversion 5-143
5.15 EFPC wetlands affected by excavation and containment actions (SWAs 2 and 4) 5-144
5.16 Typical sound levels for equipment used during remedial activities 5-145
5.17 Summary of short-term risks associated with excavation activities at EFPC (SWA 3) 5-146
5.18 Summary of short-term risks associated with disposal activities at the Y-12 Plant facility (SWA 3) 5-147
5.19 EFPC wetlands affected by excavation actions (SWAs 3 and 5) 5-148
5.20 Summary of short-term risks associated with excavation activities at EFPC (SWA 4) 5-149
5.21 Summary of short-term risks associated with containment activities at EFPC (SWA 4) 5-150
5.22 Summary of short-term risks associated with soil treatment at the K-25 Site (SWA 4) 5-151
5.23 Summary of short-term risks associated with excavation activities at EFPC (SWA 5) 5-152
5.24 Summary of short-term risks associated with soil treatment at the K-25 Site (SWA 5) 5-153
5.25 Estimated ex situ volumes of soil covers for containment of mercury-containment soil in the EFPC floodplain for SWA 6 5-154
5.26 Summary of short-term risks associated with containment activities at EFPC (SWA 6) 5-155
5.27 EFPC wetlands affected by SWA 6 5-156
5.28 Summary of short-term risks associated with removal activities at EFPC (SWA 7) 5-157
5.29 Summary of short-term risks associated with disposal activities at the Y-12 Plant disposal facility (SWA 7) 5-158
5.30 Riparian habitat type, current lengths, remediated lengths, and percentage converted for SWA 7, summarized by segment and RU 5-159
5.31 EFPC wetlands affected by excavation and containment actions (SWA 7) 5-160
5.32 Major monitoring and mitigative measures for the action alternatives 5-161
5.33 Actions on the ORR 1993-1998 5-164
6.1 Comparison of sitewide alternatives by evaluation criteria 6-9
6.2 Habitat impacts summary 6-13
6.3 Comparative impacts of sitewide alternatives on ecological measurement endpoints 6-14
6.4 Comparative analysis summary and ranking of alternatives 6-21

FIGURES

2.1 Location map for EFPC and SLB 2-183
2.2 EFPC and its tributaries 2-185
2.3 Regional physiographic map 2-186
2.4 Climatological data for EFPC and vicinity, January 1981 - December 1991 . . . 2-187
2.5 Isohyetal map of the Oak Ridge, Tennessee, area showing a northwest-to-southeast decline in average precipitation. 2-188
2.6 Average wind frequency and direction for the DOE ORR and vicinity 2-189
2.7 Map of EFPC and tributaries showing ecological sampling sites 2-191
2.8 Map of 17 sections for habitat analysis 2-192
2.9 Aquatic habitat areas by stream segment 2-193
2.10 Drawings of four riparian habitat types in Lower EFPC 2-194
2.11 Relative abundance of redbreast sunfish, stonerollers, striped shiners; and the collective remaining fish species captured at each site in EFPC and Hinds Creek 2-195
2.12 Total family richness, EPT richness, and density of benthic macroinvertebrates collected from EFPC and Hinds Creek, October 22-29, 1991 2-196
2.13 Relative abundance of the dominant benthic macroinvertebrate taxa collected in EFPC and Hinds Creek, October 22-29, 1991 2-197
2.14 Terrestrial habitats in the EFPC 100-year floodplain by stream section 2-198
2.15 Mean mercury concentrations (mg/kg) in the surface layer of EFPC floodplain soils 2-199
2.16 Mean total uranium concentrations (pCi/g) in the surface layer of EFPC floodplain soils 2-200
2.17 Mean uranium activity and mercury concentrations in EFPC floodplain soils by horizon 2-201
2.18 Mercury concentrations (mg/kg) in EFPC sediments 2-202
2.19 Total uranium concentrations (pCi/g) in EFPC sediments 2-203
2.20 Cycle of mercury conversions in nature (Jonasson and Boyle 1972) 2-204
2.21 Water-sediment inflow relationship, EFPCM 3.3 2-205
2.22 Water-sediment inflow relationship, EFPCM 6.89 2-206
2.23 Water-sediment inflow relationship, EFPCM 10.0 2-207
2.24 Water-sediment inflow relationship, EFPCM 14.36 2-208
2.25 Elevation/discharge rating curve, EFPCM 1.66 2-209
2.26 The physical system and process represented in the GLEAMS model (after Leonard et al. 1987) 2-210
2.27 Flow chart of CREAMS model operation (adapted from USDA 1984) 2-211
2.28 GLEAMS modeling schematic 2-212
2.29 Erosion loss from areas of disturbed Hamblen soil predicted by the GLEAMS model simulation during 24-h rainfall events 2-213
2.30 Hazard index for noncarcinogens for adults under current land use scenario . . . 2-214
2.31 Hazard index for noncarcinogens for adults under future land use scenario 2-215
2.32 Excess cancer risk for carcinogens for adults under current land use scenario . . 2-217
2.33 Excess cancer risk for radionuclides for adults under future land use scenario . . 2-219
2.34 Excess cancer risk for radionuclides for adults under current land use scenario . 2-221
2.35 Excess cancer risk for radionuclides for adults under future land use scenario . . 2-223
2.36 Hazard index for noncarcinogens for children under current land use scenario . 2-225
2.37 Hazard index for noncarcinogens for children under future land use scenario . . 2-227

2.38 Excess cancer risk for carcinogens for children under current land use scenario 2-229
2.39 Excess cancer risk for carcinogens for children under future land use scenario . 2-231
2.40 Excess cancer risk for radionuclides for children under current land use scenario 2-233
2.41 Excess cancer risk for radionuclides for children under future land use scenario 2-235
2.42 Framework for ecological risk assessment 2-236
2.43 Food web relationships of aquatic biota sampled (clear boxes) or modeled (shaded boxes) for EFPC ecological risk assessment 2-237
2.44 Food web relationships of terrestrial biota sampled (clear boxes) or modeled (shaded boxes) for EFPC ecological risk assessment 2-238
2.45 Hinds Creek ecological reference sampling sites 2-239
2.46 Mill Branch ecological reference sampling sites 2-240
2.47 Percentage of captured fish species from EFPC and Hinds Creek classified as tolerant of degraded water quality, October 7-12, 1991 2-241
2.48 Observed fish species diversity and maximum possible fish diversity at sites in EFPC and Hinds Creek, October 7-12, 1991 2-242
2.49 Ecological risk for aquatic and terrestrial resources under current conditions . . 2-243
3.1 Location map for borrow and disposal locations 3-57
3.2 On-site landfill disposal location 3-58
4.1 Areas of contamination to be addressed at EFPC OU (SWAs 1 through 5) 4-23
4.2 Areas of contamination to be addressed at EFPC OU (SWA 6) 4-51
4.3 Areas of contamination to be addressed at EFPC OU (SWA 7) 4-63
4.4 Sitewide alternatives for remediation of the EFPC floodplain 4-75

ACRONYMS

ACL	alternative concentration limit
AFDW	ash-free dry weight
ANOVA	analysis of variance
ARAR	applicable or relevant and appropriate requirement
A:T	ratio of aquatic-origin to terrestrial-origin arthropods
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	ambient water quality criteria
BAF	bioaccumulation factor
BCF	bioconcentration factor
BEA	Bureau of Economic Analysis
BMAP	Biological Monitoring and Abatement Program
BTF	biotransfer factor
CAPCA	closure and postclosure activities
CDI	chronic daily intake
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CLP	Contract Laboratory Program
CMS	corrective measures study
COC	contaminant of concern
COE	U.S. Army Corps of Engineers
COPC	chemical of potential concern
CREAMS	Chemicals, Runoff, and Erosion from Agricultural Management Systems
CSF	cancer slope factor
CWA	Clean Water Act
D&D	decontamination and decommissioning
DCG	derived concentration guide
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DQO	data quality objective
EA	environmental assessment
EFK	East Fork kilometer
EFPC	East Fork Poplar Creek
EFPCM	East Fork Poplar Creek mile
Eh	oxidation-reduction potential
EIC	effectiveness, implementability, and cost
EIS	environmental impact statement
EOC	Emergency Operations Center
EPA	U.S. Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, Trichoptera
EQAB	Environmental Quality Advisory Board
ER	Environmental Restoration
ERAP	Emergency Readiness Assurance Plan
ERWM	Environmental Restoration and Waste Management
FDA	U.S. Food and Drug Administration
FEMA	Federal Emergency Management Agency
FFA	Federal Facilities Agreement
FICWD	Federal Interagency Committee for Wetland Delineation

FONSI	Finding of No Significant Impact
FPC	fixed price contractor
FPPA	Farmland Protection Policy Act
FR	Federal Register
FS	feasibility study
FTE	full-time equivalent
FWS	U.S. Fish and Wildlife Service
GLEAMS	Groundwater Loading Effects of Agricultural Management Systems
HAZMAT	Hazardous Materials
HDPE	high-density polyethylene
HEAST	Health Effects Assessment Summary Tables
HEC	Hydrologic Engineering Center
HI	hazard index
HQ	hazard quotient
HSDB	Hazardous Substances Data Bank
HSWA	Hazardous and Solid Waste Amendments
IA	Institutional Action
IRIS	Integrated Risk Information System
K_d	distribution coefficient
K_{oc}	organic carbon partition coefficient
L_{dn}	yearly day-night average sound levels
LDR	land disposal restrictions
LOAEL	lowest observed adverse effect level
LOEC	lowest observed effects concentration
LLW	low-level waste
LTTD	low-temperature thermal desorption
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MLE	most likely exposure
MMC	Methodist Medical Center
MOU	memorandum of understanding
NAA	neutron activation analysis
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NCR	nonconformance report
NEPA	National Environmental Policy Act
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NHP	New Hope Pond
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no observed adverse effect level
NOEC	no observed effects concentration
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRDA	Natural Resource Damage Assessment
NWI	National Wetland Inventory
O&M	operation and maintenance
ORAU	Oak Ridge Associated Universities
OREPA	Oak Ridge Environmental Peace Alliance
ORHASP	Oak Ridge Health Agreement Steering Panel
ORNL	Oak Ridge National Laboratory

ORO	Oak Ridge Operations
ORR	Oak Ridge Reservation
ORSA	Oak Ridge Sportsmen's Association
OSHA	Occupational Safety and Health Administration
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PARCC	precision, accuracy, representativeness, completeness, and comparability
PCB	polychlorinated biphenyl
PDF	probability density function
pH	negative log of the hydrogen ion concentration
PPE	personal protective equipment
PRG	preliminary remediation goal
QA	quality assurance
QC	quality control
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
REAC/TS	Radiation Emergency Assistance Center/Training Site
RfC	reference concentration
RfD	reference dose
RFI	RCRA facility investigation
RI	remedial investigation
RIMS	Regional Input-Output Multiplier System
RIMS II	Regional Input-Output Modeling System
RME	reasonable maximum exposure
ROI	Region of Influence
RMPE II	Reduction of Mercury in Plant Effluent Phase II
RQ	reportable quantity
RU	remedial unit
SAIC	Science Applications International Corporation
SARA	Superfund Amendments and Reauthorization Act
SCS	U.S. Soil Conservation Service
SDWA	Safe Drinking Water Act
SLB	Sewer Line Beltway
SOCM	Save Our Cumberland Mountains
SVOC	semivolatile organic compound
SWA	sitewide alternative
TBC	to-be-considered
TCLP	toxicity characteristic leaching procedure
TDEC	Tennessee Department of Environment and Conservation
TEMA	Tennessee Emergency Management Agency
TLV	threshold limit value
TOC	total organic carbon
TSCA	Toxic Substances Control Act
TSD	treatment, storage, and disposal
TSDF	treatment, storage, and disposal facility
TSS	total suspended solids
TVA	Tennessee Valley Authority
UCL	upper 95% confidence limit of the mean
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

VOC	volatile organic compound
WAG	waste area grouping
YWCA	Young Women's Christian Association

EXECUTIVE SUMMARY

Past mercury releases from the Oak Ridge Y-12 Plant have directly contaminated Lower East Fork Poplar Creek (EFPC) and its associated floodplain. In addition, the contaminated floodplain soil was used as fill material during the construction of the Sewer Line Beltway (SLB). In December 1989, the U.S. Environmental Protection Agency (EPA) placed the Oak Ridge Reservation, including EFPC, on the National Priorities List. The Oak Ridge Reservation is located in Oak Ridge, Tennessee, ~32 km (20 miles) west of Knoxville, Tennessee. Investigation of EFPC is required under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and must follow specific procedures required by CERCLA, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986. In addition, the U.S. Department of Energy (DOE) is considering the potential environmental impacts of the proposed action in accordance with the National Environmental Policy Act (NEPA) and has taken the position of incorporating NEPA values within the requirements of CERCLA. This FS report is based on the nature and extent of contamination and human health and ecological risk assessment results presented in the *East Fork Poplar Creek/Sewer Line Beltway Remedial Investigation Report* (DOE 1994).

The primary medium of concern for EFPC is the floodplain soil, with mercury being identified as the principal contaminant. The results of the human health risk assessment indicate that the soil ingestion pathway is the most appropriate basis for determining the need for site remediation. The remediation goal options developed as part of the remedial investigation identified for human health a level of 180 ppm mercury in soil for Residential and Agricultural land use and a level of 938 ppm mercury in soil for Commercial/DOE and Other land use. The ecological remediation goal options developed as part of the remedial investigation established a level of 200 ppm mercury in soil for ecological receptors. Approximately 41,400 m^3 (54,000 yd^3) of mercury-contaminated soil have been estimated to exist within the EFPC floodplain above remedial action objectives.

EPA requires that remedial alternatives be protective of human health and the environment by eliminating, reducing, and/or controlling risks. To accomplish this goal, remedial action objectives were developed that specify the contaminants and media of concern, exposure pathways, and remediation goals. The defined remedial action objectives must provide for the protection of human health and the environment and comply with applicable or relevant and appropriate requirements (ARARs). The EFPC site was divided into six subunits, or remedial units (RUs). These RUs are Surface Water/Sediments; Sewer Line Beltway (soil); Residential (soil); Agricultural (soil); Commercial/DOE (soil); and Other (soil).

General response actions and remedial technologies were identified, screened, and retained, as appropriate, for mercury-contaminated soil. Potential general response actions included: no action, institutional actions, containment, removal, treatment, disposal, and beneficial use. The general response actions were combined to form generic alternatives, which were applied to each RU and evaluated and screened for effectiveness, implementability, and cost. The remaining RU alternatives were combined using site-specific criteria to reduce the large number of potential sitewide alternatives to a manageable number.

ES.1 DESCRIPTION OF SITEWIDE ALTERNATIVES

The following sitewide alternatives were developed and evaluated. On the basis of the uncertainties associated with the surface water/sediment environmental pathways, an administrative decision was made to defer consideration of surface water and sediment. Therefore, EFPC sitewide alternatives include only interim institutional actions for EFPC surface water and sediments due to the continuing releases from the Y-12 Plant and other sources. Because of the relatively low level of mercury contamination and the projected land use, the SLB does not require action. In addition, the Agricultural RU parcels do not contain levels of contamination above the remedial action objectives and, therefore, do not require remedial action.

Sitewide Alternative (SWA) 1. The No Action alternative is evaluated in accordance with CERCLA and NEPA and provides a baseline for comparison of the other sitewide alternatives. Environmental monitoring would be performed as part of this alternative and would include a 5-year periodic review.

Sitewide Alternative 2. SWA 2 involves the excavation of soil contaminated with >180 ppm mercury on the Residential [~25,100 m^3 (32,800 yd^3)] RU and disposal at an approved lined landfill with leachate collection at the Y-12 Plant (i.e., Landfill V or Landfills VI or VII could be modified). Landfill VII, modified to include a liner and leachate collection, was used as the representative option for this evaluation. For Commercial, DOE, and Other RUs, containment and institutional actions would be implemented; a 45-cm (18-in.) soil cover would be installed where soil contamination is >200 ppm. Total surface area to be contained for Commercial property is 0.05 ha (0.12 acre), for Other RU property is 1.64 ha (4.05 acres), and for DOE property is 0.81 ha (2.02 acres).

Sitewide Alternative 3. SWA 3 involves the excavation of soil contaminated with >180 ppm mercury on the Residential [~25,100 m^3 (32,800 yd^3)] RU, and removal of soil contaminated with >200 ppm mercury on the Commercial, [~400 m^3 (500 yd^3)], DOE [~6500 m^3 (8500 yd^3)], and Other [~9400 m^3 (12,200 yd^3)] RUs and disposal at an approved lined landfill with leachate collection at the Y-12 Plant (i.e., Landfill V or Landfills VI or VII could be modified). Landfill VII modified to include a liner and leachate collection was used as the representative option for this evaluation.

Sitewide Alternative 4. SWA 4 involves the excavation and treatment of soil contaminated with >180 ppm mercury on the Residential [~25,100 m^3 (32,800 yd^3)] RU. A low-temperature thermal desorption process would be used to treat the soil. The "cleaned" treated soil would be beneficially reused for backfill in the excavated areas of the floodplain. Containment and institutional actions would be implemented on Commercial, DOE, and Other RUs; a 45-cm (18-in.) soil cover would be installed where soil contamination is >200 ppm mercury. Total surface area to be contained is 0.05 ha (0.12 acre) for Commercial property, 1.64 ha (4.05 acres) for Other property, and 0.81 ha (2.02 acres) for DOE property. Residuals from the low-temperature thermal desorption unit would be stored temporarily, awaiting transport to an approved off-site disposal facility.

Sitewide Alternative 5. SWA 5 involves the excavation and treatment of soil contaminated with >180 ppm mercury on the Residential [~25,100 m^3 (32,800 yd^3)] RU and soil contaminated with > 200 ppm mercury on the Commercial, [~400 m^3 (500 yd^3)], DOE [~6500 m^3 (8500 yd^3)], and Other [~9400 m^3 (12,200 yd^3)] RUs. The low-temperature thermal desorption process would be used to treat the soil. The treated soil would be beneficially reused

for backfill in the excavated areas of the floodplain. Residuals from the low-temperature thermal desorption unit would be stored temporarily, awaiting transport to an approved off-site disposal facility.

Sitewide Alternative 6. SWA 6 involves containment and institutional actions for all RUs where soil contamination is >200 ppm. To ensure protectiveness of containment and institutional actions on Residential soils, DOE would acquire the real estate interest for areas containing mercury concentrations >180 ppm, and access controls (fencing) would be installed around the acquired areas. Residential receptors would thus be excluded from the acquired areas; residential or agricultural land use would also be prohibited in the future. A total of ~7.35 ha (18.16 acres) of soil with mercury concentrations >180 ppm would be acquired and contained using soil cover.

Sitewide Alternative 7. SWA 7 involves the removal of 18,700 m^3 (24,500 yd^3) of soil contaminated with >180 ppm mercury from the Residential RU and disposal at an approved lined landfill with leachate collection at the Y-12 Plant (i.e., Landfill V or Landfills VI or VII could be modified). Landfill VII, modified to include a liner and leachate collection, was used as the representative option for this evaluation. Institutional actions (future land use limitations, construction permit restrictions, signs) would be implemented for soil with >200 ppm mercury for the Commercial, DOE, and Other RUs. This alternative would involve reclassification of future land use (no residential or agricultural use) for three properties. These properties, which are included in the Residential, Commercial, and DOE RUs in the other sitewide alternatives, would be considered components of the DOE RU, and remedial actions would be taken accordingly.

ES.2 COMPARATIVE ANALYSIS OF SITEWIDE ALTERNATIVES

The comparative analysis identifies the advantages and disadvantages of the sitewide alternatives when compared with each other, based on the results of the detailed analysis. The comparative analysis allows the identification of key tradeoffs the decision maker must balance during the final selection of a preferred alternative. The results of this analysis are summarized below for each of the CERCLA criteria.

Overall Protection of Human Health and the Environment. SWAs 2 through 7 are protective of human health and the environment if institutional controls are maintained. SWAs 2 through 7 involve some risk during transport of contaminated soil and borrow soil; however, transportation risks are low for all sitewide alternatives (<1 injury or fatality projected). Risk related to construction accidents ranges from 4.3 (SWA 7) to 10.3 (SWA 3) injuries. However, no fatalities would be expected during implementation of these sitewide alternatives. Worker exposure during treatment would be higher for SWAs 4 and 5, because of the additional handling of the soil, than for alternatives without treatment (SWAs 2, 3, 6, and 7).

The greatest risk during implementation of SWAs 2 through 7 is to ecological receptors, and the alternatives vary in the degree of impacts. SWA 7 would result in fewer adverse impacts to these receptors than SWAs 2 through 6. No excavation would occur in SWA 6, but stream banks and terrestrial habitats would be permanently altered in the areas contained. Excavation of residential soils would occur in SWA 7; however, the number of excavated properties and the volume of excavated soil would be reduced relative to SWAs 2 through 5.

SWA 7 involves residual risk to ecological receptors in one segment of the floodplain above levels considered protective, but this residual risk is considered to be acceptable when weighed against the more direct impacts to ecological receptors resulting from taking action at that location. The time required for recovery of areas disturbed during remediation varies for the sitewide alternatives. Recovery to natural habitat in containment areas would not occur in SWAs 2, 4, and 6 because these areas would be maintained in grass and would have an intrusion barrier to deter burrowing animals that would prevent deep rooting of trees. Stream banks would be stabilized with gabions, thereby preventing recovery of the riparian zone. Areas excavated in SWAs 2 through 5 and 7 would recover from loss of vegetation; some properties would recover quickly (e.g., lawns or pasture), while others, such as those in mature bottomland hardwood, would be expected to regenerate within ~50 years to their preremedial action condition.

Considering both short-term and long-term effects, SWA 7 is considered to provide the highest degree of overall protection based on low risk during implementation and rapid recovery of the floodplain to pre-remedial action conditions. SWAs 3 and 5 provide the next highest level of overall protection because unacceptable residual risk is eliminated in the floodplain; although impacts during implementation are high for ecological receptors, there would be no permanent alteration of the floodplain habitats. SWAs 2 and 4 provide for a moderate level of overall protection because residual contaminants remain, and permanent alterations of habitat and land use would occur. SWA 6 provides the lowest overall protection for the action alternatives; extensive fencing and containment throughout the floodplain would result in permanent habitat alteration, and maintaining fencing and access controls is considered difficult. SWA 1 is the least protective of all sitewide alternatives, reflecting the conclusion of the baseline risk assessment that unacceptable risk is present in the floodplain; no action would be taken to reduce that risk.

Compliance with ARARs. SWAs 2 through 7 would comply with ARARs. Because no remedial action would be taken under SWA 1, action- and location-specific ARARs are not invoked. Currently, there are no chemical-specific ARARs for soil.

Long-term Effectiveness and Permanence. This criterion addresses long-term risk to human health; long-term risk to the environment is addressed under Short-term Effectiveness and Environmental Impacts. Risks to human health after completion of remedial action at a site and the reliability of controls give an indication of the long-term effectiveness of an alternative. SWAs 3 and 5 are considered to be most effective in the long term because they would remove contaminated material above a level of concern at the site, thereby eliminating unacceptable residual risk. The excavated contaminated material would be isolated in a disposal facility at the Y-12 Plant. SWAs 2 and 4 are less effective in the long term because they would only remove some of the contaminated material from the floodplain and would cover the remaining contaminated areas with a soil cover; the covered residual contaminated soil would require active controls (maintenance of the soil cover and land use restrictions) to prevent unacceptable exposure. SWA 7 is moderately effective in the long term because contaminated material on some properties would be removed. SWA 6 would involve leaving all contaminated material in place, restricting access with fencing, and covering the most contaminated (>200 ppm mercury) areas. The active control measures over the entire site required to ensure long-term effectiveness result in SWA 6 being considered the least effective in the long term. SWA 1 is ranked low because no action would be taken to reduce risk to humans over the long term.

Short-term Effectiveness and Environmental Impacts. This criterion addresses risk to human health and the environment during implementation and environmental impacts after implementation. SWA 1 would cause no impacts during implementation but would have significant potential for negative impacts to the environment after implementation. All action alternatives have comparable transportation and construction accident risk (< 10 injuries and no fatalities would be expected during implementation). Risk to the community from exposure to contaminants is low and within acceptable limits for all alternatives. Risk to workers varies by alternatives but would be within acceptable limits if mitigative measures (e.g., engineering controls, personal protective equipment) are used.

Impacts to ecological receptors and environmental media during implementation would be less for SWAs 6 and 7 than for SWAs 2 through 5 because both excavation and containment actions would negatively impact biota and habitat to a greater degree in SWAs 2 through 5. SWA 7, with its institutional actions, would result in even less habitat destruction in the floodplain than SWA 6 because the areas would be left as is rather than be maintained as mowed areas. SWA 7 provides the highest level of short-term protectiveness; SWA 6 provides a slightly lower level of short-term protectiveness due to the impact to ecological receptors. SWAs 2 through 5 provide the next level of short-term effectiveness and degree of environmental impacts.

Reduction in Toxicity, Mobility, or Volume through Treatment. SWAs 4 and 5 provide for a reduction in toxicity of mercury-contaminated soil through treatment. All other alternatives do not provide for reduction in toxicity, mobility, or volume through treatment.

Implementability. SWA 1 requires no action and thus is implementable. SWAs 2 through 7 are considered implementable; however, some may be more difficult to implement than others. Excavation and containment actions in SWA 2 through 7 are well known and readily implemented. The treatment technology, low-temperature thermal desorption, proposed for SWAs 4 and 5 has not been proven in full-scale tests to be effective in removing mercury from EFPC soils; however, treatability bench-scale and pilot-scale tests indicate that the process would be effective and implementable. SWAs 4 and 5, which include treatment, provide for the second level of implementability (in comparison to SWAs 2 and 3, which provide for the highest level of implementability) because of the uncertainty of the treatment technology. The use of an on-site disposal area at the Y-12 Plant contributes to the high degree of implementability for SWAs 2, 3, and 7. Though a special waste approval from the Tennessee Department of Environment and Conservation is necessary, on-site disposal is considered more implementable than any other disposal option, including hauling the waste to a commercial disposal facility. SWA 7 is considered comparable to SWAs 2 and 3 because treatment is not used and institutional actions necessary for implementation (e.g., rezoning and future use restriction) are not considered difficult. SWA 6 would require DOE to acquire real estate interests along several portions of the creek, and this may prove difficult if landowners are reluctant to negotiate agreements with DOE for contaminated portions of their properties. Therefore, SWA 6 provides for the lowest level of implementability for the sitewide alternatives.

Cost. Costs for the seven sitewide alternatives range from $12 million to $70 million (1993 dollars, without escalation or discount):

Sitewide alternative	Cost in 1993 dollars (× $1,000,000)
1	12
7	31
6	41
2	48
3	52
4	59
5	70

ES.3 PROPOSED PLAN/ADDENDUM

The comparative analysis of sitewide alternatives provides the basis for the decision maker in selection of the preferred alternative. The preferred alternative, which will be described in the Proposed Plan, will be selected from among the sitewide alternatives evaluated in this FS.

1. INTRODUCTION

1.1 PURPOSE AND ORGANIZATION OF THE REPORT

Lower East Fork Poplar Creek (EFPC), the associated floodplains, and the Sewer Line Beltway (SLB) [hereafter referred to as the EFPC operable unit (OU)] have been directly and indirectly contaminated by past releases from the Oak Ridge Reservation (ORR) Y-12 Plant. The chemicals of potential concern (COPCs) in soil include 13 heavy metals, 7 polycyclic aromatic hydrocarbons (PAHs), 2 polychlorinated biphenyls (PCBs), and 10 radionuclides. The primary contaminant is mercury. Because of this contamination and contamination of other areas on the ORR, the U.S. Environmental Protection Agency (EPA) placed the ORR and its environs on the National Priorities List in December 1989. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requires that an investigation be conducted to determine if remediation is warranted. The investigation of the EFPC OU must follow the specific procedures mandated by CERCLA, as amended by the Superfund Amendments and Reauthorization Act (SARA) in 1986. Because EFPC involves off-site releases of contaminants from the Y-12 Plant, its remediation also must conform with the procedures in Section 3004(v) of the Resource Conservation and Recovery Act (RCRA), as amended by the Hazardous and Solid Waste Amendments (HSWA) of 1984. Additionally, because the actions taken to remediate the EFPC OU could significantly affect the environment, the National Environmental Policy Act (NEPA) values are incorporated into the Feasibility Study (FS).

The environmental restoration activities on the ORR are primarily governed by three federal laws, CERCLA, RCRA, and NEPA. The CERCLA process consists of three phases: (1) a preliminary assessment, (2) a thorough study of the site, and (3) design and implementation of the chosen plan. RCRA requires a progression of measures, similar to those for CERCLA, to determine whether a site requires environmental restoration. Under NEPA, federal agencies must consider possible environmental impacts when making decisions on proposed and alternative actions. Investigations, analyses, documentation, and community relations activities required by the three laws are combined to streamline the process and to avoid the duplication of effort and the larger commitment of resources needed to implement the three statutes separately. Furthermore, integration minimizes the risk that remedial actions may be delayed on procedural grounds.

This document evaluates the alternatives for remedial action at the EFPC OU. The proposed action for the site is remediation; it is based on historical data and the results of the remedial investigation (RI), which present information on the nature and extent of contamination, and the baseline risk assessment, which evaluates potential health and ecological risks that could result if no remedial action is taken at the site. Action is warranted because of the potential for unacceptable exposure if existing access restrictions are not maintained in the future. The FS evaluates potential remedial actions to address risk at the site. The RI, FS, and baseline risk assessment compose the primary evaluation documents for the integrated RI/FS package. The Proposed Plan is published separately but is considered an integral part of the RI/FS process. The Proposed Plan highlights information from the FS and identifies the preferred alternative. It is the fourth major document of the RI/FS package. After completion of the RI, baseline risk assessment, FS, and Proposed Plan, and after public and agency review, the process will conclude with the issue of a Record of Decision that will identify the remedies selected for the site.

The RI, which includes the baseline risk assessment, has been summarized and incorporated by reference in this FS.

Overall, this FS is organized in accordance with U.S. Department of Energy (DOE) and EPA guidance [e.g., *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA,* Interim Final (EPA 1988b)]. The format of the FS was reviewed by DOE Oak Ridge Operations' (ORO) Document Content and Response Committee. Section 5 of this document was modified to incorporate the NEPA values and RCRA applicable or relevant and appropriate requirements (ARARs).

In general, the need for action, the format of the report, a review of scoping activities, a description of related federal actions, and a summary of consultation and coordination with other agencies are presented in Sect. 1. Section 2 of this report describes the EFPC OU, its history, and its environmental setting. Section 2 also contains a summary of the nature and extent of contamination, the transport and fate of contaminants, and results of the baseline risk assessment for human health and the environment. In Sect. 3, remediation goal options are defined and remedial action technologies are identified and screened for their effectiveness in meeting the remedial action objectives. In Sect. 4, several remedial unit (RU) alternative actions are developed and screened; the overall sitewide alternatives are also developed in this section. The detailed analysis of alternatives in Sect. 5 incorporates NEPA values. The comparative analysis of the sitewide alternatives is presented in Sect. 6. References are listed in Sect. 7. A list of preparers and a distribution list are included in Sects. 8 and 9, respectively. To enhance readability and avoid interrupting the flow of text, tables and figures are presented at the end of each section in which they occur. The Proposed Plan will be issued as a separate, stand-alone document.

1.2 SCOPING PROCESS SUMMARY

The objective of the scoping process is to determine the range of issues to be addressed during the combined CERCLA and NEPA process. Scoping involves the identification of potential actions and significant issues to be addressed, preliminary identification of the range of alternatives to be evaluated, a review and analysis of existing data, and identification of data gaps.

DOE announced its intent to prepare an integrated FS/corrective measures study (CMS)-environmental impact statement (EIS) on the EFPC Remedial Action Project at the ORR in the *Federal Register* (*FR*) on November 18, 1988 [*FR* 53(223):46648-46651]. A broad range of generic alternatives was given in the Notice of Intent, including no action, source treatment and disposal on site and off site, effluent discharge and disposal, containment, and institutional controls. The Notice of Intent also listed the environmental issues tentatively identified to be analyzed in the RI/FS.

Interested agencies, organizations, and members of the public were invited to submit comments or suggestions to assist DOE in identifying significant environmental issues and determining the appropriate scope of the integrated document. A public scoping meeting was held on Tuesday, December 6, 1988, in the Main Auditorium of the American Museum of Science and Energy, 300 South Tulane Avenue, in Oak Ridge, Tennessee. During the scoping

meeting, five individuals presented oral comments. Citizens expressed a number of concerns about the contamination identified with EFPC. Among those concerns were the nature and extent of contamination in residential areas along the creek, short- and long-term health effects of exposure to the contaminants on the elderly and the young, marketability and resale value of lands in the floodplain of EFPC, present and future land use, downstream impacts of sediment and soil disturbances during the proposed cleanup, the potential for the spread of contamination by flooding in the Jefferson Avenue area, and the latent health effects of contamination. These concerns are part of the public record for the environmental restoration program for EFPC and will be considered by DOE in the remediation planning process. No written comments were received during the 30-d comment period following the date of the notice.

On June 13, 1994, the Secretary of Energy issued a policy statement concerning NEPA which addressed several changes in how NEPA will be implemented in the Department. Among the process improvements listed in the policy statement is a change designed to facilitate meeting the environmental objectives of CERCLA. This change indicates that hereafter DOE will rely on the CERCLA process for review actions to be taken under CERCLA with NEPA values and public involvement procedures included. After consultation with agency and public stakeholders and the general public, the Department concluded that an EIS was redundant with the CERCLA process and, thus, no longer necessary. DOE is preparing a withdrawal of its Notice of Intent to prepare an EIS for the East Fork Poplar Creek Remedial Action Project. However, as indicated earlier, NEPA values will be incorporated into this FS and public review and participation will be strongly encouraged.

A formal community relations program was developed and implemented to keep the public informed of activities associated with EFPC. Through this program, DOE interacts with the local communities by means of news releases, the DOE periodic Environmental Update Newsletter and updated fact sheets, the annual DOE Open House, EFPC property owner workshops, discussions with and presentations to local groups, ongoing informal interactions with property owners in the EFPC OU, local officials, and interested citizens and organizations regarding the status of the RI/FS process, receiving and responding to public comments, public meetings to discuss project milestones, and a citizens' working group.

Property owners have been the focus of an extensive community outreach program since the beginning of the EFPC project. Property access agreements were obtained in 1990-1991 from 136 landowners for access to perform the RI activities. Status letters were periodically transmitted to the property owners informing them of all major on-site sampling activities (1991-1992) and sampling results (1992-1993). DOE held numerous one-on-one meetings with property owners to present the sampling results and discuss the related issues. In November and December of 1991, two property owner workshops were conducted specifically to address concerns of the property owners and provide an avenue for preliminary discussions of remedial alternatives. In addition to the property owner workshops, DOE provided an RI/FS briefing and question-and-answer session for more than 50 Oak Ridge realtors in 1992. Following the submittal of the draft RI report to EPA and the Tennessee Department of Environment and Conservation (TDEC) in April 1993, a property owner workshop was held on May 15, 1993. More than 150 people attended a public meeting held on May 18, 1993, to receive updated information on the status of the EFPC RI studies and the potential technologies for remediation of the floodplain soils. Issues of concern were recorded and compiled for use in developing the FS.

When the results of the RI became available in early 1993, a number of critical issues related to remedial options were identified that would affect the development of the FS. Due to the unique and complex nature of the project, it was apparent that the effort to address these issues would benefit from the involvement and concurrence of several interested and affected agencies. To assist in this effort, DOE sponsored a 2-d technical workshop on EFPC to obtain the input and identify the concerns of involved federal, state, and local agencies.

The EFPC Citizens' Working Group was formed as a voluntary organization of interested and concerned citizens to provide feedback on the proposed remedial alternatives for the creek's floodplain soils. A series of meetings was held from the summer of 1993 through the summer of 1994 to help DOE gain new perspectives about potential remedial alternatives as they were being developed. The group also provides DOE with a better understanding of community concerns related to remediation of the floodplain soils and provides an additional way for the public to identify concerns about the proposed cleanup options.

1.3 RELATED FEDERAL PROJECTS

In the past several years, DOE has gained considerable experience in the remediation of hazardous waste sites through the Environmental Restoration and Waste Management (ERWM) Program. The draft Implementation Plan for the Programmatic EIS for the ERWM Program was published in January 1992 and proposes alternatives for handling waste at all DOE facilities. In addition, DOE ORO, which is managing the EFPC remediation, has also been involved for several years in managing hazardous wastes and remediating waste sites on the ORR. DOE and ORO, therefore, have considerable expertise in managing projects such as the EFPC remediation.

At the ORR, ~700 waste sites, divided into 40 primary units (waste areas), are under investigation for possible contamination under the ORR environmental restoration program. Remediation at these waste areas will vary because each area has different characteristics and types of contamination. Remediation of each waste group will be conducted under the process specified by CERCLA.

The Oak Ridge National Laboratory (ORNL) is the largest of the three facilities on the ORR, occupying 1175 ha (2900 acres). The five programs that have generated most of the on-site waste are fuel reprocessing, isotope production, radioisotope applications, reactor development, and multiprogram laboratory operations. Most of the wastes produced by these programs include radioactive and chemical, or mixed, wastes. When these wastes were treated, stored, or disposed of at ORNL, small quantities of certain contaminants may have been released to the environment. Studies are now under way to determine the type and extent of contamination, if any, at the sites. Both groundwater and surface water are being monitored. Evaluations of 20 ORNL waste areas show that 7 have released no contaminants to the environment; the other 13 waste areas require further study.

The Oak Ridge Y-12 Plant comprises ~324 ha (800 acres) of the ORR. Originally built to separate ^{235}U from other uranium isotopes, the plant today primarily serves as a key manufacturing technology center for the development and demonstration of unique materials, components, and services of importance to DOE and the nation. Waste water generated at the Y-12 Plant since 1943 has included both radioactive and chemical wastes. Other wastes at the

Y-12 Plant include ash from coal-burning steam plants, PCBs, and asbestos. More than 175 waste sites at the Y-12 Plant are now under remedial-action review.

Formerly known as the Oak Ridge Gaseous Diffusion Plant, the K-25 Site is located on 608 ha (1500 acres). Until 1985, the plant process separated ^{235}U from other uranium isotopes for eventual use in nuclear reactors. Since that time, plant production equipment has been shut down. The wastes produced by the K-25 Site included low-level radioactive waste, hazardous waste, mixed wastes, and PCBs. Remediation alternatives are being considered for the 110 waste sites identified at the K-25 Site.

Some contamination has migrated from the three ORR plant sites by means of waterways to off-site locations. In addition to EFPC, which is the focus of this study, another of these off-site locations is the Clinch River, which borders the ORR on the south and west for ~63 km (39 miles). Contaminants have, in some cases, entered the Clinch River through White Oak Creek from ORNL, Bear Creek and EFPC from the Y-12 Plant, and Poplar Creek from the K-25 Site. Contaminants including ^{137}Cs, mercury, and PCBs have been transported downstream into Watts Bar Reservoir, but the extent of contamination has not yet been definitively determined.

1.4 CONSULTATION AND COORDINATION

DOE, EPA Region IV, and TDEC are working under a Federal Facilities Agreement to remediate contamination on the ORR and its environs, of which EFPC is a part (EPA, DOE, and TDEC 1992). This cooperative agreement, required by CERCLA and RCRA, was implemented on January 1, 1992, to ensure that environmental requirements are met or exceeded and that remediation is performed as quickly and responsibly as possible. A key component of this process is the identification of federal and state regulations that will affect site remediation; this endeavor is being coordinated with EPA Region IV and TDEC, respectively.

Through its community relations plan for the EFPC OU, DOE enables federal and state legislators, local and county officials, and the general public to participate in the decision-making process for site remediation. Because part of the EFPC floodplain lies within the city of Oak Ridge, the city is kept informed of all ongoing activities. More than 130 people who own property in the EFPC floodplain are also kept informed through a series of DOE-sponsored information updates.

Several other agencies were consulted for data acquisition and regulatory responsibility for natural or cultural resources addressed in the FS. These include the U.S. Fish and Wildlife Service (FWS) for fisheries and wildlife protection, the U.S. Army Corps of Engineers (COE) for floodplains and wetlands protection, the Tennessee Valley Authority (TVA) for water flow data, and the State Historic Preservation Office for cultural resources protection. Letters of consultation are in Appendix B.

Per CERCLA provisions, DOE, FWS, and TDEC are designated as trustees for the Natural Resource Damage Assessment (NRDA) for the EFPC remediation project. DOE is identified as the CERCLA lead response agency.

2. SITE BACKGROUND INFORMATION

This section provides background information about the EFPC OU based on results of the RI and other previous studies. Section 2.1 presents a site description including descriptions of soil and prime farmlands, water quality, climate and air quality, land use, and ecological resources. Site history is summarized in Sect. 2.2. A summary of the nature and extent of contamination at the site is presented in Sect. 2.3. Section 2.4 discusses contaminant fate and transport, and Sect. 2.5 summarizes the results of the baseline human health and ecological risk assessments for the site and the development of the human health and ecological remediation goal option.

2.1 SITE DESCRIPTION

EFPC originates within the Y-12 Plant and runs 23.3 km (14.5 miles) from Lake Reality at the Y-12 Plant to its confluence with Poplar Creek (Fig. 2.1). The SLB consists of 16 km (10 miles) of sewer lines; one portion has two branches in the city of Oak Ridge, and another portion is primarily within the floodplain of EFPC. EFPC is a perennial stream located in Anderson and Roane counties in Oak Ridge, Tennessee, ~32 km (20 miles) west of Knoxville, Tennessee. This area is part of the Valley and Ridge Physiographic Province and consists of thrust-fault-controlled ridges and valleys trending in a northeast-southwest direction. The EFPC watershed has a trellis drainage pattern and covers an area of ~77.2 km^2 (29.8 miles^2) above the confluence of EFPC and Poplar Creek (Fig. 2.1). The watershed lies within East Fork Valley and is bounded by Black Oak Ridge on the northwest and East Fork Ridge to the southeast. The EFPC headwaters are within the Y-12 Plant in Bear Creek Valley. After it leaves the Y-12 Plant, the creek flows northward through a gap in Pine Ridge and enters Gamble Valley and the city of Oak Ridge. From there, the stream flows northwestward along Illinois Avenue through commercial and light industrial areas in Oak Ridge, then trends generally westward parallel to the Oak Ridge Turnpike in East Fork Valley through primarily residential, agricultural, and open areas until its confluence with Poplar Creek (Fig. 2.1).

2.1.1 Soils and Prime Farmlands

Soils mapped in the EFPC floodplain in Anderson County belong to the Newark, Newark Variant, and Hamblen series (Moneymaker 1981). Soils in the EFPC floodplain in Roane County are mapped as the Sequatchie, Pope, and Roane series (Swann et al. 1942). Soils in Roane County, which were mapped in 1938, were classified under a taxonomic system no longer used by the U.S. Soil Conservation Service (SCS) and were mapped at a different scale than that used in the Anderson County soil survey. Consequently, the Roane County soil survey was of considerably less value for planning and reconnaissance purposes than the more recent Anderson County soil survey. Many of the Roane County soils would probably correspond more closely to the soil series mapped in Anderson County today.

In Anderson County, >40% of the floodplain is mapped as the Hamblen series, ~25% is mapped as the Newark series, and <10% is mapped as the Newark Variant series (Moneymaker 1981). In Roane County, Pope and Roane soils each make up >25% of the EFPC floodplain, and Sequatchie soils make up ~10% of the floodplain (Swann et al. 1942). A short description

of the properties of each soil series follows. More detailed information about soil properties and management is contained in Moneymaker (1981) and Swann et al. (1942).

Newark Series. The Newark series consists of nearly level (slope range 0 to 2%), somewhat poorly drained soils on floodplains (Moneymaker 1981). These soils formed in recent loamy alluvium derived from soils underlain by dolomite, shale, limestone, and sandstone. Newark soils are found adjacent to the moderately well drained Hamblen soils. Newark soils are medium acid to mildly alkaline and have a moderate to high available water capacity (Moneymaker 1981). These soils are saturated with water to within a foot or less of the surface in late winter and early spring. Most areas are flooded for several days after rains of a few days duration. Agricultural, domestic, and commercial uses of Newark soils are limited because of excess water in the soil and frequent flooding. The Newark series is classified by the SCS as a hydric soil, one criterion of a wetland (SCS 1991; Environmental Laboratory 1987). Newark soils are mapped at the National Oceanic and Atmospheric Administration (NOAA) site, the Bruner site, and one of the Hinds Creek reference sites sampled during Phase Ia of the RI.

Newark Variant. The Newark Variant consists of deep, somewhat poorly drained soils that formed in alluvium washed from soils formed in residuum of shale, limestone, and sandstone (Moneymaker 1981). These soils occur on nearly level stream terraces with slopes ranging from 0 to 3%. Newark Variant soils are found in association with Hamblen and Newark soils, but on higher topographic positions than either the Newark or Hamblen soils. These soils are medium acid to moderately alkaline, permeability is moderately low, and available water capacity is high. Wetness and hazard of flooding limit its potential for development.

Hamblen Series. Hamblen soils are deep, moderately well drained, nearly level (0 to 2% slope) soils (Moneymaker 1981). They formed in recent alluvium on stream bottoms in floodplains. These soils are medium acid to neutral, and have a high available water capacity. Permeability is moderate, and most areas of Hamblen soils are flooded after heavy prolonged rains. Occasional flooding in most areas and excess water in the soil in late winter and early spring limit urban and agricultural use of Hamblen soils. Hamblen soils are classified as hydric soils by the SCS because of inclusions of wetter soils too small in area to delineate separately (SCS 1991). Hamblen soils are mapped at the Sturm site and one of the Hinds Creek reference sites sampled during Phase Ia of the RI.

Pope Series. Pope soils are well-drained soils found in the nearly level first bottoms (Swann et al. 1942) along streams. They formed in alluvium derived from upland soils underlain by shale and sandstone. They are acid to strongly acid and are subject to periodic flooding. Pope soils have slow external drainage but excellent internal drainage.

Roane Series. Roane soils occupy strips of bottomland along small creeks. They formed in alluvium derived from upland soils (Swann et al. 1942). Roane soils are subject to periodic flooding and alteration by deposition and scouring associated with flood events. They occur on nearly level to gently sloping landforms. Roane soils are well drained, acidic, and have low water-holding capacity.

Sequatchie Series. Soils of the Sequatchie series are developed from alluvium on stream terraces, which is derived from uplands underlain by sandstone and sometimes shale (Swann et al. 1942). They are well drained, strongly acidic, and have a moderate to low water-

holding capacity. Sequatchie soils are found on nearly level to gently rolling landforms with slopes ranging from 1 to 15%.

Prime Farmlands. Prime farmlands are protected by the Farmland Protection Policy Act, which seeks ". . . to minimize the extent to which Federal programs contribute to the unnecessary and irreversible conversion of farmlands to nonagricultural uses . . ." [7 USC 4201(b)]. The act is administered by the SCS. Prime farmland is land that has the best combination of physical and chemical characteristics for producing food, feed, fiber, forage, oilseed, and other agricultural crops with minimum inputs of fuel, fertilizer, pesticides, and labor, and without intolerable soil erosion. All soils mapped in the EFPC floodplain in both Anderson and Roane counties are classified as prime farmland (SCS 1983).

The central issue in assessing impacts to prime farmlands is whether *designated* prime and unique farmlands would be converted to other uses. Most of the undeveloped land in the floodplain is designated as residential or commercial or is owned by DOE and, thus, is not available for agricultural use. Because land in the EFPC floodplain is already in or committed to urban development or water storage [7 USC 4201(c)(1)(a)], these floodplain soils would not qualify for designation as prime farmland and, therefore, will not be considered further.

2.1.2 Water Quality

This section includes discussions on surface water and groundwater.

2.1.2.1 Surface water

EFPC originates from springs and surface water drainage at the Y-12 Plant, on the northwest slope of Chestnut Ridge (Fig. 2.2). The headwaters are contained in underground collection pipes that extend to near the central area of the Y-12 Plant, where the above-ground portion of the creek begins. The creek then flows northeast across the plant site and enters Lake Reality, a lined 1-ha (2.5-acre) surface impoundment. The creek receives discharges of water from various processes at the Y-12 Plant as it flows through the plant. The discharges include cooling water and cooling tower blowdown, process wastewaters, coal yard runoff and storm drainage (Loar 1992). Melton Hill Lake (Fig. 2.1) is the source of the process waters; therefore, these discharges constitute an augmentation of the flow of EFPC. An average daily runoff of ~0.06 m^3/s (2.1 cfs) would have been expected from the drainage area upstream of former New Hope Pond (Fig. 2.2) before Y-12 Plant construction (TVA 1985). The Y-12 Plant augmented flow by 0.33 m^3/s (11.7 cfs) based on the average daily flow of 0.39 m^3/s (13.8 cfs) over the 7-year period before the closure of New Hope Pond. At the current average flow rate of 0.24 m^3/s (8.6 cfs), EFPC flow is augmented by 0.18 m^3/s (6.5 cfs) (DOE 1994a). Thus, a majority of the flow of EFPC as it leaves the Y-12 Plant is process water that was originally pumped from Melton Hill Lake.

The portion of EFPC upstream of Lake Reality is referred to as Upper EFPC. The outfall of Lake Reality marks the beginning of Lower EFPC and the OU under consideration in the EFPC RI/FS process. The EFPC OU includes the 23.3-km (14.5-mile) stretch of EFPC flowing from Lake Reality to the confluence with Poplar Creek and its 270 ha (670 acres) of floodplain.

After the outfall of Lake Reality (LE in Fig. 2.2), EFPC travels ~1.1 km (0.7 mile) before crossing the Y-12 Plant property boundary and entering the city of Oak Ridge. EFPC has been channelized from the discharge at Lake Reality to Pine Ridge Gap. The cross sectional area within the channelized section of the creek is roughly trapezoidal with limestone riprapped banks. Shale and limestone bedrock outcroppings occur in the creek bed and limestone riprap also covers the bottom. The bank height is ~3.7 m (12 ft), and the bank span is ~9 to 12 m (30 to 40 ft) at ground surface. Shallow-rooted vegetation is common throughout this reach, indicating some degree of bank stability. At Pine Ridge Gap, the presence of rock outcrops along the west bank indicates a potential link to the bedrock groundwater system. Here, the creek is ~6 m (20 ft) wide. The creek bottom appears to grade from a rocky limestone riprap below Lake Reality to a somewhat smooth and muddy floor, which begins just beyond Pine Ridge Gap.

A widening of the creek at the downstream end of Pine Ridge Gap allows deposition of channel sediments. This floodplain area extends to just south of East Tulsa Road behind the NOAA office building. This floodplain area is stable, with little susceptibility to scour, as evidenced by deep-rooted vegetation.

EFPC continues to flow generally northwest, parallel to Illinois Avenue, a major thoroughfare in Oak Ridge. The channel has a muddy bottom, and the average width is in excess of 4.6 m (15 ft). The confluence of Gamble Branch with EFPC occurs at location TO (Fig. 2.2). Gamble Branch drains all of Gamble Valley, which is a moderately developed residential area. EFPC is ~4.6 m (15 ft) wide at this confluence and has a muddy gravel bottom. Continuing to the north, the creek is channelized where it flows adjacent to Illinois Avenue. In this section of the creek, EFPC receives runoff from highly developed commercial properties near the intersection of the Oak Ridge Turnpike and Illinois Avenue; the banks are protected by riprap, and no vegetation is present. The lack of vegetation may be the result of recent disturbance during development of commercial property, and insufficient time for reestablishment may have passed. In addition, the creek banks are relatively steep, and no evidence of bank failure has been recognized. At location CC (Fig. 2.2) a tributary that drains a large portion of the residential and commercial properties west of Lafayette Avenue, including the Civic Center area, enters EFPC.

EFPC turns generally west where Illinois Avenue intersects Oak Ridge Turnpike. From this intersection to the Oak Ridge Sewage Treatment Plant, the SLB falls within the EFPC floodplain. In this reach, the creek is generally well defined, although the channel is broad and undefined near Wiltshire Drive. This floodplain, ~91.4 m (300 ft) wide, contains significant sediment deposits, and deep-rooted vegetation is common. The creek bottom consists of clay, cobbles, and/or gravel. The channel varies from 4.6 to 6.1 m (15 to 20 ft) in width. Rock outcrop is locally present on the south side of Oak Ridge Turnpike.

The confluence of Mill Branch and EFPC occurs at location TJ (Fig. 2.2). Mill Branch drains 10 to 15% of the EFPC watershed, which is primarily woodland and pasture. The Mill Branch watershed does include several houses, a small horse farm, and the western half of a public golf course. At the confluence, the creek is ~6.1 to 7.6 m (20 to 25 ft) wide. Deep-rooted vegetation is present, and the creek bottom consists of mud and gravel.

The Oak Ridge Sewage Treatment Plant discharges into EFPC at creek kilometer 12.89 (8.01 miles upstream of the confluence with Poplar Creek). Here, the creek is ~3 to 4.6 m

(10 to 15 ft) wide. In this area, limestone rock outcrop can be observed along the south bank, which may provide a direct link to bedrock groundwater from EFPC surface waters. The Oak Ridge municipal water supply originates from Melton Hill Lake, so this discharge augments the flow of EFPC. The average daily discharge from the Oak Ridge Sewage Treatment Plant is 0.25 m^3/s (8.8 cfs) (Currier 1993).

From the Oak Ridge Sewage Treatment Plant, EFPC continues westward roughly paralleling Oak Ridge Turnpike. West of Gum Hollow Road, two major tributaries enter EFPC, Gum Hollow Branch and Pinhook Branch. About 15 to 20% of the EFPC watershed drains into Gum Hollow Branch, and ~10% drains into Pinhook Branch. Both branches receive runoff from primarily residential areas and from the Oak Ridge Country Club golf course. At Gum Hollow, EFPC is ~4.6 to 6.1 m (15 to 20 ft) wide and has a muddy to gravelly bottom. Gum Hollow Branch is ~1.8 m (6 ft) wide at the confluence. At Pinhook, EFPC spans from 6.1 to 9.2 m (20 to 30 ft). Pinhook Branch is ~0.9 m (3 ft) wide at this point. Vegetation covers both sides of EFPC in this area, and there is scattered outcrop in and along the stream channel between the two confluences.

EFPC re-enters the ORR and crosses to the north side of Oak Ridge Turnpike west of the Oak Ridge Country Club. This section of the creek is surrounded by undeveloped woodland. Several unnamed tributaries enter EFPC before its confluence with Bear Creek (BC in Fig. 2.2). The Bear Creek watershed drains an area of 19.2 km^2 (7.4 $miles^2$), which includes the western end of the Y-12 Plant.

As it approaches the confluence with Poplar Creek, EFPC is 30.5 m (100 ft) wide and has a muddy bottom with a channel depth of 1.2 to 2.4 m (4 to 8 ft). The floodplain is heavily vegetated above the normal water level elevation and extends >30.5 m (100 ft) on the east side of EFPC and farther on the west. Pooling caused by high water elevations in Watts Bar Reservoir is often evident in this section of the creek.

Overall stream gradient for EFPC is 0.0027 (14 ft/mile), producing laminar base flow conditions over most of the length of the creek. Average flows for EFPC, which is perennial, have been measured since 1960 by U.S. Geological Survey (USGS) gauge No. 03538250 (LB in Fig. 2.2). The average flow for 25 years of record (1960 to 1985) was 1.5 m^3/s (51.4 cfs). Although the USGS gauge is no longer operating, the flow from the Y-12 Plant has decreased by 0.15 m^3/s (5.2 cfs) since 1985; therefore, EFPC flow may have been reduced by a similar amount. The largest known flood since 1900 occurred September 29, 1944, and had a peak discharge of ~1393 m^3/s (4600 cfs) (Welch 1987).

Most of the Oak Ridge SLB is within the EFPC watershed. East of the intersection of Emory Valley and Fairbanks Roads, where the SLB forks, runoff from the SLB flows eastward into two unnamed branches of Melton Hill Lake (Fig. 2.1).

2.1.2.2 Groundwater

The conceptual model for groundwater flow in the EFPC floodplain is an extension of the stormflow zone flow model of Moore (1988). In this model, during heavy precipitation events, infiltration is impeded by low hydraulic conductivity in residuum, and a temporary "stormflow zone" of water saturation forms in the soils and shallow residuum. Hydraulic conductivity in this

zone is higher than that in the underlying vadose zone because of large pores in the soil that have developed as a result of tree roots and the activities of burrowing animals. Water in the stormflow zone moves downslope and either discharges at seeps and springs or recharges to the true water table aquifer in the valley floor.

Recharge to the groundwater system is supplied by precipitation and takes place primarily during the nongrowing season, from about November 1 to April 30 (Sect. 2.1.3, Climate and Air Quality). Water percolates through the residuum to the water table or the top of rock in locations with shallow soils. The average hydraulic conductivity of the bedrock is typically less than that of the soil; thus, water may move laterally downslope along the bedrock surface (Watson and Luxmoore 1986). Some of the water eventually recharges the bedrock aquifer, but the remainder is discharged to streams or evaporates.

In the humid environment of the East Tennessee Valley and Ridge Province, there is typically a close relationship between shallow groundwater movement and the surface water system. Where stream channels like EFPC, located on valley floors, intersect a shallow water table, groundwater discharges into the stream and supplements its flow.

A survey of shallow wells in the EFPC floodplain by the USGS (Carmichael 1989) indicates that the EFPC floodplain structures [alluvium overlying glei (impermeable, sticky clay layer) and carbonate bedrock] are hydraulically connected and comprise the water table aquifer. Carmichael postulated that a glei horizon may exist, which may act as a barrier to vertical migration of water and contaminants. However, the results of Phase Ia groundwater sampling, which included recompletion and monitoring of the existing USGS wells in addition to installing four deep wells concurrently with eight shallow wells, failed to show a distinct hydraulic barrier identifiable as the glei layer. The four bedrock wells installed as part of Phase Ia sampling and analysis were augered to refusal and would have encountered the glei layer if it existed.

Bedrock Aquifer. The bedrock aquifer is composed primarily of limestone containing mudstone and shale partings, but there are also lithologies composed of sandstone, calcareous siltstone, shale, and dolostone. These lithologies typically have tightly bound matrices with insignificant intergranular permeability. However, a moderately well developed secondary porosity permits transmission of groundwater within the bedrock. The secondary porosity is composed of fractures, some of which have been solution enlarged. These fractures, believed to have formed both during lithification (shortly after deposition) and later during the Allegheny Orogeny, are highly variable in length, spacing, and aperture (Moore 1988). Most fractures are of limited lateral extent, but as noted in previous structural studies (Sledge and Huff 1981), different fracture systems commonly intersect one another, providing a moderate degree of interconnection in the bedrock aquifer. Recent studies at ORNL on the Copper Creek overthrust block suggest that solution activity and groundwater movement in fractures in the Chickamauga Limestone exhibit a high degree of stratigraphic control (Welch 1989). This supports a previous study (Webster 1976) that postulates a significant flow component parallel to geologic strike. If these interpretations are correct, then secondary porosity should produce locally high hydraulic conductivities along strike and down dip, resulting from solution within a particular stratum or along bedding planes. Hydraulic conductivity across bedding and oblique to dip may be lower because it is dependent in part on solution of fractures that cross lithologies having variable rates of weathering.

Groundwater in communication with EFPC is restricted to the unconfined shallow aquifer within the floodplain and portions of the adjoining bedrock aquifer. Though the RI did not investigate deep groundwater flow paths within the bedrock zone, no significant groundwater movement across the drainage divides is conceptualized between the East Fork and adjacent valleys. The fate and transport of contaminants in groundwater within the EFPC floodplain is considered to be the same as in the surface waters of EFPC.

Even if this conceptualization is incorrect and EFPC does provide groundwater recharge to deep flow paths within the bedrock aquifer, there is probably little chemical migration along these paths. First, groundwater velocities in the deep surface are relatively slow (with notable exceptions in well-developed karst regions), and any impact from recharge would be minimal. Second, the majority of contamination within the groundwater medium is related to particle-bound metals, which would not be transported in large quantities into the deep subsurface. Accordingly, the deep bedrock aquifer is not included in the site conceptual model.

Shallow Aquifer. The shallow or alluvial aquifer in the EFPC floodplain consists primarily of alluvial silt and clay with lesser amounts of sand and gravel. Thickness of the shallow aquifer ranges from essentially zero to as much as 6 m (0 to 20 ft) (Carmichael 1989). Water in the shallow aquifer occurs under water-table (unconfined) conditions, with recharge principally from precipitation and discharge through springs and seeps to EFPC and its tributaries. During spring, summer, and fall, evapotranspiration also accounts for the removal of water in storage in the shallow aquifer. Water levels in the shallow aquifer fluctuate seasonally in response to variations in recharge and evapotranspiration. Generally, the depth to water in USGS observation wells within the EFPC floodplain ranged from ~0.3 to 1.2 m (1 to 4 ft) below land surface in late winter and from ~0.6 to 2.1 m (2 to 7 ft) below land surface in late fall (Carmichael 1989). The groundwater wells installed as part of this investigation had water depths ranging from 0.39 to 2.1 m (1.3 to 6.9 ft) below land surface. During extremely dry periods, the water table recedes below the top of bedrock in some floodplain areas (Carmichael 1989).

The depth of freshwater circulation is an unknown but potentially important issue with regard to interhydraulic basin transport and contaminant fate analysis. On a large scale, groundwater moves from potentiometric highs beneath area ridge tops to potentiometric lows below valley floors.

Groundwater elevations within the shallow aquifer vary significantly with rainfall, as does base flow within EFPC. Seasonal variations produce localized changes in the hydrologic balance between EFPC and the alluvial aquifer. During the wet season, EFPC is a gaining stream (groundwater discharge); conversely, during the dry season, portions of the creek may experience a net loss (groundwater recharge). However, even under low-flow conditions, the overall movement of shallow groundwater across the valley (from ridge to ridge) is toward the confluence of EFPC and Poplar Creek. The approximate piezometric surface of the EFPC alluvial aquifer (in relation to mean sea level - taken from the hydrographs) is at ~270 to 265.5 m (875 to 870 ft) in the upper reach. The westernmost monitoring wells near creek kilometer 14.5 (9 miles upstream of the confluence with Poplar Creek) show the piezometric surface to be in the 252.5- to 251-m (828- to 824-ft) range.

There is no current agricultural, industrial, or residential use of groundwater from the EFPC watershed study area. A memo dated September 17, 1992, confirmed that no groundwater wells for residential use currently exist on EFPC floodplain property (McCartney 1992).

2.1.3 Climate and Air Quality

This section includes discussions on climate and air quality.

2.1.3.1 Climate

Oak Ridge, Tennessee, is part of the southeast climatological region of the United States. This region is characterized by a moderate continental forest climate with mild winters [coldest month above 0°C (32°F) but below 18°C (64.4°F)]. The southeast region is consistently moist, with rainfall throughout the year (Espenshade 1980). The Oak Ridge area has a temperate climate with warm, humid summers and mild, cool winters. The Blue Ridge Mountains to the east and the Cumberland Plateau to the west have a protective and moderating influence on the area's climate (Fig. 2.3). As a result, the climate is milder than the more continental climate found just to the west on the Cumberland Plateau or on the eastern side of the Smoky Mountains. The mountains similarly divert hot, southerly winds that develop along the south Atlantic Coast. Slow-moving high-pressure cells, which may remain nearly stationary for days, suppress rain in the fall and provide mild weather. The atmosphere can be considered to be in inversion status 36% of the time.

Precipitation in this portion of the Tennessee Valley is seasonally distributed (McMaster 1967). Winter storms are generally of low intensity and long duration; brief, heavy rains associated with thunderstorms are common in the summer. Peaks in precipitation usually occur in late winter and early spring and in mid-late summer (Fig. 2.4). The annual minimum precipitation usually occurs in the fall. According to the local climatological data published by NOAA for Oak Ridge, Tennessee (NOAA 1991), the 30-year mean annual precipitation in the Oak Ridge area is 138 cm (54.2 in.). The 30-year mean annual snowfall is 25 cm (9.8 in.). In 1991, there were 81 sunny days, 127 partly cloudy days, and 157 days with full cloud cover.

An isohyetal map of the Oak Ridge area (Fig. 2.5) shows that mean annual precipitation ranges from >150 cm (59 in.) in the west to ~ 115 cm (45 in.) in the east. Rainfall is at a maximum near the Cumberland Plateau and decreases from northwest to southeast, reaching a minimum at the foot of the Blue Ridge Mountains.

Loss of water to the atmosphere by evapotranspiration is ~ 76 cm (30 in.) annually in the Oak Ridge area, or $\sim 55\%$ of the total annual precipitation. Evapotranspiration is at a maximum from July to September during the vegetative growing season. Runoff is greatest in the winter when evapotranspiration is low and precipitation is high. Precipitation not lost as evapotranspiration or as quick surface and shallow-groundwater runoff percolates through the soil and eventually recharges the deep groundwater system.

Year-round mean temperatures are about 15°C (58°F) with a January mean of about 3.5°C (38°F) and a July mean of about 25°C (77°F). The prevailing winds in the Oak Ridge area follow the general topography of the surrounding ridges: up-valley winds come from the southwest during the day, and down-valley winds come from the northeast at night (Fig. 2.6).

The average wind speed recorded for 1991 was 7.2 km/h (4.5 mph) with a predominant southwest wind direction. A maximum velocity of 94.9 km/h (59 mph) was recorded at NOAA in January 1959.

2.1.3.2 Air quality

Atmospheric contaminant concentrations occurring in the general environment around the ORR and the surrounding region are monitored or sampled continuously by an air monitoring network. Measurements of air concentrations of gross alpha, gross beta, fluorides, sulfur dioxides, total suspended particulates, and mercury indicate that the ORR operations are not measurably impacting the regional air quality. Ambient air monitoring of EFPC-specific locations for mercury also has been conducted by ORNL researchers at sites selected for known high mercury soil concentrations. This monitoring included both short-term high-sensitivity and long-term high-volume measurements. All concentrations were at levels similar to those at uncontaminated sites, indicating that mercury volatilization cannot be distinguished from background levels (Turner and Bogle 1992).

2.1.4 Land Use

EFPC and the SLB are within the city limits of Oak Ridge. Oak Ridge contains 238.3 km^2 (92 $miles^2$) and encompasses portions of two counties, Roane and Anderson. Approximately 74% of the property in the city is owned by DOE and is titled the Oak Ridge Reservation (ORR). Three DOE facilities are located on the ORR: the Oak Ridge National Laboratory, the Y-12 Plant, and the K-25 Site. The actual developed city of Oak Ridge is bounded by the ORR to the west and south, Black Oak Ridge to the north, and the Clinch River to the east.

Two main highways traverse Oak Ridge: State Highway 95 and State Highway 62. The portion of Highway 95 that runs through the developed area of Oak Ridge is called the Oak Ridge Turnpike; the portion of Highway 62 that runs through this area is called Illinois Avenue.

Land uses are divided into five categories for this study: Residential, Commercial, Agricultural, Other, and DOE-owned. The Residential land use category consists of single-family and multifamily housing units. Public educational facilities are included in this category because children are only considered in the residential exposure category of the RI. The Commercial category includes offices, restaurants, retail stores, meeting places, and other commercial establishments. The Agricultural land use category includes lands that are used for grazing, horse ranches, etc. No crops or family gardens are presently being grown within the floodplain proper. The Other category is similar to the open land use in the RI in that it contains those lands that may have incidental use and those lands that are vacant. The DOE-owned land use category includes all lands owned by DOE.

Land uses are regulated through a zoning ordinance administered by the City of Oak Ridge Department of Community Development, Planning Division. The city is divided into zoning districts; applicable zoning regulations determine the type and extent of development that can occur within each district. Any future land development that wants a variance other than the existing zoning district must present its case before the Board of Zoning Appeals. Building and other permits are also necessary to develop property.

A special zoning district exists for areas in floodplains. The Floodway District was established to ensure that major waterways, including EFPC, can carry abnormal flows of water in time of flood; to prevent increases in flood heights and damage; and to prevent loss of life and excessive damage to property. The boundaries of the Floodway District "are designated by hydraulic engineering criteria" and documented on several maps in the City of Oak Ridge Department of Community Development Office (zoning ordinance, City of Oak Ridge, 1989). Permitted uses in the Floodway District include parking lots, car lots, gardens, storage yards for equipment and materials not subject to major damage by floods, open-type recreational facilities, agricultural uses, and utilities (zoning ordinance, City of Oak Ridge). Construction is strictly regulated in the Floodway District, and no structures for human habitation are permitted.

The portion of the areas outside the Floodway District designation but within the areas covered by the maximum probable flood are classified as "Floodway Fringe" (zoning ordinance, City of Oak Ridge, 1989). The Floodway Fringe is not intended to restrict development but to advise potential users of flood risks. There are development regulations, such as extending fill dirt 7.6 m (25 ft) beyond any structure, that are intended to protect properties and prevent stream restrictions (zoning ordinance, City of Oak Ridge).

The land use maps presented in Appendix H were developed using the following method: (1) a windshield survey of each parcel was conducted; (2) each parcel was then classified into one of four land-use categories oriented toward the four RU designations in the FS; and (3) the City of Oak Ridge 1993 zoning maps and 1993 Comprehensive Plan were consulted.

Land uses along EFPC and the SLB will be described separately. EFPC originates within the Y-12 Plant area and flows ~23.3 km (14.5 miles) before its confluence with Poplar Creek near the K-25 Site. The stream flows northward, paralleling South Illinois Avenue until the intersection of South Illinois with Oak Ridge Turnpike, where it heads westward until its confluence with Poplar Creek. Approximately 25% of the stream passes through DOE property. Appendix H provides detailed maps of applicable land uses, parcel boundaries, the floodplain, the creek, and roads.

The headwaters of EFPC flow into Lake Reality at the Y-12 Plant. From there, EFPC travels a short distance, leaves DOE property, and enters privately owned property. From this point to the intersection of South Illinois and Oak Ridge Turnpike, the land uses are primarily commercial. Two businesses, K-Mart and Kroger, were constructed during the summer and fall of 1992; these stores were the first two developments to be constructed near EFPC since this study began. The developer used borrow soil from a large vacant parcel on the southern side of the stream as fill dirt for the foundations of the two buildings. This vacant parcel is primarily zoned for residential uses except for a small area zoned for general business. Other land uses near this stretch of the creek include an apartment complex, a condominium complex, single-family homes, a public housing area, and a public ballfield.

Next, the stream flows under Oak Ridge Turnpike, makes a slow 180-degree arc, and flows back underneath the Turnpike. Several commercial establishments are located in this area. Other land uses in the area include a public housing area, an apartment building, Robertsville Junior High School, a day care center, and a private school. The Oak Ridge Girls' Club (Girls', Inc.) recently purchased a property where public tennis courts are located. A softball field has been constructed, and future plans include construction of a recreation building.

After flowing back underneath Oak Ridge Turnpike, EFPC heads west and passes through several larger, primarily undeveloped properties, generally paralleling Oak Ridge Turnpike until it reenters the ORR. The stream passes through three large parcels; two are privately owned, and the other belongs to the city. The two properties are primarily zoned for residential use, and the city's property is zoned as a greenbelt. Development along this stretch of the stream has been limited by the owner's decision to develop the property slowly, the need to add fill dirt in places where the Floodway Fringe exists, and the knowledge that contaminants exist in the area. A cluster of three commercial businesses and an oil change facility was built in the fall of 1992. Since that time, the property owner has actively sought to lease other areas. Future land uses north of the stream will likely include commercial developments. The currently undeveloped and hilly area south of EFPC may be developed for residential uses in the future.

EFPC next flows through a large-lot residential area called Wiltshire Estates. The stream flows through six properties, one of which is used for horses. After leaving Wiltshire Estates, EFPC passes through a large property occupied by a residence and several horses. The next property, also very large, is the East Fork Horse Farm. Cattle and horses graze on the property. The property owner has sold one part of the parcel adjacent to Oak Ridge Turnpike to a convenience store, and another parcel is available for lease. The stream then crosses into city property, where it flows past the Big Turtle Park (primarily used for baseball and soccer) and the new Oak Ridge Sewage Treatment Plant. EFPC then enters property owned by the Oak Ridge Sportsmen's Association that is used as a shooting range.

EFPC then crosses under Gum Hollow Road and flows by a vacant parcel zoned for business uses, a residential development, and an apartment complex to the north and the Oak Ridge Country Club golf course to the south. The residential area is a mixture of single-family houses, duplexes, and quadplexes. The stream then flows through open fields, where plans are underway to convert the area north of Lower EFPC to a large-lot residential area.

EFPC then flows back under Oak Ridge Turnpike and reenters the ORR before its confluence with Poplar Creek. This area is primarily wooded and undeveloped.

As a result of recent activities along Lower EFPC, the land uses documented in Appendix H deviate in several instances from those identified in the Lower EFPC RI. A parcel that contains an apartment building was previously defined as half residential, half open space (for the area adjacent to the stream). In order to remediate the property consistently, it was determined to classify the entire parcel residential. A new K-Mart/Kroger shopping center was constructed near the corner of South Illinois Avenue and East Tulsa Avenue. This parcel was previously classified as half commercial, half open space; the entire parcel is now used for commercial purposes. A motel was constructed on a vacant parcel off South Illinois Avenue, resulting in change to a commercial land use.

Another reclassification includes a car wash business on West Tulsa Road on a parcel that was previously identified as open space. A new single-family residential area behind businesses on West Tulsa Road is being developed on a parcel previously identified as open space. A small portion of the area occupied by the Garden Apartments on Oak Ridge Turnpike was inadvertently classified as open space, not residential. The property at the corner of Jefferson Avenue and Oak Ridge Turnpike that was recently purchased by Girls', Inc. was assigned a conservative

residential classification because of the presence of children and the location adjacent to Lower EFPC.

2.1.4.1 Sewer Line Beltway

The SLB consists of 16 km (10 miles) of sewer lines, some of which were backfilled with soil from EFPC. The city of Oak Ridge maintains an easement along the SLB in case repairs need to be made. It is located primarily along EFPC from the Oak Ridge Sewage Treatment Plant to the intersection of South Illinois Avenue and Oak Ridge Turnpike. The land uses described for EFPC also apply to the SLB.

After passing underneath South Illinois Avenue, the SLB parallels an EFPC tributary with commercial land uses to the north and a vacant shopping center to the south. It then goes underneath Raccoon Road and passes through the grounds of the Oak Ridge Civic Center, which includes a running track, library, and recreation area. The running track area was remediated in the 1980s to remove mercury-contaminated soils. After exiting the Civic Center property, the SLB passes through a vacant parcel (zoned for business uses) and crosses the Turnpike to go near two churches, a bank, and a private school. The SLB then goes back across the Turnpike and passes by several restaurants and vacant parcels (zoned for business uses) and underneath a recently built shopping center, Manhattan Place. Next, the SLB passes by a residential area comprised of duplexes and then in front of a church. It then crosses Lafayette Avenue and heads south in front of a meeting hall and church. The SLB enters the city right-of-way at the intersection of Lafayette and Laboratory Road and continues through the city right-of-way until it terminates at the end of two branches.

The SLB passes by an office complex before turning west onto Emory Valley Road. It then follows Emory Valley Road past a vacant parcel and the Roane State Community College extension. Just past the college, the SLB separates into two branches. The southern branch continues along Emory Valley Road, passing by a meeting hall, a convenience store, and a neighborhood swimming pool and then by several single-family homes before reaching its terminus at a pumping station.

The northern branch follows Fairbanks Road and passes through a vacant lot (zoned for business uses), through a small city park, and then in front of Jefferson Junior High School. After passing the school, the SLB crosses Fairbanks Road and runs in front of a retirement home, a vacant building formerly used by the Fraternal Order of the Police, two businesses, and two animal clinics. The SLB then runs by a vacant parcel on Belgrade Road (zoned for business uses) before reaching its terminus at another pumping station.

2.1.5 Ecological Resources

Within the EFPC watershed, the ecological resources that could be affected by remedial activities on Lower EFPC and the SLB consist of the aquatic and terrestrial habitats, animals, and plants. These ecological resources comprise the creek, its tributaries, and the floodplain. Many species of migratory birds, as well as birds and mammals with large home or feeding ranges, could be affected, even though they may not be permanent residents of the EFPC floodplain. Section 2.1.5.1 discusses ecological resources in the aquatic ecosystem of EFPC; Sect. 2.1.5.2

discusses the terrestrial ecosystem. Linkages between the aquatic and terrestrial ecosystems are also discussed.

Information sources regarding aquatic and terrestrial ecological resources in EFPC include the EFPC OU RI report (DOE 1994a, Sect. 6, Ecological Risk Assessment); the addendum to the EFPC RI report (DOE 1994b); and the first and second reports on the Y-12 Plant Biological Monitoring and Abatement Program (BMAP) (Loar 1992; Hinzman 1992). The BMAP was initiated in May 1985 as required by the National Pollutant Discharge Elimination System (NPDES) permit issued to the Oak Ridge Y-12 Plant. Objectives of the BMAP include documentation of ecological effects resulting from implementation of a Water Pollution Control Program and consist of performing four major tasks, most of which are performed semiannually: (1) ambient toxicity testing, (2) bioaccumulation studies, (3) biological indicator studies, and (4) ecological surveys of stream communities, including fish, benthic macroinvertebrates, and periphyton. Additional data were obtained from various other technical reports, as indicated later in this section.

Six aquatic and six nearby terrestrial sampling sites for the EFPC ecological risk assessment, as shown in Fig. 2.7, were selected to represent a gradient of biological and physical conditions and allow comparison and contrast with historical data. The sampling sites are described in Sect. 2.5.2 (Ecological Risk Assessment). Because EFPC originates on the Y-12 Plant site, an aquatic reference site could not be obtained upstream from the EFPC OU. Thus a site on Hinds Creek, near Norris, Tennessee, was selected as the aquatic reference site. The Hinds Creek soil reference site was judged to be unsuitable for use as the terrestrial vegetation reference site because the surrounding vegetation is pasture, while most of the study sites along EFPC are forested. Thus, a site on Mill Branch, a tributary within the EFPC watershed, was selected as the terrestrial reference site. An expanded description of the aquatic and terrestrial reference sites is provided in Sect. 2.5.2 (Ecological Risk Assessment). In addition to the six EFPC sampling sites and two reference sites, three sites along the EFPC floodplain were sampled for grasses and browse. Grasses and browse were also sampled at the Hinds Creek reference site.

2.1.5.1 Aquatic habitats and biota

The aquatic ecosystem consists of the entire 23.3-km (14.5-mile) stretch of Lower EFPC surface water and sediments and its four habitat types (pool, riffle, run, other), plants, and aquatic biota. These components are discussed in the following subsections.

Aquatic Habitats (Including Surface Water and Sediments)

Surface water and sediments are the two primary physical media comprising the EFPC aquatic ecosystem. These two media provide the matrices that form the pool, riffle, and run aquatic habitat types in EFPC, which, in turn, support various plants and animals. These media are major exposure pathways for contaminants to resident organisms that utilize the media. Surface water is a highly mobile, transient medium containing a mixture of soluble and suspended contaminants from the Y-12 Plant and a variety of point and nonpoint sources outside the Y-12 Plant. Surface water is a medium of exposure for fish, crayfish, aquatic insects, bottom-dwelling organisms, such as some benthic macroinvertebrates, and algae or periphyton. It can also expose terrestrial mammals and birds that drink from creeks or eat aquatic animals. Sediments are the home for benthic macroinvertebrates and some fish species. Suspended

sediments provide an exposure source to biota living predominantly in the upper water column. During floods, terrestrial plants can also be exposed to contaminants in surface water by contact with dissolved contaminants and by deposition of contaminated suspended sediments. Characteristics of the surface water in Lower EFPC are discussed in Sect. 2.1.2.1 of this report. In addition, surface water samples were collected during the fish surveys conducted in October 1991 as part of the ecological risk assessment (DOE 1994a). Water quality characteristics for these samples are summarized in Table 2.1. Potential impacts to aquatic biota from these water quality parameters are discussed in Sect. 2.5.2.4 (Risk Characterization).

Habitat differences can account for differences in animal populations among sites. Similarities in habitat can minimize the variability in animal populations that can result from habitat-related differences, suggesting that other factors, including contaminant concentrations, could be the reason for population variations. During the preparation of the Lower EFPC ecological risk assessment in the spring of 1992, aquatic habitats for the entire length of Lower EFPC were identified and classified into four distinct types (pools, riffles, runs, and other) (DOE 1994a). Characteristics that define these four aquatic habitats are as follows:

- **pool:** stream section of deeper (compared to riffles or runs), slower-moving water that occurs in areas of relatively flat gradients. This usually occurs at bends in a channel. Velocity of current is reduced and can exhibit back-current at the surface. Pools generally have well-defined boundaries with bowl-shaped bottom areas and are characterized by deposition. Silt and other suspended materials tend to settle out in pools, forming a soft substrate suitable for burrowing organisms.

- **riffle:** section consisting of faster, shallower water than occurs in pools. Riffles typically occur in higher gradient reaches. Velocity of current is great enough to keep the bottom clear of silt and other loose materials, providing a firm substrate that is occupied largely by specialized benthic macroinvertebrates, periphyton, and some fish species. Riffles are distinguished from run areas by turbulent flow with disturbed/broken surface tension.

- **run:** section similar to riffle areas, but usually lower in velocity and gradient. A run exhibits a more laminar flow of water with little or no disruption of surface tension. Runs generally have a more constant depth than pools.

- **other:** log jams and other debris, small impoundments.

Aquatic habitats comprised a total of ~21 ha (52 acres). To facilitate evaluation of exposures in different EFPC habitats, the entire Lower EFPC was divided into 17 segments (Fig. 2.8). The segments were based on the EFPC Phase Ib sampling grid and were each ~1 km (0.6 mile) in width from east to west. The distribution and surface area of aquatic habitat type in each of the 17 segments are shown in Fig. 2.9. The area of runs in each segment increases downstream as the stream widens, and the majority of the pool areas are in the downstream half of the creek. There are riffle areas starting in the uppermost segments and continuing downstream to the mouth of the creek.

Riparian Habitats

The riparian zone of a stream includes the stream channel, left and right stream banks, and floodplain (Platts et al. 1983) and, as such, includes the area of transition between aquatic and terrestrial habitats and communities. Areas with abrupt changes between diverse communities are known as ecotones (Odum 1983) and often contain greater numbers and densities of some species than are present in either of the two communities comprising the ecotone. In addition, some organisms require, as part of their habitat or life history, both of the communities comprising the ecotone. For example, many insect families (which are present in EFPC) have larval stages that are aquatic and adult stages that are terrestrial (Baetidae, Chironomidae, Gomphidae, Heptageniidae, and Hydropsychidae).

For this report, riparian habitat is defined as the stream bank and a relatively narrow band [~10 to 30 m (11 to 33 yd) wide, depending on the floodplain width] of contiguous floodplain vegetation or land-use type parallel to the stream. Four types of riparian habitat are identified in this FS report: commercial/built-up, pasture, old field, and bottomland hardwood (Fig. 2.10). The quantity and quality of aquatic habitat, which affects the structure of resident biological communities, is somewhat influenced by the riparian habitat (Plafkin et al. 1989). For example, riparian vegetation provides cover and food for fish, helps stabilize stream banks, and intercepts and stores solar radiation (Platts et al. 1987). The influence of these attributes as they relate to aquatic habitat and/or aquatic biota, as well as the importance of the stream channel-bank angle (angle formed by the downward sloping stream bank as it meets the more horizontal stream bottom) is discussed in the following subsections.

Cover and Food. Riparian habitats that are well vegetated provide escape cover or resting security for fish by shading the stream and by creating refuge areas when branches, logs, stumps, and leaves fall into the stream. Stream banks where the dominant vegetation is shrub are the most desirable for fish (Platts et al. 1983; 1987). A streamside dominated by trees was considered next most desirable; a streamside in which the dominant vegetation is grass or forbs was less desirable, but better than no vegetation. In addition to cover, vegetation in riparian habitats provides indirect sources of food to many fish species. For example, the vegetation can attract numerous types of insects that land on or fall into the stream, providing food for insectivorous fish (Hunt 1975). Furthermore, some vegetation falls into the stream and is decomposed through microbial degradation. Microbial decomposition of the vegetation results in the production of coarse organic particulate matter, which is a food source for many benthic macroinvertebrates on which fish feed. In many small streams running through predominantly woodland habitats, riparian vegetation provides the major food supply (i.e., energy source) for the stream (Odum 1983; Platts et al. 1987). Of the 52,000 m (57,000 yd) of Lower EFPC riparian habitat, nearly 45,000 m (49,000 yd) is bottomland hardwood. Thus, the importance of riparian habitat vegetation with respect to cover and food for fish in Lower EFPC is clear.

Stream Bank Stabilization. Stream banks that are well vegetated are usually stable, regardless of bank undercutting. Bank undercutting provides excellent cover for fish and is often considered a condition favorable to producing high biomass of fish (Platts et al. 1983). However, as stream bank vegetation decreases, the banks tend to erode severely and can also be undercut too quickly and slough off into the stream bottom. If the stream bank erodes too quickly, the advantages of bank undercutting are lost, and increased siltation can occur, with detrimental

impacts to fish and benthic macroinvertebrates (Sect. 5.4.2.5). Thus, well-vegetated stream banks are highly desirable for protecting instream aquatic habitat and its biota.

Stream Channel-Bank Angle. Fish tend to congregate near the stream banks (especially if they are well vegetated) because the riparian habitats provide cover and food, as described in the preceding paragraphs. Stream channel-bank angle is an important property of the riparian habitat; if the stream bank is cut away or moved back from the water column, cover and sources of food for fish are diminished.

Interception of Solar Radiation. The type and amount of riparian vegetation affects the amount of solar radiation that reaches the stream. Unshaded streams in the United States commonly receive 1.2 to 1.8 $\times$ 10^6 kcal/m^2/year of sunlight, whereas shaded streams may receive $<10\%$ of the total available light (Platts et al. 1987). The amount of solar radiation entering a stream directly influences the water temperature, which is an important factor regulating biological activity in the stream (Platts et al. 1983).

Reduction or absence of riparian vegetation can allow increased solar radiation input to the stream, which can result in two types of deleterious impacts to aquatic organisms. First, fish may be harmed by rapid increases in water temperature following removal of riparian vegetation (especially forest) (Platts et al. 1983;1987). Second, increased sunlight to the stream could lead to increased blooms of undesirable algae, which could affect nutrient cycling and instream habitat structure (Ohio EPA 1988a). More specifically, because nutrients are tied up in the production of undesirable algal blooms, they are unavailable for the production of aesthetically desirable biota. In addition, algal blooms can reduce the availability of bare gravel substrate required for lithophilic spawning fish (species that require bare gravel for spawning), thereby potentially reducing the abundance of those fish species.

Conclusions. The riparian zone includes the area of transitional changes in the habitats and communities comprising a stream and its adjacent terrestrial environment. Riparian vegetation provides cover and food for fish, helps stabilize stream banks, and intercepts solar radiation, all of which are beneficial for instream biota. Thus, riparian zones and the habitat type(s) and vegetation comprising them are important components for the aquatic biota in the stream, and the destruction or modification of riparian habitat can have direct negative influences on those biota.

Aquatic Biota

Fish. Fish are the predominant representative aquatic vertebrates residing in the water column in EFPC. Fish are important components of the aquatic ecosystem for several reasons. First, fish represent consumers at several trophic levels (i.e., steps within the aquatic food chain). For example, central stonerollers (stonerollers) (*Campostoma anomalum*) feed almost exclusively on periphyton (which is largely composed of algae). Thus, stonerollers are generally considered primary consumers because they feed mostly on plant material. Redbreast sunfish (*Lepomis auritus*) may ingest some plant material but feed primarily on animals such as insects, crayfish, worms, etc. Thus, redbreast sunfish are examples of secondary consumers. Largemouth bass (*Micropterus salmoides*) feed primarily on other fish and are an example of the top predator in EFPC. The trophic structure is important because it represents the one-way flow of energy for the ecosystem. Second, fish are sources of food for some predatory or scavenger birds and mammals. Third, fish have social and recreational value.

Species Richness

During October 1991, Science Applications International Corporation (SAIC) conducted fish population surveys at six sites in Lower EFPC and one reference site in Hinds Creek (Fig. 2.7) (DOE 1994a). Twenty-two species plus one hybrid sunfish were collected from the six sites in EFPC, compared to 14 species from the single sampling site at Hinds Creek (Table 2.2). Table 2.3 summarizes the family names, common and scientific names, relative abundances, population estimates and 95% UCL intervals, and tolerance classifications (defined in next paragraph) for all fish species captured in EFPC and Hinds Creek. Only one of the species collected at the reference site [the stripetail darter (*Etheostoma kennicotti*)] was not captured at any of the EFPC sites. Nine species were captured in EFPC that were not found at the reference site. The number of species captured at each of the six EFPC sampling sites ranged from 8 to 12 and was always less than at the reference site. Sites 2 and 3 yielded the fewest species (43 and 37% less than the reference site, respectively), whereas the remaining EFPC sites each yielded 22% or fewer species than the reference site. The number of species captured increased progressively downstream, from 8 at Site 2 to 12 at Sites 5 and 6. It is noteworthy that, although taxonomic richness (and presumably diversity) might be expected to increase in a typical stream as its drainage area or stream order increase (Fausch et al. 1984), the argument may be less applicable to EFPC because it does not possess the characteristics of a true headwater stream because of the augmented flow from the Y-12 Plant. Therefore, the increased taxonomic richness and diversity downstream from the Y-12 Plant probably results more from the reduction in toxicant concentrations downstream than from the increase in drainage area.

Tolerant fish species are defined as those better adapted to survive in various conditions of degraded water quality, including both physical (i.e., habitat) and chemical degradation (including toxicant exposure) (Plafkin et al. 1989; Ohio EPA 1988a). A fish community dominated by tolerant species indicates degraded environmental conditions.

Tolerant fish species comprised nearly 75% of the species captured at Site 1, but steadily decreased downstream to 17% of the species captured at Site 6 (Table 2.2). Of the species captured at the reference site, 29% were tolerant species. The decrease in percentage of tolerant species downstream from the Y-12 Plant suggests a gradual improvement in water quality with increased distance from the plant. Although the percentage of tolerant species captured at Sites 5 and 6 in EFPC was less than at the reference site, the relative abundance of all tolerant species at the reference site was still less than at any of the EFPC sites.

Striped shiners (*Luxilus chrysocephalus*) and stonerollers were the dominant species at every site except Site 6 (Fig. 2.11); their combined relative abundances ranged from 64 to 94%. Striped shiners and bluntnose minnows (*Pimephales notatus*) were the two dominant species at Site 6, having combined relative abundances of 55%. The relative abundance of redbreast sunfish generally increased downstream from Site 1 but decreased at Site 6 and was very low at the reference site (<1%).

The BMAP studies (Hinzman 1992) reported more total species in EFPC (i.e., 30 versus 22) and generally more species per site than were reported in the EFPC ecological risk assessment (DOE 1994a). However, the BMAP sampled biannually from 1986 to 1988, whereas the

ecological risk assessment sampled only once in the fall of 1991. The increased number of samples over a longer period of record in the BMAP investigations could have resulted in the larger number of observed species.

Trends for species richness and composition in the ecological risk assessment (DOE 1994a) were similar to historical results for EFPC reported during the BMAP (Hinzman 1992). Both studies reported that species richness generally increased downstream from the Y-12 Plant. In both studies, common stonerollers and striped shiners were the dominant species.

Abundance (Density)

Fish population density varied considerably among the six EFPC sites (Table 2.2) (DOE 1994a). Sites 3 and 1 had the greatest estimated fish densities. Both sites had over 16 fish/10 m^2, which was nearly double the reference site fish density of 9.34 fish/10 m^2. Site 2, located between Sites 1 and 3, yielded an estimate of only 4.35 fish/10 m^2. The remaining downstream sites in EFPC (from Site 4 to Site 6) had decreasing population density estimates, ranging from 2.78 to 0.43 fish/10 m^2.

Total fish densities (DOE 1994a) were considerably less than those reported during the BMAP investigations from 1985 through 1988 (Loar 1992; Hinzman 1992). For example, mean total fish densities during BMAP studies conducted from 1986 through 1988 ranged from 35.4 fish/10 m^2 at East Fork Kilometer (EFK) 23.4 (near Site 1) to 2.2 fish/10 m^2 at EFK 6.3 (between Sites 5 and 6). However, a general trend of decreasing fish density with increasing stream size and downstream distance from the Y-12 Plant was observed in the ecological risk assessment and the second BMAP study.

Diversity

Species diversity, expressed as the Shannon-Wiener Diversity Index, progressively increased downstream from Site 1, except for a decrease at Site 3 (Table 2.2) (DOE 1994a). Only the EFPC site farthest downstream had a greater species diversity index than the reference site. The lowest diversity indices were observed at the three ecological risk assessment sampling sites located the shortest distance downstream from the Y-12 Plant, where the highest surface water mercury concentrations were observed.

Benthic Macroinvertebrates. Benthic macroinvertebrates are a major taxonomic component in EFPC. They perform several important functions, including mineralizing and recycling organic matter and serving as food for other organisms, especially fish (Lind 1979). Benthic macroinvertebrates that live in or on sediment will have maximum potential for exposure to sediment porewater- and sediment-bound contaminants. As a result, they are susceptible to direct toxic effects from contaminants present in these media. In addition, these organisms may bioaccumulate contaminants. Thus, when they are fed upon by predators, they can pass the contaminants up the food web and/or present a toxicological risk to predators. Crayfish and other benthic invertebrates are found on the substrate surface, living on cobble or in stream litter. Crayfish are omnivorous and scavenge on worms, dead fish, and plant debris. Therefore, crayfish can be exposed to and bioaccumulate contaminants.

Taxa Richness

During October 1991, SAIC conducted population surveys of benthic macroinvertebrates at six sites in EFPC and one reference site at Hinds Creek. Twenty-two different families of benthic macroinvertebrates were collected from the six sites in EFPC, compared with fifteen families from the single site in Hinds Creek. Table 2.4 summarizes the taxonomic and functional feeding group classifications, number of individuals per family, tolerance values, and relative abundances of benthic macroinvertebrates captured in Lower EFPC and in Hinds Creek [functional feeding group classifications for the aquatic insects were based on the designations of Merritt and Cummings (1984)]. Oligochaete worms were also collected in Lower EFPC but were not enumerated because individuals were torn into too many pieces during capture to accurately count the number of whole individuals. The majority of families collected from Lower EFPC (15 of 22) as well as from Hinds Creek (12 of 15) were insects. Two families collected at the reference site, Taeniopterygidae (Plecoptera) and Limnephilidae (Trichoptera), were not found at any of the Lower EFPC sites. Nine families found in EFPC were not collected at the reference site (Table 2.4).

The number of families collected at each of the 6 EFPC sites, ranging from 7 to 14, was always less than the number collected at the reference site, which was 15 (Fig. 2.12). Total family richness was lowest at Site 1 (at 54% less than at the reference site), increased downstream to Site 4, decreased to 40% of the reference site total at Site 5 and increased to 80% of the reference site total at Site 6.

The Y-12 Plant BMAP studies (Hinzman 1992) reported 19 more families in EFPC than were observed during the ecological risk assessment (DOE 1994a). However, the BMAP study sampled monthly from June 1986 through May 1987, versus one sampling in the fall of 1991 for the ecological risk assessment. The increased number of samples over a longer period of record in the BMAP investigations could explain the larger number of observed families.

Although more families were captured during the Y-12 Plant BMAP investigations than during the ecological risk assessment, three trends were observed in both studies. First, total richness was less at all EFPC sites than at the respective reference sites (i.e., Brushy Fork or Hinds Creek). Second, total richness was lowest at the sites nearest the Y-12 Plant. Finally, total richness increased downstream from the Y-12 Plant, reaching a maximum at EFK 13.8 in the BMAP studies (Hinzman 1992) or at Site 4 (EFK 10.8) (DOE 1994a), then decreased slightly further downstream.

The number of mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) insect families (EPT families) were summed to determine total EPT richness, which is a biotic indicator of water quality. Although some families from these three orders are tolerant of degraded water quality conditions (including chemical pollutants), most are sensitive to degraded water quality conditions, especially families in the order Plecoptera. Total EPT richness is, therefore, expected to be lower in degraded streams.

Total EPT richness was lower at all six EFPC sites than at the reference site (Fig. 2.12) (DOE 1994a). The lowest total EPT richness in EFPC was observed at Site 1, with only one family present. The remaining sites in EFPC each hosted three or four EPT families, compared

with seven found at the reference site. Sites in EFPC not only contained fewer families than the reference site but also had a larger proportion of non-EPT (i.e., tolerant) families (Fig. 2.12).

Some trends for total EPT richness in the ecological risk assessment were similar to those reported in the Y-12 Plant BMAP investigations, whereas other trends were dissimilar (Loar 1992; Hinzman 1992). In all studies, total EPT richness was lower at every EFPC site than at the reference site. Total EPT richness was lowest at the site nearest the Y-12 Plant during both investigations. The pattern of total EPT richness downstream from the Y-12 Plant was dissimilar, however, in the two studies. The BMAP studies reported that the downstream trend for total EPT richness was similar to the trend for total taxa richness, that is, generally increasing downstream to EFK 13.8, then decreasing downstream to EFK 6.3 (Hinzman 1992). However, total EPT richness during the ecological risk assessment increased from Site 1 to Site 2, then remained nearly constant for the remainder of the downstream EFPC sites. The pattern for total EPT richness in this investigation suggests that all of the sample sites in EFPC have degraded conditions in relation to the reference site and that Site 1 is the most degraded.

The dominant invertebrate families collected during the ecological risk assessment (DOE 1994a) were families from either Trichoptera, Ephemeroptera, or, at Site 6 only, Pelecypoda (Fig. 2.13). Hydropsychidae (Trichoptera) was the dominant family at Sites 1, 2, 4, and 5 and at Hinds Creek, ranging from ~25% to 84% of individuals (Fig. 2.13). Heptageniidae (Ephemeroptera) was the most dominant family at Site 3, at 70%, and was also a co-dominant at Sites 4 and 5 and at Hinds Creek. Tricorythidae (Trichoptera) and Corbiculidae (Pelecypoda) were the dominant families at Site 6, having combined relative abundances of 78%.

All of the sites sampled in EFPC had benthic communities dominated by one or two families. According to Plafkin et al. (1989), a benthic community dominated by relatively few families indicates environmental stress.

Benthic macroinvertebrate community composition during the ecological risk assessment varied greatly from the results during the Y-12 Plant BMAP studies in three respects. First, the BMAP studies found that chironomid relative abundance was greatest at the three sites upstream from EFK 13.8. In the ecological risk assessment, however, chironomids were absent at two sites in EFPC and at the reference site and were 8% of the individuals at the remaining EFPC sites. Diptera (especially Chironomidae) were the most abundant insects found during the BMAP studies and were the dominant taxon at five of the six EFPC sites, representing >61% of all individuals (Hinzman 1992). Second, the BMAP studies reported that Trichoptera were rarely collected at sites above EFK 13.8 or at EFK 10.6, having relative abundances <0.9%. During the ecological risk assessment, Trichoptera constituted 84% of individuals at Site 1, 74% at Site 2 (4.6 and 3.7 km, respectively, upstream from EFK 18.2), and 57% at Site 4 [~200 m (656 ft) upstream from EFK 10.6]. Third, Hinzman (1992) stated that mollusks were rarely collected at any EFPC site except EFK 13.8, where they were only about 2.7% of the total density. In contrast, mollusks (Gastropoda and Pelecypoda) ranged from 5 to 35% of individuals at the six sites in EFPC during the ecological risk assessment (DOE 1994a). Potential reasons for these differences are discussed in the following three paragraphs.

The differences in community composition between the Y-12 Plant BMAP investigations and the ecological risk assessment suggest that the benthic macroinvertebrate community composition in the sampled areas in EFPC has changed since 1987. However, the ecological risk assessment

supports the conclusions from the second BMAP report (Hinzman 1992) and suggests that the benthic communities in EFPC still (1) are dominated by large numbers of individuals from only a few families, (2) are dominated by tolerant organisms, (3) have less total taxa or EPT richness than the reference stream, and (4) have lower diversity than the reference stream. Thus, the benthic communities in lower EFPC appear to be environmentally stressed.

Abundance (Density)

Benthic macroinvertebrate density during the ecological risk assessment (DOE 1994a) varied considerably among the six EFPC sites and did not follow a consistent trend (Fig. 2.12). Site 2 had the highest density at 339/m^2, nearly twice that of the reference site (186/m^2). Sites 3, 4, and 6 yielded the lowest densities (67 to 73/m^2), whereas Sites 1 and 5 had densities similar to that of the reference site. The variation in densities among the EFPC sites may be attributable to differences in physical and/or chemical characteristics at the sites. Also, the three sites having lowest densities each had a unique feature that may have influenced benthic macroinvertebrate density. Site 3 had been physically disturbed 4 weeks prior to the sampling. Site 4 was downstream from the Oak Ridge Sewage Treatment Plant, and Site 6 was just downstream from the confluence of Bear Creek and EFPC.

Densities of benthic macroinvertebrates reported in the ecological risk assessment (DOE 1994a) were generally an order of magnitude lower than those reported in the second BMAP study (Hinzman 1992). Mean annual density of benthic macroinvertebrates (including all taxa) during the BMAP studies June 1986 through May 1987 ranged from 595.0/0.1 m^2 at EFK 13.8 (between ecological risk assessment Sites 3 and 4) to 105.7/0.1 m^2 at EFK 6.3 (between ecological risk assessment Sites 5 and 6). Several factors could account for the dramatic reduction in observed densities between the two investigations, including (1) natural seasonal variability, in combination with between-site differences in physical factors such as substrate and stream flow characteristics; (2) differences in sampling efficiencies between field crews as the result of potentially different levels of effort; and (3) differences in the efficiency of processing samples in the laboratory.

Diversity

Family diversity, expressed as the Shannon-Wiener Diversity Index, was lower at all six EFPC sites than at the reference site. The diversity index was lowest at Site 1, then progressively increased downstream to Site 4 before slightly decreasing at Sites 5 and 6. The three ecological risk assessment sampling sites in EFPC that were closest to the Y-12 Plant had the lowest diversity indices for benthic macroinvertebrates and the highest mercury concentrations in surface water.

Diversity values and trends for benthic invertebrates during the ecological risk assessment (DOE 1994a) were similar to those reported in the second BMAP study (Hinzman 1992). Both studies show that the diversity index was lower at every site in EFPC than at the reference site. In addition, both studies reported that the lowest diversity index occurred nearest the Y-12 Plant. Lastly, both studies observed that the diversity index increased downstream from the Y-12 Plant, reaching a maximum at Site 4 (EFK 10.6), near the Oak Ridge Sewage Treatment Plant.

Periphyton. Periphyton is a complex matrix of algae and heterotrophic microbes attached to submerged surfaces. Periphyton serves as a major food source for many stream invertebrates and herbivorous fish (Loar 1992). Since the biotic component of periphyton may replace itself in a matter of days, the periphyton community is useful for detecting short-term environmental changes. In addition, because the periphyton community is sessile and continually exposed to ambient stream conditions, bioconcentration observed in periphyton is a good indicator of instream toxicants.

Colonization Rate

Periphyton colonization rate varied considerably among the sites in EFPC, with chlorophyll *a* ranging from 0.006 to 0.712 $\mu g/cm^2/d$. Four of the sites in EFPC, including the three sites closest to the Y-12 Plant, had colonization rates greater than or equal to the rate at the reference site. Site 3 had the highest colonization rate, more than sevenfold greater than at the reference site. The lowest colonization rate was observed at Site 4. The site farthest downstream from the Y-12 Plant, Site 6, had a colonization rate ~50% greater than that of the reference site.

Periphyton colonization rate is influenced by many factors, including concentrations of dissolved nutrients, current velocity, irradiance, substrate, grazing pressure, and species composition of the propagule pool (the physical source of individuals potentially available to colonize a new substrate). The propagule pool directly relates to the species availability, dispersal ability, and performance regarding ecophysiology, life history strategies, and competitive abilities and is also influenced by instream physical and chemical conditions.

The high colonization rate at Sites 1, 3, and 6 suggests that the propagule pool is dominated by pioneer species having high reproduction rates and short generation times, whereas Sites 4 and 5 are populated by more effective late colonist species.

Standing Crop

Periphyton standing crop or biomass, whether expressed as ash-free dry weight or chlorophyll *a* per cm^2, varied among sites in EFPC and generally followed the same pattern observed for colonization rates. For both measures, only Sites 4 and 5 in EFPC were lower after 14 d than at the reference site. However, after 21 d, both measures at Sites 3, 4, 5, and 6 were much lower than at the reference site, with the exception that ash-free dry weight at Site 4 did exceed the reference site.

In general, periphyton biomass was greater at the three sites closest to the Y-12 Plant (DOE 1994a). This trend was also reported in the second BMAP report for the Y-12 Plant after examination of periphyton attached to rocks in EFPC (Hinzman 1992). Although the greater growth of periphyton at sites closest to the Y-12 Plant might suggest that these sites have unstressed, structurally and functionally desirable periphyton communities, the opposite may actually be true. Periphyton communities in highly stressed environments appear to be more resistant to disturbance than those growing in low-stress environments (Steinman and McIntire 1990) and are quicker to recover, in terms of biomass. However, it is unknown whether periphyton taxonomic structure and functional processes recover as quickly. Therefore, periphyton biomass may not be the best indicator of lotic ecosystem recovery.

Aquatic and Terrestrial Ecosystem Linkages

Erosion and surface runoff are the major pathways for transport of contaminants within the EFPC floodplain and out of the floodplain system. During storms, soil may erode into EFPC, where it can be transported downstream, subsequently settling out as instream sediment or as new alluvial deposits. Nonpoint sources throughout the watershed can contribute contaminants that may accumulate in sediment in the tributaries and be washed into EFPC. Instream sediments can be scoured and redeposited further downstream or are washed into Poplar Creek and the Clinch River. A correlation has been demonstrated between both flow rates and sediment concentration and bulk transport of mercury in EFPC (TVA 1985). Soluble contaminants may leach from the soil into surface runoff or shallow groundwater, which can transport them to the creek.

Uptake of contaminants by plants and animals may result in migration of contaminants from place to place within the floodplain and out of the system. For example, soil contaminants may be incorporated by worms and insects, which are consumed by small mammals and birds, which may move about in the floodplain and outside it. Plants may incorporate contaminants by root absorption and subsequently be eaten or die and be washed downstream to be redeposited or removed from the system. The movement of biota, especially animals, is probably an important mechanism for transport of contaminants in the EFPC floodplain. During floods, terrestrial plants can also be exposed to contaminants in surface water by contact with dissolved contaminants and by deposition of contaminated suspended sediments. Terrestrial animals can be exposed via contact with and ingestion of contaminated surface water and/or sediments. Terrestrial piscivorous or scavenging birds (e.g., great blue herons and belted kingfishers) and mammals (e.g., raccoons, mink, opossums) can receive contaminant exposures through the food chain by consumption of aquatic biota.

Amphibians and Reptiles. Amphibians and reptiles are discussed in the aquatic and terrestrial linkage section because many of the herpetofauna species utilize both ecosystems. Nearly all of the herpetofauna indigenous to the ORR area are found in or near water, including wetlands.

Herpetofauna surveys were not conducted during the ecological risk assessment (DOE 1994a). However, a survey of herpetofauna of the ORR was conducted by Johnson (1964) and was summarized by Kitchings and Mann (1976). Johnson described six habitat types (Appendix G, Table G.1) and a total of 61 different herpetofauna species associated with one or more of these habitat types (Appendix G, Table G.2) (Kitchings and Mann 1976). The herpetofauna species included 13 toads and frogs, 12 salamanders, 9 turtles, 19 snakes, and 8 lizards. Because each of the habitat types described by Johnson is present in the EFPC floodplain, it is reasonable to assume that these findings are still relevant and any of these species could occur in its respective habitat along EFPC.

2.1.5.2 Terrestrial habitats and biota

The terrestrial ecosystem consists of the entire 23.3-km (14.5-mile) floodplain of Lower EFPC. Soil and air are the primary physical media in the EFPC terrestrial ecosystem. Exposure of plants and animals to contaminants in soil and attendant vegetation varies according to the feeding habits of the organisms. Each component is discussed below.

Terrestrial Habitats. During the ecological risk assessment (DOE 1994a), terrestrial habitats in the EFPC floodplain were identified and their areas were tabulated to make it easier to estimate exposure of plants and animals of different types to contaminants in soil. Terrestrial habitats were identified and classified by type for the entire length of EFPC (using the 100-year floodplain as the boundary). A total of 254 ha (627 acres) was identified as terrestrial habitat consisting of a variety of cover types (Fig. 2.14). The cover types (more broadly grouped as built-up, forest, and field) are described as follows:

- **Built-up**
  - **Commercial:** Pavement, parking lot, or riprap.
  - **Fill:** Area of natural floodplain that has been filled but is not currently in commercial use.
  - **Right-of-way:** Utility right-of-way, typically mowed once a season, sometimes mowed every other year. Grasses, forbs, shrubs, and small trees are present.
  - **Transportation:** Road.
- Forest
  - **Bottomland Hardwood Forest:** Forest dominated by tree species well adapted to growth in deep, alluvial soil along a stream subject to periodic flooding.
  - **Hardwood Plantation:** Planted forest of nonconiferous trees. Understory varies depending on the degree of canopy closure.
  - **Pine Plantation:** Planted forest of pine trees, typically loblolly and white pine. Understory is typically sparse in mature stands but more diverse if some areas have been harvested without replanting.
  - **Upland Forest:** Mixed forest growing on the edge of the floodplain or in upland areas adjoining the floodplain.
- Field
  - **Grass:** Grass that is cut periodically. It is not necessarily a monoculture of grass; it may have many forbs present. It is not used for recreation.
  - **Lawn:** Maintained lawn in recreational use (e.g., a golf course or residential lawn).
  - **Old Field:** Former agricultural or pasture lands dominated by grasses and forbs. Tree and shrub seedlings typically are present. It is neither grazed nor mowed.
  - **Pasture:** Open, grassy areas used for grazing by cattle or horses.

The majority of the terrestrial habitats are bottomland hardwoods (50%); right-of-way and transportation corridors (<0.4%) are the smallest two types. The other habitats are intermediate in areas as shown in Fig. 2.14. Wetlands are areas that meet all three wetland criteria [presence of hydrophytic vegetation, hydric soil, and wetland hydrology (COE 1992)] and are discussed in more detail in Sect. 2.1.5.3.

Terrestrial Biota

Large Mammals. Population surveys of large mammals were not conducted during the ecological risk assessment (DOE 1994a). However, a survey on the terrestrial ecology of the ORR (Kitchings and Mann 1976) listed large mammals present in various habitats on the ORR. Fifteen species were identified as occurring on the ORR and thus could be expected to occur in similar habitat areas in the EFPC floodplain. The list of potential expected species includes opossum (*Didelphis marsupialis*), raccoon (*Procyon lotor*), white-tail deer (*Odocoileus virginianus*), bobcat (*Lynx rufus*), mink (*Mustela vison*), three species of squirrels, red and grey foxes (*Vulpes fulva* and *Urocyon cinereoargenteus*), woodchuck (*Marmota monax*), striped skunk (*Mephitis mephitis*), long-tail weasel (*Mustela frenata*), eastern cottontail (*Sylvilagus floridanus*), muskrat (*Ondatra zibethica*), and beaver (*Castor canadensis*).

Small Mammals. Small mammal population surveys were conducted in the fall of 1991 during the ecological risk assessment (DOE 1994a). Four small mammal species were captured among the seven sites (six in EFPC and one reference site in Mill Branch). The four species included the white-footed mouse (*Peromyscus leucopus*), shorttail shrew (*Blarina brevicauda*), woodland vole (*Microtus pinetorum*), and eastern chipmunk (*Tamias striatus*). Not all species were captured at each site. The white-footed mouse was the species captured most often, with only Site 6 lacking a white-footed mouse capture. The shorttail shrew was captured only at Sites 4 and 5, and the woodland vole and eastern chipmunk were captured only at Site 4.

Sites 1, 4, and 5 exhibited similar abundance of all small mammal species (Table 2.5). Although Site 1 had the highest abundance index (at 5.25), only the white-footed mouse was captured at this site. Differences in habitat diversity, the length of edge or boundary between habitat types, and short interhabitat patch distances could account for the relatively high abundance index generated at Site 1. Site 4, having an abundance index of 3.44, had a total of four captured species. The species with the greatest number of individuals captured was the white-footed mouse. Site 5 had captures of the white-footed mouse and shorttail shrew and an abundance index of 4.19.

Sites 2 and 3 yielded abundance indices of 1.88 and 1.91, respectively. Both had captures of only the white-footed mouse. Although Site 2 yielded only four individuals, the third lowest number of white-footed mice captured, the abundance index was fourth highest of the seven sites. An unusually high percentage of traps were disturbed throughout the trapping period at this site, often approaching 80% on any given night. The habitat at Site 3 was somewhat different from the other sites (an "early-stage" old field). Areas in a slightly later successional stage located in an adjacent county yielded abundance indices of 3.49 and 3.41 during February 1991 and included the golden mouse (*Peromyscus nuttalli*) and the harvest mouse (*Reithrodontomys humulis*) (Hnilicka and Wenzel 1991). At Site 3, several traps were visited but left untripped. The fecal pellets on and within these traps indicated that these visits probably were made by harvest mice. The habitat at this site contained a large percentage of grass cover that could be

expected to be inhabited by woodland voles. The absence of this species, as well as that of the shorttail shrew, is notable. A previous study involving the trapping and removal of shorttail shrews from a portion of this site was conducted a year before this survey.

A single shorttail shrew was captured once at Site 6, resulting in the lowest abundance index (0.37) in the survey. The absence of other species of small mammals at this site, especially of the white-footed mouse, is notable. In a similar study performed in an adjacent county during February 1991, Hnilicka and Wenzel (1991) reported abundance indices of 2.86 and 0.60 from grids located in a 3-year-old sweetgum plantation where the groundcover had been controlled by herbicide application.

The reference site at Mill Branch yielded an abundance index of 1.11, roughly three times that of Site 6 but only one-fourth of that of Site 1. Only the white-footed mouse was present at the Mill Branch site.

A survey on the terrestrial ecology of the ORR (Kitchings and Mann 1976) listed 13 species of small mammals and 9 species of bats present in various habitats on the ORR. It is reasonable to assume that any of these species could also occur in similar habitats in the EFPC floodplain.

Birds. Bird populations on the lower EFPC floodplain were studied in the fall of 1991 during the ecological risk assessment (DOE 1994a). Birds were counted at six sites on EFPC and at one reference site on Mill Branch. Eleven counts were made at all sites between September 26 and November 10, 1991. During the fall in Tennessee, most birds are not spatially distributed in territories and often group in flocks. On any one day, there may be no individuals of a species present on a given site, whereas on the next day, a flock of several individuals may be present. In addition, many migrants could occur for brief periods. The data illustrate the variety of species encountered and indicate possible trends in abundance, but insufficient samples were obtained to determine accurate population estimates (DOE 1994a).

During the ecological risk assessment, 552 birds representing 45 species were counted on Sites 2, 3, 4, 5, and 6 on EFPC and on the Mill Branch reference site (Appendix G, Table G.3). Because of the low numbers of individuals of some species and the fact that many species were migrants, only those species that are known to be permanent residents and that were found in relatively high numbers (i.e., >25 birds counted during the study) were evaluated for possible trends. These species, hereafter designated as "high-population species," are listed in Table 2.6. The presence of birds indicates that conditions are not acutely lethal. Although possible, it is considered unlikely that birds observed on the EFPC floodplain are being exposed to acutely lethal concentrations of contaminants and dying later off site.

As shown in Table 2.6, Sites 2, 3, 4, 5, and 6 on EFPC had higher total numbers of individuals of high-population species than did the Mill Branch reference site, with Sites 2 and 3 having more than twice as many birds and Site 4 having more than three times as many. This is probably because the Mill Branch site had a predominantly upland mesophytic plant community habitat rather than the lowland bottomland habitat found along EFPC. Lowland bottomland habitats typically have higher bird populations than upland areas. The fact that the Mill Branch site was not a suitable reference area for the terrestrial biotic study hindered comparisons with EFPC as to the abundance and distribution of organisms; however, the Mill Branch site was satisfactory in its lack of chemical contamination.

Bird populations at the EFPC sampling sites tended to be higher in the more contaminated areas. However, these differences were probably attributable to the diversity of habitats in these areas (DOE 1994a). In areas where diversity of habitat was highest, the numbers of bird species and individual birds were also highest. Table 2.6 shows that total numbers of individuals for the two species with the largest populations [the Carolina chickadee (*Parus carolinensis*) and Carolina wren (*Thryothorus ludovicianus*)] were higher on Sites 2, 3, and 4 (the most contaminated sites at which birds were counted) than on Sites 5 and 6 (the least contaminated EFPC sites) and at the Mill Branch reference site. An exception to this trend was the Carolina wren, whose numbers were slightly higher on Site 6 than on Sites 2, 3, and 4.

Thirty-nine individuals and ten species were counted on Site 1 (Appendix G, Table G.4). Because the birds on Site 1 were counted by a different sampling method using a different sample size area than that for other sites, the results cannot be compared directly with data from the other sites. However, the data do indicate that birds were using the area, and that some of the most abundant species of birds on other EFPC sites (e.g., the Carolina chickadee, tufted titmouse, and Carolina wren) were also the most abundant birds on Site 1.

A survey on the terrestrial ecology of the ORR (Kitchings and Mann 1976) listed bird species present in various habitats on the ORR (Appendix G, Table G.5). The 152 species identified in this survey did not include six species reported during the ecological risk assessment survey (DOE 1994a) (i.e., yellow-billed cuckoo, chimney swift, Tennessee warbler, yellow-rumped warbler, hooded warbler, and Canada warbler). The birds of Knox County were reported by Howell and Monroe (1957) to consist of the following number of species: permanent residents, 52; summer residents, 51; winter residents, 42; migrants, 65; visitants, 13; and accidental, 9. It is reasonable to assume that any of these species could potentially occur at appropriate habitat in the EFPC floodplain.

Insects. Flying insect population surveys were conducted in the fall of 1991 during the ecological risk assessment (DOE 1994a). Trapping was conducted for six nights at each of the six sampling sites within the EFPC floodplain and for four nights at the Hinds Creek reference site, using ultraviolet collection equipment.

A total of 135 families from 19 arthropod orders were collected. Three of the families belonged to three orders of the class Arachnida; the remaining 132 families belonged to the class Insecta. Unidentified insects were included as a separate family under each order. Separation of the samples by location of juvenile origin yielded 26 aquatic origin and 109 terrestrial arthropod families. Twenty-eight families were found at all sampling sites. Twelve aquatic families collected from EFPC were not found at the Hinds Creek reference site. Fifty-nine terrestrial families collected from EFPC were not found at Hinds Creek, and three were collected from Hinds Creek but not from EFPC.

The mean number of aquatic individuals per sample increased with sampling distance downstream from the Y-12 Plant, with the exception of a dramatic decrease in captures at Site 3 (Table 2.7). Site 3 is one of the two sites on EFPC that have the greatest mercury contamination concentrations in soils. Site 6 had the greatest number of captures. Except for Site 3, all of the EFPC sites had more captures than did the Hinds Creek reference site. With the exception of Site 2, the mean number of terrestrial individuals per sample also increased with sampling

distance downstream from the Y-12 Plant. Site 6 had the greatest number of captures, but fewer than the number of captures at the Hinds Creek reference site.

The ratio of aquatic to terrestrial arthropods (A:T) varied from a low of 1:2.3 at Site 3 and at the Hinds Creek reference site to a high of 5:1 at Site 2 (Table 2.7). The ratio of aquatic-origin to terrestrial-origin arthropods was greater at all sites except at Site 3 and at the Hinds Creek reference site. The A:T ratio increased at Site 2, decreased significantly at Site 3, increased at Site 4, was the same at Site 5, and increased again at Site 6. The sharp dropoff of aquatic-origin arthropods is the reason for the decrease of the A:T ratio at Site 3, but at the Hinds Creek reference site the decrease of the A:T ratio is more attributable to a substantial increase in terrestrial-origin arthropods than to a major decrease in aquatic-origin arthropods.

Taxonomic richness exhibited a distinct longitudinal gradient along the EFPC sampling sites (Table 2.7). Richness was lowest at Site 1 and increased with distance from the Y-12 Plant, reaching a maximum at Site 6. Richness at the Hinds Creek reference site was greater than at all EFPC sites.

The Shannon-Wiener diversity indices of aquatic arthropods were similar at the two EFPC sites farthest upstream (Sites 1 and 2) and also at the remaining four downstream sites (Sites 3, 4, 5, and 6). The diversity of aquatic arthropods at all the EFPC sites was less than that for the Hinds Creek reference site (Table 2.7). The diversity of terrestrial arthropods at EFPC was similar at all sites and higher than at the Hinds Creek reference site.

For Sites 1 and 2, Unidentified Trichoptera with aquatic juveniles was the dominant taxon (at 91 and 93%, respectively). The Unidentified Trichoptera were probably Hydropsychidae, based upon the large proportion of Hydropsychidae larval individuals collected at these sites (DOE 1994a). At Sites 3, 4, and 5 and at the Hinds Creek reference site, Chironomidae were found in greatest relative abundance (at 33, 31, 42, and 45%, respectively). Unidentified Diptera were most abundant at Site 6 (at 44%). Cicadellidae was the terrestrial taxon found in greatest relative abundance at all sites (at 32, 18, 23, 19, and 41%, respectively) except at Site 3 and Site 5, where Unidentified Lepidoptera was the most abundant (at 21 and 19%, respectively).

Plants. Plant communities are one of the major components of terrestrial habitat and thus largely influence the types, distribution, and numbers of organisms that are present in an area. Accordingly, plant surveys were conducted in the fall of 1991 at six sites on EFPC and one reference site at Mill Branch during the ecological risk assessment (DOE 1994a). The purpose of the survey was twofold. The first was to provide information on the types of vegetation to help evaluate potential explanations of differences in fauna among the sites. The second purpose of the vegetation survey was to investigate potential direct effects of contaminants on the vegetation.

A summary of dominant species and the contribution of each species to relative cover and percent of cover for the six EFPC and the Mill Branch terrestrial reference sample locations are shown in Table 2.8. The relative abundance of each tree species is also indicated. Site 3 consisted of two distinct habitats: a bottomland hardwood forest and an old field, labeled 3A and 3B, respectively. At Sites 3A, 4, 5, and 6, boxelder (*Acer negundo*) had the greatest percent cover, relative cover, and relative abundance. Site 1 is dominated by redbud (*Cercis canadensis*) in terms of percent cover and relative cover; however, boxelder stems are twice as numerous.

More than 50% of the tree seedlings at Site 1 are boxelder. Assuming stable or climax conditions in this part of the floodplain, boxelder will most likely dominate the site in the future. Site 2 is dominated by ironwood (*Carpinus caroliniana*) and boxelder in terms of percent cover and relative cover; however, green ash (*Fraxinus pennsylvanica*) is more abundant and comprises >50% of tree seedlings present. Barring further disturbance, Site 2 may undergo a shift in dominance from ironwood/boxelder to ash. Mill Branch reference site, is dominated by sweetgum (*Liquidambar styraciflua*), Virginia pine (*Pinus virginiana*), and dogwood (*Cornus florida*). Dogwood and three other tree species [sugar maple (*Acer saccharum*), red maple (*Acer rubrum*), and hazelnut (*Corylus americana*)] are the most abundant on the site. This site is apparently in a state of ecological succession toward a more mesic community.

Species richness was greater in forest habitats at a younger seral stage than in bottomland hardwood sites. Younger forest habitat at Sites 1 and 2 had 45 and 49 species, respectively. In contrast, species richness on bottomland hardwood (Sites 3A, 4, 5, and 6) was relatively low and ranged from 20 to 30. This pattern of decreasing species richness as forests develop is typical of forests in the eastern United States that are comparable in topographic complexity.

For most sites, nonjuvenile trees were <55% of the stems per square meter, but for Site 3A, the community consisted of 86% nonjuvenile trees. There is relatively little recruitment at Site 3A; juveniles made up only 14% of the total density compared to a range of 25 to 91% for the other sites. The low level of recruitment of trees at Site 3A did not appear to be explained by a larger population of seed-eating rodents at the site, or by high levels of contaminants. Available information indicates that the site has not been grazed in the past 20 years; therefore, grazing by domestic herbivores is not the cause of the observed pattern.

With the exception of Site 3A, the bottomland hardwood sites (4, 5, and 6) are most similar to each other. Although Site 3A exhibits the physical characteristics of a bottomland hardwood site (i.e., broad floodplain and deep alluvial soil) and supports a mature forest of typical bottomland hardwood species, the herb layer and tree seedlings were sparse. The site most similar to Site 3A was Site 2; however, the level of similarity (0.21) was less than for any other pairs of most similar sites.

Mill Branch shows relatively little similarity to bottomland hardwood sites on EFPC. This site is an immature forest in the process of change in dominance. Species richness is high, particularly for tree species. Therefore, Mill Branch is not considered a reference area for plant communities on the EFPC floodplain because of the differences in physical characteristics (e.g., soil type and hydrologic regime) of the site compared to the other sites. Therefore, although the EFPC sites are dissimilar to the reference site in terms of species composition, contaminants in the EFPC floodplain are not considered to be a primary cause of the differences.

2.1.5.3 Wetlands

Wetlands are those areas inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions (40 CFR 230.3; 33 CFR 328.3). Wetlands generally include swamps, marshes, bogs, and similar areas. Wetlands possess three basic attributes—wetland hydrology, hydrophytic vegetation, and hydric soils. All three criteria must be present for an area to be defined as a wetland.

DOE's requirements for compliance with Executive Orders 11988, Floodplain Management, and 11990, Wetlands Protection, are contained in 10 CFR 1022. On October 4, 1993, DOE published a Notice of Floodplain and Wetlands Involvement (58 *FR* 51623-4). As specified in 10 CFR 1022, a floodplain and wetlands assessment and a Floodplain Statement of Findings were prepared and are included as Appendixes J and K, respectively. The floodplain and wetlands assessment describes the functions, the effects of each remedial alternative, and measures to mitigate adverse effects to floodplains and wetlands. The Floodplain Statement of Findings summarizes the proposed action, the remedial alternatives evaluated, and mitigative measures. After final approval by DOE HQ, the statement of findings will be published in the *Federal Register* and included in the final FS report.

Wetlands were inventoried within the floodplain of EFPC by the COE between October 1991 and June 1992 (COE 1992). The delineation was performed using procedures developed by the Federal Interagency Committee for Wetland Delineation (FICWD) and detailed in the *Federal Manual for Identifying and Delineating Jurisdictional Wetlands* (FICWD 1989). The purpose of the delineation was not to identify jurisdictional wetlands, but rather to produce an inventory of wetlands solely for planning and assessment purposes in the FS. In the fall of 1991, Congress prohibited use of the 1989 manual for jurisdictional purposes.

To initiate the wetland inventory, National Wetland Inventory (NWI) maps, SCS soil surveys, USGS topographic maps, and other available, pertinent information sources were studied to determine the locations of possible wetlands. Field work began in October 1991 with visits to areas identified during the study of NWI and soil survey maps. Eventually, the entire length of the creek was inspected from the Y-12 Plant boundary to the confluence with Poplar Creek. Field work in the fall focused on vegetation identification and documentation of field indicators of wetland hydrology. During the winter, soils at potential wetlands were examined for morphology indicative of hydric soils. Field work continued into May to document spring vegetation and to confirm wetland boundaries.

COE identified 17 wetlands in and around the floodplain of EFPC (Table 2.9). These wetlands ranged in size from 0.01 ha (0.02 acre) to 1.14 ha (2.81 acres). Of the 17 wetlands inventoried, only 16 are located within the 500-year floodplain of EFPC. The locations of the wetlands are shown in Appendix G. Of a total of 5.17 ha (12.72 acres) of wetland inventoried, 5.16 ha (12.70 acres) are within the 100-year floodplain of EFPC. These wetlands occur in three habitat types within the floodplain. Approximately 2.49 ha (6.16 acres) of wetlands are found in the bottomland hardwood forests comprised principally of green ash *(Fraxinus pennsylvanica)*, American sycamore *(Platanus occidentalis)*, and boxelder *(Acer negundo)*; 2.47 ha (6.10 acres) are dominated by shrub such as dogwood (*Cornus* spp.), alder (*Alnus* spp.), or buttonbush (*Cephalanthus* spp.); and 0.18 ha (0.45 acre) is a shallow pond dominated by duckweed (*Lemma* spp.). Most of the wetlands in the EFPC floodplain provide highly productive wildlife habitat. Other wetland functions include floodwater attenuation and sediment (and contaminant) retention. The following narrative provides descriptions of each wetland in the EFPC floodplain from the Y-12 Plant to the confluence of EFPC and Poplar Creek.

Reference to the RU classification of the areas comprising wetlands indicates the predominant land use surrounding the wetland; it does not mean that wetlands will be treated the same as nonwetland habitats should remediation be necessary in the RU. Because the total

wetland area within the floodplain is very small and wetlands are geographically dispersed throughout the floodplain, they were not evaluated as a separate RU.

Wetland 1 - 0.33 ha (0.82 acre). Wetland 1 is located on DOE property near Transect 152, coordinate N 9800 m (32,144 ft), in Pine Ridge Gap. Transect 152 traverses the south end of the wetland. Vegetation in the wetland is a mixture of bottomland hardwoods in the southern end and shrubs in the wetter northern end. The northern end typically has standing water all year long. The wetland appears to be the result of seasonal floods and poor surface drainage that has apparently been enhanced by filling the floodplain to allow construction.

Wetland 2 - 0.01 ha (0.02 acre). Wetland 2 is located in the Residential RU along Transect 150, coordinate E 10,000 m (32,800 ft), outside the 500-year floodplain in what appears to be an old borrow pit. Vegetation consists of emergent marsh vegetation (cattails, sedges, and rushes). No samples were taken because the wetland is so far outside the floodplain. This wetland appears to be the result of a small seep or spring in the borrow pit that may have been enhanced by modification of the topography by earth-moving in the past.

Wetland 3 - 0.23 ha (0.57 acre). Wetland 3 is located in the Residential RU on Transect 149, coordinate N 10,100 m (33,128 ft), and Transect 148, coordinate N 10,200 m (33,456 ft) at the NO site. Transect 148 traverses the northern lobe of the wetland. One sample was taken in the wetland. Vegetation is a mixture of bottomland hardwoods. The wetland appears to be the result of a combination of seasonal floods, small seeps or springs, and poor surface drainage.

Wetland 4 - 0.23 ha (0.56 acre). This wetland is located in the Residential RU at the NO site along Transect 147, coordinate N 10,300 m (33,784 ft) near the USGS monitoring well transect. Vegetation is a mixture of bottomland hardwoods. This wetland appears to be the result of a combination of seasonal floods, small seeps or springs, and poor surface drainage.

Wetland 5 - 0.35 ha (0.85 acre). Wetland 5 is located in the Other RU near Transect 145, coordinate N 10,500 m (34,440 ft). Wetland 5 is located east of EFPC. Transect 145 traverses the southern boundary of the wetland. Vegetation is bottomland hardwoods (mostly young second growth green ash). The wetland appears to be the result of a combination of seasonal floods and poor surface drainage.

Wetland 6 - 0.04 ha (0.09 acre). Wetland 6 is located in the Residential RU on Transect 122, coordinate E 17,700 m (58,069 ft), north of EFPC behind Robertsville Junior High School and Robertsville Baptist Church. Transect 122 traverses the western end of wetland. Vegetation is dominated by emergent marsh plants and shrubs adjacent to a nonwetland dominated by bottomland hardwoods. The wetland appears to be fed mainly by drainage from a seep or spring located behind the church.

Wetland 7 - 0.81 ha (2.00 acres). Wetland 7 is located in the Other RU along Transect 111, coordinate E 16,600 m (54,448 ft), at the BR site. The transect bisects the wetland into western and eastern halves. The wetland is bounded on the north by Oak Ridge Turnpike and on the south by EFPC. Vegetation is a young bottomland hardwoods stand (mostly green ash). The wetland appears to result from seasonal flooding and poor drainage. The surface is often inundated for several days after heavy rains and floods. It appears that an attempt was

made to drain this wetland in the past; a small drainage ditch leading to EFPC is located near the western end of the wetland. Construction of the Oak Ridge Turnpike may have affected the northern boundary, but this is not easy to determine. This wetland is very similar to Wetland 5.

Wetland 8 - 0.37 ha (0.91 acre). Wetland 8 is located in the Residential RU on Transect 109, coordinate E 16,400 m (53,792 ft), and Transect 108, coordinate 16,300 m (53,464 ft), at the BR site. Wetland 8 is located on the south side of EFPC near the second USGS monitoring well transect. The two soil transects roughly divide the wetland into thirds. Vegetation is similar to that at Wetland 7 (bottomland hardwoods), but slightly younger with a little more diversity of species. The wetland appears to result from seasonal flooding and poor drainage. The surface is often inundated for several days after heavy rains.

Wetland 9 - 1.14 ha (2.81 acres). Wetland 9 is located mostly in the Other RU and partially in the Agricultural RU on Transect 77, coordinate E 13,200 m (43,296 ft), which cuts the wetland roughly in half. The wetland is located north of EFPC and is bounded on the north by Oak Ridge Turnpike, on the east by Big Turtle Park, and on the west by the Oak Ridge Sportsmen's Association property. Vegetation is mostly shrubs and grasslike plants with a few small trees scattered throughout the area. The wetland is apparently the result of perennial seeps or springs; it may also receive additional water from two small tributaries and backwater from EFPC during floods. Recent beaver activity has turned the site into a small pond, enlarging the area of wetland.

Wetland 10 - 0.05 ha (0.12 acre). Wetland 10 is located in the Other RU on Transect 74, coordinate E 12,900 m (43,312 ft), on Oak Ridge Sportsmen's Association property. The wetland is roughly crescent-shaped parallel to the outer edge of a meander bend. Transect 74 cuts across the middle of the wetland. The wetland is close to the south bank of EFPC. Vegetation is bottomland hardwoods. The wetland apparently formed in an old meander bend and receives water from flood events; surface drainage is poor.

Wetland 11 - 0.08 ha (0.21 acre). Wetland 11 is located in the Other RU along Transect 67, coordinate E 12,200 m (40,016 ft), on Oak Ridge Sportsmen's Association property near Gum Hollow Road. Transect 67 roughly bisects the wetland. The wetland is located north of EFPC near the point where two intermittent tributaries (TQ and TG) enter EFPC. Vegetation is bottomland hardwoods.

Wetland 12 - 0.18 ha (0.45 acre). Wetland 12 is located on DOE property on Transects 38 and 39, coordinates E 9300 m and E 9400 m (30,504 ft and 30,832 ft). The two transects roughly split the wetland into thirds. Wetland 12 is located on the south side of EFPC and Highway 95/58 and apparently formed when highway construction cut off a meander bend in EFPC. The date when this may have occurred is unknown. A culvert placed at the western end of the wetland is apparently plugged. This is the only wetland in the EFPC floodplain with an obligate hydrophytic plant (duckweed) as dominant vegetation.

Wetland 13 - 0.28 ha (0.68 acre). Wetland 13 is located on DOE property near Transects 7 and 8, coordinates E 6200 m (20,336 ft) and E 6300 m (20,664 ft). The coordinates referenced are the closest transects to the site, which is actually located about halfway between Transects 7 and 8. Wetland 13 is located on the north bank of EFPC. The wetland probably formed as a result of fluctuations in the water level in EFPC due to the backwater effect from

Watts Bar. The wetland is roughly elliptic in shape, with distinct narrow concentric bands of different vegetation types, grading into nonwetland away from the site. In the center, where ponding is most frequent, there is virtually no vegetation. Next is a band of sedges, rushes, and other plants; a zone of shrubs; and a zone of bottomland hardwood trees. A small distinct channel leading from the wetland to EFPC indicates that an attempt may have been made to drain this area in the past. A small spring also feeds into this wetland. Water levels may rise or fall rapidly, depending on operations at the dams on Melton Hill and Watts Bar.

Wetland 14 - 0.56 ha (1.39 acres). Wetland 14 is also located on DOE property near Transect 7, coordinate E 6200 m (20,336 ft). Transect 7 cuts across the western end of the wetland near the point where it meets EFPC. Wetland 14 is very similar to Wetland 13 in terms of origin, vegetation, and hydrology. It is located on the north bank about 170 m (560 ft) downstream from Wetland 13. There was evidence that beavers have been using the site.

Wetland 15 - 0.05 ha (0.12 acre). Wetland 15 is located on DOE property about halfway between Transects 6 and 7, coordinates E 6100 m (20,008 ft) and E 6200 m (20,336 ft). The coordinates referenced are the closest transects to the site, which is actually located about halfway between Transects 7 and 8. Wetland 15 is similar to Wetlands 13 and 14 in terms of origin and vegetation. Hydrology appears to be controlled by the backwater effect from the reservoirs; no creeks or springs flow into the wetland. Wetland 15 is located on the south bank, directly across the creek from Wetland 14.

Wetland 16 - 0.16 ha (0.39 acre). Wetland 16 is located on DOE property on Transect 5, coordinate E 6000 m (19,680 ft). The transect bisects the wetland. Wetland 16 is similar to Wetlands 13, 14, and 15 in terms of origin and vegetation; hydrology is controlled by the backwater effect from the reservoirs and no creeks or springs flow into the wetland. Wetland 16 is located on the south side of EFPC, immediately across the creek from Wetland 17.

Wetland 17 - 0.30 ha (0.73 acre). Wetland 17 is located on DOE property on Transect 4, coordinate E 5900 m (19,352 ft). The transect bisects the wetland. Wetland 17 is similar to Wetlands 13, 14, 15, and 16 in terms of origin and vegetation. Hydrology is controlled by the backwater effect from the reservoirs; no visible creeks or springs flow into the wetland. Wetland 17 differs from the other wetlands only in the large size of the mudflat in this wetland in relation to the area occupied by other zones of vegetation. Wetland 17 is located on the north side of EFPC immediately across the creek from Wetland 16.

Sixteen wetlands covering a total of 5.16 ha (12.70 acres) are located in the EFPC floodplain, representing four vegetation types and varying degrees of disturbance by humans in addition to contamination from the Y-12 Plant and other sources. Many terrestrial and aquatic animals have been observed utilizing these areas during different seasons of the year.

2.1.5.4 Threatened and endangered species

Protected Terrestrial Plants

The following protected plant species are known to occur in the Oak Ridge area (FWS 1991; Tennessee Department of Conservation 1991; Parr 1984) and potentially occur in EFPC or its floodplain or the SLB based on the presence of suitable habitat:

Spreading false-foxglove (*Aureolaria patula*) — This member of the snapdragon family is a large, showy-flowered perennial that is narrow in range and rare within its range. The species is currently listed as a candidate for federal listing as threatened. The category of current listing is C1, which means that formal listing is expected based on information to date concerning its rarity. It is present on the Clinch River in the Oak Ridge area and is present on Poplar Creek, into which EFPC flows. Apparently suitable habitat (limestone outcrops or rocky banks along a creek or river) is present along EFPC; however, the species was not observed.

Pink lady-slipper (*Cypripedium acaule*) — The species is listed as endangered in the state based on evidence of large numbers being taken from the wild and lack of commercial success with propagation. Its habitat is moist to dry woods.

Golden seal (*Hydrastis canadensis*) — Golden seal is a fairly widely distributed perennial species but is relatively rare within its range because it is collected for its reputed medicinal value. It is found primarily in rich moist woods. It is listed as threatened in Tennessee.

Butternut (*Juglans cinerea*) — Butternut is similar to the common black walnut and grows in rich woods. Butternut is listed as threatened in Tennessee and is a candidate for federal listing as threatened. The category of current listing is C2, which means that more information is needed to determine whether it should be proposed for formal listing.

Canada lily (*Lilium canadense*) — Canada lily grows in moist to wet lowlands, typically at the edge of woods. It is listed as threatened in Tennessee.

Ginseng (*Panax quinquifolium*) — Ginseng is widely distributed in Tennessee but is heavily collected from the wild for its reputed medicinal value. It is typically found in rich woods.

Purple fringeless orchid (*Platanthera peramoena*) — This member of the orchid family grows in open, wet habitat (e.g., wet meadows). It is listed as threatened in Tennessee.

Carey's saxifrage (*Saxifraga careyana*) — Small basal rosettes of this species grow in limestone outcrops on bluffs along the Clinch River. It is listed as of special concern in Tennessee.

Lesser ladies-tresses (*Spiranthes ovalis*) — This is typically a diminutive orchid on the ORR, with only one of two basal leaves each season. It flowers in early fall and grows in moist to dry woodland.

A field survey of the EFPC floodplain and stream banks was conducted to determine the presence of rare plant species. No protected species were observed.

Prairie goldenrod (*Solidago ptarmicoides*), listed as endangered in Tennessee, grows within 15.3 m (50 ft) of the SLB on Fairbanks Road at a state registered natural area, the Oak Ridge Barrens, and across Fairbanks Road from the Barrens.

Protected Terrestrial Vertebrates

Federally and state-protected terrestrial vertebrate species designated as threatened or endangered and that occur or for which suitable habitat exists within the EFPC floodplain (FWS 1991; Tennessee Department of Conservation 1991; Kroodsma 1987) are discussed briefly below:

Indiana Bat (*Myotis sodalis*) — In the warmer months of the year, Indiana bats are widely dispersed in suitable habitat throughout a large proportion of their range. The Indiana bat hibernates in caves during the winter and raises its young in maternal colonies during the warmer months. The preferred areas for these maternity colonies are hardwood forests along streams. The Indiana Bat is listed as Federally Endangered. A field sampling of bats on EFPC failed to find individuals of this species (Harvey 1992).

Gray Bat (*Myotis grisescens*) — Gray bats are cave residents year-round, although different caves are usually occupied in summer and winter. They forage primarily over water along rivers or lake shores. The gray bat is listed as endangered by FWS and has been reported present in Anderson County (FWS 1991). No individuals of this species were captured during the sampling for bats on EFPC (Harvey 1992).

Bachman's Sparrow (*Aimophila aestivalis*) — Typically occurring in open pine stands with heavy groundcover, in old fields, in open wooded pasture, and in very young pine plantations, this once common species is now rare and local within the state in spite of available suitable habitat. The last recorded observation of this species near EFPC was of two singing individuals on ORR in 1982 (Kroodsma 1987). The Bachman's sparrow is listed as State Endangered.

Northern Harrier (*Circus hudsonius*) — An uncommon-to-rare migrant/winter resident, this harrier frequents weedy or grassy open fields throughout the state. This species has been observed nearby in habitats similar to open fields along EFPC. It is listed as State Threatened.

Cooper's Hawk (*Accipiter cooperii*) — A very secretive permanent resident of dense forest throughout the state. Uncommon to rare as a breeding bird, it has been sighted several times during the breeding season on ORR. The Cooper's hawk is listed as State Threatened.

Sharp-shinned Hawk (*Accipter striatus*) — A rare permanent resident that may be expected in every county in Tennessee, it prefers dense stands of conifers for nesting. A sharp-shinned hawk nest with one young hawk was observed in 1957 in Melton Valley, which is several miles from EFPC. The sharp-shinned hawk is listed as State Threatened.

Bewick's Wren (*Thryomanes bewickii*) — Formerly very common within the state, this permanent resident suffered severe population declines for unknown reasons and now is locally uncommon to rare. It occurs more frequently in rural areas, often near old homesites, farms, or residences having nearby grassy areas, gardens, hedgerows, and thickets. This wren has not been recorded recently on ORR. Suitable habitat may exist within the privately owned areas of the EFPC floodplain. The Bewick's wren is listed as State Threatened.

Grasshopper Sparrow (*Ammodramus savannarum*) — Formerly a common summer resident in grassy or weedy fields throughout the state, its populations are much reduced and are extirpated from some former breeding areas that still have suitable habitat. This sparrow has been recorded in the past during the breeding season on ORR in idle pasture with tall grasses. It is listed as State Threatened.

The Tennessee Wildlife Resources Agency has designated several species as "Wildlife in Need of Management." Species within this category known to occur on or near EFPC are listed below.

Black-crowned Night Heron (*Nycticorax nycticorax*): known to occur along Clinch River.

Black Vulture (*Coragyps atratus*): known to occur along EFPC.

Red-shouldered Hawk (*Buteo lineatus*): known to occur on ORR.

Common Barn Owl (*Tyto alba*): known to occur on ORR.

Yellow-bellied Sapsucker (*Sphyrapicus varius*): secondary observation (drilled trees) in floodplain (winter visitor).

Southeastern Shrew (*Sorex longirostris*): known to occur on ORR based on studies conducted in 1975.

Protected Aquatic Vertebrates

Tennessee dace (*Phoxinus tennesseensis*) (formerly included in P. oreas) is a small fish listed as in need of management in Tennessee. The species is present in five tributaries to EFPC (between the mouth of Mill Branch and Poplar Creek) and has been collected in EFPC near the mouth of Mill Branch (M. Ryon, ORNL, personal communication, 1993). Tennessee dace breeds and lives primarily in the headwaters of the tributaries rather than in EFPC; however, EFPC may serve as a dispersal pathway for the species.

2.1.6 Archaeological, Cultural, and Historical Resources

At the request of COE, Nashville District, Nashville, Tennessee, an archaeological reconnaissance of the potential impact areas of the ER Project along EFPC was conducted from December 16, 1991 to March 3, 1992 (DuVall 1993). The reconnaissance to assess adverse impacts to cultural resources located within the boundaries of federally licensed, permitted, funded, or assisted projects was conducted in compliance with the National Historic Preservation

Act of 1966, National Environmental Policy Act of 1969, and Executive Order 11593 (May 13, 1971).

The reconnaissance of the floodplain and associated terraces of EFPC identified six historic period sites, two prehistoric sites, and a steel truss bridge. The reconnaissance also determined that the potential for archaeological sites on the floodplain is extremely low.

Of the eight sites identified within the floodplain and associated terrace slopes, only two (probable 19th century mill site and probable 19th century house site) are potentially eligible for inclusion in the National Register of Historical Places. These two sites are located on the ORR. Four of the historic sites and the bridge are located on the ORR in proximity to where the creek flows under Oak Ridge Turnpike on the west end of the city. Two historic sites are located on the Sportsmen's Association property. One prehistoric site is located on the East Fork Horse Farm, and the other is located on the Y-12 Plant site.

2.1.7 Socioeconomic and Institutional Issues

2.1.7.1 Institutional considerations

Institutional entities with responsibility for implementing, regulating, and/or monitoring program activities include DOE, EPA, and the State of Tennessee, as prescribed by the Federal Facilities Agreement for the ORR. According to the Federal Facilities Agreement, EPA and TDEC must approve all decision-making documents. In addition, a Monitoring and Oversight Agreement between DOE and TDEC, signed on May 13, 1991, reflects the obligations and agreements regarding technical and financial support provided by DOE to the State for its oversight of cleanup activities and emergency response efforts for the ORR and surrounding areas. The State's roles are (1) to establish programs for environmental monitoring, emergency response, and project oversight and (2) to promote a better understanding by the public and local governments of past and present operations at the ORR and their impacts on human health and the environment (DOE 1991). The State and DOE agreed to coordinate their actions with EPA and with local governments. A third document, the Oak Ridge Health Agreement, provides the State with funds to conduct an independent assessment of the effects of Oak Ridge operations on populations living near the ORR and downstream. DOE works closely with the Agency for Toxic Substance and Disease Registry (ATSDR), which provides consultation on health issues related to exposure to hazardous or toxic substances. ATSDR, an agency of the U.S. Public Health Service under the U.S. Department of Health and Human Services, is chartered under Section 104 of CERCLA to perform health assessments for each new site added to the National Priorities List.

The institutional environment includes government entities, interest groups, organizations, and individuals who may be affected by or who have a stake in the outcome. The public involvement process for EFPC was designed to consider public concerns, needs, and values prior to determining a sitewide alternative. The input of stakeholders (i.e., groups most likely to be affected by the decision outcome) is useful to improve prediction of how different sitewide alternatives may affect the community and whether institutional arrangements are available to serve as a buffer against impacts that cannot be avoided. A related goal of the institutional analysis is to gauge the acceptability of an alternative to the community and whether the institutional environment may affect an alternative's implementability.

The assessment method involved qualitative data-gathering techniques using a variety of sources: face-to-face interviews; telephone interviews; solicitation of public input via display ads in three area newspapers; observing interaction and public comments at program-related workshops and meetings; and scanning relevant articles in local newspapers. No comments were received in response to the display ad that ran in *The Oak Ridger* on May 5 and May 8, 1993, *The Roane County News* on May 12, 1993, and *The Knoxville News-Sentinel* on May 19, 1993. Program-sponsored forums to obtain public input included the NEPA scoping hearing held in December 1988; a technical workshop involving regulators, contractors, City of Oak Ridge representatives, and DOE representatives held March 24-25, 1993; a workshop for EFPC property owners held May 15, 1993; and a public meeting held May 18, 1993. In addition, DOE initiated two types of ongoing working groups to obtain institutional and citizen input on the EFPC FS report: (1) issue-specific task force groups to incorporate the thinking, observations, and experience of interested organizations and agencies in issue resolution and (2) a citizen working group to review and provide feedback to DOE on preliminary sitewide alternatives. The output of both of these groups is available for review at the Information Resource Center in Oak Ridge.

Several institutional forums already existing in the local area provide mechanisms for public input into DOE activities in Oak Ridge. These include:

1. the Oak Ridge Local Oversight Committee, a group of officials and citizens from Anderson, Roane, Meigs, and Rhea counties and the City of Oak Ridge, charged by the State with monitoring cleanup operations on the ORR and the Watts Bar Reservoir;

2. DOE's Environmental Restoration and Waste Management Advisory Committee, a 23-member committee formed in 1992 to report on environmental restoration and waste management issues to DOE's assistant secretary for ERWM and to assist in the process of securing consensus recommendations and providing for public comment on health issues, cleanup and land use;

3. the Environmental Quality Advisory Board (EQAB), a board of local citizens appointed by Oak Ridge City Council to review and advise the City on environmental issues;

4. the Oak Ridge Environmental Advisory Committee, created in 1984 to provide independent peer review to Martin Marietta Energy Systems, Inc., on remedial and waste management activities at its three Oak Ridge facilities;

5. the Oak Ridge Regional Planning Commission, a State-chartered group with members nominated by the Oak Ridge City Council to work on a broad range of planning issues; and

6. the Roane County Environmental Review Board, a board of local citizens appointed by the Roane County Commission to review and advise the County on environmental issues.

Other forums for stakeholder input include independent citizen and environmental groups in Oak Ridge and neighboring communities. Groups with local representation identified during this assessment include the Oak Ridge Environmental Peace Alliance (OREPA), Citizens for Better Health, Save Our Cumberland Mountains (SOCM), the League of Women Voters, Tennessee Citizens for Wilderness Planning, and the Sierra Club.

The process of characterizing the affected population yielded eight potential stakeholder groups, which overlap in some instances:

1. Private residents who own and live on property in the EFPC floodplain;
2. Owners of commercial businesses along EFPC;
3. Real estate investors and developers with interests affected by EFPC;
4. Other resident groups who may be affected by EFPC, whether or not they live on the floodplain;
5. City of Oak Ridge government;
6. Residents of east Roane County in proximity to the K-25 Site, the proposed location of the treatment facility;
7. Citizen and environmental groups in Oak Ridge and neighboring communities; and
8. Public or private facilities located along EFPC, such as schools, child care centers, and youth recreational areas.

Anderson and Roane County governments and the State of Tennessee are considered to be less directly affected than those stakeholders listed above.

SAIC conducted interviews and informal discussions with ~60 individuals representing various stakeholder groups. Whenever possible, SAIC identified a key person who was knowledgeable about that stakeholder group and whose input would likely reflect the values and/or priorities of the group as a whole, such as the chair of a residents' association, an organizer in a citizens' group, or the president of a board. In the case of most commercial and residential property owners along EFPC, no formalized group was available to represent their collective interests. A structured telephone interview format was used to obtain responses from individual resident/owners along the creek, including those who have been less vocal and active in the program to date.

Interview questions, tailored to the particular institution, generally covered the following topics: past and current effects attributed to EFPC; concerns about EFPC and the bases for their concerns; institutional actions, positions, or expectations related to EFPC; beliefs about institutional adequacy to address needs and concerns; preferences regarding sitewide alternatives; and beliefs about the potential impacts of sitewide alternatives.

Community-wide, there is no sense of urgency or immediate risk attributable to public concern about the potential effects of EFPC contamination on human health. Some parental concerns are evident. At least one participant in the Citizens' Working Group has expressed concerns about her young children's safety. Also, when contacted, the president of the Residents Association of the Oak Ridge Housing Authority explained that parents' concerns about young children who play in the creek have been a primary issue with the Association since its formation a year ago. In her opinion, the concerns are mostly based on a need for information about the contamination and risk, although at least one resident is skeptical about the credibility of information from DOE sources. There are 37 units in this Housing Authority development, with a household size of ~1.25 persons per household (Carson 1993).

By far, the majority of concerns expressed in the community are related to one or both of two topics - property issues (e.g. liability, property values, ability to use or develop property), or Oak Ridge's image as presented to outsiders. Most of the persons who were interviewed mentioned the State-posted public restriction signs along EFPC and the stigma they believe the signs perpetuate. Several community members expressed aversion to what they believe is excessive time and money devoted to the EFPC topic with no resolution to date.

The public disclosure of the EFPC contamination in the early 1980s drew little alarm or fear from Oak Ridge residents, unlike residents of communities elsewhere, in which elevated levels of mercury and other toxic substances from industrial operations have been identified (Steinberg 1993; Barry 1993). Several persons who were interviewed commented that early response to the contamination was minimal, including responses from parents and teachers of schoolchildren at Robertsville Junior High School and Jefferson Junior High School where contamination was discovered on school grounds (Smallridge 1993; Hayes 1993). Staff of day care centers, the Young Women's Christian Association (YWCA), Girls' Inc., and other public facilities located along the creek reported no expressed concerns about health effects from parents and staff. Although Oak Ridge's economic dependency on DOE activities may be a factor in the relatively muted response, interviewees more often attributed it to a relatively high level of scientific understanding among Oak Ridgers and their confidence in the ability of science and technology to resolve the problem. Some interviewees noted that self-selection in residential distribution may be a factor. In other words, Oak Ridge workers and their families who choose to live in Oak Ridge rather than neighboring communities may be more tolerant of proximity to hazardous technologies.

Twenty-seven privately owned residences were identified as being located immediately next to the creek. Among these, 16 residents were contacted for interviews. One person declined to be interviewed. Most of the residents who were interviewed are long-time Oak Ridge residents. They have lived in Oak Ridge for an average of 33 years, and next to EFPC for an average of 15 years. Most have known about the contamination since it was publicized in the early 1980s. One, however, said that he would not have bought the property had he known about the contamination. Eleven residents said they are not likely to move from their present home in the next few years, two said they would move but would remain in Oak Ridge, and two were unsure. All respondents are over 50 years of age, and all but one are retired. None of the residents interviewed had children living at home.

Of the 15 interviewees, 13 responded "No" to the question "Do you ever feel concerned that the contamination in East Fork Poplar Creek and its floodplain may be affecting anyone's

health?" Of the two residents who responded "Yes," one expressed concern about a friend who believes that her health problems may be related to the creek, and the other expressed concern for people who have eaten animals that have had contact with the creek. When asked how they and their families have been affected by the EFPC situation, ten residents said they have not been affected at all. One responded that the creek has affected property values, two said that it has hindered their ability to use their property as planned, and another mentioned concerns about the creek's effects on other people. When asked whether EFPC has caused them to postpone or change any business decisions, one person stated a decision not to place a parcel of land on the market until the Record of Decision is released.

When asked to describe any effect that EFPC has had on the Oak Ridge community as a whole, five residents said that it has had no effect, and five mentioned negative effects associated with excessive or inappropriate attention, publicity, or money directed to the topic. One long-time property owner, for example, referred to the EFPC studies as a "high-tech boon-doggle." Others mentioned property issues, concerns about children playing in the creek, and the problems caused by delay in making a decision about EFPC. Most residents reflected trust in DOE's ability to deal with future issues about EFPC. Eight pointed to DOE as the one agency, organization, or institution they would expect to be most helpful in addressing any issues related to EFPC that might affect them. One named EPA as most helpful and said that neither DOE nor Martin Marietta would be helpful, and others had no opinion.

When presented with a range of remedial scenarios, at least six residents indicated a firm belief that no remedial action at all is necessary. For example, one respondent stated that any action "is a ridiculous waste of money." Eleven residents were in favor of the least costly alternative, whatever it may be. One person stated a preference that the creek be rerouted, and at least two people preferred an alternative that would allow trees to be saved or replanted. Several residents who own homes in the area known as Grand Cove Lane in particular stressed the value of the creek to their quality of life, particularly the attractiveness of the shade trees and other vegetation along the creek. One resident stated that the creek "is the reason we bought the property." Feedback from the Citizens' Working Group for EFPC over several meetings has confirmed the overall community preference for a minimal-action approach to the cleanup. Many individuals stress that attention should be focused on stopping releases from the Y-12 Plant and remediating the few "very hot spots" in the floodplain.

Property owners, for the most part, are opposed to DOE's acquisition of property rights on residential property, particularly if the acquisition were to apply to a part, rather than all, of a parcel. One owner expressed very strong resistance to a proposed alternative that could involve acquisition of property rights on a portion of his property. He explained that reducing the size of his pasture would decrease the value of his barn, which could affect the value of the house and remaining property. To this owner, acquisition affecting the whole parcel would be the only acceptable arrangement.

When publicity about EFPC emerged in the early 1980s, there were news reports focusing on the effects of the creek on the Scarboro neighborhood of Oak Ridge, a predominantly black neighborhood. SAIC contacted some residents of the Scarboro neighborhood to examine whether concerns and impacts are still evident there. According to an EQAB member who lives in Scarboro, the news reports about EFPC's effects on Scarboro residents contained incorrect information (Chambles 1993). Although Scarboro is located near the Y-12 Plant, EFPC does not

travel through the neighborhood as the news reports led people to believe. The Scarboro resident expressed the belief that this initial impression had a negative effect on African-Americans in Oak Ridge, in addition to the stigma of being a segregated community. Also, he believes the reports may have deflected concerns away from those areas that actually were contaminated. The resident commented that the stories have negatively affected individuals' self-esteem, property values, and community goals and development. Another resident, however, expressed very serious concerns about emissions from the Y-12 Plant and the other three plants generally. He expressed distrust of DOE and the belief that the problem has been downplayed. Another former resident of the Scarboro neighborhood offered the comment that some residents had been afraid to plant gardens on their property after the news reports and were concerned about what they believed were high rates of cancer; she stated that most people had become resigned because they see no options. These comments, while they are anecdotal, suggest that attitudes and beliefs about possible health impacts vary widely in the Scarboro neighborhood.

Representatives of the City of Oak Ridge, including EQAB members, confirmed that property and image issues are most important from the City's perspective. An issue facing the Oak Ridge Regional Planning Commission concerns whether the City would be legally liable if it approves development on property that is contaminated. The City's Subdivision Regulations, Article III (p. 15), state that:

> Land which the Planning Commission has found to be unsuitable for subdivision due to flooding, bad drainage, steep slopes, rock formation or other features likely to be harmful to the safety, health, and general welfare of the future residents shall not be subdivided unless adequate methods approved by the Planning Commission are formulated by the developer for meeting the problems created by the subdivision of land.

The Planning Commission also questions whether the City may be liable for the owner's not being able to develop the property if development is denied (Fitzgerald 1993). The issue has been prompted by a proposed subdivision bordering EFPC, but the concern extends beyond this proposal. The Planning Commission has been advised by its legal counsel that it should not approve subdivision of the property as long as the liability question is unresolved. The situation was described in an interview as a "liability vise," in need of a mechanism from DOE absolving the City of legal responsibility if it approves development (Domm 1993a). The Planning Commission has submitted to DOE a list of members' primary concerns about responsibilities and liabilities related to approval and denial of development (Domm 1993b).

Some City officials couched their concerns about development along EFPC within the context of a shortage of developable land in Oak Ridge, particularly for moderately priced housing. The topographical barriers around Oak Ridge and DOE ownership of surrounding property, including tracts the City would like to purchase from DOE, already place considerable constraints on development (Nephew 1993; Noey 1993). City representatives believe that issues of liability associated with EFPC floodplain property are helping to suppress healthy competition among developers, resulting in concentration of high-priced housing and a shortage of moderately priced housing in the community. For example, a major proposal for residential development

near the Oak Ridge Country Club was lost because lenders would not provide financing due to liability concerns about EFPC (Noey 1993).

A local lending representative and Chairman of the Oak Ridge Housing Development Corporation confirmed that the contamination has affected lending for properties in the floodplain (Southard 1993). He explained that the problem reflects the current cautiousness among lenders nationwide to be sure there are no liabilities connected with collateral. Guidelines in the lending business have supported a "hands-off" policy where there is any potential environmental hazard. The Federal Home Loan Bank Board's Office of Regulatory Activities issued Thrift Bulletin 16 on February 6, 1989, as a guide to lenders on how to recognize and deal with environmental risks in real estate lending and ownership (United States League of Savings Institutions 1989). Thrift Bulletin 16 recommends that institutions designate one or more in-house environmental analysts, adopt an environmental risk policy, obtain environmental evaluations for properties when appropriate, and employ these evaluations in real estate buying and lending decisions. Noncomplying institutions risk being found negligent. Several district Federal Home Loan Banks have alerted their members to the risk and liability stemming from ownership of a contaminated property. The Federal National Mortgage Association and the Federal Home Loan Mortgage Corporation have adopted environmental requirements for underwriting and appraising certain properties. Fannie Mae regulations permit in-house staff of savings institutions to do first-level (Phase I) environmental evaluations. The Phase I evaluation typically includes a historical review of the property's uses, investigation of the property and nearby properties with regard to inclusion on the National Priorities List or state toxic site lists, and other determination of hazardous substances. Concerns raised by the Phase I evaluation would indicate the need for a professional Phase II evaluation, which is a more detailed evaluation of the type and degree of contamination that may include core samples (Southard 1993; United States League of Savings Institutions 1989, pp. 1-10).

City of Oak Ridge representatives are particularly sensitive to the image problem they perceive to be a result of negative publicity from the EFPC contamination, as well as other contamination and credibility questions that have been highlighted by the mass media. During the early 1990s, controversies ranging from whistleblower claims against DOE contractors to radioactive frogs being found on the ORR attracted the attention of major television networks, national newspapers, and news magazines. City officials, the Chamber of Commerce, and EQAB report having undertaken efforts to deflect the negative publicity and to demonstrate that Oak Ridge is a safe, attractive place to live. Most City representatives confirmed that the primary goal with regard to preference for remedial alternatives on EFPC is to remove the contamination as an issue facing the community. They emphasized the need to remove the signs posted along the creek and other visible indications of contamination. One City official described the signs as a "black eye" on the community, a psychological blow to the city (Issell 1993). Most city representatives confirmed a preference for a sitewide alternative that would be viewed as reasonable and practical, not necessarily protective under a worst-case scenario.

Several interviewees representing the City cited indirect evidence that prospective newcomers to Oak Ridge are being turned away because of the stigma of contamination. They believe that families, particularly younger professionals with children, may not view Oak Ridge as a safe place to live. The question of residential and business recruitment was posed to area real estate professionals and local economic development leaders. The Vice President of Economic Development with the Oak Ridge Chamber of Commerce confirmed that the creek has had some

impact on business and industry recruitment (Young 1993). He recalls that on at least 3 or 4 occasions in the past 5 years, the specific question of EFPC contamination has been raised; it is not known how many potential candidates have avoided Oak Ridge from the outset. He noted a distinct effect due to EFPC's location through the heart of the community. In the past, an effective argument could be made that the contamination was confined to the ORR, not affecting the community. Since signs were posted along EFPC, that argument is no longer valid. He added that those businesses desiring to locate along EFPC are unable to obtain financing, making the land valueless for commercial properties. As noted by a local commercial real estate professional, however, many businesses are attracted to Oak Ridge because of work related to contamination on and off the ORR (Mullins 1993).

The President of the Clinch Valley Association of Realtors expressed a belief that residential recruitment also is affected by EFPC (Gass 1993). He recalled anecdotal cases where prospective buyers have raised questions about contaminants in Oak Ridge or requested soil tests for toxins. For example, a recent prospective home buyer moving from another state to work in Oak Ridge expressed a reluctance to move to Oak Ridge due to his wife's concerns about their children's health. Volunteer Realty has a policy to make a disclosure statement to prospective buyers of any hazard that is known on the property. Gass noted that this is standard practice in conformance with the Code of Ethical Conduct of the National Association of Realtors. The National Association of Realtors has distributed a model form to members for Property Environmental Information Disclosure. He also expressed his belief that the signs posted behind the townhomes in the Grand Cove area seriously affected the sales of some of those homes.

There are approximately five real estate developers and/or investors who have been identified as owning large parcels of land along the creek. Some of these property owners have expressed significant concerns to DOE about the long-term inconvenience and frustration they have experienced because of liability issues related to property development. DOE has met with at least two owners who are particularly affected in an attempt to address issues. SAIC conducted an in-depth interview with one of these property owners. The owner planned to develop acreage south of the creek as multiple family housing and acreage north of the creek as commercial property. He stated he has postponed this development to avoid creating an environment in which people's health might be damaged. He has attempted since the early 1980s to have DOE clear the cloud that prevents his use of the land. The inaction to do so, in his belief, may constitute a temporary taking of property rights. Although he has not been inclined to take legal action, he seeks payment in rent from DOE and an institutional mechanism relieving him from future liability for perceived environmental and health insults to third parties.

Several commercial businesses are located along the creek, as well as the Oak Ridge Country Club and the Oak Ridge Sportsmen's Association. Three business owners have been contacted. They are primarily concerned about potential loss of property values and future liability issues.

Citizen and environmental groups expressed a need for additional information prior to making substantial comments. OREPA is a Knoxville-based organization that addresses issues of public health, environmental responsibility, economic conversion, and nuclear weapons production. An OREPA representative emphasized the importance of addressing all contaminants from the Y-12 Plant, declassifying and disclosing all information pertinent to defining the problem, addressing the problem in context of DOE's overall cleanup problem, and addressing off-site public health risks, such as from treatment options (Hutchison 1993). OREPA believes

the need to stop releases from the Y-12 Plant should be a priority. Likewise, a representative of the League of Women Voters expressed concern about conducting remediation without addressing potential recontamination upstream (Gawarecki 1993).

Concerns have been expressed in Oak Ridge and Roane County about multiple thermal source waste facilities in the area. There are two incinerators and one industrial boiler that burn radioactive or mixed waste operating in Roane County in an 8-km (5-mile) stretch between the K-25 Site and the I-40/Gallaher Road exit. According to a letter from EQAB to the Oak Ridge City Manager dated April 6, 1993, EQAB is investigating concerns about cumulative effects on air quality from waste incinerators in and near Oak Ridge at the request of the City Council. According to the Vice-Chair of EQAB, there has been no active opposition from Oak Ridge against the facilities, but there has been an undercurrent of public concern (Smith 1993). The City's primary concern with regard to the facilities is one of image, as described above. EQAB's focus has been on addressing the question of whether Oak Ridge is a safe place to live and to provide independent reassurance to the Oak Ridge community.

Activism against thermal waste processing facilities has emerged in east Roane County around facilities located near Gallaher Road (McLeod 1993). The efforts are being organized by the Roane County Chapter of SOCM. SOCM members have dubbed the area "Incinerator Alley." According to a SOCM organizer, ~70 residents have attended meetings in opposition to the growth of hazardous waste industries in that part of the county. According to a member of the Roane County Commission, Roane County residents are concerned about existing incinerators and are likely to see a roaster for mercury as another incinerator (Peele 1993). He emphasized that people do live close to the K-25 Site and should be given consideration. He and others in the Citizens' Working Group have expressed a preference for transportable treatment units.

2.1.7.2 Public services and facilities

The public utilities potentially affected by alternatives include water, sewage, electricity, and natural gas. The City of Oak Ridge contracts with the DOE for public water services to residents. The current carrying capacity of the water system is adequate for present and estimated future needs at ~0.197 m^3/s (4.5 million gal/d). The City's contract with DOE provides that if water usage increases substantially [by ~0.0110 m^3/s (250,000 gal/d)], rates charged to consumers would increase (Cinder 1993).

The City's sewage collection and treatment system is adequate for current and planned needs. Water and sewer lines follow the SLB, buried ~1 m (3 ft) underground (Cinder 1993).

The City disposes of nonhazardous solid waste at the Chestnut Ridge Landfill in Anderson County. The landfill is currently being expanded, and it has at least 12 to 14 years of projected capacity, depending on flow diversion through recycling and other methods (Cinder 1993). Nonhazardous solid waste generated on the ORR is disposed at the on-site sanitary landfill located at the Y-12 Plant (Little 1993).

Emergency services for the area affected by EFPC are provided by Tennessee Emergency Management Agency, Anderson and Roane County Emergency Management Agencies, County Sheriff's Offices, County Fire Departments, City of Oak Ridge Police and Fire Departments,

Martin Marietta Energy Systems, DOE, and Methodist Medical Center. Incident command and first response to any incident or transportation accident would be provided by the jurisdiction's primary response agency. Coordination within the affected county is accomplished through the respective county's Emergency Operations Center (Fritts 1993). One major hospital, Methodist Medical Center, located off Oak Ridge Turnpike, serves the area. According to local emergency responders, the level of emergency preparedness surpasses credible accident scenarios associated with the EFPC alternatives. They express confidence that any incident would be well within local capabilities (Swabe 1993; Edwards 1993; Fritts 1993; Jones 1993).

Several facilities for public use are located along EFPC, including public schools, day-care centers, youth service centers, a public park, and a community college. At Robertsville Junior High School, in the Oak Ridge City School District, the soccer field, football field, and softball field abut the creek. They are used throughout the year by the school, the City Recreation Department, Girls, Inc., and a variety of other groups. The athletic fields were backfilled during the 1980s with several inches of soil (Hayes 1993). Robertsville Junior High School plans to build a new building with space for 12 classrooms, but it will not be located near the floodplain.

Three child care facilities are located along EFPC: the Montessori Center of Oak Ridge, Nana's Kiddie Kampus, and La Petite Academy. The Montessori Center, located on Oak Ridge Turnpike west of Jefferson Avenue, provides day care services for ~50 pre-school children, ages 2 1/2 to 6 years. The Center operates on the same schedule as the Oak Ridge Schools. Normal hours of operation during the school year are 7:30 a.m. to 2:00 p.m., with outdoor play between 11:15 and 11:30 and 12:15 and 12:45. A Summer Enrichment Program, not a component of the Montessori program, is held for 2 weeks in June and 2 weeks in July. One group meets from 8:30 a.m. to 11:30 a.m., and the other meets from 12:30 to 3:30. The Center's facilities include an outdoor fenced playground located ~61 m (200 ft) south of EFPC.

Nana's Kiddie Kampus, located on Adams Lane north of the Oak Ridge Turnpike, provides private day-care services for ~110 to 120 pre-school children. It is licensed to serve 138 children ranging in age from 6 weeks to 12 years. Hours of operation are from 6:00 a.m. to 6:00 p.m. Monday through Friday, year-round. Outdoor activities may occur throughout the morning and afternoon within a fenced playground (Baker 1993).

La Petite Academy, located on West Tulsa Road off South Illinois Avenue, provides day care services and an after-school program for ~100 children, ages 6 weeks to 12 years. The facility is open year-round from 6:30 a.m. to 6:00 p.m. Outdoor play activities typically occur twice a day, between 10:00 and 11:00 a.m. and between 3:00 and 5:00 p.m. The play area is enclosed by a fence (Crockett 1993).

The YWCA of Oak Ridge and Girls, Inc. are located along EFPC. Both are located in the YWCA building on Oak Ridge Turnpike west of Illinois Avenue. The YWCA of Oak Ridge is a membership-based organization of ~850 members. Its programs include a shelter for battered women and children, used clothing shop, adult education classes, literacy training sessions, a nursery, and fitness classes, among others. For example, in 1991, the YWCA provided 2806 nights of emergency shelter for 255 women and children and provided child care for 2988 children (YWCA 1991). The YWCA owns 0.8 ha (2 acres) adjoining the central facility that abut EFPC. Consideration has been given to developing the property for a subsidized housing

complex for battered women and children. Due to liability concerns, the YWCA Board of Directors voted in February 1992 to take no action on developing the property until the Record of Decision on the selected remedial alternative is released (Campbell 1993).

Girls, Inc., funded by Anderson County United Way, is temporarily housed in the YWCA building. Girls, Inc. purchased the Jefferson Tennis Courts and surrounding property from the City of Oak Ridge. Development plans call for removing the tennis courts and constructing a softball playing field, a gymnasium, and a central facility by 1996. Development has begun on the site. The center has phased in use of the site as a softball field, which would serve at least 500 girls daily and on weekends through the season. The City of Oak Ridge still uses tennis courts at the site, and Girls, Inc. is leasing that space back to the City (Sides 1993). Sampling was conducted on the site after Girls, Inc. representatives requested that DOE evaluate the area. To be protective and allow Girls, Inc. to proceed with plans to develop a softball field, DOE agreed to install a soil cover on the ballfield area. This work was completed in May 1993 (Caruthers 1993).

2.1.7.3 Economic and demographic resources

The first step in providing background for economic and demographic impact analysis is to define a region of influence for the cleanup activities. All activity related to the alternatives could take place in the areas immediately surrounding EFPC and SLB, which are physically located in Anderson and Roane counties, Tennessee. Although the site itself represents a small portion of the entire two-county area, the actions taking place at the site could have repercussions for the whole area's economy. Therefore, it was assumed that Anderson and Roane counties were the appropriate definition for the region of influence.

Demographics

The contaminated areas of EFPC and SLB are predominantly located in Oak Ridge, Tennessee, which includes portions of both Anderson and Roane counties. Oak Ridge is located in the east central section of the state, ~32 km (20 miles) west of Knoxville, Tennessee. There were 27,310 people living in Oak Ridge in 1990, as reported by the U.S. Census (Table 2.10).

Of the total population within the region, the population potentially most affected by contamination within the EFPC floodplain consists of those households within 152.5 m (500 ft) of the creek. The total number of housing units within this area was estimated to be 448; the associated population was estimated to be 1189 (for details on estimation methodology and distributions by age and sex, see DOE 1994). Table 2.10 presents the estimated distribution of the populations surrounding EFPC by age groupings, and compares those estimates with values for the area surrounding SLB, the two counties, the region of influence, and the state. The largest share of the population is in the "baby boom" cohort (between 25 and 54 years of age), with an estimated 40.0% of the population. The share of the population under 5 years old (with the highest probability of ingesting soil) is the smallest at only 5.0%, or 59 children. The distributions of population by age are similar for the other regions shown in the table.

Residences within 153 m (500 ft) of EFPC are primarily located in clusters along several points of the creek. Near the intersection of Oak Ridge Turnpike and South Illinois Avenue, there are two public housing sites, Wilderness Trace Condominiums, three apartment buildings, and two quadplexes. As the stream flows westerly, parallel to Oak Ridge Turnpike, it passes several farms and homes situated on large lots. The Grand Cove subdivision and three apartment buildings are located adjacent to the creek in west Oak Ridge.

The population living within 153 m (500 ft) of SLB was estimated in the same way as the population in the EFPC area. It is estimated that 528 residences are located within 153 m (500 ft) of SLB, with an estimated associated population of 1437. The residences along SLB are primarily single-family homes along Emory Valley Road. The beltway also passes within 153 m (500 ft) of a retirement home, five apartment buildings, and 29 duplexes.

Table 2.11 shows the trends in population growth for the regions surrounding EFPC and SLB. Oak Ridge population declined slightly over the decade, as did the population for the region of influence. This decline was in contrast to the modest growth recorded for the state over the same period. Average household size in Oak Ridge and the region of influence was slightly lower than for the state in 1990. The Oak Ridge population represented 23.6% of the total population in the region of influence in that year.

Economic Issues

This section explores the economic factors that may be affected by the remediation alternatives considered for EFPC and SLB. Each alternative will be evaluated for its impact on population, housing, and employment. Population has been discussed above. The focus of this section is on baseline information on housing and employment.

Tables 2.12 and 2.13 report summary statistics on housing in Oak Ridge, Anderson County, Roane County, the region of influence, and the state of Tennessee. As shown in Table 2.12, the total number of housing units has grown over the last decade for both the city and the counties. The number of housing units has increased at an average annual rate of 1.0% in Oak Ridge from 1980 to 1990, which is less than the average annual growth of 1.3% reported for Anderson County, 1.1% for the region of influence, and 1.5% for the state.

Table 2.13 shows that most of the housing units in Oak Ridge are single-family homes (70.7%), followed by multifamily units (28.9%), and mobile homes (0.4%). This distribution differs from that for the region of influence, which shows a similar share of units in the single family category (72.2%), but a lower share of multifamily units (15.1%) and a higher share of mobile homes (12.7%). Vacancy rates for homeowner housing units were the same for Oak Ridge and the region of influence; however, this vacancy rate was higher at the state level. The pattern for rental vacancy rates was slightly different. The rental vacancy rate was higher for Oak Ridge (14.5%) than for either the region of influence (9.5%) or the state (9.6%).

Tables 2.14 through 2.16 provide background data on employment in the region of influence. There were a total of 63,317 people employed in the region of influence in 1990. Of this total, 53,388 (84.3%) were employed in the nonfarm, private sector; 8687 (13.7%) were employed by government enterprises; and 1242 (2.0%) were employed on farms. The services sector accounted for the most employment in 1990 (32.6%), followed by manufacturing (28.3%),

retail trade (11.8%), and state and local governments (9.2%). The greatest average annual growth in employment between 1970 and 1990 occurred in the services sector (6.5%), followed by construction (5.2%), agricultural services (5.1%), and finance, insurance, and real estate (3.7%). The biggest employment declines over the same 20-year period occurred in mining (-4.3%), military (-1.3%), and manufacturing (-0.5%).

Table 2.15 shows the breakdowns in average annual earnings per employee by sector. The highest earnings in 1990 were for federal civilian employees ($34,390), followed by manufacturing ($30,977), mining ($28,511), services ($24,860), and agricultural services ($24,128). The greatest average annual growth in earnings between 1970 and 1990 was in services (3.8%), followed by military (2.9%), farming (2.4%), and agricultural services (1.2%).

Table 2.16 shows the number of establishments by industry sector in Anderson County, Roane County, and the region of influence. The most establishments were reported in services (841), followed by retail trade (607), finance, insurance and real estate (170), and construction (166). The most growth in establishments between 1980 and 1990 has been experienced by agricultural services (7.2%), followed by services (5.4%), construction (4.0%), and manufacturing (3.8%).

Table 2.17 shows per capita income trends for the region of influence. It shows values in both nominal dollars and constant dollars (estimated using the personal consumption expenditures deflator with a 1987 base year). Per capita income increased at an average annual rate of 6.6% in the region of influence over the decade; however, the real rate of increase averaged only 1.8% per year.

2.1.7.4 Transportation infrastructure

The area surrounding Oak Ridge and the ORR is served by a highly developed network of efficient transportation systems including water, rail, highway, and air.

Oak Ridge is ~32 km (20 miles) west of Knoxville. The area is served by three arterial interstate highways: I-40 (east-west), I-81 (northeast-southwest), and I-75 (north-south). State Highways 61, 62, 162, 95, and 58 connect to the interstates and local communities. State Highway 95 connects the west end of the ORR with I-40 and I-75. The Pellissippi Parkway (State Highway 162) connects Oak Ridge to the interstate system in the east and serves as the major link between West Knoxville and Oak Ridge.

The Knoxville-Oak Ridge area is connected by navigable waterways maintained by TVA and COE. All seaports are accessible through the Ohio and Mississippi Rivers. Completion of the Tennessee-Tombigbee Waterway in 1985 increased barge traffic in the area. The Clinch River and Melton Hill Lake, which bound the ORR to the south, are components of this inland waterway system. A barge facility, located on the east bank of the Clinch River south of State Highway 58, is maintained in operable condition but is rarely used.

Two railroads serve the local area. CSX Transportation (Seaboard System Railway, Inc.) transports goods and services to the Y-12 Plant. The CSX spur line extends 7.4 km (4.6 miles) west from the main line at Elza to the point of DOE ownership near Scarboro Road and the northeast corner of the Y-12 Plant. From this point, DOE owns and maintains ~12 km

(7.5 miles) of railroad. The Norfolk Southern Railway provides service to K-25 via a spur from its main rail line in Harriman about 14.5 (9 miles) to the west.

Table 2.18 shows routes that may potentially be affected during remedial actions on EFPC and the SLB. Certain routes may be deleted and others added based on further development and screening of remedial action alternatives.

Average daily traffic counts for some of the potentially affected routes are shown in Table 2.19. South Illinois Avenue and Oak Ridge Turnpike are heavily travelled routes, while the others carry a light to moderate volume of traffic on a daily basis. Level-of-service analysis was not conducted for all of the potentially affected routes. However, a traffic impact evaluation recently conducted for the city of Oak Ridge (Sullivan 1993), contained a level-of-service analysis for the intersection of Oak Ridge Turnpike at South Illinois Avenue. This intersection is signalized and is currently a point of significant peak-hour congestion and delay particularly during the afternoon peak hour. The overall level of service is estimated to be "D" at the present time. Proposed future commercial development in the vicinity of this intersection is expected to increase traffic volumes and delay, and lower the level of service to "F."

2.1.7.5 Ambient noise

Humans can hear a large range of sound pressures. The decibel (dB) is used to express these sound levels over a wide physical range. Decibels are not linear units like miles or pounds; rather, they are representative points on a sharply rising, logarithmic curve. Each 10 units represents an increase of tenfold, 20 units means a hundredfold (10×10), 30 units a thousandfold ($10 \times 10 \times 10$), and so on. Thus, 100 dB is 10 billion times as intense as 1 dB. For comparison, the rustle of leaves is rated at 10 dB, moderate traffic noise ranges around 65 dB, and a jet takeoff at 60 m (197 ft) is 120 dB or greater. The human ear does not perceive sound at low frequencies in the same manner that it does at higher frequencies. Sounds at low frequency do not seem as loud as those of equal intensity at higher frequencies. The A-weighting network is provided in sound analysis systems to simulate the human ear. A-weighted sound levels are expressed in units of decibels and are used throughout this section unless noted otherwise.

Several federal agencies have established guidelines and standards for sound level emission (noise). These agencies have also recommended ambient sound levels requisite to protect human health and welfare from excessive noise impact. EPA (1974) recommended a 70-dB $L_{eq(24)}$ exposure limit (ambient sound level) as a guideline for continuous exposure and a 55-dB L_{dn} as a level where ambient noise is an annoyance to outdoor activity [$L_{eq(24)}$ represents the sound energy averaged over a 24-h period, while L_{dn} represents the L_{eq} with a 10-dB increase for noise that occurs at night]. These are only guidelines and not regulatory standards. The Federal Highway Administration (1976) established a 70-dB standard for noise levels during the peak hour of traffic. This standard is used as an indication of what is an acceptable limit for highway noise. EPA (1976 a,b) established noise emission standards for various types of construction equipment, railroad operations, and specific vehicles. These standards must be met by the manufacturer and maintained by the operator.

Ambient noise levels along EFPC are related to the various current land uses. No known studies are available on existing background noise levels for potentially affected properties or

adjacent transportation routes. The city of Oak Ridge zoning ordinance contains a performance standard for noise (Table 2.20). Noise is not regulated at the state level. The U.S. Occupational Safety and Health Administration (OSHA) regulates worker safety related to noise levels.

No measurements of ambient sound levels were obtained for potentially affected properties along EFPC; instead, yearly day-night average sound levels (L_{dn}) were characterized according to typical values of L_{dn} that have been measured in similar situations (National Academy of Sciences 1977).

Estimates of L_{dn} for potentially affected properties along EFPC were derived from information on existing land uses and the area's population density. Land use along EFPC includes five main categories: residential, commercial, agricultural, DOE-owned and other (see Sect. 2.1.4). Population densities were obtained by using census tract data included in the RI. In the upper reaches of Lower EFPC, the population density ranges from ~39 to 154 people/km^2 (100 to 400 people/mile^2), with the average being around 77 people/km^2 (200 people/mile^2). Based on this area's land uses and the average population density, the L_{dn} would be around 45 dB, as shown in Table 2.21. This is a rough estimate, and it should be noted that the sound levels may be as much as 10 dB less than or greater than the values listed in Table 2.21 (National Academy of Sciences 1977). In the lower reaches of EFPC, the population density is ~23 people/km^2 (60 people/mile^2), and the L_{dn} would be around 40 dB. However, much of the lower section of the creek is on DOE-owned property that is not developed, and the L_{dn} would be around 35 dB.

2.2 SITE HISTORY

DOE's Y-12 Plant is located on 324 ha (800 acres) in Bear Creek Valley, 3.2 km (2 miles) south of downtown Oak Ridge. Operations at the Y-12 Plant began in 1943 as part of the Manhattan Project. Its original function was to separate ^{235}U from other isotopes of uranium. After World War II, the Y-12 Plant was called upon to undertake the first production-scale separation of lithium isotopes. The chemical exchange process ultimately used in the lithium separation process was called "COLEX," which is a contraction of "column-exchange." Many millions of pounds of mercury were essential to the project. Between 1955 and 1963, the primary sources of contamination were the releases of mercury from the "COLEX" process to the creek in a dilute, neutralized acid waste form. Estimated total releases of mercury to EFPC between 1950 and 1983 ranged from 108,000 kg (239,000 lb) to 212,000 kg (470,000 lb) (*Draft RFI Plan for Mercury Use Areas* 1989).

Although the "COLEX" waste stream discharges were eliminated in 1963, mercury continued to be released into EFPC. Secondary sources (e.g., building drain systems, sewers, and lines connecting the process buildings to the creek headwaters or ditch) were determined to be the cause of the continued releases to the creek. The lines from the process buildings contained contaminated sludges as well as mercury in some of the joints.

In an effort to reduce the contribution of mercury contamination from the sewers, they were relined in 1986 and 1987. Additional efforts to clean up the primary and secondary sources of mercury contamination are visible through the various remediation programs at the Y-12 Plant (e.g., decontamination and decommissioning, reduction of mercury in plant effluents, and

mercury-use areas remediation). These remediation programs are particularly important in addressing the sources of contamination at EFPC since past operations have resulted in extensive contamination of the entire EFPC operable unit. The watershed of Upper EFPC encompasses most of the Y-12 Plant area and is completely derived from plant runoff, controlled NPDES discharge points, and groundwater seepage. Upper EFPC is the source of contaminants in Lower EFPC. Lower EFPC, which is the focus of this FS, includes the 271-ha (670-acre) floodplain and the Oak Ridge SLB.

The first evidence of mercury contamination in EFPC was discovered by researchers in the early 1970s. A memorandum of understanding was signed by DOE, the Tennessee Department of Health and Environment (now TDEC), and EPA in May 1983 to investigate the environmental contamination of EFPC. DOE organized the Oak Ridge Task Force to investigate the extent of off-site environmental contamination of EFPC and other Oak Ridge-area streams related to the ORR and to determine whether any immediate public health impacts resulted from such contamination. The results of the early studies between 1985 and 1988 indicated that sediments and soils are contaminated with an estimated 77,000 kg (170,000 lb) of mercury. Other contaminants found in EFPC and the associated floodplain soils included additional heavy metals, radionuclides, and some organic compounds. The results of the early studies indicated that contamination was present and identified the need for further detailed investigations.

Detailed site characterization planning was initiated in 1987 under RCRA 3004(v) permit requirements, and a RCRA Facility Investigation was prepared. In 1988, DOE published a Notice of Intent to prepare an EIS for EFPC to fulfill requirements under NEPA. However, in 1989 the entire ORR, including the EFPC site, was placed on the National Priorities List and designated as a CERCLA site. Pursuant to the CERCLA designation, and in accordance with the draft Federal Facilities Agreement, the combined RCRA/CERCLA/NEPA strategy was defined, and an EIS Implementation Plan was published by DOE to describe the proposed process. The first action of the combined program involved the development of a phased RI Plan. Both Phases Ia and Ib of the Sampling and Analysis Plan are complete. The work conducted under Phases Ia and Ib of the RI enabled the determination of the nature and extent of contamination, definition of potential contaminant migration, and definition of the exposure pathways. The results are documented in the *East Fork Poplar Creek/Sewer Line Beltway Remedial Investigation Report*, Volumes I through VI (DOE 1994a).

Results of additional studies on the chemical form of mercury in the floodplain and transfer of mercury among ecological receptors are summarized in the *Addendum to the East Fork Poplar Creek - Sewer Line Beltway Remedial Investigation Report* (DOE 1994b).

Lower EFPC reaches ~23.3 km (14.5 miles) from the outfall of Lake Reality just inside the Y-12 Plant boundary, through the city of Oak Ridge, to its confluence with Poplar Creek. The course and streambed of Lower EFPC have been modified during the growth of Oak Ridge. Modifications to the creek include channelization in some sections of town, installation of riprap to protect the banks, and the construction of drainage ditches and lateral culverts. Box culverts and bridge piers have also been located at roadway crossings over EFPC. Ephemeral and perennial tributaries feed into Lower EFPC. The Oak Ridge Sewage Treatment Plant is another significant influent source to the creek. Historical storm flow depositions are responsible for the presence of the majority of the contaminants of concern (COCs) in the floodplain areas. Over

the years, creek sediments and floodplain soils were removed and redistributed as additions to local gardens, fill, and backfill and topsoil used during construction of portions of the SLB.

The Oak Ridge SLB was constructed in 1982-1983 by the city of Oak Ridge to serve as an interceptor sewer. The beltway contains over 16 km (10 miles) of sanitary interceptor sewers and force mains. The upper portion of the SLB, which parallels Oak Ridge Turnpike to the Oak Ridge Sewage Treatment Plant, consists of two branches that converge near the Daniel Arthur Rehabilitation Center. In certain instances, floodplain soils from EFPC were used to provide the topsoil used during sewer construction. Several locations along SLB have already been the subject of remedial actions due to the need for construction in limited areas or due to public request. Typically, these areas have either been covered with clean soil to eliminate direct contact with contaminants or removed and packaged for disposal.

2.3 NATURE AND EXTENT OF CONTAMINATION

During several previous studies data were collected concerning the type, extent, and levels of contamination in the EFPC floodplain. Surveys of the Y-12 Plant effluents and EFPC sediments and groundwater have been conducted to varying degrees since 1977, and biological monitoring has been provided at selected locations along the creek since 1984. A major investigative effort was undertaken in 1983 as part of the Oak Ridge Task Force. It involved large-scale sediment, soil, water, groundwater, and vegetation sampling in an early effort to understand the potential public health impact of the watershed contamination. These and other ancillary studies provided critical information for the planning of the CERCLA RI efforts. Detailed summaries of the scope and results of the historical studies are contained in the RI report (DOE 1994a). However, due to the lack of CERCLA-required rigor and documentation, the results from these historical studies could be used only for screening-level assessments and developing conceptual models to define sampling strategies, not as the basis for the human health and ecological risk assessments.

The conceptual model for contaminant transport in the EFPC watershed is based on the premise that soil contamination in the EFPC floodplain is closely linked with hydrologic events. Contaminants from the Y-12 Plant were washed down EFPC during high-flow conditions following rainstorms. At least some of the contaminants were adsorbed onto sediment particles and were transported downstream in a suspended phase (TVA 1985). Other contaminants were transported in a dissolved phase. During flood events, the creek flows out of its banks and spreads out across the floodplain, depositing contaminated sediments on vegetation and soils. Hence, the EFPC RI focused on the evaluation of surface water, creek sediments, floodplain soils, and groundwater as potentially affected media. Sampling and laboratory analysis to support the RI was conducted in two phases. Phase Ia, which began in the autumn of 1990, was designed to determine the nature of the contaminants. This phase involved a screening-level assessment for 182 analytes identified from the primary groups of metals, volatile and semivolatile organic compounds, pesticides/herbicides, PCBs, and radionuclides. Phase Ib, which began in the summer of 1991, was designed to establish the extent and level of contamination. Both phases were used to identify COPCs. Both Phases Ia and Ib were conducted under Level IV Data Quality Objectives (established for data utilized in the baseline risk assessment), with all analyses performed under the EPA Contract Laboratory Program (CLP) or approved equivalent.

The COPCs were identified on the basis of Phases Ia and Ib sampling data. A toxicity concentration scoring system was used which ranks potential health effects of chemicals on the basis of measured concentrations and established toxicity measures without making quantitative assumptions about exposures and dose (EPA 1989a). With the exception of lead, all chemicals lacking EPA-approved toxicity measures were excluded from the COPCs for quantitative evaluation. For inorganic analytes, the presence of the chemical in reference site (background) samples was also a factor used in determining the COPCs (i.e., twice background). Chemicals that were detected in <5% of the samples tested were not designated as COPCs.

As shown in Table 2.22, the COPCs for EFPC media are extensive. The concentration toxicity scoring system showed that mercury was the most significant noncancer contributor (responsible for >60% of the total toxicity) and that arsenic was the major cancer contributor (responsible for >40% of the total toxicity) in soils and sediments. In groundwater and surface water, manganese was responsible for the majority of the noncancer toxicity score. The COPCs identified in Table 2.22 are quantitatively evaluated in the baseline risk assessment and are discussed in Sect. 2.5.

2.3.1 RI Implementation and Results

Data quality objectives were established during the initial scoping process for the EFPC RI and revised prior to Phase Ib of the RI. The data quality objectives development generally followed the three-stage process outlined by EPA (EPA 1987c). Meetings were held in 1990 with the primary data users: Region IV EPA, TDEC, DOE, Energy Systems, and the EFPC RI team. Historical data, primarily from the Oak Ridge Task Force and the TVA Instream Contaminant Study (TVA 1985), were reviewed, and a conceptual model was developed. The structure of a phased investigation was conceived, and the overall project objectives were established.

Both qualitative and quantitative data quality objectives were established for the EFPC RI. Of the PARCC parameters (precision, accuracy, representativeness, completeness, and comparability), analytical precision and accuracy were controlled by adopting EPA CLP criteria and Quality Control (QC) frequency and types. Data verification and validation of the resulting analytical data packages ensured that the laboratories produced an acceptable quality level for results. Sampling precision was evaluated by the use of collocated samples (field replicates) and split samples (field duplicates). Representativeness of data from the EFPC RI was accomplished by selecting sampling methods and performing repetitive sampling events to accurately represent the characteristic population. Intervals for soil sampling were chosen to obtain the strata with the highest concentrations of contaminants in order to achieve the most conservative representation and to optimize the number of samples required. To achieve comparability, the EFPC RI utilized one laboratory to perform its CLP analyses and the same sampling methods for each medium. Data quality objectives for completeness for the EFPC RI were set at 90% for the laboratory completeness for both Phases Ia and Ib. Percent completeness for field sampling was established at 90% for Phase Ia but only 70% for Phase Ib. Completeness for field sampling was defined as the percentage of planned samples that were actually taken and submitted for analysis.

Data uses were identified as primary inputs into the site characterization study, the human health and ecological risk assessments, the initial screening of alternatives, the FS, and the EIS. A decision was made by DOE to obtain the highest quality data possible for critical studies. The data collection program was compiled into a sampling and analysis plan for each phase of the RI.

During the design of the data collection activities for Phase Ib, assistance was obtained from the EPA-Environmental Monitoring Systems Laboratory in Las Vegas. The question of adequate sampling density/data quantity to properly characterize the floodplain was supported by EPA modeling studies using the historic data set. Procedures were adopted or written to guide field activities and data management tasks, and analytical methods were selected for each environmental sampling activity. Phase Ib relied upon neutron activation analysis, a non-CLP method, for the large-scale soil sampling of the floodplain to determine the extent and distribution of contamination. Data quality objectives for neutron activation analysis were established to meet the precision and accuracy of CLP methods but with an exception for analytical sensitivity. The desired lower limit of detection for mercury in floodplain soils was determined to be 11 mg/kg (or ppm). This limit was established to meet any potential remedial action level or risk-based need.

Metals were the focus of Phase Ib sampling because metals (in particular, mercury) were identified as the primary source of risk from hazard scores for noncarcinogenic and carcinogenic substances and radionuclides. Neutron activation analysis was chosen as the preferred method of analysis for metals because it was cost effective and results could be obtained relatively quickly. Additional limited sampling using CLP protocols was used as a comparison to neutron activation analysis methods and also provided additional data about PAHs and PCBs that neutron activation analysis methods could not accomplish. The results of the organics analyses confirmed that the contribution of PAHs, PCBs, and other organic compounds to health risk was small enough not to require more extensive sampling.

As discussed briefly above, the RI was conducted in two phases (Ia and Ib) from 1990 to 1992. Phase Ia of the RI involved collection of base flow surface water and sediment samples from EFPC and its tributaries to define source contributions. Storm flow samples were collected from EFPC during two flood events and from selected tributaries during one flood event. Analyses were performed for filtered and unfiltered samples to distinguish contaminants attributable to suspended particles from those in solution. Groundwater was sampled for four consecutive quarters from 22 monitoring wells. Soil samples for contaminant analyses and undisturbed geotechnical samples for soil chemistry and engineering parameters were taken from three areas of known contamination (NOAA, Bruner's Center sites, and Sturm sites). Corresponding sampling and analysis was performed for a reference site (Hinds Creek) to allow comparison with an equivalent noncontaminated site. Hinds Creek was selected as a site that possessed the same soil and bedrock types but was devoid of any contamination including urban contaminants. This was necessary to provide for a true comparison against a noncontaminated reference site without complications of municipal impacts.

Phase Ib was initiated to determine the extent and distribution of the COPCs and to provide additional data to support the human health and ecological risk assessments. While the focus was on large-scale sampling of the floodplain soils, several supplementary studies also were conducted (DOE 1994a). A second round of surface water sampling at certain creek sites was performed to allow comparison of data from two different periods. Soil samples were investigated by optical and electron microscopic methods to ascertain mercury form and association. Lysimeters were installed to obtain adsorbed pore water from the unsaturated zone within the floodplain; however, recovery was insufficient to permit analysis for total or methyl mercury concentrations. As a substitute, methyl mercury analyses were performed on a set of soil samples taken from the study areas. The proportion of total methyl mercury to total mercury in the soils averaged about

0.003%, which was in agreement with published results (Revis et al. 1989a). As part of the ecological study, analysis was performed of the methyl mercury attributable to the suspended sediment fraction in surface water of Lake Reality. The proportion of methyl mercury in the suspended sediments to total mercury in unfiltered water samples (0.008%) was equivalent to the proportion in soils.

Extensive sampling of all primary affected media was conducted along the entire length of the EFPC floodplain and the SLB. As shown in Table 2.23, the Phase Ia sampling plan specified soil, sediment, surface water, and groundwater sampling at 5 permanent creek sampling sites, 20 tributaries to EFPC, 3 primary floodplain study sites, and 2 locations on the Hinds Creek reference site. Phase Ib expanded the soil and sediment sampling by conducting soil/sediment sampling in transects across the floodplain at 100-m (330-ft) intervals. Soil samples were taken along each transect at 20-m (66-ft) spacing from the creek bank to the elevation of a 100-year flood. Surface and subsurface core samples were taken to a depth of 1.2 m (4 ft), with >3000 samples collected and analyzed from the 159 transects. Stream sediment samples were collected at odd-numbered transects. Every three sequential sediment samples were composited for analysis to represent 600 m (1969 ft) of the creek. Twenty-seven sediment analyses numbered from 003 to 152 provide results for the full suite of analytes. Soil sampling along the SLB was accomplished during Phase Ib, primarily to determine the extent of contamination (contaminant types and levels were well established through the creek sampling program). The results of this extensive sampling and analysis effort along the EFPC and SLB are summarized by principal media as follows.

2.3.1.1 Soils

Of all the media, the floodplain soils have the largest volume and highest concentration of contaminants. Contamination includes a suite of inorganic metals (including mercury), a number of PAHs, PCBs, and several radionuclides (uranium and thorium). Because mercury accounts for 85% of the total toxicity, most attention was directed toward this metal. Based on nonparametric correlations between mercury and other contaminants, mercury was found to be a sufficient predictor of the occurrence of the other metals and radionuclides and was used as a surrogate to determine the distribution and extent of contamination (with the exception of the organic compounds).

As illustrated in Fig. 2.15, mercury and most other inorganic contaminants decrease significantly in the lower half of the creek, although isolated sites are present throughout with elevated concentrations. In fact, mercury and the other inorganic contaminants are situated in defined areas of the floodplain and not randomly scattered throughout its length. The creek bank within a few meters of the water has received at least some contamination along its entire length. The concentrations along the bank decrease as distance from the Y-12 Plant increases. Only four extended areas within the floodplain (NOAA site, Bruner's Center site, Sturm site, and Grand Cove Subdivision) display significantly elevated concentrations of mercury and other metals. Areas that are frequently inundated, such as upstream reaches of the creek behind culverts and roadway underpasses, also show elevated levels. Except for these areas, excessive levels found adjacent to the creek drop off drastically with distance from the creek. For the uranium isotopes, concentrations were relatively low throughout the length of the creek (see Fig. 2.16), with little discernable pattern of distribution. PCB and PAH concentrations also were found to be low (mean concentrations per segment of <2 mg/kg and <5 mg/kg, respectively). Their appearance

is more general and widespread, possibly related to municipal contributions in addition to the Y-12 Plant source. Their presence is most common in the upper segments of the floodplain near commercial development and urban runoff.

Geotechnical investigations were undertaken to determine soil morphology and chemistry, hydraulic parameters for the unconsolidated zone aquifer, and relationships between particle size distribution and contaminants. The particle size distribution results revealed that mercury is fairly evenly distributed across all size fractions, not concentrated in the fine fraction as previous investigations reported (TVA 1985). As shown in Fig. 2.17, mercury levels are highest in Horizon 2 and decrease in Horizon 1, probably reflecting the decreased output of mercury into the EFPC system by the Y-12 Plant in recent years. Similarly, no relationship between uranium concentrations and particle size was apparent. The highest uranium concentrations occur in Horizons 1 and 2, with uranium highest in the fine fraction in Horizon 1 but in the coarse fraction in Horizon 2. Uranium levels for the deepest three horizons are relatively constant with particle size classes.

Even with the large number of surface and subsurface samples analyzed from the floodplain, the spatial variability was found to be significant, and little direct correlation could be made between overall contaminant concentrations and individual sampling points. To provide estimates of contaminated soil volumes, soil samples were obtained every 20 m (22 yd) across the width of the 100-year floodplain from 159 transects over the length of the creek. Samples were taken from 3 layers [0 to 0.41, 0.41 to 0.82, and 0.82 to 1.2 m (0 to 16, 16 to 32, and 32 to 48 in.)]. To make sense of this large volume of data, a mathematical tool was used to help estimate contaminant concentrations between sampling points. The EFPC RI employed a geostatistical method that used an interpolation technique called kriging to calculate mercury concentrations on 20- × 20-m (22- × 22-yd) blocks. Due to time constraints, kriging estimates were only calculated for the top layer [0 to 0.41 m (0 to 16 in.)]. The extent of contamination was also delineated by hand contouring mercury concentrations. Boundaries were interpolated between sample points by following the same topographic elevation as the sampling locations. Soil concentrations of mercury were estimated for portions of the EFPC floodplain using the surface area of the contoured estimates and the depth of the top two sampled layers [0 to 0.41, and 0.41 to 0.82 m (0 to 16, and 16 to 32 in.)]. Only isolated samples within layer 3 (0.82 to 1.2 m) displayed measurable concentrations; therefore, no calculations were performed on this layer.

Soil contamination along the SLB was found to be isolated to three principal areas (the Tulane, Fairbanks, and Emory Valley Road areas). As expected, the measured contaminant types and levels were similar to the distribution found along the creek. The average mercury concentrations in the SLB are shown in Table 2.24. Contamination was found to be present within the upper 15 to 30 cm (6 to 12 in.) of the soil horizon or completely absent. No concentration gradient was obvious along the SLB based on the sampling data.

2.3.1.2 Sediments

As would be expected, creek sediments contain the same contaminants as floodplain soils but at lower concentrations. Because of the transient nature of sediments, the distribution of metals is not as predictable as it is for soils. The same general patterns do exist, however. The upper reaches of the creek show somewhat elevated levels of the various metals (especially mercury) compared to other sections of the creek. Figure 2.18 shows the measured mercury concentrations

by transect sampling location, with most locations exhibiting < 10 mg/kg in the creek sediments. The few locations showing higher levels of mercury still had contaminant levels below the respective floodplain soils levels (see Fig. 2.15). For total uranium, sediment levels were consistently low (all < 12 pCi/g), with a less discernable pattern of contaminant location along the stream length (Fig. 2.19). The significantly higher concentrations of metals (including mercury) and uranium in the EFPC sediments compared to the tributary sediments seem to confirm a Y-12 Plant source for this instream contamination. The results of the PCB and PAH sampling indicate contaminant source(s) in the upper third of the creek, immediately downstream of the Y-12 Plant and along the commercial areas of Oak Ridge. The results are characteristic of virtually every urban environment and do not necessarily point to the Y-12 Plant as the sole source of these low-level organic contaminants. A sampling results anomaly is observed immediately downstream of the confluence of Bear Creek and EFPC. This area displays slightly elevated concentrations of several contaminants compared to adjacent segments of the creek. This occurrence is thought to result from either the input of Bear Creek or the "pooling" of the sediments from creek back flow. Back flow of EFPC occurs when the Watts Bar Reservoir level is raised and temporary reverse flow takes place in the lower reaches of EFPC.

To determine the location and distribution of sediments within EFPC, mapping was done in the spring of 1992. Field crews walked the creek from Lake Reality to the confluence of EFPC and Poplar Creek. They identified and measured depths at locations of sediment accumulation. Many reaches of EFPC were found to be barren of sediment and have a bedrock base. The accumulations of sediments that do exist are primarily coarse-grained in nature. Apparently, the normal stream velocity and frequent storm events carry fine-grained sediments downstream to Poplar Creek. Because of the transient nature of sediments within the creek, the data derived from this mapping represent only a gross estimation of sediment location and thickness at a single point in time. Based on this study, an estimated 55,400 m^3 (72,500 ft^3) of sediments are present in the creek. Only 8 of 27 composited sediment samples had mercury concentrations in excess of 10 ppm. Because samples were composited over 600-m (2000-ft) reaches, no estimates were made of contaminated sediments.

2.3.1.3 Surface water

Surface water was sampled under two scenarios as part of the RI, base and storm flow, to determine present contaminant source contributions to the EFPC watershed. This sampling included locations at the discharge of Lake Reality to measure Y-12 Plant input to the system, at the confluence of EFPC with Poplar Creek to measure output from the system, and at one location adjacent to an area of known high floodplain soil contaminant concentrations. Also, surface water samples were obtained for the six ecological study sites (Table 2.1). Except for isotopic uranium and concentrations of mercury ($< 1 \mu g/L$), no COPCs were identified during base flow conditions at any of these creek stations. Three sites also were sampled to characterize potential runoff of pesticides, herbicides, and residual hydrocarbon products from selected residential and commercial areas of Oak Ridge. In addition, two major tributaries—an unnamed tributary (which drains a residential and commercial area near the Civic Center) and Bear Creek (which drains the western half of the Y-12 Plant site)—were sampled. Concentrations at these sites were very similar to the low values obtained for the EFPC sites.

Collection of surface water samples from three EFPC sites during two storm events and from three residential and commercial tributaries during one storm event allowed comparison of base

flow and storm flow concentrations of total and dissolved contaminants. Several metals (arsenic, chromium, copper, lead, manganese, mercury, nickel, vanadium, and zinc) were detected at EFPC locations in much higher concentrations (10 to 100 times higher than background levels) during storm flow than during base flow. Detection of no or minimal dissolved concentrations of most metals indicates primarily particle-bound transport. Total activity of uranium isotopes was observed in detectable quantities only in EFPC but it was present during both base flow and storm flow. Noteworthy by their absence in either storm or base flow, in total or dissolved concentrations, are beryllium, cadmium, and PCBs. Also noteworthy is the presence of chromium, copper, lead, vanadium, and zinc in storm flow samples at the Civic Center tributary and the absence of these contaminants at the other tributaries. This appears indicative of urban impacts on EFPC water quality.

2.3.1.4 Groundwater

Groundwater was investigated to determine whether it is a pathway for contaminant migration; the results are discussed in Sect. 3.2.4 of the RI report (DOE 1994a). The conceptual model for groundwater indicates that the EFPC valley is an alluvial aquifer receiving surface water from Bear Creek Valley and recharge from the watershed along Black Oak and East Fork ridges. Deep groundwater flow paths are not postulated to cross surface water divides. Twenty-two wells were sampled for the full suite of analytes for four consecutive quarters. In addition, water level, precipitation, and geochemical data were collected to support interpretation of the analytical results for contaminants. Four of the 22 wells were screened in the bedrock aquifer. Groundwater field parameters and analytical results were examined to define whether a shallow aquifer exists separately from an underlying bedrock aquifer. Hydrogeochemical modeling was utilized which demonstrated two findings. First, no difference could be ascertained between deep versus shallow groundwaters; therefore, no aquitard is inferred to exist between the two aquifers. Second, the geochemistry of the EFPC groundwaters is such that mercury is not likely to persist in a dissolved phase and will precipitate out, probably as a mercury sulfide.

Filtered and unfiltered samples were analyzed to compare total and dissolved concentrations of metals because contaminant transport in groundwater is mainly concerned with those contaminants that are found in solution under ambient pH, temperature, and other environmental conditions. As for surface water, most of the detectable concentrations of COPCs found in groundwater were associated with total rather than dissolved analytes. Total concentrations exceeding Safe Drinking Water Act maximum contaminant levels were found for beryllium, copper, lead, manganese, mercury, nickel, radium, and vanadium, but only manganese, which is a common element in local groundwaters, had dissolved concentrations exceeding the Safe Drinking Water Act levels. This association of contaminants with total analyses suggests that the particle-reactive contaminants are attached to fine-grained particles in the total sample and are not necessarily mobile in groundwater. Equilibrium geochemical modeling of the analytical results from the groundwater monitoring wells using MINTEQA1 (EPA 1987a) supported the contention that mercury concentrations measured in groundwater samples are related to particulate-bound mercury. A survey was conducted to ascertain the use of groundwater as a potable water supply. No wells are located within the floodplain, and groundwater is not being used as a water source.

Y-12 Plant personnel have monitored three wells in the EFPC drainage below the former site of New Hope Pond. Volatile organic compounds were not detected in the groundwater. Dissolved mercury also was below levels of detection. The USGS survey of shallow wells in the

EFPC floodplain (Carmichael 1989) produced similar results but indicated the presence of dissolved uranium in the groundwater. Carmichael concluded that contaminants in the water samples from the USGS transect wells were associated with particulates and thus were likely to be artifacts of the installation process rather than reflecting actual groundwater transport of contaminants.

Groundwater was investigated as a potential migration pathway within the EFPC system. No outside sources of contaminants are considered to impact the groundwater medium and groundwater contributions to other areas and systems are considered negligible. No spatial or temporal gradient or plume of contamination was observed from the groundwater monitoring results. Higher levels of most contaminants (including mercury) were noted in the wells located in the upper reaches of the floodplain, which also have elevated levels of soil contamination. COPCs for groundwater included the metals and radionuclides listed for soils but none of the organic compounds. Total analyses (unfiltered) showed much higher contaminant concentrations than the filtered analyses (except for noted problems). In fact, many of the filtered analyses were below the analytical detection limit, which indicated that the majority of contamination is due to suspended sedimentation within the water column and not within the groundwater medium itself.

2.3.1.5 Biomonitoring

A number of historical and ongoing studies, especially the BMAP, have measured population densities and contaminant body burdens within the aquatic and terrestrial biota of the EFPC watershed. In general, these studies have found elevated levels of mercury and PCBs in fish, with the highest concentrations in the upper reaches of EFPC nearest the Y-12 Plant. Relative abundance estimates of fish collected in the creek indicated that greater densities were present in the upper reaches of the stream, in the area most accessible to the public and also where the highest contaminant concentrations were observed. Other related studies of garden plots and mice populations have added to the accumulating knowledge of heavy metal (particularly mercury) interactions in the environment. This information base was the starting point for the comprehensive EFPC ecological risk assessment performed for the RI. Further discussion of the scope and results of that assessment is provided in subsequent sections of this FS report.

2.3.1.6 Air pathway

Atmospheric contaminant concentrations occurring in the general environment around the ORR and the surrounding region are monitored or sampled continuously by an air monitoring network. Measurements of air concentrations of 15 radioactive parameters, fluorides, sulfur dioxides, total suspended particulates, and mercury indicate that the ORR operations are not measurably affecting the regional air quality (including the EFPC floodplain) (Kornegay 1992). Ambient air monitoring of EFPC-specific locations for mercury also has been conducted by ORNL researchers at sites selected for known high mercury concentrations in soil. This monitoring included both high-sensitivity and high-volume measurements. Concentrations were at levels similar to those at an uncontaminated reference site, indicating that mercury volatilization cannot be distinguished from background levels (Turner and Bogle 1992).

2.3.1.7 Direct radiation

Historically, most of the large-area radiation survey information on the ORR and in the surrounding area has been provided by the Aerial Measuring System, an aerial radiological surveillance capability maintained by DOE. The most recent Aerial Measuring System survey of the EFPC watershed was conducted during the period of March-April 1992. Measurements were made from a helicopter at an altitude of 46 m (150 ft) and calibrated to terrestrial exposure rates at 1 m (3.3 ft) above ground level. Gross gamma counts were recorded to determine the ground level exposure rates and spectral windows were used for photopeak count rates to identify specific man-made radionuclides. While the majority of the floodplain measurements were less than the background level of 13 μR/h, one site was identified with rates between 13-20 μR/h. This site correlates with an area of known contamination (Bruner's Center sites) but is not statistically different from background, given the measurement error inherent in the method. Therefore, no gamma radiation due to contamination can be differentiated from background sources.

2.3.1.8 Wetlands

The Special Field Investigation for Wetland Soils, Vegetation, and Animals (Radian 1993) was conducted in September and October 1993 to refine knowledge about the nature and extent of mercury contamination in wetlands. Seven wetlands and two reference sites were selected for study. Five of these wetlands were selected because preliminary information from the RI report indicated that contamination in these wetlands was present at levels that might require remediation (Wetlands 3, 4, 5, 7, and 8). Two other wetlands were selected because very little information was available about these areas from the Phase 1b investigation (Wetlands 14 and 17). Sixty-four soil samples, 59 animal samples (amphibians, crayfish, and shrews), 16 plant foliage samples, and 15 tree core samples were collected for the special field investigation and analyzed by neutron activation analysis. Total mercury was determined for all samples; a subset of 16 soil samples and 16 crayfish samples was also analyzed for methyl mercury content.

Results of this study indicated that mercury is being accumulated by wetland animals at concentrations comparable to levels found in other animals studied in other nonwetland areas of the floodplain and that some of this mercury has been converted to methyl mercury in crayfish. Methyl mercury is also found in wetland soils at very low concentrations (from 0.004 to 0.02%). Plant foliage samples generally had mean mercury concentrations of 0.2 ppm. Tree cores from wetlands had mercury concentrations ranging from ~0.1 to 0.4 ppm. Average mercury concentrations of animals residing in EFPC wetlands ranged from 0.2 to 5.5 ppm in amphibians, 0.2 to 5.5 ppm in shrews, and 1.2 ppm to 7.1 ppm in crayfish. Average methyl mercury concentrations in crayfish ranged from 0.2 to 0.5 ppm and averaged between 31 and 74% of the mercury in their bodies. These data were used to refine ecological risk assessment calculations and to revise contaminant boundary maps that were used to calculate the volumes and surface areas of contaminated soils used in the FS.

2.3.1.9 Sediment toxicity

Although evidence in the ecological risk assessment that was presented in the RI report (DOE 1994a) indicated that ongoing releases of contaminants from the Y-12 Plant into EFPC were causing the majority of observed impacts to aquatic biota, no sediment toxicity tests had

been conducted. Without sediment toxicity tests, it was not reasonable to exclude the possibility that contaminated sediments could be a contributing factor in explaining biota. Thus, sediment toxicity tests along with measurements of sediment and elutriate contaminant concentrations were initiated in May 1994.

One purpose of the toxicity tests was to help verify whether the impacts to fish and benthic macroinvertebrate community structure that were reported in the ecological risk assessment could have been due to toxicological effects from contaminated sediments as opposed to water-borne contaminants or nontoxicological stressors. The toxicity test measured the chronic toxicity of sediment elutriates to the cladoceran, *Ceriodaphnia dubia*, during a three-brood, 7-d, static renewal exposure. Any toxic effects would include the synergistic, antagonistic, and additive effects of all chemical and physical components that adversely effect the physiological and biochemical functions of the organisms.

A second purpose of the sediment toxicity tests was to provide data for equilibrium partitioning equations and more accurately define sediment remediation goal options for mercury. Remediation goal options, which are chemical-specific numerical cleanup limits for affected environmental media, are derived as one of the response objectives for hazardous waste site remediation. The sediment remediation goal options must protect aquatic ecological receptors. Ecological remediation goal options for sediments were developed in the RI report (DOE 1994a) and RI addendum (DOE 1994b) based on concentrations specified in ARARs and analytical data obtained during sampling of biota and physical media, as well as published toxicity information on the contaminants of concern (COCs). However, as mentioned above, no sediment toxicity tests were actually performed. Accurate, risk-based remediation goal options developed from the site-specific sediment toxicity tests would help protect the environment and could lead to a more cost effective and defensible selection of remedial method.

The study used a phased approach to determine sediment chronic toxicity. Phase 1 consisted of screening level tests with a single concentration of elutriate (100%) to establish a "pass-fail" "presence/absence" of toxicity. Test endpoints were survival and reproduction. A failed test occurred if survival was $<80\%$ and/or reproduction was <15 young per surviving female. If any sample failed the screening test, it was a candidate for Phase 2 definitive tests, which would use at least five dilution concentrations of the elutriate plus a control to establish the magnitude of toxicity by calculating the "No Observed Effects Concentration" (NOEC) and "Lowest Observed Effects Concentration" (LOEC) levels. The NOEC is the highest concentration of material (e.g., elutriate) in a toxicity test that has no statistically significant adverse effect on the exposed population of test organisms. The LOEC is the lowest concentration of material in the test that has a statistically significant adverse effect on the exposed test organisms.

Sediments were collected from four sites used during the ecological risk assessment sampling (Sites 1, 2, 3, and 5), including the three closest downstream from the Y-12 Plant. The three sites closest to the Y-12 Plant (Sites 1 through 3) had the greatest impacts to aquatic biota during the field surveys of the ecological risk assessment (DOE 1994). An additional sediment sample was collected from a location where the mercury concentrations were among the highest observed in the Lower EFPC during the RI (just downstream of Site 5 (DOE 1994). One field duplicate (at Site 5) was also collected along with a sample from the reference site in Hinds Creek near Oak Ridge, Tennessee. Sediment elutriates were used in 7-d tests with *Ceriodaphnia dubia*, according to EPA methods (EPA 1989) with mortality and number of offspring as the test

endpoints. Subsamples of bulk sediment, along with elutriate samples from days 1, 3, and 7 of the toxicity tests, were sent to analytical laboratories for determination of total mercury and other contaminants.

All of the sediment elutriates passed the screening tests. Survival was 100% for elutriates from Sites 2,3, and one of the two samples from Site 5, plus the control. Survival was 90% for the remaining tests. Average number of young per surviving female ranged from 32 for the Hinds Creek sample, to 44 for one of the two samples from Site 5. Consequently, definitive toxicity tests were not performed.

The highest total mercury concentration in any of the EFPC sediment samples used during the screening toxicity tests was 73 mg/kg at Site 3. Total mercury concentrations in the EFPC sediments ranged from 17 to 73 mg/kg, but was only 0.04 mg/kg in the sample from the reference site at Hinds Creek. The results of the tests indicate mercury concentrations as high as 73 mg/kg in sediments from EFPC yielded elutriates were not chronically toxic to *Ceriodaphnia*. Further discussion of these results as they relate to sediment remediation goal options are presented in Sect. 2.5.3.2 in this FS.

2.3.1.10 Food web study

In the RI report (DOE 1994a), it was reported that the stoneroller minnows had much higher body burdens of mercury than redbreast sunfish or crayfish. The food habits of the stonerollers are different from those of most fish: these minnows are specialized grazers of periphyton. The specialized feeding habit and relatively high body burdens of mercury in stoneroller minnows suggest the possibility that periphyton may be an important link between contaminants in water/sediments and higher trophic levels in EFPC. This study investigated the relationship between methyl mercury in periphyton and methyl mercury body burdens in stoneroller minnows and other grazers in upper EFPC. The work was performed by Walter Hill and Art Stewart at ORNL. Remediation goal options were calculated using results from the Hill and Stewart study (see Sect. 2.5.3.2).

2.3.2 Data Quality Assessment

A primary goal of the EFPC quality assurance (QA) program is to ensure that the results of analysis of all environmental samples are fit for their intended use. To this end, a QA Program Plan, a QA Project Plan, and technical procedures were compiled to guide the investigation. Audits and surveillances were conducted to determine the adequacy of field and laboratory performance against the QA plan and procedures. For the project as a whole, surveillances were performed covering field activities as well as procedural activities such as training and document review. Nonconformance reports were written concerning quality deficiencies, and all but a few (which do not affect data use) have been resolved.

Analytical data generated under this project have been subjected to a rigorous process of data verification, validation, and review. Upon receipt of data reports from the laboratory data, the verification staff performed a systematic examination of the reports following standardized data checklists to ensure the content, presentation, and administrative validity of the data. Discrepancies identified during this process were recorded and documented utilizing the QA Program nonconformance report system.

During the data validation phase, data were subjected to a systematic technical review by examining all analytical quality control (QC) results and laboratory documentation, following the appropriate functional guidelines for laboratory data validation. The primary objective of this phase was to assess and summarize the quality and reliability of the data for the intended use and to document factors which may affect the usability of the data. As an end result of this phase of the review, data were qualified based on the technical assessment of the evaluation criteria. Qualifiers were generated for each analytical result to indicate the usability of the data for intended uses. For the overall purposes of this investigation, however, data were either accepted or rejected as meeting Level IV quality requirements. With certain exceptions (such as defining the extent of contamination), data from the RI were designed to meet the highest qualification for their intended use in the human health and ecological risk assessments.

To date, procedures for radiological analyses and procedures for radiological data validation have not been firmly established in the same manner as with the inorganic/organic analyses under CLP. EFPC radiochemical analytical data were validated using "Laboratory Data Validation Guidelines For Evaluating Radionuclide Analyses" (SAIC, Rev 4, 1992) and "Laboratory Data Validation Guidelines For Evaluating Neutron Activation Analyses" (SAIC, Rev 2, 1992). These documents were developed with the intent to provide data validation guidelines for radioanalytical data equivalent to those provided by EPA under CLP guidance. These documents provide a systematic process for reviewing the data against the data quality objectives to provide assurance that the data are adequate for their intended use.

On a project-wide basis, 96% of the data were accepted as usable based on the formal validation process. Of the major analytical groupings, only the toxicity characteristic leaching procedure (TCLP) and neutron activation analysis have overall rejection rates exceeding 10%. neutron activation analysis provided acceptable data for 89% of the analyses, while TCLP provided 82%. Specific analytes that were below the 90% level included:

Anions	— Sulfide (68%)
Neutron activation analysis	— Antimony (87%)
	— Arsenic (69%)
Semivolatiles	— 2,4-Dinitrophenol (89%)
TCLP	— Phenols (25%)
	— Other organics (66-75%)
	— Silver (85%)

None of the above analytes were considered critical to the investigation. Sulfide was part of the water analyses and not a COPC. A large number of antimony and arsenic results (including CLP analyses) are available for soils, even given an 87% and 69% acceptance rate with neutron activation analysis. The single semivolatile organic compound listed above is only one of several phenols and was not a COPC. The organics from the TCLP samples were not compounds of particular interest. In summary, only a very limited number of analyses did not meet the laboratory objective, and assessments for the investigation were not restricted due to lack of data.

Overall, precision for soils analysis as well as water analysis is considered adequate for the EFPC project. Accuracy on a project-wide basis was deemed acceptable for both CLP analysis and neutron activation analysis. While some of the data were qualified as usable but estimated,

or unusable due to poor matrix spike recoveries, the accepted data are sufficient for use by all phases of the project.

The radiological isotopes of most interest were the uranium series. From the combined use of neutron activation analysis and alpha spectroscopy, large amounts of uranium data are available for these isotopes. Of all the radiological results, those for thorium had the highest rejection rates, with <50% of the analyses validated as usable data. However, the available results do not indicate that a problem exists, and additional thorium results were not required. Moreover, thorium would be expected to be present in the same general area as uranium; therefore, uranium can act as a surrogate for remedial decisions concerning thorium.

The number of samples taken for analysis to characterize the primary media within the EFPC OU are summarized as follows:

Medium	No. samples
groundwater	159
surface water	77
floodplain soils	4181
creek sediments	195
miscellaneous	111
TOTAL	4723

2.4 CONTAMINANT FATE AND TRANSPORT

2.4.1 Fate and Transport Profiles

This section contains fate and transport profiles for the COPCs at EFPC. These transport and fate profiles provide general background information on the COPCs and summarize information that is available in the literature. They are not intended to conclusively depict how these chemicals may or may not behave in the EFPC ecosystem. For detailed information on chemical toxicity and site-specific ecological data, the reader is referred to the RI report. The COPCs were identified during the baseline human health and ecological risk assessments. Mercury has been implicated as the human health COPC. Floodplain soils are the only medium of concern for human receptors. Mercury, cadmium, chlordane, PCBs, and PAHs have been implicated as ecological (aquatic species) COPCs in surface water and sediment; mercury is the ecological (terrestrial species) COPC in the floodplain soils. Mercury is considered to be the principal contaminant of concern in the EFPC system. The derivation of human health and ecological COPCs is detailed in Sects. 5 and 6, respectively, of the RI report; brief summaries are given in Sect. 2.5 of this FS report.

2.4.1.1 Mercury

Mercury in natural systems can exist in many forms, and a complex series of conversions is possible, depending on chemical, physical, and biological factors as indicated in Fig. 2.20 (Moore and Ramamoorthy 1983). Elemental mercury and mercuric ions are the predominant natural forms in water, and the sulfide (mercuric sulfide is cinnabar) is commonly found in soils and anaerobic sediments (Baudo et al. 1990). In aquatic systems, mercury binds to dissolved

matter or fine particulates; however, the dominant process controlling the distribution of mercury compounds in the aquatic environment appears to be the sorption of nonvolatile forms to sediment particulates (EPA 1979; HSDB 1992). Mercury can be desorbed into the water column, transported by water (probably bound or chelated to some fine particles or dissolved substances), and redeposited on the sediment bed (HSDB 1992). The adsorption rate of mercury on sediment is 10^3 to 10^5 times greater than the rate of desorption. Evidence shows that mercury sorption in soils and sediment is controlled by the amount of organic matter present. Regardless of pH, the affinity of humic acid or organic-rich sediments for mercury is stronger than for most other trace metals (cadmium, copper, zinc) (Battelle 1984).

Mercury can be methylated via two processes: microbial (enzymatic) and chemical (non-enzymatic by methylcobalamine). Bacteria produce methyl mercury through the methylation of inorganic mercury (EPA 1987b). The conversion of inorganic mercury compounds to methyl mercury implies that recycling of mercury from the sediment to water to air and back could be a rapid process (HSDB 1992). Jernelov (1970) reported that methylation rates increase with temperature, and the rate is higher with suspended material and in the surficial sediment rather than deep sediment. The rate of methylation is also higher at low oxygen concentrations. Formation of dimethylmercury is not favored in acidic environments, and the amount of dimethylmercury formed is usually several orders of magnitude less than that of monomethylmercury ion (EPA 1987b). Studies have shown that methyl mercury sorbs to sedimentary material in the following order (EPA 1979):

organics > > illite > > montmorillonite > > sand

Results of the RI and previous studies support the conclusion that the mercury in EFPC water, sediment, and soil is predominantly in bound form. Bound forms of mercury are less bioavailable to biota than unbound forms. Only a very small fraction of the mercury in this ecosystem is methylated, although most of the mercury in fish tissues is methylated (Moore and Ramamoorthy 1983). According to D'itri (1990), the rate at which mercury is methylated, rather than the total mercury in the ecosystem, is the principal determinant of how much mercury is concentrated in fish. In addition, because the methyl mercury is assimilated rapidly and depurated very slowly, its synthesis in the sediments doesn't have to be rapid in water for it to be bioconcentrated by fish. Mercury in natural waters associates very strongly with particulate matter, with partition coefficients reported in the literature in the range of $1.3 - 1.8 \times 10^5$ L/kg, and this strong partitioning is not sensitive to the nature of the suspended solids (Moore and Ramamoorthy 1983). Mesocosm studies were carried out to evaluate the relative roles of surface water and sediment as sources of mercury contamination to biota in EFPC (DOE 1994, Appendix Q). In this study, aquatic communities were placed in enclosures with either EFPC sediment or no sediment and either water from Upper EFPC or clean groundwater. The distributions of inorganic mercury and methyl mercury in the sediments were measured after time had been allowed for equilibration of water-borne and sediment-bound mercury species. The partition coefficients observed in this fish study were in the range of $\sim 7.1 \times 10^5$ L/kg to $\sim 8.9 \times 10^5$ L/kg. These compare with 8.9×10^4 L/kg observed for EFPC soil in the treatability studies. Desorption of mercury is generally a very slow process (Moore and Ramamoorthy 1983).

Mercury bioaccumulation in the food chain may lead to concentrations of as much as 10,000 to 100,000 times the concentrations found in ambient waters (EPA 1979). Reported

bioconcentration factors for freshwater fish vary from 1000 to 63,000 (EPA 1979; HSDB 1992). The biological half-life of mercury in fish has been reported to be ~2 to 3 years (HSDB 1992). A bioaccumulation factor of 65-140 has been reported for the edible mushroom *Pleurotus ostreatus*, grown on compost containing mercury with concentrations up to 0.2 ppm (ATSDR 1992).

In general, the availability of soil mercury to plant roots is low, and mercury concentrations are lower in leaves, stems, fruits, and seeds than in roots. Studies on vegetation growing in the EFPC floodplain have demonstrated the low availability of mercury to plants (Gist 1987; DOE 1994a,b). Gist (1987) reported mercury bioaccumulation factors in root crops of 1×10^{-3} to 1.6×10^{-2} for plants grown in soil with >300 mg mercury/kg; the garden crop study (DOE 1994a) reported a root bioaccumulation factor of 2×10^{-3}. The reported bioaccumulation factor for leafy crops was 1×10^{-3} (DOE 1994a), which confirmed the bioaccumulation factor range of 1×10^{-4} to 7×10^{-2} reported by Gist (1987). The concentration of mercury in EFPC floodplain vegetation was more variable than it was in trees and garden crops. One of 16 foliage samples taken in the wetland study (DOE 1994b) contained 10.6 mg/kg; the remainder were at or below 1 mg/kg. Seven samples of live grasses, 2 samples of browse, and 5 of 6 samples of dead grass analyzed in Phase Ib of the RI contained ≤1 mg mercury/kg, whereas one sample of dead grass contained 17 mg/kg (DOE 1994a). These results may be explained by the observation of Van Winkle et al. (1984) that EFPC floodplain vegetation contains low levels of mercury but may be contaminated by surficial soil or sediment deposited by floods. These results indicate that there is little transport of mercury from EFPC floodplain soils into plants. Therefore, there is little risk of toxicity either to the plants or to animals that consume them.

Results from studies in Canada showed that 50 ppm of mercury in soil impairs the growth of plants, and soils with levels higher than 1000 ppm must be considered toxic (HSDB 1992). In contrast, there has been no direct evidence of toxic effects of plants that are growing in EFPC floodplain soils with mercury levels ranging as high as 2000 ppm, indicating that mercury in the soils used in the Canadian study was probably in a more biologically available form than mercury in EFPC floodplain soils.

2.4.1.2 Cadmium

Transformation processes for cadmium in soil are mediated by sorption and desorption from water and include precipitation, dissolution, complexation, and ion exchange. Important factors affecting transformation in soil include the cation exchange capacity, the pH, and the content of clay minerals, carbonate mineral oxides, organic matter, and oxygen (McComish and Ong 1988). Many studies have shown that loss of cadmium due to leaching is not a major component of the total losses from soil (Adriano 1992).

In aquatic environments, cadmium is more mobile than most other heavy metals, such as lead (EPA 1979). Cadmium is primarily present as the Cd^{+2} ion; however, if high concentrations of organic material are present, more than half may occur in organic complexes. Cadmium precipitates as cadmium sulfide in reducing environments (McComish and Ong 1988). The most important removal processes for cadmium compounds is the precipitation and sorption to mineral surfaces and organic materials. Sediment bacteria may also assist in the partitioning of cadmium from water to sediments (Burke and Pfister 1988). In the aquatic fate of cadmium compounds, photolysis is not an important mechanism (EPA 1983), and biological methylation of cadmium

is unlikely to occur (EPA 1979). Cadmium is not known to form volatile compounds, so partition to the atmosphere from water is unlikely to occur (ATSDR 1991b).

Cadmium bioaccumulates in all levels of the food chain (ATSDR 1991b). In freshwater and marine species, cadmium concentrations have been reported at hundreds to thousands of times higher than in the water (EPA 1979). Levels of cadmium in plants grown in uncontaminated soil are normally <1 ppm in dry matter, but levels up to several hundred ppm in edible plants grown on cadmium-contaminated soil has been observed. Evidence shows that cadmium is quite phytotoxic for a number of crops (levels >20 ppm are generally undesirable for crop production), with the adverse effect being largely a consequence of the ease with which cadmium enters the plant through the root system (Purves 1985).

2.4.1.3 Chlordane

In many environments, chlordane has been released primarily through its application as an insecticide. Between 1983 and 1988, chlordane was approved in the United States only for use as an underground termite control. As of April 1988, all commercial use of chlordane in the United States has been canceled by EPA (Howard 1991). When released to soil, chlordane has the potential to persist for long periods of time; soil half-lives have been reported at 100 d to 3.3 years. Chlordane is expected to be immobile or only slightly mobile in soil; however, chlordane has been found in New Jersey groundwater, indicating that leaching is possible. Chlordane volatilizes rapidly from soil surfaces; however, once incorporated into the soil, losses are restricted (HSDB 1992).

Based on soil adsorption data and estimated organic carbon partition coefficient (K_{oc}) values, the major fate process of chlordane in surface water is expected to be adsorption to sediment. Chlordane is not expected to undergo significant hydrolysis, oxidation, or direct photolysis. Based on experimentally determined Henry's Law constants, chlordane can be expected to volatilize significantly from the water column; however, adsorption to sediment significantly attenuates the importance of volatilization (HSDB 1992).

Chlordane does not appear to be extensively concentrated in the higher members of the terrestrial food chain (i.e., raptors) (HSDB 1992); however, in aquatic species (bacteria, daphnids, fish), bioconcentration is expected to be important based on experimental bioconcentration factor values, which are generally above 3200 (EPA 1979; Howard 1991). The bioconcentration factors for fish in flowing water and static ecosystem tests have been reported to be 11,500 and 8320, respectively (Howard 1991; HSDB 1992).

2.4.1.4 PCBs

The low water solubility of PCBs, their high octanol/water partition coefficients, and their strong adsorption to soils and sediment indicate that leaching should not occur in soil under most conditions. Leaching is expected to be greatest from soils with low organic carbon, and the least chlorinated congeners are expected to have the greatest tendency to leach. PCBs are not known to be degraded by any chemical processes in soil, and biodegradation of PCBs is expected to be slow, especially in soils that have a high organic carbon content (ATSDR 1991c).

In general, the persistence of PCBs increases with an increase in the degree of chlorination. In soil, PCBs experience tight adsorption, with adsorption, generally increasing with the degree of chlorination of the PCB. Although biodegradation of higher chlorinated congeners may occur very slowly on an environmental basis, no other degradation mechanisms have been shown to be important in soil systems; therefore, biodegradation may be the ultimate degradation process in soil. The volatilization rate of PCBs from soil is very low; however, the total loss by this process over time may be significant because of the persistence and stability of PCBs (HSDB 1992). PCBs will generally not leach significantly in aqueous soil systems (HSDB 1992).

In water, adsorption to sediment and suspended matter is a major fate process. Experimental and monitoring data have shown that PCB concentrations are higher in sediment and suspended matter than the associated water column (ATSDR 1991c; HSDB 1992). Although adsorption can immobilize PCBs for relatively long periods of time, eventual resolution into the water column has been shown to occur (HSDB 1992). However, PCBs may be effectively sequestered from environmental redistribution when they reach the lower layers of sedimentary deposits (ATSDR 1991c). Volatilization of dissolved PCBs is an important aquatic process, and although the rate of volatilization may be low, as is the case in soils, the total loss over time may be significant. Aquatic hydrolysis and oxidation are not important processes with respect to the PCBs (HSDB 1992).

PCBs have been shown to bioconcentrate significantly in aquatic organisms. In studies with Cape stumpnose (*Rhabdosarqus holubi*), an estuarine fish, the bioconcentration factors for an exposure of 1 μg/L were 1100, 5900, and 24,000 for 20, 30, and 90 days, respectively (HSDB 1992). Estimated bioconcentration factors for PCBs in the fathead minnow have been reported to range 43,000 to 200,000 (ATSDR 1991c).

The bioconcentration factor for plants in the uptake of PCBs from soil and the translocation to aerial parts of the plant is reported to be <0.02, indicating that translocation from soil to aerial plant parts is not important for PCBs (ATSDR 1991c).

2.4.1.5 PAHs

In general, PAHs released to soil are expected to adsorb very strongly to the soil and are not expected to leach below the top few centimeters of soil or to groundwater. Hydrolysis and evaporation from soils and surfaces are not expected to be significant. PAHs with 4 or less aromatic rings are degraded by microbes and are readily metabolized by multicellular organisms (HSDB 1992). The ultimate fate process of PAHs is thought to be biodegradation and biotransformation by benthic organisms. However, these processes may be very slow (EPA 1979).

In aquatic systems, PAHs adsorb very strongly to sediments and particulate matter. Neither hydrolysis nor evaporation is expected (HSDB 1992). Biodegradation is probably slower in aquatic systems than in the soil, and biodegradation may be much more important in those aquatic systems which are chronically affected by contamination (EPA 1979).

Bioconcentration of PAHs may occur, although fish and many other vertebrates can rapidly metabolize PAHs by the action of microsomal oxidase. Organisms which lack a metabolic

detoxification enzyme system (such as phytoplankton, certain zooplankton, mussels, scallops, and snails), tend to accumulate PAHs (HSDB 1992).

2.4.2 Approach to Fate and Transport Modeling

The assumption that the COPCs are associated with particulate matter in soils, creekbed sediments, and suspended sediments and that transport of these contaminants will be via movement of the particles is supported by the results of the RI and previous investigations of the EFPC environment and is consistent with the known properties of the contaminants, as discussed in the previous paragraphs. Consequently, the analysis of contaminant fate and transport has centered on estimating the potential for movement of soil and sediment particles.

Computer modeling was conducted to assess: (1) the potential for movement of sediment and associated contaminants of concern in EFPC and the adjoining floodplain, and (2) the potential erosion of contaminated floodplain soils into the creek. In addition, modeling was used to evaluate the potential for transport of contaminated soil within Segment 1 of EFPC to recontaminate floodplain soil downstream following remediation. Two models were used to simulate sediment and contaminant movement. These models were chosen to reflect the distinct hydrogeologic conditions of the creek and its associated floodplain.

The computer model simulations were designed to show the expected mobilities of the contaminants, not the absolute value of concentrations that would be found at any particular point in floodplain soils and creek sediments. These models include a number of simplifications and assumptions. The uncertainty associated with these assumptions, however, is not sufficient to affect the general pattern of contaminant mobility or the conclusions of the simulations. Brief descriptions of the computer models are included in this section.

2.4.3 Sediment Transport Modeling

2.4.3.1 The HEC models

The Hydrologic Engineering Center (HEC)-6 model, developed by the U.S. Army Corps of Engineers (COE 1991), is a one-dimensional numerical model of river mechanics that computes scour and deposition by simulating the interaction between the hydraulics of flow and the rate of sediment transport. By joining the hydraulic properties of the flow with the characteristics of the sediment material, one can calculate the rate of sediment transport. HEC-6 embodies these concepts to compute the movement of sediment materials for a temporal sequence of flows and, through volumetric conservation, the changes in channel dimensions. The model is designed to simulate the long-term trends of scour and/or deposition in a stream channel that might result from modifying the frequency and duration of the water discharge and/or stage or from modifying the channel geometry (e.g., encroaching floodplains). The basic hydrologic calculations performed by HEC-6 are very similar to those performed by HEC-2, the model used in previous studies by TVA and the U.S. Army Corps of Engineers to calculate water surface profiles to determine floodplain extent. This program is widely used for Federal Emergency Management Agency and other floodplain and floodway studies.

Data required by the HEC-6 model consist of four categories: geometric, sediment, hydrologic, and operating rule. The geometric file includes descriptions of cross sections at

various points along the channel (specified by coordinate points and the distance between cross sections), characteristics of bridges and other structures that may control flow, and roughness or loss coefficients (Manning's "n") for each reach. The sediment file includes data describing the sediment load, sediment size distributions for both the suspended sediment and bed sediment, gradation of material in the stream bed, and fluid properties. The program accommodates clay (up to 0.004 mm), four classes of silt (0.004 to 0.0645 mm), five classes of sand (0.0625 to 2 mm), and five classes of gravel (2 to 64 mm). The hydrologic file includes information describing water discharges, temperatures, and flow duration. The operating rule describes the functional relationship between the starting water surface elevations and time. It controls the water surface elevation at the downstream end of the study area and can be either a curve or a single elevation.

2.4.3.2 The scenarios modeled and model setup

The objective of the HEC-6 modeling was to: (1) determine the relative mobility of contaminant-laden sediment during various flow conditions and (2) determine the feasibility and/or effectiveness of sediment control via weirs and/or sediment traps.

Much of the input used in the data files was developed during previous modeling studies of EFPC by TVA using HEC-2 (TVA 1991) and was then updated by the U.S. Army Corps of Engineers during additional EFPC modeling studies (COE 1993). Geometric input data include cross sections, reach lengths, Manning n-values, presence of bridges, and areas of ineffective flow conveyance. Locations and elevations of movable sediment beds and fixed beds were determined based on data collected during the RI. A weir was placed at EFPC mile (EFPCM) 1.71 with a pool elevation of 227 m (745 ft), which is ~0.91 m (3 ft) higher than normal at intermediate flows. Additional weirs were placed at EFPCM 5.74, 7.15, 9.0, and 12.55. For a point of reference, EFPCM 0.0 is at the confluence of EFPC and Poplar Creek.

Data used in the sediment files relating to the inflowing sediment load and the gradation of material in the bed were obtained from the TVA Instream Contaminant Study (TVA 1985), which examined the potential off-site contamination problems associated with the DOE facilities near Oak Ridge. This project was divided into five tasks covering the instream water, sediment, fish, and floodplain sampling of several watersheds, including EFPC. The sediment load entering the upstream end of the geometric model is needed for each inflowing water discharge. Referred to as the inflowing load, it includes both bed load and suspended load and can be expressed as a log-log function of water discharge in cubic feet per second (cfs) versus sediment load in tons/day. Figures 2.21 through 2.24 describe the water-sediment inflow relationship for several points along EFPC. These figures were derived from data on total suspended solids and physical characteristics of suspended sediment presented in the Instream Contaminant Study (TVA 1985). The total suspended solids rating curve for EFPCM 3.3 was based on sampling of suspended solids during three storm events monitored during 1984 and 1985. Log transformed data from all three storms were used to develop a linear regression equation. Based on this rating function, the total suspended sediment discharge of 907 kg/d (1 ton/d), 6804 kg/d (7.5 tons/d), 31,752 kg/d (35 tons/d), 163,293 kg/d (180 tons/d), and 725,748 kg/d (800 tons/d) would correspond to flow rates of 0.57 m^3/s (20 cfs), 1.42 m^3/s (50 cfs), 2.83 m^3/s (100 cfs), 5.66 m^3/s (200 cfs), and 11 m^3/s (400 cfs), respectively.

Similar rating curves were developed for EFPCM 6.89, 10.0, and 14.36 using flow and depth-integrated sediment measurements for April 5 and 6, 1985. As discussed in the TVA report (TVA 1985), concentrations of the total suspended solids for specific size classes were determined at EFPCM 3.3, 6.89, 10.0, and 14.36 during two of the storm events. For input into the model, results were used to calculate the percentage fraction for the following sediment sizes: silt (<62 μm); very fine sand (62 to 125 μm); fine to medium sand (125 to 500 μm); coarse to very coarse sand (500 to 1000 μm); and fine gravel (>2000 μm). The 125- to 500-μm size class was evenly divided between fine and medium sand (125 to 250 μm and 250 to 500 μm); the 500- to 2000-μm class was evenly divided between coarse and very coarse sand (500 to 1000μm and 1000 to 2000 μm); and the >2000-μm class was assumed to be no greater than 4000 μm. These percentages were then used to calculate the loading rate at the above water discharge flows for EFPCM 3.3, 6.89, 10.0, and 14.36.

To calculate gradation of material on and beneath the bed surface, the percentage of each sediment grain size class in the stream bed must be specified (Table 2.25). These percentages were based on particle size analyses of the EFPC streambed during the Instream Contaminant Study (TVA 1985). During these analyses, only the percentages of sediment <62 μm and <500 μm were measured. For input to the model, percent sediment between 62 and 500 μm was split into three size classes (see above), and the unaccounted sediment was assumed to fall into three size classes >500 μm (see above).

The sediment transport relationship for noncohesive material (sand and larger-sized particles) was assumed to follow the Yang's streampower principle. The transport relationship expresses the sediment transport capacity of the stream for specific flow conditions and sediment size distribution. The critical sheer stresses for the deposition and erosion of silt were assumed to be 0.7 Pa (0.015 lb/ft^2) and 1.5 Pa (0.031 lb/ft^2), respectively (Yeh 1983). Sediment properties such as specific gravity and fall velocity were based on default values given in the HEC-6 manual (COE 1977).

In the hydrologic file, water discharges and durations were input into the model to represent those of 1985 and a "typical" year. Typical values were based on 23 years (1961-1984) of daily flow data collected at EFPCM 3.3 (TVA 1985), and 1985 average weekly flows were also based on EFPCM 3.3 (Loar 1992). The operating rule, which is contained in the hydrologic file, consisted of an elevation/discharge rating curve (Fig. 2.25). The rating curve provides the necessary boundary condition at the downstream end of the model.

2.4.3.3 Accuracy and limitations of modeling predictions

During the development of HEC-6, high flow situations were the primary cases of interest because, as a general rule for rivers, 90% of all alluvial sediment movement occurs during 5 to 10% of the time when large flows occur. Erosive forces at high flow may be ~100 times those at intermediate and low flows (COE 1988). The distribution for EFPC is likely to be even more skewed because of the size of the drainage basin.

There is no provision for simulating the development of meanders or specifying a lateral distribution of sediment load across a cross section. Density currents and secondary currents are not accounted for.

HEC-6 allows several different choices of method for calculating the transport capacity of a stream. The accuracy of several of these methods was reviewed by Dawdy and Vanoni (1986), who showed that the best of these methods generally predict sediment discharge within a factor of two. Among the available methods, Yang's streampower function was chosen because it gave a relatively stable solution.

2.4.3.4 Conclusions

The modeling shows that sediment movement can be partially controlled by weirs designed to trap sediment. Nearly all silt and smaller particles will be carried downstream in spite of these weirs, while sands can be mostly trapped under usual flow conditions. If large flows occur, the trapped sediment can be expected to begin scouring (because of higher water velocities) from where it has been trapped. Consequently (within the range normally exceeded several times each year), if traps were effective at preventing sediment movement downstream, they would have to be cleaned periodically before high flows occur. Sediment traps would not provide long-term control of sediment movement, and they would have the detrimental effect of impeding water flow and raising flood levels.

2.4.4 Floodplain Erosion/Runoff Modeling

2.4.4.1 The GLEAMS model

The Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) model, developed by the U.S. Department of Agriculture (USDA) Agricultural Research Service (Leonard, Knisel, and Still 1987; Leonard et al. 1988), is a computerized mathematical model developed for field-size areas to evaluate the movement and degradation of chemicals within the plant root zone under various crop management systems. The model has been tested and validated using a variety of data on pesticide and bromide movement (Leonard, Knisel, and Still 1987). The hydrology and erosion components of GLEAMS are essentially the same as those of the Chemicals, Runoff, and Erosion from Agricultural Management System (CREAMS) model (Knisel 1980). CREAMS is a physically based model that had been validated using data from diverse climatic and physiographic regions (Foster and Ferreira 1981; Knisel 1980; Knisel, Foster, and Leonard 1983; Lorber and Mulkey 1981). Improvements made during the development of GLEAMS included a new emphasis on prediction of chemical losses through leaching to groundwater and a more sophisticated handling of irrigation. Figure 2.26 illustrates the processes represented by GLEAMS. The structure and function of the model will be discussed briefly here. The GLEAMS and CREAMS documentation should be consulted for more detailed information.

The hydrology component of GLEAMS subdivides the soil within the rooting zone into as many as 12 computational layers. The surface layer is taken to be 1 centimeter thick, and the other layers are adjusted to account for the remainder of the rooting zone. Soils data describing porosity, water retention characteristics, and organic matter content for the site-specific soil layers (horizons) are collected for model initialization. During a simulation, GLEAMS computes a continuous accounting of the water balance for each layer, including percolation, evaporation, and transpiration. Evaporation of chemicals from the soil surface is not represented, but evaporation can cause chemicals to move upward through the soil.

The erosion component of GLEAMS accounts not only for the basic soil particle size categories (sand, silt, and clay), but also for small and large aggregates of soil particles. Furthermore, the program accounts for the unequal distribution of organic matter between soil fractions, and uses this information and surface-area relationships to calculate an enrichment ratio that describes the greater concentration of chemicals in eroding soil compared with the concentration in surface soil.

The chemical component of GLEAMS can represent deposition directly on the soil, the interception of chemicals by foliage, and subsequent washoff. Degradation rates are allowed to differ between plant surfaces and soil, and between soil horizons. Degradation calculations are performed on a daily time interval. Redistribution of chemicals because of hydrologic processes is also calculated on a daily time step. The distribution of a chemical between dissolved and sorbed states is described as a simple linear relationship, being directly proportional to the K_{oc} (a property of the chemical) and the organic matter content of the soil. The extraction of chemicals from the soil surface into runoff is calculated accounting for sorption (assumed to be relatively rapid) and using a related parameter describing the depth of the interaction of surface runoff and surficial soil. Percolation of chemicals is calculated through each of the soil layers, and the amount that passes through the last soil layer is accumulated as the potential loading to the vadose zone or groundwater.

The overall sequence of operation of model components is illustrated in Fig. 2.27, taken from the Washington Computer Center CREAMS manual (USDA 1984). The interrelationship of components is essentially the same in GLEAMS, except that the components are integrated into a single program, allowing intermediate files to be passed in memory. Input data required by the GLEAMS model consist of four separate files: rainfall data, hydrology parameters, erosion parameters, and chemical parameters.

The hydrology parameter file contains information on the geometry and topography of the field, hydraulic conductivity, soil water storage, leaf area indices, and irrigation practices. This file also contains the SCS "curve number," which describes the tendency for water to run off the surface of the soil.

The erosion parameter file contains information needed to calculate erosion, sediment yield, and particle composition of the sediment on a storm-by-storm basis. The input data can represent a number of optional configurations of fields, channels, and impoundments, but the representative scenario for analysis in this study represented a single site. The erosion parameter file input to GLEAMS contained parameters describing soil erodibility, soil particle size distributions, and other surface characteristics only relevant to erosion.

The chemical parameter file contains information on the water solubility, foliar and soil half-lives, K_{oc}s, the tendency for the chemicals to wash off plant surfaces, and the current concentrations in the soil profile.

Output from the GLEAMS model includes a storm-by-storm accounting of concentrations by soil layer for each chemical, and the movement of chemical residues in percolating soil waters, surface runoff waters, and those residues sorbed to eroded soil particles. Separate output files are produced describing hydrology and erosion in more detail.

2.4.4.2 The scenarios modeled and model setup

The objective of the GLEAMS modeling effort was to evaluate the potential for mass loading of contaminants from the EFPC floodplain soils into the creek. During the modeling, two types of mass loading were examined: Scenario 1, short-term loading, contaminant runoff resulting from a period of heavy rainfall and Scenario 2, long-term loading, contaminant runoff occurring over a 1-year period. In addition, contaminant loading was analyzed under several environmental conditions, referred to as undisturbed and disturbed. These conditions are meant to be a generic representation of remediation or landowner initiated activities which may occur along EFPC and its associated floodplain. In the case of undisturbed conditions, neither remediation activities nor landowner initiated activities are assumed to occur in any given area along the creek. For disturbed conditions, remediation activities or landowner initiated activities have occurred where vegetation/cover is removed and the underlying soil has been disturbed. Soils along EFPC are dominated by the Newark Series and the Hamblen Series. Each of these soils is represented in the GLEAMS model simulations. In addition, two types of vegetative cover, wooded and pasture/grass, found along the EFPC floodplain, are used when simulating contaminant runoff under the undisturbed conditions. The GLEAMS modeling scheme is represented by Fig. 2.28. The GLEAMS model scenarios described above were carried out for each of the nine segments [described in the RI report (DOE 1994a) and in Sect. 2.5.2.5 of this FS report].

The chemical and physical properties of both soils and contaminants used in the GLEAMS model simulations are listed in Tables 2.26 and 2.27, respectively. Additional assumptions and inputs to the model included the following:

- Soil characteristics for the silt loam soils were assumed as appropriate for hydrologic soil group C, indicating slow infiltration potential (Moneymaker 1981).

- Rainfall data used for both model scenarios were simulated for Knoxville, Tennessee, using a "climatic generator" obtained from Dr. Frank Davis, USDA Agricultural Research Service, Tifton, Georgia.

- A 5-year 24-h rainfall of 11.3 cm (4.5 in.) (Hershfield 1961) was inserted into the simulated rainfall for Scenario 1 (short-term loading).

- The SCS runoff curve number for woods and pasture land under undisturbed conditions on both Newark and Hamblen soils was assumed to be 70 and 74, respectively (Knisel et al. 1992).

- The SCS runoff curve number for Newark and Hamblen soils under disturbed conditions was assumed to be 92. This value is the expected number for fallow land in poor condition.

- The overland flow distance was assumed to be 61 m (200 ft), with a hydraulic field slope of 5%.

- The C factor (cover management factor) was assumed to be 1.0 for disturbed conditions, the expected value for construction sites with no cover. The C factor for undisturbed pasture land was assumed to be 0.013, the expected number for pasture land with 80% ground cover - 25% consisting of brush or bushes and the remaining cover being made up of grass.

The C factor for undisturbed woodland conditions was assumed to be 0.003, the expected number for a "medium stocked" woodland having canopy cover of 40-70% (McElroy et al. 1976).

- The P factor (management practice factor) was assumed to be 0.7 for disturbed conditions and 1.0 for both undisturbed conditions (pasture and woodland).

- Manning's "n" was assumed to be 0.046 for disturbed conditions, 0.046 for undisturbed pasture areas, and 0.032 for undisturbed woodland areas (Knisel et al. 1992).

- The size of the area modeled in each simulation was a nominal 0.4 ha (1 acre) and does not include the creek bank. This parameter was not important because lateral uniformity was assumed.

- The contaminants chosen to be modeled were based on results of the human health baseline risk assessment (in floodplain soils: mercury, arsenic, cadmium) and the ecological baseline risk assessment (aquatic species in sediment and surface water: mercury, cadmium, chlordane, PCBs, PAHs; terrestrial species on floodplain soils: mercury). Aroclor 1260 was chosen as a representative PCB, and benzo(a)pyrene and benzo(b)fluoranthene were chosen as representative PAHs.

- The soil concentrations of the contaminants entered into the model were based on reasonable maximum exposure (RME) concentrations calculated for use in the baseline human health risk assessment presented in the RI report. These concentrations, listed in Table 2.28, were given for each segment along the creek. No RME values were available for chlordane because it was not examined in the baseline human health risk assessment. The concentrations used for chlordane in the model were calculated by multiplying the means (see Table 3.32 of the RI report) by the maximum coefficient of variation (standard deviation relative to the mean) between the RME and most likely exposure (MLE) for all other contaminants examined.

- Uniform concentration of contaminants to the depth of the rooting zone in each segment was assumed.

As part of a Vertical Integration Study (described in the RI report), 46-cm (18-in.) soil cores were taken at the NOAA site and the Bruner site. The cores were divided into 2.5-cm (1-in.) depth intervals, and the soil from each interval was submitted for neutron activation analysis. The results are listed in Table 2.29.

For transport and fate modeling, these results were used to model site-specific contamination and environmental conditions at the NOAA and Bruner sites for Scenarios 1 and 2 described above. The GLEAMS model only allows the definition of five or fewer soil horizons in the hydrology input parameter. Based on the distribution of mercury at the NOAA and Bruner sites, three soil layers were defined, and a weighted-average concentration for mercury was used for the model input parameters (Table 2.30).

2.4.4.3 Results

Results of the GLEAMS model simulations are given in Tables 2.31 through 2.50. The model predicts that the highest loss of contaminants will occur from the floodplain soils in areas that have been disturbed, with losses from Hamblen soils being slightly greater than those from Newark soils. With the exception of cadmium, the majority of contaminant lost from the floodplain is adsorbed onto the soil. A much smaller percentage is lost in the form of the dissolved chemical. In the case of mercury, Segment 4 shows the greatest potential for loss to the creek surface water and sediment, with 6.36 g/ha dissolved mercury and 4576 g/ha adsorbed mercury being lost over the course of a year. When looking at the Bruner site, where floodplain soil concentrations of mercury are greater than the Segment 4 average, the predicted loss is 9.15 g/ha dissolved and 4150 g/ha (4.15 kg/ha) adsorbed mercury.

To put the contaminant loadings presented above into perspective, the concentrations that could occur downstream in EFPC as the result of runoff from a disturbed site can be calculated. At EFPCM 3.3, the flow corresponding to a recurrence interval of 5 years is 2300 cfs (5.63×10^9 L/d). If we assume that an area of 20 ha (50 acres) is disturbed and exposed to erosion with the current soil mercury concentrations, the concentrations presented in Table 2.51 could be expected to result at EFPCM 3.3 due to runoff from the Bruner and NOAA sites. Other sources of mercury in the stream are ignored, and the calculations ignore any instream processes that may decrease concentrations. Table 2.52 presents similar estimates of potential concentrations for 20-ha (50-acre) disturbed sites, with average concentration for each EFPC segment.

Figure 2.29 shows erosion loss from disturbed Hamblen soils during rainfall events. Based on these results, sediment loading into EFPC is dependent on rainfall amount. During the 5-year, 24-h rainfall [11.25 cm (4.5 in.)], 5088 kg/ha (2.27 tons/acre) of erosion occurs. Mercury potentially adsorbed to this sediment is dependent upon the mass of mercury present in the floodplain soils. Tables 2.31 through 2.49 (odd-numbered tables) and Table 2.50 present the predicted mass of mercury adsorbed to sediment during the 5-year, 24-h rainfall. For example, for Newark soils at the Bruner site, 4.2 kg/ha of mercury could be potentially associated with the 5088 kg/ha of sediment (Table 2.49).

2.4.4.4 Accuracy and limitations of modeling predictions

For a detailed discussion of the validation of CREAMS and GLEAMS, their sensitivity to input parameters, and their expected accuracy, the reader should refer to the publications referenced at the beginning of this section. In addition to these studies, Mueller et al. (1992) evaluated the ability of the GLEAMS model to simulate movement of three herbicides using site-specific soil, environmental, and pesticide data. The movement of alachlor and metribuzin in sandy loam soil in which cotton was grown and the movement of norflurazon in a loamy sand soil were examined in field studies. During the course of the study, actual herbicide concentrations were always greatest near the soil surface. The total herbicide present in each profile <20 d after application was accurately predicted by the GLEAMS model simulations. Herbicide movement into the soil profile in later simulations was overestimated by the model. Predictions from the model generally agreed with the relative location of alachlor and metribuzin in simulations <7 d after herbicide application. Beyond 7 d after herbicide application, simulations deviated from actual concentrations. GLEAMS inaccurately predicted that

norflurazon would be located throughout the soil profile, although the predicted depth to the limit of detection by the model was accurate (Mueller et al. 1992).

The GLEAMS model can predict for weather and site conditions outside the range of those for which data are available. However, the model is sensitive to input parameters. Any site-specific parameters that were not directly measured and had to be based on available literature introduce potential sources of error into the model. These parameters include contaminant decay rates, K_{oc}, and soil runoff curve numbers. The decay rates govern the quantity of the contaminant available for movement, whereas the sorption coefficients and the runoff curve numbers govern the actual movement of the contaminants. Errors in estimation of these parameters are the major contributors to model error; however, to minimize this contribution, conservative input parameters were used.

2.4.5 Contaminated Soil Deposition

Modeling was conducted to evaluate the potential for transport of contaminated soil within Segment 1 of EFPC to recontaminate soil in sections of the creek that are farther downstream following remediation. The evaluation involved modeling the quantity of contaminated soil transported within EFPC during the 1- and 5-year storm events and then calculating the resulting concentration of mercury deposited in the stream section (river mile 13.55 to 13.32) that is directly downstream of the area of concern. A sediment transport model (HEC-6, described in Sect. 2.4.3.1) was used to determine where the contaminated soil would be deposited downstream of river mile 13.65 and also the quantity of soil that would move into the depositional area during the 1- and 5-year storm events. An overland flow model (GLEAMS, described in Sect. 2.4.4.1) was used to determine the quantity of additional soil that would be transported into the stream bed from the stream valley slopes adjacent to the depositional area during the 1- and 5-year storm events. The resulting mercury concentration within the depositional area was determined by comparing the total volume of contaminated soil deposited in the reach (assuming an average concentration of 544 ppm) during each storm event to the total volume of soil that the contaminated soil will mix with in the depositional area. Resulting mercury concentrations were determined to be <60 ppm. In conclusion, the evaluation indicated that it is not probable that contaminated soil between river miles 14.02 and 13.65 would recontaminate the downstream sections of the creek.

2.5 BASELINE RISK ASSESSMENT

Using the data collected during Phases Ia and Ib of the RI, a risk assessment was performed to characterize the current and potential future risks to human health and the environment that may be posed by contaminants released to and/or migrating within environmental media. The overall objective of risk assessment is to provide risk-based information for deciding whether remediation of EFPC is needed because of potential threats to human health or the environment. The baseline risk assessment was performed and is presented in summary form in two parts: a human health risk assessment and an ecological risk assessment. The full and detailed baseline risk assessments are found in the RI report (DOE 1994a).

2.5.1 Human Health Risk Assessment

The baseline risk assessment process uses concentrations of contaminants measured in environmental media to predict what individuals might be exposed to under current and future land use scenarios if the EFPC site were not remediated.

During the first step, **data collection and evaluation**, data are examined to determine whether they are of sufficient quality for use in the risk assessment. Those data that were rejected during the data validation process are excluded from use for the risk assessment. Next, COPCs are selected and their concentrations are summarized by calculating the mean and 95% UCL for each current and future land use type for each medium.

These summary statistics, mean and UCL, are then used to estimate individual exposures. The **exposure assessment** is the second step in the risk assessment process. During this phase, current and future land uses are identified, and assumptions are made on the amount of the COPCs to which an individual is exposed, the duration of the exposure, and the frequency of exposure for each pathway.

The next step, **toxicity or hazard assessment**, looks at the capacity of the COPC for causing cancer or other adverse effects in laboratory animals and in humans. Hazard identification is a qualitative description based on factors such as the kind and quality of toxicity data on humans or laboratory animals and availability of ancillary information from other studies. During this phase, dose-response relationships are considered with respect to extrapolation from laboratory studies of animals to humans and to uncertainty in the data. Many of these data come from the EPA Integrated Risk Information System (IRIS), a data base of EPA verified toxicity measures.

The final step, **risk characterization**, integrates conclusions about hazard and dose response with those from the exposure assessment. In addition, confidence about these conclusions, including information about the uncertainties associated with the final risk summary, is highlighted.

2.5.1.1 Data collection and evaluation

Concentrations of COPCs were aggregated and statistically manipulated to derive a meaningful estimate of the exposure point concentrations. In human health risk assessment, the exposure point concentration is used to estimate average daily intake or dose. Following EPA guidance, the lifetime average daily intake or dose was calculated based on two summary statistics for concentrations of COPCs in environmental media: (1) the arithmetic mean and (2) the UCL of the arithmetic mean. The UCL is the basis for deriving the RME estimate, which is defined by EPA as "the highest exposure that could reasonably be expected to occur for a given exposure pathway at a site" (EPA 1989a).

RME estimates were determined for "exposure units," along EFPC. Exposure units are geographic areas within which a receptor would realistically be expected to spatially and temporally average exposure to contaminants.

Within EFPC and the floodplain, data were aggregated using different methodologies for different environmental media. For groundwater, data from the bedrock wells and the soil

horizon wells were treated separately, thus dividing the data into two groups. Note that no one is currently using groundwater from either unit as a source of drinking water or is likely to do so in the future.

Data for surface water and sediments were each aggregated into a single set, representing the entire length of the creek. Data were aggregated in this way based on the assumption that residents of EFPC are free to wander the creek and may be exposed to surface water and sediments at any location along the system. However, in an effort to address isolated areas of contamination, two different sets of exposure point concentrations were used to calculate risk. One includes the 95% UCL on the arithmetic mean as the RME exposure point concentration. The other uses only the maximum concentration as the exposure point concentration. The analysis was conducted using two different sets of exposure point concentrations at the request of EPA Region IV.

Two different approaches were used in evaluating levels of chemicals in fish tissue. First, data over the entire length of the creek were aggregated and a mean and UCL value was derived for the full data set. In the second approach, data were aggregated into three groups representing upper, middle, and lower portions of the creek. This division of the creek into three areas was based on a statistical analysis of difference between sampling locations. The objective of this second method was to develop the most conservative exposure point concentrations for use in the baseline risk assessment.

For soil, rather than summarizing data along the entire creek, the floodplain was divided into nine segments based on an understanding of the nature and extent of the contamination and a knowledge of current and projected future land uses. Summary statistics (mean and UCL) were calculated for each COPC in soil by segment.

The SLB was divided into three segments based on levels of mercury contamination. COPCs were summarized for each of these three segments. The land use along the SLB was designated as open, as it was the only scenario applicable for these three segments.

2.5.1.2 Exposure assessment

The purpose of the exposure assessment is to identify the receptors at potential risk from contact with contaminants, to determine the exposure pathways of importance, and to quantify intake, or dose, for all contaminants and pathways of concern. The exposure scenarios for the EFPC baseline risk assessment, based on land use type, include (1) current and future exposure in the agricultural setting, (2) current and future exposures to residential populations, (3) current and future exposure in the commercial setting, and (4) current and future exposure resulting from occasional use of open land. The receptor groups at greatest risk of exposure were assumed to be children and adults who reside in the community along EFPC. For each exposure scenario and receptor group, the intensity, duration, and frequency of exposure were characterized. The exposure evaluations were primarily based on RME exposure assumptions. EPA Region IV requested that RME values be used as the principal basis for risk assessment of EFPC. MLE estimates were also calculated as a point of comparison but were not included in the risk characterization section of the report. The RME estimate is not a "worst case" measure, but a "high end" conservative estimate of exposure in the population at potential risk. In addition to

RME point estimates, Monte Carlo simulations were used to generate probabilistic estimates of exposure and risk that were used in uncertainty analysis, and as a supplement to the single-point RME estimate.

Current and future exposure pathways for residential receptors include:

- dermal exposure to surface water while swimming,
- dermal exposure to surface water while wading,
- incidental ingestion of surface water while swimming,
- dermal exposure to sediments while wading,
- dermal exposure to soil,
- incidental ingestion of soil,
- ingestion of groundwater and inhalation of groundwater vapors (future exposure only),
- ingestion of homegrown produce, and
- ingestion of recreationally caught fish.

Current and future exposure pathways for the agricultural setting include those identified for residential exposure plus the following:

- ingestion of home-raised beef,
- ingestion of home-produced milk (future exposure only), and
- inhalation of particulates while mowing.

Risks to both children and adults were assessed for both the current and future exposure scenarios. Two age groups of children were assessed: 3 to 12 years for RME and 6 to 9 years for MLE.

The open land use scenario is designed to account for occasional exposure to EFPC soils, surface water, and sediment by individuals who are not residents of the EFPC community. Exposure to both children and adults was assessed, with the assessment of children focusing on ages 9 to 18 for the RME and on ages 12 to 15 for the MLE.

Because commercial zones are now built on paved areas at a distance from the creek and are located outside the floodplain, the exposure assessment assumed no exposure of commercial receptors to contaminants under the current land use scenario. In the future, commercial exposure is assumed to be limited to use of groundwater by the business community. Therefore, the only pathway evaluated was ingestion of groundwater by adult receptors. This is a very conservative assumption because the availability of municipal water makes it unlikely that groundwater will be a source of drinking water, either now or in the future.

Ideally, exposure factors should be derived from estimates of site-specific activities and behavior patterns of receptor groups at potential risk of exposure. Because of the size of EFPC, such information has not been developed for the EFPC baseline risk assessment and could be meaningfully developed only through a large-scale survey of Oak Ridge residents. In the absence of such data, EPA guidance was used whenever possible in selecting or deriving values for exposure variables. The principal sources of information used are *Superfund Exposure Assessment Manual* (EPA 1988a); *Exposure Factors Handbook* (EPA 1989b); *Risk Assessment Guidance for Superfund: Human Health Evaluation Manual* (EPA 1989a); *Human Health*

Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors (EPA 1991a); and *Dermal Exposure Assessment: Principles and Applications* (EPA 1992a). Exposure factors for adults were assumed to remain relatively constant over the duration of exposure. However, because exposure factors vary as children grow to adulthood, weighted-averaged values were used to characterize RME estimates for children over a specified period of time.

To estimate uncertainty in the exposure assessment, a probabilistic method employing Monte Carlo simulation was used. Exposure variables were characterized by probability density functions that reflect the inherent variability in the exposure factors. In looking at the probability density functions for the exposure variables, it is apparent that the RME point estimates are generally quite conservative and fall in the upper tail (>90%) of the probability distribution. This is expected given the desire of the regulatory agencies (in light of the inherent variability and uncertainty in risk assessment) to protect human health.

2.5.1.3 Toxicity or hazard assessment

Toxicity assessment involves evaluating the inherent toxicity of the COPCs and identifying and selecting toxicological measures for use in estimating risk to receptors. Because the baseline risk assessment for EFPC required the evaluation of both hazardous and radiological releases, toxicity values were selected for both chemical substances and radionuclides. The toxicity values used for chemicals are:

- reference doses (RfDs) for oral exposure—acceptable intake values for subchronic and chronic exposure (noncarcinogenic effects),
- reference concentrations (RfCs) for inhalation exposure—acceptable intake values for subchronic and chronic exposure (noncarcinogenic effects),
- cancer slope factors for oral exposure, and
- cancer slope factors for the inhalation route.

EPA derives RfDs for noncarcinogens from estimates of the no-observable-adverse-effect level (NOAEL) or lowest-observable-adverse-effect level (LOAEL) in humans or test animals. The inhalation RfC is also derived from the NOAEL but requires conversion of the levels observed in animals to human equivalent concentrations before data sets and effects levels can be evaluated and compared.

The assessment of the potential for noncarcinogenic effects (i.e., the use of RfDs and RfCs to assess risk) is based on the assumption of a threshold below which adverse health effects are not expected to occur. Carcinogenesis, however, is thought to be a phenomenon for which the presumption of threshold effects is inappropriate (EPA 1989a). Therefore, rather than estimate an effects threshold for these chemicals, EPA first assigns a weight-of-evidence classification and then calculates its cancer potency, or slope factor. Weight-of-evidence classifications include (A) human carcinogen; (B1) probable human carcinogen, limited human data are available; (B2) probable human carcinogen, sufficient data in animals but inadequate or no data for humans; (C) possible human carcinogen; (D) not classifiable as to human carcinogenicity; and (E) evidence of noncarcinogenicity for humans. EPA develops a cancer slope factor, which is a plausible

upper-bound estimate of the slope of the dose-response curve in the low dose range, for all chemical compounds that have been rated A, B1, or B2 and for many that have been rated C.

EPA has not developed RfDs or slope factors for dermal exposure. In the absence of these factors, the toxicity values for oral exposure were used in the EFPC baseline risk assessment to calculate dermal exposure, as recommended by EPA (EPA 1992a). Information for identifying and selecting toxicity values was obtained from the two sources recommended by EPA, IRIS and Health Effects Assessment Summary Tables (HEAST), with priority given to IRIS. Toxicity values used for all COPCs and the toxicological information used to select those values are provided in the baseline risk assessment.

The baseline risk assessment includes the potential for health effects from low-level exposure to ionizing radionuclide contaminants at EFPC. Primary health effects include an increase in the occurrence of cancer in specific organs and possible genetic effects that may extend to future generations. Note, however, that noncarcinogenic effects (i.e., mutagenic and teratogenic) of radionuclide exposures are not considered in this assessment, and in all cases the cancer risks are assumed to prevail.

The EPA method used at EFPC to evaluate exposure to radionuclides involves multiplying a route-specific cancer slope factor by the intake estimate (in units of radionuclide activity) to yield risk. Note that EPA has classified all radionuclides as Group A carcinogens on the basis of epidemiological studies of cancer in humans and animals.

EPA's Office of Radiation Programs has published ingestion, inhalation, and external exposure cancer slope factors based upon compound-specific properties and information contained in reports from national and international scientific organizations. The cancer slope factors for the ingestion and inhalation routes (which are used in the baseline risk assessment) are median or 50th percentile estimates of the age-averaged lifetime probability of a carcinogenic effect occurring in an exposed individual. These cancer slope factors are taken from HEAST (EPA 1993).

Unfortunately, EPA has no verified oral and inhalation RfDs for mercury (EPA 1993). EPA is currently evaluating the potential noncarcinogenic effects of mercury and has, in the interim, published a tentative oral RfD of 0.0003 mg/kg (or ppm) per day for inorganic mercury, which was used in the baseline risk assessment. The RfD was based on toxicity tests using soluble mercuric chloride in rats, and not the less soluble forms (mercuric sulfide and metallic mercury), which predominate in EFPC floodplain soils.

2.5.1.4 Risk characterization

Risk characterization integrates the results of the exposure and toxicity assessments by combining estimates of dose with appropriate toxicity values to determine the likelihood of adverse effects in exposed populations. Risks are calculated for each chemical or radionuclide, for each pathway, for each receptor group (adults and children), each current land use scenario, and each future land use scenario. These individual risks are then summed over chemicals or radionuclides and pathways to obtain a total risk for each receptor group and for current and future land use scenarios. These total risks are calculated differently for each of three contaminant types: (1) chemical carcinogens, (2) chemical noncarcinogens, and (3) radionuclide

carcinogens. For each of these contaminant types there is a different equation for estimating risk, but all integrate the exposure and toxicity assessments. Table 2.53 identifies the exposure and toxicity values, the equations for calculating risk, the methods for combining results in deriving an estimate of total risk, and EPA target risk levels. Risks have been presented for individual pathways and exposure routes, and for risks summed across multiple pathways and exposure routes. Note that the combined risk estimates are very conservative because they are simple summations of the results across all pathways to a single receptor. It is unlikely that a human receptor would aggregate exposure in this manner. These chemicals, which contribute to a pathway that exceeds a 10^{-4} (1 in 10,000) risk or a hazard index (HI) of 1 or greater, are classified as COCs, as opposed to COPCs.

A tiered approach to risk characterization was implemented, beginning early in the RI process. The first tier was a screening-level deterministic risk assessment using data from Phase Ia from the known areas of high mercury contamination. This was performed to estimate the magnitude of potential risks, assist in the identification of pathways of importance, and refine COPCs. The second tier was a deterministic risk assessment using all valid data. The final tier was a probabilistic risk assessment and quantitative uncertainty analysis using Monte Carlo simulations. Because the first tier was only useful during the early stages of the RI and is essentially a subset of the Tier II analysis, it will not be discussed here.

Tier II

The Tier II risk estimates indicate that the most substantial risk levels are associated with exposures that are hypothetical and highly uncertain (e.g., the food chain pathways). The Tier II results indicate that cancer risks from radionuclides are either below or fall within the EPA target cancer risk range of 10^{-6} to 10^{-4} (1 in 1,000,000 to 1 in 10,000). In the case of nonradionuclide chemicals, however, noncancer and cancer risk estimates exceed EPA targets. Results of the Tier II assessment are illustrated in Figs. 2.30 through 2.41. These maps show summed RME risks that account for multiple contaminants and pathways for each receptor group (adult and child), for both current and future land use scenarios within the nine EFPC segments.

For the current land use scenario, the risk estimates are below or within EPA targets for the majority of the 271 ha (670 acres). Figures 2.30, 2.32, 2.36, and 2.38 indicate that there are four areas—three of which are residential (in Segments 3, 6, and 8) and one that is agricultural (in Segment 7)—where both noncancer and cancer risks exceed EPA targets. Open land use resulted in risks either below or within EPA noncancer and cancer risk targets. In each case, the pathway contributing the most is the food chain (in particular produce) and the contaminants contributing the most are mercury (noncancer) and arsenic (cancer). Individual substances with a hazard quotient (HQ) > 1 or cancer risk $> 10^{-4}$ (1 in 10,000) are associated with only the food chain pathway, and only at segments that included the food chain pathway: Segments 3, 6, 7, and 8.

Risks projected for the future are above EPA targets at each segment, for both children and adults, as indicated in Figs. 2.31, 2.33, 2.37, and 2.39. This results primarily from food chain exposures and the use of groundwater as a hypothetical source of drinking water. Risks in the future are, in many cases, greater than current risks because of projected increases in exposure resulting from the change over time to a more conservative land use (from open to residential). Commercial noncancer risks exceeded the EPA target. This resulted entirely from groundwater

exposures. For the food chain, noncancer and cancer risks for both children and adults exceeded EPA targets anywhere the food chain pathway was evaluated (in all nine segments). Individual substances with an HQ >1 or cancer risk $>10^{-4}$ (1 in 10,000) identified on the basis of the produce pathway include arsenic, cadmium, manganese, mercury, silver, and vanadium. When the beef and dairy pathways are included, Aroclor-1260, barium, chromium, copper, and selenium are added. For soil exposures in the future, only the noncancer target was exceeded, and only for Segments 1 and 4. The primary COC based on the risk estimates for soil exposures is mercury.

The primary health concern for either current or future soil exposures is most consistently noncancer effects related to exposures to mercury. When considering both current and future total risk estimates (e.g., summed across multiple substances), the soil pathway risks exceeded EPA targets at Segments 1, 3, 4, 5, and 8. As noted for the food chain pathway, EPA targets for both noncancer and cancer effects were exceeded anywhere the food chain pathway was considered (in all nine segments).

To put the food chain pathway in perspective, risks were estimated for the reference site at Hinds Creek using the agricultural exposure assumptions. Despite the absence of substantial mercury contamination in the reference soils, risk for the produce, beef, and dairy ingestion pathways exceeded EPA targets for both noncancer and cancer effects. For the produce and beef ingestion pathways, arsenic and manganese account for $>90\%$ of the risk. For the dairy ingestion pathway, arsenic, barium, copper, manganese, and zinc account for $>90\%$ of the risk. The magnitude of the food chain risk estimates is primarily attributable to the very conservative biotransfer factors that were used to model contaminant uptake from soil into the food chain.

Groundwater risks do not vary by segment because the groundwater sample data are aggregated over the entire creek and not by segment, and the same exposure assumptions were used for both the agricultural and residential scenarios. Commercial use of groundwater in the future also results in risks in excess of EPA targets. Individual substances with an HQ >1 or cancer risk $>10^{-4}$ (1 in 10,000) include arsenic, beryllium, manganese, and mercury.

Using unfiltered groundwater data, the levels of mercury and manganese result in HI scores exceeding the EPA target. A comparative risk assessment was conducted using filtered groundwater samples. Overall, HI scores are lower, and the HQ score for mercury is lower by a factor of nearly 20. The HQ for manganese, however, remains >1. Additional differences are identified between groundwater from the soil horizon wells and groundwater from the underlying bedrock wells. Both noncancer and cancer risks are generally greater in the soil horizon wells, and this remains true when comparing unfiltered and filtered samples. Whether filtered or unfiltered, or from soil horizon or bedrock, the groundwater noncancer and cancer risks are above EPA targets. Manganese is the chemical that is driving the elevated risk estimates.

Risk assessment was included for three areas along the SLB. This included soil exposures for open land use only, since commercial, agricultural, or residential land use is considered unlikely within the sampled portions of the SLB. Little or no change in land use was assumed for the SLB over time, and exposures at the SLB do not overlap those considered at EFPC. The noncarcinogenic or carcinogenic risk estimates were within or below EPA targets. The HIs are <1, and the greatest combined cancer risks are on the order of 10^{-6} (1 in 1,000,000).

Risk characterization for exposures to lead required an alternative approach in which lead uptake into children's blood is estimated. EPA has developed a computer program to evaluate blood lead uptake in children less than 6 years old, the most sensitive receptors of lead exposures. Under current land use assumptions, only Segments 3, 6, 7, and 8 include exposures to children less than 6 years old.

None of the blood lead levels associated with current exposure at any of these segments approach the EPA target for blood lead levels. When considering future exposures, blood lead levels are generally within EPA targets. For a child residing at Segments 3 and 4, the target was exceeded only when soil and groundwater exposures were combined. This is a marginal exceedance and includes soil, unfiltered groundwater, and built-in exposures from air and dietary sources of lead that are not site related. Soil exposures did not approach the target when considered independently of groundwater exposures. Only unfiltered groundwater exposures are associated with blood lead levels exceeding the EPA target, and the remaining exposures are well below the EPA target. As an additional point of comparison, the soil lead concentrations at each segment fall substantially below EPA soil cleanup guidelines for lead.

Tier III

The third tier, or probabilistic risk assessment, focused on exposure pathways that contributed the most to the overall risk, including inadvertent ingestion of soil, the produce ingestion pathway, and the hypothetical ingestion of groundwater. The outcomes of the Monte Carlo simulation include both receptor groups (adult and child) for each pathway and for current and future land use. For the soil-related pathways (soil and produce ingestion), results are presented only for Segment 4. An illustrative uncertainty analysis for the soil pathways is presented in the report for the segment with the highest observed soil concentration. The uncertainty analysis is presented only for the single segment because the exposure assumptions for the residential and agricultural scenarios are the same across segments. The only difference between segments is the exposure point concentrations. Therefore, an analysis of one segment may be used in understanding the magnitude of the uncertainty in the risk estimates.

The RME point estimates are generally quite conservative and fall in the upper tail of the probability distributions. In some cases, the RME estimates exceed the 95% UCL values. Of particular concern are the conservative point estimates used for the food chain biotransfer factors. These factors predict the biotransfer of each contaminant from soil to plant tissue. Based on these data, and an experimental garden study, it is concluded that the biotransfer factor for mercury obtained from the literature and used in the baseline risk assessment is likely to be one to two orders of magnitude too high.

The Tier II and III results, the results of the garden uptake study, and the risk assessment of Hinds Creek all indicate that there is considerable uncertainty in the risk estimates associated with the food chain pathways. Given this and the assumption that very limited agricultural or gardening activity is occurring along EFPC (or is likely to occur in the future), the results for the food chain pathways are clearly hypothetical, "high-end" or "bounding" estimates of risk to human health.

Risk estimates for the groundwater ingestion pathway exceed the target range established by EPA. However, no one is currently using groundwater in the vicinity of EFPC as a source of drinking water or is likely to do so in the future because city water is provided. Though contaminant concentrations were considerably reduced in filtered samples, the overall HI score for the pathway is still > 1 by a small margin. This is principally due to dissolved concentrations of manganese. The presence of arsenic is responsible for the excess lifetime cancer risk estimate exceeding 10^{-4} (1 in 10,000). Manganese is present in background soils at levels comparable to those in EFPC soils and, therefore, occurs naturally in this geographic area. Although levels of arsenic in floodplain soils exceed those at the reference location, the presence of arsenic in groundwater cannot clearly be attributed to releases from DOE's Y-12 Plant. The results of the Tier III analysis of groundwater indicate a range of uncertainty of less than an order of magnitude based on variability in exposure assumptions.

The results of the risk assessment indicate that RME estimates of risks of adverse noncarcinogenic effects associated with inadvertent ingestion of soils exceed the target range established by EPA at locations throughout the floodplain. The risk results primarily from mercury concentrations in soil with cadmium and arsenic contributing to a lesser degree. Concentrations of mercury, cadmium, and arsenic were significantly higher than those found at the reference location. The Tier III assessment demonstrates that there is less than an order of magnitude uncertainty in the RME point estimates for soil ingestion.

As noted, the risk from the soil ingestion pathway was estimated using an RfD for mercury of 0.0003 mg/kg (or ppm) per day. This RfD is based on toxicity testing using soluble mercury species (mercuric chloride) in laboratory animals, not the less soluble forms (mercuric sulfide) believed to predominate in EFPC floodplain soils. The baseline risk assessment conservatively assumed that all mercury in EFPC is present in its most bioavailable form.

2.5.2 Ecological Risk Assessment

The purpose of the EFPC ecological baseline risk assessment was to determine baseline levels of risk to various animal and plant populations and habitats in EFPC. This information was then used to determine whether contaminants pose an imminent and substantial danger to the health of various ecological resources and whether and where site remediation may be needed. The ecological risk assessment process differs from the human health risk assessment process in that it focuses on populations and communities rather than on individuals. Individuals are addressed only if they are protected under the Endangered Species Act. Rather than attempt to examine every species living in and around EFPC, a weight-of-evidence assessment was conducted to determine the effects of contaminants on indicator species (representative species from each major aquatic and terrestrial habitat) and to extrapolate from them to project the overall effects of other and unmeasured contaminants on the ecosystem.

The ecological risk assessment, as described in *Framework for Ecological Risk Assessment* (EPA 1992c), involves four basic steps occurring in three primary phases (Fig. 2.42): (1) problem formulation, (2) exposure characterization, (3) effects characterization, and (4) risk characterization. These interrelated activities are defined as follows.

Problem formulation establishes the goals, breadth, and focus of the assessment. It provides a preliminary characterization of (1) chemical and physical stressors present in the

ecosystem, (2) the components and especially indicator organisms of the ecosystem likely to be at risk, and (3) the potential ecological effects. This preliminary characterization, along with a selection of assessment and measurement endpoints, is used as the basis for developing a conceptual model of stressors, components, and effects. Assessment endpoints are values that, if exceeded, suggest the need for remediation.

Exposure characterization evaluates the interactions of the stressors with the ecosystem attributes and describes the biotic and abiotic ecosystem attributes, along with the route, magnitude, frequency, duration, trend, and spatial pattern of exposure of each indicator population or habitat component in relation to a chemical or physical stressor.

Effects characterization evaluates the ecological response to chemical and physical stressors in terms of the selected assessment and measurement endpoints. Depending on the parameters of exposure, it results in a profile of response to stressors at concentrations or doses or other units of stress to which populations and habitats are exposed. Data from both field observations and controlled laboratory studies are used to evaluate ecological effects.

Risk characterization integrates the effects of exposure and stressor response on indicator populations or habitat components, using risk quotients (a ratio of exposure value to effect value); interprets these data according to the weight-of-evidence approach; and then further interprets the ecological significance, including the potential for ecosystem recovery.

2.5.2.1 Problem formulation

Critical to the performance of an ecological assessment is the early establishment of goals and objectives for the study. For the EFPC ecological risk assessment, seven primary goals and 12 associated assessment/measurement endpoints were developed (Table 2.54). These goals reflect government environmental policy, such as NEPA compliance or ARARs attainment, as well as important characteristics of the specific populations and habitats within the EFPC OU that are potentially at risk. The approved sampling and analysis plan (Radian 1993) emphasized the measurement of contaminant body burdens of various specific indicator organisms for the assessment and measurement endpoints.

Also important to the initial formulation of the problem and to the development of conceptual models and sampling plans is a thorough understanding of the historical information on contaminant types, locations, and the respective ecological receptors of these contaminants. Contaminants within the EFPC environment have been described and characterized in several previous studies (Van Winkle et al. 1984; TVA 1985; Gist 1987; Carmichael 1989; Loar 1992; Hinzman 1992; Turner et al. 1992; and DOE 1994, and Appendix Q). The Oak Ridge Associated Universities (ORAU) (Gist 1987) study, conducted between 1983 and 1987, included surveys for mercury in the surface soil along 100-m (328-ft) transects across the floodplain from the Y-12 Plant to the Oak Ridge city limits in Roane County, grid sampling for mercury within a highly contaminated floodplain property, sampling for mercury from vertical profiles at various sites, and sampling of selected lawns and gardens in Oak Ridge. Vegetation, sewage sludge, groundwater, and two road-killed deer were sampled and analyzed for radionuclides, mercury, and other metals. The TVA study, performed during 1984, sampled soils, sediments, surface water, fish, amphibians, crustaceans, and reptiles, which were then analyzed for mercury and other metals, radionuclides, organics, pesticides, and PCBs. The Y-12 Plant BMAP, begun in

1985, performs semiannual sampling of natural populations of fish, which are then analyzed for mercury, PCBs, and cesium (Loar 1992; Hinzman 1992). Bioaccumulation studies of PAHs and PCBs have been conducted annually using caged clams. The USGS conducted a survey of groundwater contamination by metals, radionuclides, and organics in 1987 (Carmichael 1989). This study sampled 14 shallow-aquifer wells at sites of known mercury contamination within the floodplain. Other one-time studies include the assessment of mercury and strontium in small mammals by Energy Systems and a 1982 rapid assessment survey of mercury contamination in multiple media (i.e., sediments, mosses and liverworts, grasses, and fish) (Van Winkle et al. 1984).

The conceptual model for the EFPC ecological risk assessment is derived from these early studies, which indicated the existence of two major exposure sources within EFPC and its floodplain. Water effluents from the Y-12 Plant continually expose aquatic organisms to contaminants and can contribute to the exposure of terrestrial organisms during floods through direct contact with biota or through deposition of water-borne contaminants on floodplain vegetation and soil. The second source, previously contaminated floodplain soil, also contributes to the exposure of terrestrial organisms through direct contact, inhalation, and ingestion and to exposure of aquatic organisms through erosion or scouring and redeposition of soil into EFPC. Direct exposure routes exist through the air, shallow groundwater, surface water, instream sediments, and soil. Indirect exposure occurs through ingestion of contaminated forage or prey. Conceptual models of the food web relationships for selected EFPC biota are depicted in Fig. 2.43 for aquatic biota and Fig. 2.44 for terrestrial biota. These show how contaminants in biotic media can be transferred to predators.

Ecological Risk Assessment Sampling Locations and Sampling Design

The area in which organisms are exposed to contaminants is defined by both their home range in habitats and the distribution of contaminants. To facilitate evaluation of exposures in different EFPC habitats, the OU was divided into sections. The sections were arbitrarily based on the EFPC sampling grid; 17 sections were created, each comprising 1 km (0.6 mile) from west to east on the sampling map. The first section begins just below the confluence of EFPC with Poplar Creek, and section 17 is located at the beginning of the study area below Lake Reality. Within these 17 sections, a wide variety of surface water/sediment and soil/vegetation habitats was identified and mapped. For surface water, four distinct aquatic habitats were defined (runs, riffles, pools, and other); for the terrestrial habitats, 12 distinctions were made, including 4 forest categories, 5 field or relatively cleared habitats, and 3 developed/commercial settings. Most of the terrestrial habitats were found to be bottomland hardwoods, while the most prevalent aquatic habitat was the stream runs. Seventeen wetlands were found to exist in or near the floodplain; some have mercury contamination, but there is no visible evidence of negative impact on the wetlands.

Locations of the ecological sampling sites for the EFPC ecological risk assessment were chosen to gain maximum information on EFPC biota and their physical environment and to allow comparison and contrast with historical data. The six aquatic sampling sites, as shown in Fig. 2.7, were selected to represent a gradient of biological and physical conditions. Site 1 is located in Pine Ridge Gap near the outfall from Lake Reality, and Sites 2 and 3 (NOAA and Bruner Center sites) are located near areas previously identified as having high mercury concentrations in soils. Coordination with BMAP sampling personnel ensured that no adverse

effects occurred to these sampling locations during the RI sampling and facilitated comparisons with the BMAP results. Site 3, or the Bruner Center site, also serves as an upstream reference for impacts of the Oak Ridge Sewage Treatment Plant. Site 4, located below the plant outfall, was selected to enable the assessment of impacts of the treated municipal wastewater on the biota. The last two sites are located in the lower reaches of EFPC; Site 5 is upstream from Bear Creek, and Site 6 is downstream. Where possible, terrestrial biota were sampled at the same sites. Sites were also selected to allow easy access for sampling equipment and personnel.

Because EFPC originates on the Y-12 Plant site, an aquatic reference site located upstream from the EFPC OU could not be obtained. Thus, a site on Hinds Creek near Norris, Tennessee, was selected as the aquatic reference site (Figs. 2.45 and 2.46). The Hinds Creek site was selected as the aquatic reference site because the available information on surface and subsurface geology, and the hydrology indicated that this site most closely approximated the EFPC watershed. The similarity between the Hinds Creek and EFPC watersheds, coupled with the relative absence of anthropogenic contaminants at Hinds Creek, qualified the site as adequate for making comparisons with the EFPC OU. In addition, BMAP has been using a location in Hinds Creek for its reference site for several years, which allowed data comparability with the ecological risk assessment investigation.

Mill Branch (Fig. 2.46), a tributary within the EFPC watershed, was selected as the terrestrial reference site. Several criteria were used in the selection process. All watersheds with known or suspected contamination were automatically eliminated from consideration, and an attempt was made to locate a site with similar vegetation. The Hinds Creek soil reference site was judged to be unsuitable for use as the terrestrial vegetation reference site because the vegetation surrounding the Hinds Creek site is all pasture, and most of the study sites along EFPC are forested. The Mill Branch site, like the Hinds Creek site, was believed to have received minimal anthropogenic chemical contamination. On this basis, the Mill Branch site was judged to be an adequate reference site for terrestrial fauna for comparisons with the EFPC OU. The location of the site within the EFPC watershed was also regarded as a positive factor. Despite the advantages of the Mill Branch site, however, its use as a reference site for terrestrial biota is somewhat limited by the fact that it supports a small, immature upland forest community rather than the many acres of mature bottomland hardwood communities typically found along EFPC. No noncontaminated reference site for terrestrial vegetation was found that was similar to the EFPC floodplain with respect to species composition and therefore suitable for direct comparisons.

In addition to the aquatic and terrestrial species sampling conducted at the EFPC and reference sites, grasses and browse were taken at three sites and browse was taken at one site along the EFPC floodplain. Grasses and browse were also sampled at the Hinds Creek Reference site. At each EFPC site, a sample of grass or browse was taken at the creek edge and at a distance of 100 m (328 ft) from the creek. Beets, kale, and tomatoes were grown at a special vegetable plot located on the floodplain and a reference location outside the floodplain, and the plant roots, leaves, and fruits were sampled. These vegetation measurements supplemented the historical studies on plants in EFPC. Also important to the ecological risk assessment were the environmental sampling results for soils, sediments, surface water, groundwater, and air.

Indicator species and other taxa for the assessment endpoints were selected by a process, outlined in *Habitat Evaluation Procedures ESM 102* (FWS 1980), which aims to identify

representatives of groups of organisms that occupy a common environmental resource (e.g., sediment, water column, vegetation). The indicator organisms were used as surrogates for the groups of organisms mentioned in the assessment and measurement endpoints. It was judged to be impractical to directly measure and/or model exposure, effects, and risk to all the species represented by the assessment/measurement endpoints. Factors included in the selection of indicator species included their presence in EFPC, ability to obtain measurable responses, adequate sample size, phenology, and small home range within the EFPC OU to ensure exposure. In addition, some species that did not necessarily meet these criteria, such as threatened or endangered species and other species of concern (e.g., migratory birds), were selected because they were important as assessment endpoints. Species of concern included those that are vital to ecosystem energy and biogeochemical cycling, are particularly susceptible or sensitive to contaminants, and are specific bioaccumulators. Indicator species are, in many cases, potentially susceptible to increased morbidity and mortality by virtue of low net reproductive rates, low immigration rates, or small home ranges. Also, plants were selected to represent the lower trophic levels in the food chain to allow modeling up the food chain.

Aquatic indicator species included fish (stonerollers, redbreast sunfish, largemouth bass), sediment-dwelling invertebrates (benthic macroinvertebrates and crayfish), and periphyton (algae and heterotrophic microbes) attached to submerged surfaces in the substrate. Terrestrial indicator species included small mammals [short-tailed shrew (*Blarina brevicauda*) and white-footed mouse (*Peromyscus leucopus*)], birds [Carolina wren (*Thryothorus ludovicianus*) and great blue heron (*Ardea herodias*]), invertebrates (earthworms and adult terrestrial insects) living in or on the soil, and plants (grasses and vegetables). These aquatic and terrestrial indicator species were targeted for population surveys and body burden analyses to represent the key exposure points in the EFPC ecosystem. A summary of the types of measurements and analyses conducted as part of the ecological risk assessment is provided in Table 2.55.

The field investigations were conducted from the late summer of 1991 through the late summer of 1992. The aquatic ecosystem is considered to be representative under conditions of stable base flow. The late summer and early fall were selected for intensive field surveys to satisfy the need for low rainfall conditions typically experienced during these seasons. Because of the present knowledge of the area, abundance of existing biological data on EFPC, and the schedule-driven constraints for the EFPC RI, as specified in the Federal Facilities Agreement, no initial field screening was performed. The schedule and funding level allowed the one-season approach. In addition, fall sampling allowed data comparability with BMAP's fall sampling of fish and benthic macroinvertebrate communities. Communication and coordination with BMAP sampling personnel ensured that no adverse effects occurred to the BMAP sampling locations or BMAP's long-term studies. Without this communication with BMAP personnel, sampling crews could have inadvertently physically damaged or sampled existing riffles used by BMAP for their benthic macroinvertebrate studies, thereby potentially leading to benthic community data that were not representative of the site(s). Data from the BMAP—a multi-season and multi-year study—were used to round out the temporal aspects of the characterization.

2.5.2.2 Exposure characterization

Exposure environments in EFPC and its floodplain consist of a heterogeneous mixture of flow regimes, streambed conditions, and terrestrial habitats varying from commercial through agricultural to woodland. Surface water is a primary medium by which aquatic organisms are

exposed to contaminants currently being released to EFPC via surface water from the Y-12 Plant and to contaminants in floodplain soils that are transported via erosion, surface runoff, and shallow groundwater. Soil is the primary medium of exposure for terrestrial biota. Stream sediments are a second major exposure route for benthic invertebrates and for terrestrial consumers by way of flood deposits on soil and vegetation. In both aquatic and terrestrial communities, indirect exposure of organisms via the food chain is important. Methylation/demethylation of mercury in sediments and stream water and biodegradation of organic contaminants are the most important chemical transformations. Methyl mercury is assumed to be the predominant form of mercury in aquatic biota. In the absence of remediation, the exposures of EFPC communities to contaminants are not expected to change dramatically from those levels identified through Phases Ia and Ib sampling of the soils, sediments, surface, and groundwater along EFPC and the SLB. Table 2.56 summarizes the expected dominant mode of exposure for the EFPC ecosystem, based on the identified media of exposure and the respective indicator species.

Exposure conditions of the indicator species were characterized by implementing the ecological risk assessment sampling plan and incorporating historical data where appropriate to fill in data gaps. The ecological risk assessment sampling results are summarized in Table 2.57 for aquatic biota and in Table 2.58 for terrestrial biota.

COPCs in biota were screened to eliminate combinations of analytes and biota in which body burdens in EFPC and floodplain samples were undetectable, were below the levels in reference site biota, or were less than five times the concentration in blank samples. Metals, PCBs, chlordane as a representative of pesticides, and PAHs were retained as COPCs for various biota. COCs were chosen after risk characterization for these analytes as described in the following sections.

Both historical and current studies of bioaccumulation show (1) higher body burdens of contaminants (mercury, PCBs, and various pesticides, PAHs, or metals) in stonerollers, redbreast sunfish, crayfish, earthworms, and terrestrial insects at EFPC sites than at noncontaminated reference sites and (2) generally decreasing body burdens with increasing distance downstream from the Y-12 Plant. Current body burdens are generally lower than those from the 1980s, possibly as a result of prior remediation activities at the Y-12 Plant. Evidence of ecological recovery in the upper part of EFPC above and below Lake Reality has been documented by BMAP [DOE 1994 (Appendix R, pages R-36 through R-65)]. Whole-body mercury concentrations found in redbreast sunfish during the baseline risk assessment were 30 to 50% less than concentrations found in bluegill (*Lepomis macrochirus*) and redbreast sunfish taken from similarly located sites in studies conducted by ORNL in 1982 (Van Winkle et al. 1984) and by TVA in 1984 (TVA 1985). Other notable findings of the EFPC ecological baseline risk assessment, which indicated a change in the general patterns documented by historical studies, were the high present body burdens of mercury in redbreast sunfish from a site located 6.4 km (3 miles) downstream from Lake Reality and increasing body burdens of PCBs in sunfish at this site and other sites downstream.

2.5.2.3 Effects characterization

Data on the toxicity of inorganic and organic mercury compounds to fish demonstrate a positive relationship between dose and effect. Toxicity tests on a variety of aquatic organisms

using EFPC surface water or sediments have shown various degrees of impact (Table 2.59). In three of the studies, impacts were greatest at the sites closest downstream from the Y-12 Plant. For example, survival and growth of fingernail clams (*Sphaerium fabale*) were lower at EFK 23.4 than at EFK 13.8 or the Brushy Fork reference site (Hinzman 1992). In October through December 1988, a second set of fingernail clam toxicity tests were conducted using the same two sites in EFPC, plus three different reference sites (Brushy Fork, Hinds Creek at kilometer 20.6, and Bull Run Creek at kilometer 20.0 in Union County, Tennessee). After 88 d exposure, survival of the clams was only 4% at EFK 23.4, compared to 94% at EFK 13.8, and 100% at all three reference sites. Lastly, survival and natality (mean number of offspring) of fingernail clams in 1990 were lowest at EFK 23.4 compared to EFK 13.8 and reference sites in Brushy Fork and Beaver Creek (Kornegay 1991).

The results of surveys of indicator organisms at EFPC also indicate effects that most likely occurred from exposure to contaminants released from the Y-12 Plant. However, effects data are a descriptive part of the field work leading to weight-of-evidence analysis, with no statistical inference implied. The number of indicator fish species, benthic macroinvertebrate families, and insect adult individuals at EFPC generally increased with increasing distance downstream from the Y-12 Plant. Compared with the Hinds Creek reference site, EFPC had fewer species of fish, fewer families of benthic macroinvertebrates, and lower mean numbers of individuals per sample of adult insects with terrestrial larval forms. The number of fish species classified as tolerant of degraded conditions decreased downstream in EFPC (Fig. 2.47). The Shannon-Wiener taxonomic diversity indices of fish, benthic macroinvertebrates, and adult insects increased downstream, except at Site 3, and were lowest at the three sites where surface water mercury concentrations were greatest (Fig. 2.48). Taxonomic diversity for fish, benthic macroinvertebrates, and adult insects with aquatic larval forms at EFPC sites was generally less than at the reference site. The richness of families from sensitive orders of arthropoda—Ephemeroptera, Plecoptera, and Trichoptera (EPT richness)—was lowest at the EFPC site nearest the Y-12 Plant and was lower at all EFPC sites than at the reference site (see Fig. 2.12). In general, the results of the benthic macroinvertebrate sampling conducted to support the ecological risk assessment parallel those of the fish sampling, suggesting that both communities (1) are dominated by large numbers of individuals from only a few of the total number of families present, (2) are dominated by tolerant organisms, (3) have less total species/taxa or EPT richness than the reference stream, and (4) have lower diversity indices than the reference stream. Taken together, these factors indicate that the benthic and fish communities in EFPC, especially in the upper part of the stream below Lake Reality, are experiencing environmental stress.

Although taxonomic richness (and presumably diversity) might be expected to increase in a typical stream as its drainage area or stream order increases (Fausch et al. 1984), the argument may be less applicable to EFPC because it does not possess the characteristics of a true headwater stream because of the augmented flow from the Y-12 Plant. Therefore, the increased taxonomic richness and diversity downstream from the Y-12 Plant is probably due more to reduction in toxicant concentrations downstream that to the increase in drainage area.

Studies of periphyton colonization and growth, populations of small mammals, earthworms, birds, and terrestrial vegetation showed less consistent patterns. A bird survey of EFPC in the fall of 1991, as well as other bird surveys, identified more than 30 species of migratory birds, which were likely ingesting contaminated worms and arthropods. White-footed mice were

captured at all EFPC sites except Site 6. Short-tailed shrews, a woodland vole (*Microtus pinetorum*), and an eastern chipmunk (*Tamias striatus*) were captured at one or more of the sites farthest from the Y-12 Plant. A limited vegetation survey revealed no patterns associated with exposure to contaminants released from the Y-12 Plant. Earthworm contaminant body burdens generally decreased as a function of distance from the Y-12 Plant. The threatened and endangered species survey, both literature and field, revealed no species requiring protection of their populations or their support habitats.

2.5.2.4 Risk characterization

Risk characterization integrates the effects of exposure and stressor response on indicator organisms, summarizes risk according to the weight-of-evidence approach, and interprets the ecological significance of these findings. This ecological risk assessment applied two interrelated approaches to ecological risk characterization for EFPC and its floodplain. The first was the application of the quotient method to various criteria and thresholds for protection of ecological resources. In this method, measured concentrations are compared to benchmark concentrations for protection of ecological resources (e.g., assessment endpoints). The ratio of the observed contaminant concentration to the protection thresholds indicates the severity of the impact or risk, with larger quotients indicating greater potential impacts or risks. The second approach was to apply weight-of-evidence arguments to evaluate the strength of the relationship between stressors and observed effects on indicator species and the implications for assessment endpoints.

Weight-of-evidence helps to identify causes of observed ecological responses, using arguments derived from human epidemiology. In this approach, a causal relationship between a stressor and a response is proposed. Then, a series of questions or criteria is applied to the proposition. Not all criteria must be satisfied to demonstrate that the proposition is true, but weight is added to a conclusion by each criterion that is satisfied in the proposition(s). Ultimately, professional judgment is used to establish the strength of the causal relationship. The weight-of-evidence approach is especially useful when (1) there are multiple lines of evidence to evaluate, (2) there are insufficient data for robust statistical analyses, (3) toxicity or other criteria are uncertain, or (4) exposure models are not sufficiently precise for statistical testing. As described by Suter and Loar (1992), the weight-of-evidence approach to ecological risk assessment is analogous to a civil court case in which physical evidence, witness accounts, and expert testimony are considered together to reach a verdict based on the preponderance of evidence. Rather than relying on a single line of evidence, the weight-of-evidence approach ideally incorporates three categories of biological investigation. First, toxicity testing of water, soil, and sediment to which biota are exposed provides direct measurement of effects on animal and plant indicator species. Second, biological surveys assess the current state of biota on the site (i.e., field-observed effects), and the results can be compared to a reference site or to the observations expected in the absence of contamination. Third, body burdens of site-related contaminants can be measured as evidence of exposure and possible effects. Hazard quotients and concentrations of contaminants in physical media can also be incorporated into the weight-of-evidence analysis.

The ecological risks in this study are based on actual body burden data and surveys of organisms occupying the floodplain; the human health risks are not based on actual measurements of exposure in human bodies and are calculated by using standard exposure scenarios and exposure to a form of mercury that is a small portion of the mercury in the floodplain.

Quotient Methods Results

Risks to biota can be characterized by comparing exposure concentrations to specific benchmark concentrations intended to be protective of the organism or its function in the ecosystem. Thus, criteria may be established to limit the concentrations of chemicals in surface water in order to protect aquatic biota (TDEC, Chap. 1200-4-3), or limits may be set on contaminant concentrations in tissues in order to protect organisms or their predators. Benchmarks may also be established by modeling the transfer of contaminants from exposure media through the food chain to the various biotic receptors, thereby taking into account bioaccumulation of contaminants. In the quotient method, if the ratio of exposure concentration to benchmark concentration is <1, there is likely no problem or risk is considered insignificant, whereas if the quotient is sufficiently >1, more study or computation is needed to define the exact degree of the risk that is inferred. Because of the uncertainty surrounding both sampling data and the benchmark concentrations themselves, this approach requires careful interpretation of quotients near 1, but it provides a clear indication of high (≥ 10) or low (<0.1) risks. The quotient method requires consideration of the uncertainty of estimating both the exposure concentration and the threshold values.

To address the assessment endpoints identified in Table 2.54 for the EFPC ecological risk assessment, specific criteria and benchmark concentrations were established for (1) ambient water quality; (2) aquatic biota and predator dietary uptake; and (3) body burdens in terrestrial mammals, birds, earthworms, and insects for predator dietary uptake. Benchmark values for specific COPCs (in particular, mercury, other heavy metals, PCBs, chlordane, and PAHs) were established for each of these measures, and measured values in EFPC media and/or biota were compared to determine a quotient range. Tables 2.60 and 2.61 present the results of the quotient method for aquatic and terrestrial exposures, respectively. The tables identify those organisms at each EFPC site that fall within five quotient ranges. As noted in the quotient ranges, risks (≥ 10) are being predicted for both aquatic and terrestrial biota, primarily through mercury toxicity to predators through the food chain. The higher quotients tended toward the upstream sample locations along EFPC; little ecological risk was noted for the reference sites. Several additional findings are highlighted below.

Toxicological effects. Comparison of mercury body burden concentrations with concentrations that have been proposed as protective against toxicological effects in the indicator organisms (Eisler 1987) showed that 2 of 7 crayfish samples and 1 of 10 common stoneroller composite samples had mercury concentrations exceeding toxicological limits [5 mg/kg (or ppm) body weight]. Body burdens of mercury in short-tailed shrews and Carolina wrens were considerably above the toxicological limit (1.1 mg/kg body weight), and the liver of a great blue heron also exceeded toxicological limits (1.1 mg/kg).

Protection of predators. Comparison of body burdens of contaminants in aquatic biota with concentrations expected to protect their predators from toxicological effects showed that mercury concentrations in fish exceeded the benchmark concentration for mercury by tenfold or more at Sites 1, 2, and 3. Concentrations in crayfish exceeded the benchmark concentration for mercury by at least tenfold at the two sites closest to the Y-12 Plant, and mercury concentrations in aquatic insects exceeded the benchmark concentration by at least tenfold at two sites. Application of the same comparison to low-level terrestrial predators (small mammals and song birds) preying on contaminated organisms showed that undepurated earthworms at every site exceeded

benchmark concentrations for dietary mercury. Assuming all the mercury in the undepurated earthworms is bioavailable, exposure was calculated to be high, even if earthworms were only a small fraction of a predator's diet. Bioaccumulation factors for mercury in earthworms may be on the order of 0.1, so that the contribution of earthworm tissue to the predator's dietary exposure is probably much lower than indicated by the undepurated body burden. Even so, predators that obtain a large fraction of their diet from EFPC earthworms and insectivores feeding exclusively or predominantly in contaminated areas of the floodplain would be at risk from ingestion of mercury. Excessive levels of mercury in short-tailed shrews and Carolina wrens likely result from their consumption of earthworms and insects, respectively, and, in turn, contribute to the risk of those animals that prey on them. Other metals, pesticides, and PAHs did not appear to pose a risk to aquatic and low-level terrestrial predators. PCBs in stonerollers exceed benchmark concentrations at Sites 1 and 2 but did not appear to pose a risk in other biota or in stonerollers at other sites.

Top predators, represented by hawks, owls, and foxes, were assumed to feed on a mix of the biota sampled in three ecological risk zones, comprising risk assessment Segments 1 through 4, 5 through 8, and 9 (Fig. 2.30), respectively, as well as the reference areas at Hinds Creek and Mill Branch. The high-end exposure was calculated with the assumption that the top predators eat no uncontaminated prey. In this case, the composite prey body burdens of mercury exceeded dietary benchmark concentrations for hawks and owls by at least 25-fold in all three zones. The mercury benchmark for foxes was not exceeded in any zone, nor were benchmarks for other metals, PCBs, pesticides, or PAHs in any top predator. When the estimated exposures were adjusted to allow for dietary intake of uncontaminated prey from outside the contaminated areas, dietary benchmarks were not exceeded for hawks or foxes and were exceeded for mercury by less than twofold in the modeled diet of owls.

Weight-Of-Evidence Results

The weight-of-evidence analysis focused on risk to both aquatic and terrestrial ecological receptors. Three propositions were advanced for aquatic biota; these propositions were conclusions based on the results of the ecological risk assessment field sampling as well as on historical studies of EFPC. The three propositions each began with the statement, "Continual releases of water-borne contaminants (including dissolved and particle-bound) such as mercury, uranium, other inorganics, pesticides, PAHs, and Aroclor 1260 from the Y-12 Plant," and are as follows:

Proposition 1. Continual releases of water-borne contaminants . . . from the Y-12 Plant are the largest source of the elevated whole-body burdens of these contaminants in fish, benthic macroinvertebrates, and crayfish in EFPC, which result in risk from toxicological effects to indicator organisms and risk to piscivorous predators feeding on the organisms.

Proposition 2. Continual releases of water-borne contaminants . . . from the Y-12 Plant impact fish community structure in EFPC, resulting in communities dominated by species tolerant of degraded water quality conditions.

Proposition 3. Continual releases of water-borne contaminants . . . from the Y-12 Plant result in reduced taxonomic richness and diversity of the fish and benthic macroinvertebrate communities in EFPC compared to these parameters in the fish and benthos communities at the reference site.

At the time the final draft of the ecological risk assessment was written, the available data were insufficient to warrant the formation and evaluation of propositions regarding the correlations between sediment and tissue contaminant concentrations, or sediments and effects. Consequently, DOE funded two field investigations to provide additional information on the fate and effects of mercury in sediments form EFPC. One study examined the toxicity of sediment elutriates from five sites; the second study examined contaminant transfer among sediments, periphyton, and herbivorous fish and benthic macroinvertebrate grazers. The results of the sediment toxicity study are discussed in Sects. 2.3.1.9 (Sediment toxicity) and 2.5.3.2 (Ecologically based remediation goal options for sediment) of this FS. Results of the contaminant transfer study as they relate to sediment remediation goal options are also discussed in Sect. 2.5.3.2.

The aquatic propositions were evaluated against five criteria (temporal association, spatial association, stressor-response, strength of association, and plausibility) and qualitatively ranked (as strong, moderate, or weak) based on the level of available evidence. Major observations from the ecological risk assessment field sampling and historical studies indicate that numerous COPC body burdens in the aquatic indicator organisms (stonerollers, redbreast sunfish, crayfish, and benthic macroinvertebrates) as well as several measures of community structure (fish and benthic macroinvertebrates, taxonomic richness and diversity, and percentage of fish species classified as tolerants) are greatest at locations closest to the Y-12 Plant, then decrease downstream in EFPC. In addition, COPC body burdens and community impacts in biota from all sites in EFPC usually were greater than equivalent impacts at the Hinds Creek reference site.

The data for mercury and PCBs indicate a clear temporal association between the release of these two contaminants from the Y-12 Plant and their subsequent bioaccumulation in aquatic biota downstream in EFPC. Several variables (such as the percentage of captured fish species that are classified as tolerant of degraded water quality conditions, fish and benthic macroinvertebrate taxa richness, and species diversity) have consistently indicated that aquatic biota in EFPC are adversely impacted in comparison to biota in the Hinds Creek reference stream. However, BMAP researchers have concluded that recent increases in taxa richness of fish and benthic macroinvertebrates, as well as increased survival and growth of clams in EFPC below Lake Reality, indicate ecological recovery that is temporally related to improved control of toxicant releases from the Y-12 Plant [DOE 1994 (Appendix R, pages R-36 through R-65)].

Both current and historical evidence suggest that spatial associations are strong for all three propositions. Body burdens of many COPCs were greatest in biota collected closest to the Y-12 Plant and decreased downstream. Also, the COPC body burdens in biota from most sites in EFPC were greater than the body burdens in biota from the reference site. Similar trends were observed for the percentage of tolerant fish species (Proposition 2). Fish and benthic macroinvertebrate taxonomic richness and diversity (Proposition 3) generally increased downstream from the Y-12 Plant, indicating that the most severe impacts occurred closest to the plant.

Stressor-response associations were evaluated by determining linear correlation coefficients between estimated COPC exposure concentrations (the stressor) and the magnitude of some response variable (e.g., percentage of fish classified as tolerants). In the absence of COPC concentration data in surface water, COPC body burden concentrations were used as an indicator of the stressor exposure level.

Mercury in surface water was significantly correlated with mercury body burdens in crayfish. Of the COPCs that were below detection limits in surface water, ten were present in at least one of the aquatic indicator organisms at body burden concentrations that were maximum in samples collected closest to the Y-12 Plant, then decreased downstream. Mercury concentrations in surface water were correlated with the percentage of fish classified as tolerants, but zinc concentrations in surface water were not correlated (Proposition 2). Five contaminant body burdens in common stonerollers were correlated with the percentage of fish classified as tolerants. Evidence of stressor-response associations between COPC concentrations and taxonomic richness or diversity (Proposition 3) were practically absent. Thus, the data suggest a strong stressor-response association for Proposition 1, a moderate association for Proposition 2, and a weak association for Proposition 3.

Strength of association for all three propositions is strong. For example, body burdens of most contaminants decreased downstream from the Y-12 Plant, whereas urban runoff and point source contaminants increased downstream. Habitat-altering activities, such as dredging or impounding (which could have potential adverse impacts to fish and benthic macroinvertebrate communities), have not been conducted extensively in EFPC. Concentrations of residual chlorine, which is a potential chemical toxicant, did not exceed the EPA ambient water quality criteria for protection of aquatic life (11 μg/L) during BMAP 7-d media toxicity tests. Loar (1992) stated that although episodic increases of chlorine concentration probably affect benthos at EFK 24.4 (above former New Hope Pond), the chlorine concentrations cannot account for the low abundance and diversity at EFK 23.4. Measurements for water quality parameters such as alkalinity, conductivity, dissolved organic carbon, pH, total suspended solids, base cations, nitrate, and sulfate were fairly uniform for each parameter among the six sampling sites in EFPC (Table 2.1). It is unlikely that these parameters would have deleterious impacts on aquatic communities in EFPC. However, the elevated ambient water temperature in EFPC (especially near the Y-12 Plant) should be considered as a possible contributing factor to impacts to fish and benthic macroinvertebrate taxonomic richness and diversity. In addition, dissolved oxygen concentration was only $\sim$55% of saturation at Site 3, noticeably lower than all other sites. The reduced dissolved oxygen concentration was not low enough to cause an acute lethal threat to resident fish populations, but it could result in increased respiratory stress and susceptibility to toxicants.

Likewise, plausibility for all three propositions is strong. The COPCs from this study are known to bioaccumulate in most aquatic organisms. Although most COPC concentrations in surface water were below detection limits, the large number of COPC body burdens displaying longitudinal decreases in concentration downstream from the Y-12 Plant suggests that the Y-12 Plant is the source of the COPCs in the biota (Proposition 1). Propositions 2 and 3 are plausible because the surface water mercury concentrations (0.54 to 0.32 μg/L) at the three sites closest to the Y-12 Plant exceed the concentration known to cause toxic effects in fish ($<$0.1 μg/L). This alone could account for the observed impacts to the fish and benthic macroinvertebrate community structure and diversity.

The conclusions from the weight-of-evidence analysis have implications for the assessment endpoints associated with Goals 4 (a fish community indicative of undegraded conditions) and 5 (no adverse effects from contaminants to aquatic organisms and/or predators that feed on them) (see Table 2.54). For example, aqueous mercury concentrations in EFPC exceeding levels known to produce toxicological impacts to sensitive [e.g., <0.1 μg/L in rainbow trout (*Oncorhynchus mykiss*)] as well as tolerant species [e.g., 0.23 μg/L in fathead minnows (*Pimephales promelas*)] have been observed. Although rainbow trout would not be expected to occur in EFPC, the toxicological concentration of mercury for rainbow trout was used in this section as a conservative estimate for the most sensitive nongame fish species that could occur in EFPC during nondegraded conditions. The observed mercury concentrations alone could affect community structure (Goal 4 and its assessment endpoint), as demonstrated by the increased proportion of tolerant fish species (Proposition 2) and the impacts to taxonomic richness and diversity (Proposition 3). Elevated aqueous mercury concentrations exceeding ambient water quality criteria also place fish and benthic macroinvertebrate communities at risk, which links to Goal 5 and assessment endpoint 5a. Elevated body burdens of mercury and other contaminants continue to place aquatic organisms and their predators at risk (Goal 5, assessment endpoints 5b and 5c). The aquatic weight-of-evidence analysis indicates that Goals 4 and 5 are not being met, most likely due to ongoing releases of contaminants from the Y-12 Plant.

The weight-of-evidence analysis for the terrestrial biota makes two propositions concerning EFPC soil contaminants. Common to both propositions is the premise that EFPC soil contaminants were released from the Y-12 Plant and were transported by and deposited from EFPC surface water. The propositions are as follows:

1. EFPC soil contaminants have resulted in elevated body burdens of these contaminants in terrestrial organisms residing on the floodplain, as indicated by field-observed measurements of earthworms, small mammals, and birds.

2. EFPC soil contaminants have resulted in reduced abundance of terrestrial organisms residing on the floodplain, as indicated by field-observed measurements of terrestrial populations.

The terrestrial weight-of-evidence analysis evaluated four criteria (spatial association, stressor-response, strength of association, and plausibility). The propositions explicitly address a subset of the EFPC terrestrial community—the animal indicator species associated with the assessment and measurement endpoints. These species are generally ubiquitous and, for one or more of their life stages, relatively sedentary inhabitants of the floodplain. The 10 families of insects considered in detail in the following analysis are inhabitants of soil, soil surface, or herbaceous vegetation, or are predators of other such inhabitants (Borror and DeLong 1964).

The spatial association for Proposition 1 is supported by the fact that concentrations of mercury and five other metals in undepurated earthworms; cadmium, zinc, and Aroclor 1260 in white-footed mice; and 6 metals, Aroclor 1260, and some pesticides in insects from most sites in EFPC exceeded those in biota from the reference site. Also, body burdens of mercury in undepurated earthworms generally decreased with increasing distance from the Y-12 Plant. This also supports the stressor-response relationship for Proposition 1 because maximum mercury concentrations in surface soils nearest the creek bank of EFPC decreased with increasing distance from the Y-12 Plant, as did soil mercury concentrations at the biotic sampling sites (with the exception of Site 1, which has only a narrow floodplain). The strength of association and

plausibility of Proposition 1 are high, given that the only known source of mercury and other contaminants to terrestrial biota is the EFPC floodplain soils.

The spatial association and stressor-response relationship for Proposition 2 are supported by the inverse relationship between soil mercury concentrations and abundances of ten families of insects with terrestrial juveniles that represent a majority of all insects captured. There are no such similar trends in abundance for small mammals, birds, and earthworms. Published dose-response data for terrestrial annelids suggest that mercury concentrations in EFPC soils may be high enough to adversely affect soil-dwelling insects. The strength of association and plausibility of Proposition 2 are moderate. Insect groups showing a spatial association with mercury concentrations in EFPC soils comprise between 70 and 84% of all terrestrial insects captured at the six biotic sampling sites. The increase in abundance with increasing distance from the Y-12 Plant exhibited by the three dominant groups of insects is strong evidence that one or more physical or chemical stressors associated with EFPC diminish with increasing distance downstream. The most plausible cause of this pattern is the decrease in soil contaminant concentration, although other stressors or subtle habitat differences may also influence the observed pattern of insect abundance.

It is concluded that increased body burdens of mercury and other contaminants in earthworms, mice, shrews, and wrens result from EFPC soil contaminants that originated at the Y-12 Plant and were transported by and deposited from EFPC surface water onto the floodplain. It is also concluded that the decreased abundances of 10 families of insects with terrestrial juveniles at EFPC biotic sample sites nearest the Y-12 Plant (especially Sites 1, 2, and 3) result from EFPC soil contaminants. While this suggests that insect abundances may have been reduced by contaminants in EFPC floodplain soils, there is insufficient evidence to conclude that the terrestrial insect community at any EFPC site is indicative of degraded conditions, as defined in assessment endpoint 6a, because of habitat differences between the EFPC and Hinds Creek sampling sites. Population densities of other terrestrial indicator organisms were typically higher than at the reference site.

These conclusions have implications for the assessment endpoints. The propositions link directly to Goal 7—the protection of terrestrial animals and their predators from the effects of contaminants. Elevated body burdens of EFPC contaminants in earthworms and their predators put still other unsampled and unanalyzed terrestrial predators on the EFPC floodplain at risk from exposure to these contaminants. The propositions link indirectly to Goal 2 because terrestrial organisms represent an essential resource for migratory birds passing through or residing seasonally on the floodplain. Reductions in insect abundances may decrease the carrying capacity of EFPC for numerous species of insectivorous birds that raise their young on the floodplain in the summer. Combined with elevated body burdens of contaminants in insects, this represents an even more potentially serious risk to bird populations. Thus, Goals 2 and 7, the protection of migratory birds and the protection of terrestrial animals and their predators, are probably not being met in some portions of the EFPC floodplain as a result of EFPC soil contaminants that originated at the Y-12 Plant and were transported by and deposited from EFPC surface water onto the floodplain.

2.5.2.5 Spatial distribution of ecological risk

The floodplain was organized into nine risk assessment segments (Fig. 2.49), based on geography, uniformity of land use, and similarity of contaminant levels. A more descriptive explanation of the criteria for segment selection is found in Sect. 5 of the RI report (DOE 1994a). Segments 1, 2, 3, and 4 are located in the upper reaches or part of the creek, below Lake Reality, whereas Segments 5, 6, 7, and 8 are located further downstream along the east-west axis of the stream. The longest segment (Segment 9) covers approximately the last 25% of the EFPC floodplain, and its western edge is located at the confluence with Poplar Creek. The nine segments used for this ecological risk assessment are the same as those used for the human health risk assessment.

Ecological risk differs from segment to segment along the 23.3-km (14.5-mile) course of EFPC. Risk varies according to noticeable trends in exposure to contaminants, as indicated by comparing contaminant body burdens relative to protective benchmarks (quotients) and weight-of-evidence discussions on spatial associations. The decrease in most contaminant body burdens, ecological community effects, and risk quotients with distance downstream from the Y-12 Plant indicates that ecological risk is highest in Segments 1, 2, 3, and 4, which are the segments closest to the source of contamination. Several contaminated wetlands with resident invertebrates, amphibians, and other animals also occur in these segments. Ecological risk is lowest in Segment 9, which is the segment farthest downstream from Y-12; contaminant body burdens and other assessment endpoint measures are also lowest in Segment 9. Ecological risk is intermediate in Segments 5, 6, 7, and 8, which are located in the midstream portion of EFPC. Table 2.62 summarizes these and related trends.

Along this overall gradient of ecological risk and within each segment, two types of ecological resources are at risk: aquatic and terrestrial. Aquatic resources—fish, benthic macroinvertebrates, and primary producers—are at highest risk because they live in the water or in sediments and are exposed continuously via body contact. Risks to aquatic biota are greatest immediately downstream from the Y-12 Plant (EFK 20-23), where the highest aqueous mercury levels were observed. Every ecological risk assessment contaminant sampling location in EFPC provided contaminated prey to fish-eating predators. Exposures to aquatic and piscivorous biota generally decrease downstream. Aquatic ecological resources are subjected to a greater risk, segment by segment, than are the terrestrial resources in the corresponding segment.

Although biomagnification has in some cases resulted in body burdens well above the benchmarks used for risk estimation, measurements of body burdens show that terrestrial resources—birds, small mammals, earthworms, arthropods, and vegetation—generally exhibit less risk and less definitive trends than the aquatic resources for any particular segment within the floodplain. Exposures to terrestrial animals are primarily via contaminated animal food, in which contaminant levels are related to soil contaminant concentrations. Initial work shows that terrestrial areas of highest mercury concentrations are sometimes found in the bottomland hardwood forests, where flooding is most likely to have occurred. As explained in the risk quotient and terrestrial weight-of-evidence sections, some available terrestrial measurements show trends, particularly decreasing contaminant body burdens as distance from the Y-12 Plant increases. Thus, both the aquatic and terrestrial organisms in the EFPC environment are at differing risks as a function of distance from the Y-12 Plant. In turn, these ecological risks are

in three large patterns: (1) highest in Segments 1, 2, 3, and 4 (upper reach); (2) intermediate in Segments 5, 6, 7, and 8 (middle reach); and (3) lowest in Segment 9 (lower reach).

Selection of COCs

On the basis of results described in the preceding risk characterization subsections, mercury and PCBs are retained as COCs for both aquatic and terrestrial biota. Other COPCs did not appear to provide exposures consistently above threshold concentrations used in the risk characterization.

2.5.2.6 Future exposures and risks

Many future exposure scenarios are possible. If there is no remediation at either the Y-12 Plant or the EFPC floodplain, exposures of the biota are not likely to change significantly. Bioaccumulation and biomagnification may cause an increase in contaminant load in long-lived terrestrial biota. However, because most of the soil contaminants have been in place for 30 years or more, most of the food taxa have probably reached steady-state body burdens. Cessation of releases from routine Y-12 Plant operations would likely reduce chronic exposures in EFPC, but releases by stormwater runoff from the Y-12 Plant into EFPC would likely continue. Changes in Y-12 Plant operations to reduce the volume of water, but not the mass of contaminants, flowing into EFPC could increase exposure concentrations to aquatic biota. Closure of the Y-12 Plant would alter the base flow of EFPC, causing disruption of many biotic communities, especially in the upper reaches of the creek. Because ongoing releases of contaminants from the Y-12 Plant into EFPC appear to dominate the effects on aquatic biota in EFPC, changes in the baseline contaminant body burdens that would result if the EFPC floodplain and sediments were the only source of contaminants to surface water are not clear. Studies are in progress to assess sediment toxicity and relationships between sediments and transfer of contaminants to aquatic biota.

The future (i.e., assuming no change from current conditions) would result in the continued exposure of (1) aquatic biota that directly contact and ingest EFPC surface water, sediment, and food; (2) aquatic predators that prey on other contaminated aquatic organisms or terrestrial insects; (3) terrestrial animals that dwell in or consume contaminated soil; and (4) terrestrial predators that prey on contaminated aquatic or terrestrial animals in the EFPC floodplain. The continued exposures of aquatic and terrestrial biota and their habitats to contaminants would result in continued elevated body burdens of contaminants in these biota and risk to their predators, along with impacts to community structure and taxa diversity.

Wetlands in contaminated areas of the floodplain would continue to receive contaminants transported by stormflow. Contaminated soils could act as a source of contamination to wetlands in the watershed. Contaminated soils could be eroded and transported as suspended load in the high flow of flood events. As flow velocity decreases and flood waters recede, contaminants transported as suspended solids drop out of suspension and are redeposited in wetlands in another part of the floodplain. Because wetlands in the EFPC floodplain have formed in low-lying areas of the floodplain subject to deposition, the wetlands could receive future contaminants. In this manner, contaminants could migrate, and relatively uncontaminated soils in the floodplain downstream from the source area could become contaminated. In the future, contaminated soils

in wetlands would remain a potential source of contamination to numerous other receptors, including soil, sediment, surface water, groundwater, plants, animals, and humans.

The floodplain contains trees, some of which have cavities and other hiding/brood places for bats. These trees are likely to remain, continuing to provide potential habitat to threatened and endangered bat species. However, the endangered Indiana bat (*Myotis sodalis*) has major population centers in Missouri and Kentucky and is not likely to reach eastern Tennessee. The endangered gray bat (*Myotis grisescens*) is also concentrated in cave regions; the species is mostly found in Arkansas, Missouri, Kentucky, Tennessee, and Alabama and forages primarily along rivers or lake shores. This bat is not likely to expand its range to the small stream area of EFPC. The Tennessee dace (*Phoxinus tennesseensis*), a state-listed fish found in several tributaries to EFPC, may move into EFPC.

2.5.2.7 Comparison of ecological risk assessment results with assessment endpoints

As documented in the Problem Formulation phase of this ecological risk assessment (Table 2.54), 12 assessment endpoints were identified that would help to determine whether existing site conditions provided attainment of the goals set for the EFPC watershed. Following the conclusion of the Exposure Characterization, Effect Characterization, and Risk Characterization phases, and within the limits of the uncertainties associated with this type of study, the risk assessment can be compared to these baseline assessment endpoints to get a clearer picture of the overall ecological risk assessment results. Table 2.63 provides a listing of the defined endpoints along with the respective ecological risk assessment results from direct surveys or risk characterization analyses (quotient or weight-of-evidence). A few key results of this comparison and conclusions from the ecological risk follow:

- a few of the assessment endpoints (assessment endpoint 1a and possibly 1b, 1c, and 2a in Table 2.63 were achieved with existing EFPC contaminant conditions;

- one assessment endpoint (6a) is achieved for some receptors at some places and not achieved for one receptor at all places; and

- measurements or risk characterization method results indicate that the rest of the assessment endpoints cannot be met in parts of the EFPC floodplain under existing conditions (i.e., many body burdens exceed the protective concentrations).

These and the following conclusions summarize the baseline ecological risk assessment for EFPC:

- There is ongoing risk to ecological resources, particularly aquatic organisms in the upper part of the creek, from exposure to contaminants in environmental and biological media of EFPC. The results of the ecological risk assessment do not indicate a need for immediate short-term action to mitigate exposures or risks to ecological health.

- Direct contact with and ingestion of surface water, sediment, and sediment pore water are primary exposure pathways for aquatic biota. The food chain is also a primary exposure pathway for aquatic fauna. Releases from the Y-12 Plant are the primary source of water-borne contaminants. Additional contributions, albeit much smaller, to ecological risk come

from the municipal sewage treatment plant and other point and non-point sources along the creek. Experiments at ORNL on fish uptake in tanks containing mercury-laden waters from Lake Reality, both with and without a contaminated sediment substrate, establish the minor role of sediments as a source of exposure to aquatic organisms. Studies are in progress to assess the toxicity of sediments from EFPC on aquatic organisms.

- The food chain is the most important exposure pathway for terrestrial fauna. Exposures to terrestrial biota also come from contaminant deposits in the EFPC floodplain soils, via direct contact and inhalation. These exposures result in ecological risk quotients in excess of 10 and 100 to predators of earthworms and insects. Predators of small mammals and birds are at risk according to modeled pathways of contaminant uptake if those predators obtain the majority of their food from the EFPC floodplain.

- Methyl mercury concentrations were very low in EFPC soils and sediments; however, methyl mercury was assumed to be the predominant mercury species in aquatic biota, including flying insects, based on data from the BMAP and other evidence. Consumption of contaminated aquatic biota provides risk to terrestrial and aquatic piscivores.

- Evidence suggests that some ecological recovery of the aquatic ecological community has been occurring in the upper reaches of the creek above and below Lake Reality as documented by the BMAP. Dechlorination of the process water and other remedial activities at the Y-12 Plant have lowered the concentrations of some water-borne chemical stressors; thus, exposure has decreased, followed by partial ecological recovery. Nonetheless, elevated contaminant body burdens and an excess of pollution tolerant species are still present.

- Water-borne contamination (especially mercury and PCBs) must be controlled for protection of aquatic biota. Sediment or floodplain soil removal alone will probably not sufficiently reduce those contaminant concentrations in aquatic biota. Results from in-progress EFPC studies on sediment toxicity and instream contaminant transfer will help clarify these relationships. The implications of this and other findings will be rigorously and systematically examined in the FS report.

2.5.3 Human Health and Ecological Remediation Goal Options

This section discusses the remediation goal options that were calculated in Sect. 7 of the RI report (DOE 1994a). Remediation goal options are chemical-specific, numeric cleanup objectives developed from site-specific exposure assumptions for each affected environmental medium. They must fulfill the CERCLA threshold criteria: protection of human health and the environment and compliance with ARARs.

Remediation goal options were calculated for each appropriate environmental medium or exposure pathway, including soil, groundwater, food chain, surface water, sediment, and air. No remediation goal options for radionuclides were calculated (e.g., either direct radiation or radionuclides detected in soil, groundwater, etc.) because no associated risks approached or exceeded EPA targets.

2.5.3.1 Human health remediation goal options

EPA guidance for deriving human health remediation goal options is presented in *RAGS* Vol. I, Part B (EPA 1991c). The remediation goal options are derived from the EPA target risk values for carcinogens and noncarcinogens by back-calculating the corresponding concentrations in the appropriate environmental medium. The 10^{-6} (1 in 1,000,000) risk level was used as the EPA target risk value for carcinogens and an HI of 1 was used for noncarcinogens. The RME exposure assumptions that were used in the baseline risk assessment were used in these calculations.

Remediation goal options were calculated for COCs in soils, groundwater, food chain, and sediments. As opposed to COPCs, COCs are chemicals emerging from the risk assessment which contribute to a pathway that exceeds a 10^{-4} (1 in 10,000) risk or an HI of 1 or greater. A list of these COCs is presented in Table 2.64. For soils, remediation goal options were calculated for both Residential/Agricultural and Open land use (DOE/Commercial and Other) scenarios, and include both adults and children. The remediation goal options based on the Residential/Agricultural land use scenario are more conservative.

It is important to note that remediation goal options do no reflect combined exposure across contaminants (they are chemical-specific) or across all environmental media in which the contaminant has been found. Rather, remediation goal options are derived for combined exposure to a given medium across exposure routes that are likely to occur simultaneously. At EFPC, both the ingestion and dermal contact routes have been incorporated into the soil remediation goal options, and ingestion and inhalation have been incorporated into the groundwater remediation goal options. Only the ingestion route is considered in the derivation of the food chain remediation goal options and only the dermal contact route is incorporated into the sediment remediation goal options.

An remediation goal option was also calculated for lead in soil and groundwater using the lead biokinetic/uptake model (LEAD 0.60, EPA 1991d). EPA has withdrawn the RfD for lead and alternately recommends use of this model. LEAD 0.60 is used to estimate blood lead uptake in children from the ages of 0 to 7 years and is currently not applicable to adults. The remediation goal option was calculated by setting the target blood level at 10 μg/dL for 95% of the population (guideline established by the Centers for Disease Control and adopted by EPA).

The remediation goal options are presented in Sect. 7 of the RI report (DOE 1994a). However, not all of these remediation goal options are used in the FS for the evaluation of alternatives; rather, remediation goal options for certain pathways and chemicals were selected as the basis for determining remedial action objectives. This is discussed in Sect. 3.1 of this report.

2.5.3.2 Ecological remediation goal options

Biota (plants and animals) in the EFPC floodplain are potentially exposed to contaminants, especially mercury, in five media sources—air, surface water, groundwater, instream sediment, and soil. These media are considered separately in the discussion of remediation goal options in the RI report and the RI addendum. Biota are a source of exposure through the food web, but it is assumed that biota cannot be remediated. Remedial goals for biota depend ultimately on

uptake from abiotic media, such as soil or sediment. Therefore, separate remediation goal options for biota were not derived in the RI report or the RI addendum.

The following section summarizes the remediation goal options for air, surface water, and groundwater. A second section deals with the range of remediation goal options for sediment. A range of soil remediation goal options under three scenarios follows with the last paragraph being a summary.

Air, Surface Water, and Groundwater Remediation Goal Options

As explained in the RI report, air is not considered a major pathway of ecological exposure to contaminants in EFPC or the EFPC floodplain. Therefore, remediation goal options for air are not proposed. However, exposures of biota to airborne contaminants in or near the ground are considered in the derivation of remediation goal options for soil in Sect. 7.3.6.2 of the RI report and in the RI addendum.

Surface water has been shown to be a major pathway transporting dissolved and particulate contaminants to aquatic biota in EFPC, either directly or through the food chain. The RI report discussion of surface water remediation goal options focused on ARARs and to-be-considered (TBC) guidance, protection of EFPC biota from contaminant toxicity, and protection of predators from contaminant toxicity. An evaluation of remediation goal options calculated for surface water and the methods used to derive them are presented in Table 7.9 of the RI report. Comparing ARARs to risk-based remediation goal options shows that the ambient water quality criteria (AWQC) for mercury are protective of biota in the EFPC environment. All of the four proposed surface water remediation goal options for mercury are below the contract-required analytical detection limit of 1 μg/L. Bioconcentration results in accumulation of mercury species in biota above detectable limits even when mercury is below concentration levels detectable in water. Therefore, attainment of surface water remediation goal options must be measured by methods more sensitive than CLP methods or by continued monitoring of aquatic biota. The concentration in water can be estimated from the observed body burdens in aquatic biota.

No remedial goals based on ecological risk are being proposed for groundwater. Deep groundwater is not considered a major exposure pathway for ecological receptors. Shallow groundwater was evaluated as a potential pathway to terrestrial insects and worms by dermal contact and ingestion, and to plants by root uptake because of the lateral migration of groundwater from the EFPC floodplain to the creek or from the creek to the floodplain under dry conditions. However, shallow groundwater is transient, and contaminants found there are presumed to come either by leaching from EFPC floodplain soils, by infiltration of EFPC surface water, or from sources outside the EFPC floodplain. Furthermore, most mercury in groundwater is particle bound and not dissolved. Treatability studies have shown that the concentration of mercury in a water leachate of EFPC floodplain soils was -0.08% of the concentration in soil (Radian 1993). This means that the mobility of soil mercury in groundwater is minor. In addition, cleanup of groundwater would not remediate the sources of contaminants to the groundwater and would not be an effective remedy. Therefore, no ecologically based remedial goals are being proposed for shallow groundwater.

Sediment Remediation Goal Options

There are three sources of remediation goal options for sediment—the RI report (DOE 1994a), the RI addendum (1994b), and results from a DOE-funded sediment toxicity study that have become available since the RI report and RI addendum were published. From the RI report, the potential remediation goal option for sediment is 210 mg/kg. This was based on a larval trout toxicity endpoint. The RI addendum provides additional remediation goal options based on additional endpoints. The exposure scenarios comprise (1) sediment-dwelling biota exposed in pore water to contaminants derived from sediment and (2) biota exposed in surface water to contaminants derived from sediment. In addition, results of the food web study that were presented in the RI addendum have been used to calculate sediment remediation goal options on the basis of steady-state equations, site inspection, and literature data.

Exposure of sediment-dwelling organisms to contaminants in sediment is assumed to result from transport of contaminants into water trapped in interstitial pores of the sediment; thus, the nature of the pore water is very important in determining exposure. Fine-grained sediments, which may be found in pools and other areas with low flow rates, have more pores than coarse-grained sediments. Pore water in fine sediments also exchanges with surface water more slowly than pore water in coarse sediments, so pore water contaminant concentrations can build up to higher levels in fine sediments. EFPC sediments are mostly coarse because the high flow rate of the creek removes the fine material. The concentration of mercury in pore water in coarse sediments is more likely to be similar to that in surface water and lower than if pore water were in steady-state with sediment.

The most conservative scenarios in this addendum assume that most contaminants to which biota are exposed in surface water come by leaching from sediment and are thus at the same concentration as in pore water in equilibrium with sediment [described by the distribution coefficient (K_d) for pore water]. This is not likely to be true of fine, deep sediments that prevent rapid water exchange. These assumptions gave a range of remediation goal options for sediment from 0.03 to 1100 mg/kg depending on endpoints and other assumptions. If it is assumed that the steady-state ratio of mercury species in surface water to mercury species in sediment is reflected by the results of the mesocosm study that represented site-specific conditions (DOE 1994a, Appendix Q), sediment remediation goal options range from 0.9 to 3600 mg/kg. Because of the wide range of calculated remediation goal options (which results from the wide range of assumptions) all available site-specific data on sediment and pore-water toxicity should be included in the final evaluation of sediment remediation goal options.

A minimum remediation goal option of 73 mg/kg was inferred from the results of the EFPC sediment toxicity study because 73 mg/kg (total mercury) was the highest of all the sediment concentrations and none of them produced elutriates that were toxic to *Ceriodaphnia dubia*. However, the remediation goal option is probably a conservative estimate because it is not possible from these sediment toxicity results alone to determine how much higher the concentration of mercury in sediment would have to be to cause toxic effects to the test organisms. The remediation goal option estimate is within the range of values presented in the RI addendum.

Remediation goal options were also calculated using results from the food web study described in the RI Addendum (DOE 1994b). Calculation of the remediation goal options was based on the food web model and site-specific and literature data that are presented in Appendix G. The remediation goal options are derived using assumptions of steady-state

equations, as well as bioconcentration and bioaccumulation factors and benchmark concentrations of methyl mercury in stonerollers and striped shiners. A narrative in Appendix G describes the procedures used to compute the remediation goal option on the basis of the site-specific food web study. A remediation goal option of 331 mg/kg was derived based on a benchmark concentration of 50 ng methyl mercury/g in stonerollers. A remediation goal option of 68 mg/kg is based on the same benchmark concentration in striped shiners. Both of these remediation goal options are within the range presented in the RI addendum. Uncertainties associated with these remediation goal options are qualitatively discussed in Appendix G.

Surface water, which receives mercury loading from the Y-12 Plant and runoff from EFPC floodplain, is currently the major source of mercury contamination to aquatic biota. The average mercury level in the sediment composite representing Site 1 was 18 mg/kg (Fig. 6.43 in the RI report). At this site, the observed mercury concentration in surface water was 0.54 μg/L, whereas the calculated equilibrium concentration would be $\sim$18,000 μg/kg/7.1 $\times$ 10^5 L/kg = 0.025 μg/L, which is lower than the observed value by a factor of $\sim$20. This implies that sediment could not supply the observed concentration of mercury. A sediment toxicity study discussed in Sect. 2.4 of the RI addendum showed no toxicity. Yet the aquatic organisms have in their bodies mercury considerably above background measurements. Therefore, risks from instream sediments should be evaluated after the source of mercury to EFPC surface water and EFPC floodplain soils have been remediated.

Soil Remediation Goal Options

Terrestrial animals and their predators were shown to have accumulated concentrations of mercury exceeding guidelines for protection from toxicity (Sect. 6.4.1.1 of the RI report). Soil is the potential source of exposure by inhalation and direct ingestion and indirectly through the food chain. These pathways and soil ingestion equations were discussed in the RI report and RI addendum.

Regarding inhalation, animals living close to or in the ground may be exposed to volatile chemicals in the soil. Remediation goal options for these chemicals in soil are addressed as soil remediation goal options because cleanup of soil would be required to reduce any deleterious inhalation exposures. The calculated allowable concentrations of mercury in the RI report were 1000 to 7475 mg/kg, depending on the values of the chronic toxicity measurements. The calculation assumed that all soil mercury is in the firmly bound ionic form. Because the majority of the mercury is actually ionic or bound in a nonvolatile form, the lower remediation goal option of 1000 mg/kg for inhalation of vapors is probably adequately conservative.

Exposure to mercury in the EFPC floodplain is demonstrated for mid-level predators . Mid-level predators are those organisms feeding on insects, earthworms, and other herbivores and being eaten by top predators (e.g., hawks, owls, and foxes). Wrens and shrews are mid-level predators found in the EFPC floodplain. Small mammals were shown to have body burdens of some contaminants above concentrations considered to be potentially toxic to their predators. The major route of contaminant accumulation is probably the food chain. Contaminants are expected to enter the food chain of these terrestrial biota by uptake from soil into plants, earthworms, and insects, as well as by the ingestion and possibly inhalation pathways described in Sects. 7.3.6.1 and 7.3.6.2 of the RI report. Because elevated body burdens were observed in shrews and wrens, but generally not in mice and voles (which are first-group consumers eating plants), it appears that a diet of soil-dwelling arthropods and worms is a likely source for bioaccumulation of contaminants.

Exposure to mercury via the food chain is modeled for higher predators. Biomagnification increases the body burdens of predators over those of their prey. For example, mercury was not detected in four of the six floodplain samples of terrestrial insects but had become magnified in wrens (average 3.5 mg/kg) and shrews (average 4.9 mg/kg). Mid-level predators, especially wrens and shrews, are prey to higher predators. Remediation goal options must protect predators from biomagnification to toxic levels as a result of eating contaminated prey. The calculated remediation goal options would provide this protection.

Soil remediation goal options for the protection of wrens, shrews, and other mid-level predators from mercury in the food chain were presented in Sect. 7.3.6.3 of the RI report. A remediation goal option of 230 mg/kg (rounded to 200) was indicated based on the protection of mid-level predators (i.e., small mammals whose diet is 100% contaminated earthworms). The observed ratios of dietary exposure to criteria for toxicological effects of mercury were 8.8 in shrews and 6.9 in wrens (Table 6.84 in the RI report). However, the highest calculated dietary exposure quotient for top predators was 1.4 in owls (Table 6.84 in the RI report). The feeding ranges of top predators and the typical dietary mix (Sect. 6.4.1.1 in the RI report) are included in these derivations and demonstrate that biomagnification of mercury by top predators is likely not to be taking place. Thus, reduction of mercury concentrations in soil to levels that are protective of shrews and wrens should adequately protect top predators as well. Therefore, one remediation goal option for protection of top predators from mercury in the food chain is 230 mg/kg soil, which was rounded downward to 200 in the RI report.

Additional data on bioaccumulation of mercury from EFPC soils and other soil/body burden relationships became available from the wetlands study described in the RI addendum (Sect. 2.2). Additional effects data were available through literature searches. The RI addendum uses these data and describes three scenarios:

- upper-bound exposure (Scenario 1)—Home ranges of predators and prey are mathematically compressed to assure maximum contact. Further, all prey is contaminated at a high measured concentration and all subsequent exposure parameters are set at 100% (e.g., methyl mercury is 100% of total mercury, 100% of ingested mercury is absorbed).

- intermediate exposure (Scenario 2)—Many parameters are intermediate between upper-bound and the lower exposure scenarios.

- lower exposure (Scenario 3)—Home ranges of predators are allowed to overlap as they do in nature with a fraction of top predator foraging time and space on the floodplain. The predators eat a realistic mix of contaminated prey with different bioaccumulation factors, and some exposure parameters are based on measured and technical common-sense values.

Scenarios 1 and 3 span the range from most mathematically contrived (upper-bound exposure) to less conservative estimate (lower exposure). Each scenario is calculated for four trophic groups comprising indicator organisms as follows:

- top predators (e.g., hawks, owls, and foxes);
- mid-level predators (e.g., wrens and shrews);
- first-level consumers (e.g., mice, insects, crayfish, and earthworms); and
- plants (e.g., grasses and trees).

The RI addendum shows the scenarios and indicator organism/trophic groups as a matrix (Table 2.65). In the cells of the matrix, remediation goal options are presented for each trophic group/scenario conformation. The assumptions are stated inside the matrix. For example, the assumptions that govern the derivation of the remediation goal options for each top predator are provided. Likewise, each of the four trophic groups and three scenarios (or twelve situations) has its own assumptions.

The most conservative soil remediation goal options for mercury (3 to 31 mg/kg) are associated with protection of the top predators under the upper-bound exposure scenario. For the lower exposure scenario, protection of top predators is assured by a soil remediation goal option of 3500 mg/kg. The intermediate exposure scenario ranges from 94 to 1100 mg/kg.

Soil remediation goal options that protect mid-level predators, such as wrens and shrews, are the lowest at 1.6 to 18 mg/kg total mercury for the upper-bound exposure scenario. Under the lower exposure scenario, soil remediation goal options of 60 to 1050 mg/kg total mercury (at 10 and 4% methyl mercury in the prey) would protect this trophic group. The middle scenario provides intermediate remediation goal options.

First-level consumers (e.g., mice, crayfish, insects, and earthworms) exhibit remediation goal options of 17 to 500 mg/kg for the upper-bound exposure assumption and 142 to ~300,000 mg/kg for the lower exposure scenario. The middle scenario shows intermediate remediation goal options.

Remediation goal options for protection of plants range from 176 to 440,000 mg/kg (upper-bound) and from ~14,000 mg/kg to even higher levels (lower exposure).

The soil remediation goal options are soil concentrations of total mercury that are expected to protect ecological receptors from an adverse effect. The receptors requiring the lowest remediation goal options in the lower exposure scenario (Scenario 3) are mid-level predators represented by shrews and wrens exposed to methyl mercury in their predominately earthworm and insect diet.

Because of the structure of the food-chain exposure equations, remediation goal options based on food-chain exposures are inversely proportional to the fraction of total mercury in the diet that is methylated. In the following comparisons, a value of 4% is assumed for terrestrial biota (see Sect. 3.2.4.6 of the RI addendum). The toxicity endpoints used to derive the remediation goal options for these species were a NOAEL for the shrew, 0.4 mg/kg of methyl mercury diet based on laboratory exposures to rats (Opresko et al. 1993), a LOAEL for wrens of 0.2 mg/kg of methyl mercury in the diet based on effects in finches (Scheuhammer 1988) and a LOAEL for wrens, 0.1 mg/kg of methyl mercury diet based on behavioral effects in mallards (Eisler 1987). These are the lowest toxicity endpoints available in the literature for these two species.

In the lower exposure scenario (Scenario 3), top predators who have large home ranges are protected at soil remediation goal options of 2300 mg/kg and above. It is the mid-level predators (shrews and wrens), which have small home ranges that show the highest risk because they both live in the floodplain and ingest organisms that also live in the floodplain. The potential remediation goal options for soil that was published in the RI report was 230 mg/kg, which was rounded down to 200 mg/kg. Additional remediation goal options for three scenarios and four trophic groups are provided in Table 2.65 with many being less and many being more than 200 mg/kg. Proposed remediation goal options that would be realistically protective of mid-level

predators under each scenario would automatically also protect top predators, first-level terrestrial consumers, and plants. They are:

- Scenario 1 (upper-bound exposure): 3.3 mg/kg,
- Scenario 2 (intermediate exposure): 30 mg/kg,
- Food chain scenario (DOE 1994): 200 mg/kg, and
- Scenario 3 (lower exposure): 300 mg/kg.

These proposed remediation goal options are evaluated further in Sect. 3 of this FS.

This page intentionally left blank.

SECTION 2
TABLES

This page intentionally left blank.

Table 2.1. Water quality summary for fish sampling sites in EFPC and Hinds Creek (October 8-10, 1991)

Parameter	Site						
	1	2	3	4	5	6	HC[a]
Alkalinity (mg/L as $CaCO_3$)	135	129	141	154	130	137	201
Biological oxygen demand (mg/L)	<5.0	–[b]	<5.0	–[b]	<5.0	5.7	5.0
Conductivity (μmhos/cm)	470	480	480	480	430	400	380
Dissolved organic carbon (mg/L)	1.2	1.0	1.4	3.0	2.5	2.3	1.9
Dissolved oxygen (mg/L)	7.5	6.2	5.6	8.4	11.4	11.2	11.0
pH	8.17		7.65	7.60	7.52	7.56	8.16
Temperature (°C)	19.7	17.9	15.2	17.2	15.9	14.0	9.9
Total organic carbon (mg/L)	22.0	3.9	13.0	13.0	11.0	2.9	8.0
Total suspended solids (mg/L)	<4.0	<4.0	<4.0	<4.0	<4.0	9.6	10.8
Calcium (mg/L)	56.2	56.8	55.7	54.0	46.5	46.4	45.3
Magnesium (mg/L)	11.0	11.6	11.5	11.2	10.6	10.3	18.6
Potassium (mg/L)	1.8	2.2	2.3	5.4	4.4	4.5	2.5
Sodium (mg/L)	14.0	14.1	12.6	21.7	18.1	17.5	2.3
Chloride (mg/L)	15.6	15.7	16.4	20.7	17.1	16.2	2.7
Nitrate/nitrite (mg/L)	3.3	3.3	3.1	6.0	0.26	0.41	0.50
Orthophosphate (mg/L)	0.24	0.26	0.24	1.46	1.25	1.20	0.01
Sulfate (mg/L)	67.4	71.6	64.7	55.5	44.2	38.3	11.8
Lead (μg/L)	3.10	<2.00	3.10	<2.00	2.90	2.40	<2.00
Mercury (μg/L)	0.54	0.43	0.32	<0.20	<0.20	<0.20	<0.20

[a] HC = Hinds Creek reference site.
[b] Invalid analysis.

Table 2.2. Fish sampling summary for sites in EFPC and Hinds Creek (Oct.7-12, 1991)

Parameter	Site						
	1	2	3	4	5	6	HC[a]
Sampling area (m^2)	610	655	670	699	815	1403	517
Sampling duration (min)	126	114	102	150	102	119	127[b]
Total number of species	12	8	9	11	12	12	14
Total number of captured individuals	690	238	242	165	78	59	366
Estimated population size[c]	998	285	1108	194	109	60	483
Estimated population density (individuals/10 m^2)	16.35	4.35	16.55	2.78	1.34	0.43	9.34
H'[d]	0.530	0.537	0.506	0.736	0.778	0.848	0.771
% Tolerants[e]	73	63	56	36	25	17	29

[a]HC = Hinds Creek reference site.
[b]Estimated; pass one was 67 min; pass two estimated 60 min.
[c]Methods of Carle and Strub (1978).
[d]H' = fish species diversity (Shannon-Wiener Index).
[e]Percentage of captured species classified as tolerant.

Table 2.3. Summary table listing fish family, scientific and common names, relative abundance, tolerance classification, trophic feeding group, and lithophilic spawner information for fish collected from EFPC and Hinds Creek during October 7-12, 1991

Species		Site 1	2	3	4	5	6	HC[a]	Tolerance classification	Trophic group	Lithophilic spawner
Clupeidae	Rel. Abund.	0.00	0.00	0.00	0.00	2.60	0.00	0.00			
Gizzard shad	Population	*b*	*b*	*b*	*b*	2.00	*b*	*b*	-	GEN	NO
(Dorosoma cepedianum)	95% Upper	*b*	*b*	*b*	*b*	*c*	*b*	*b*			
Cyprinidae	Rel. Abund.	0.00	0.00	0.00	0.00	0.00	20.30	0.80			
Bluntnose minnow	Population	*b*	*b*	*b*	*b*	*b*	12.00	4.00	TOL	OMN	NO
(Pimephales notatus)	95% Upper	*b*	*b*	*b*	*b*	*b*	12.00	*c*			
Blacknose dace	Rel. Abund.	3.80	6.30	1.20	1.20	0.00	0.00	3.00	TOL	GEN	YES
(Rhinichthys atratulus)	Population	38.00	17.00	3.00	2.00	*b*	*b*	16.00			
	95% Upper	86.00	36.32	*c*	3.04	*b*	*b*	*c*			
Creek chub	Rel. Abund.	0.10	3.80	2.10	1.20	0.00	0.00	2.20	TOL	GEN	NO
(Semotilus atromaculatus)	Population	1.00	9.00	6.00	2.00	*b*	*b*	8.00			
	95% Upper	1.27	9.99	*c*	2.00	*b*	*b*	9.61			
Fathead minnow	Rel. Abund.	1.00	0.00	0.00	0.00	0.00	0.00	0.00	TOL	OMN	NO
(Pimephales promelas)	Population	7.00	*b*	*b*	*b*	*b*	*b*	*b*			
	95% Upper	16.59	*b*	*b*	*b*	*b*	*b*	*b*			
Rosefin shiner	Rel. Abund.	0.00	0.00	0.00	0.00	0.00	11.90	0.20	MIN	INS	YES
(Notropis ardens)	Population	*b*	*b*	*b*	*b*	*b*	7.00	1.00			
	95% Upper	*b*	*b*	*b*	*b*	*b*	7.00	2.10			
Striped shiner	Rel. Abund.	34.20	50.00	62.40	29.10	35.90	35.60	22.10	TOL	GEN	YES
(Luxilus chrysocephalus)	Population	443.00	138.00	839.00	54.00	49.00	21.00	93.00			
	95% Upper	646.38	158.90	3990.00	66.49	151.66	21.00	111.46			
Common stoneroller	Rel. Abund.	52.50	34.50	17.40	37.60	25.60	1.70	43.70	-	HER	NO
(Campostoma anomalum)	Population	439.00	108.00	199.00	75.00	27.00	1.00	217.00			
	95% Upper	483.88	143.92	*c*	96.29	64.28	1.00	275.55			
Catostomidae	Rel. Abund.	0.00	0.00	0.00	1.20	2.60	0.00	1.90			
Golden redhorse	Population	*b*	*b*	*b*	2.00	2.00	*b*	7.00	MIN	BIN	YES
(Moxostoma erythrurum)	95% Upper	*b*	*b*	*b*	*c*	2.11	*b*	7.21			
Northern hogsucker	Rel. Abund.	0.00	0.00	0.40	8.50	6.40	5.10	6.80	MIN	BIN	YES

Table 2.3 (continued)

Species		Site 1	2	3	4	5	6	HC[a]	Tolerance classification	Trophic group	Lithophilic spawner
(Hypentilium nigricans)	Population	[b]	[b]	1.00	14.00	5.00	3.00	25.00			
	95% Upper	[b]	[b]	1.00	20.10	6.06	[c]	27.76			
White sucker	Rel. Abund.	1.70	1.70	2.10	0.00	0.00	0.00	0.00	TOL	GEN	YES
(Catostomus commersoni)	Population	21.00	4.00	5.00	[b]	[b]	[b]	[b]			
	95% Upper	[c]	4.35	11.26	[b]	[b]	[b]	[b]			
Ictaluridae	Rel. Abund.	0.40	0.00	0.00	1.80	2.60	0.00	0.00			
Yellow bullhead	Population	3.00	[b]	[b]	3.00	2.00	[b]	[b]	TOL	BIN	NO
(Ictalurus natalis)	95% Upper	6.83	[b]	[b]	3.05	3.04	[b]	[b]			
Poeciliidae	Rel. Abund.	0.70	0.80	0.80	0.00	0.00	0.00	0.00			
Mosquitofish	Population	5.00	2.00	2.00	[b]	[b]	[b]	[b]	TOL	INS	NO
(Gambusia affinis)	95% Upper	[c]	3.04	3.04	[b]	[b]	[b]	[b]			
Centrarchidae	Rel. Abund.	1.70	0.40	0.40	4.80	1.30	5.10	0.50			
Bluegill sunfish	Population	12.00	1.00	1.00	11.00	1.00	4.00	2.00	-	INS	NO
(Lepomis macrochirus)	95% Upper	12.00	1.27	2.76	[c]	1.00	[c]	2.81			
Green sunfish	Rel. Abund.	0.10	0.00	0.00	0.00	1.30	0.00	0.00	TOL	INS	NO
(L. cyanellus)	Population	1.00	[b]	[b]	[b]	1.00	[b]	[b]			
	95% Upper	2.76	[b]	[b]	[b]	1.00	[b]	[b]			
Redbreast sunfish	Rel. Abund.	3.50	2.50	13.20	10.90	16.70	8.50	0.80	-	INS	NO
(L. auritus)	Population	27.00	6.00	52.00	25.00	16.00	5.00	3.00			
	95% Upper	39.29	[c]	122.93	76.38	[c]	5.23	3.00			
Rockbass	Rel. Abund.	0.00	0.00	0.00	0.60	1.30	1.70	4.40	SIN	PIS	NO
(Ambloplities rupestris)	Population	[b]	[b]	[b]	1.00	1.00	1.00	16.00			
	95% Upper	[b]	[b]	[b]	1.27	1.00	1.00	18.27			
Largemouth bass	Rel. Abund.	0.00	0.00	0.00	0.00	0.00	1.70	0.00	-	PIS	NO
(Micropterus salmoides)	Population	[b]	[b]	[b]	[b]	[b]	1.00	[b]			
	95% Upper	[b]	[b]	[b]	[b]	[b]	1.00	[b]			
Percidae	Rel. Abund.	0.00	0.00	0.00	0.00	0.00	1.70	0.00			
Logperch	Population	[b]	[b]	[b]	[b]	[b]	1.00	[b]	MIN	INS	YES
(Percina caprodes)	95% Upper	[b]	[b]	[b]	[b]	[b]	1.00	[b]			

Table 2.3 (continued)

Species		Site 1	2	3	4	5	6	HC[a]	Tolerance classification	Trophic group	Lithophilic spawner
Stripetail darter	Rel. Abund.	0.00	0.00	0.00	0.00	0.00	0.00	0.80	SIN	BIN	NO
(Etheostoma kennicotti)	Population	*b*	*b*	*b*	*b*	*b*	*b*	3.00			
	95% Upper	*b*	*b*	*b*	*b*	*b*	*b*	*c*			
Snubnose darter	Rel. Abund.	0.00	0.00	0.00	0.00	0.00	1.70	3.30		BIN	NO
(E. simoterum)	Population	*b*	*b*	*b*	*b*	*b*	1.00	12.00			
	95% Upper	*b*	*b*	*b*	*b*	*b*	1.00	16.18			
Sciaenidae	Rel. Abund.	0.00	0.00	0.00	0.00	1.30	0.00	0.00			
Freshwater drum	Population	*b*	*b*	*b*	*b*	1.00	*b*	*b*	-	BIN	NO
(Aplodinotus grunniens)	95% Upper	*b*	*b*	*b*	*b*	0.00	*b*	*b*			
Cottidae	Rel. Abund.	0.00	0.00	0.00	3.00	2.60	5.10	9.30			
Banded sculpin	Population	*b*	*b*	*b*	5.00	2.00	3.00	76.00	MIN	BIN	NO
(Cottus carolinae)	95% Upper	*b*	*b*	*b*	6.06	2.00	3.56	487.82			

MIN= Moderately intolerant
SIN= Slightly intolerant
TOL= Tolerant
"-"= Moderately tolerant
BIN= Benthic insectivore
GEN= Generalist feeder
INS= Insectivore
OMN= Omnivore
HER= Herbivore

[a] = Hinds Creek reference site.
[b] = No individuals of this species were captured at the site.
[c] = Unable to calculate upper population estimate because number of fish captured did not decrease each pass; thus, the formula fails.

Table 2.4. Taxonomic and functional feeding group classifications, tolerance values, number of individuals, and relative abundance of benthic macroinvertebrates in EFPC and Hinds Creek, October 22 - 29, 1991

Class	Order	Family	Functional feeding group	Tolerance values[a]	Number of individuals per family	Relative abundance (%)
			Site 1			
Crustacea	Decapoda	Astacidae	Scav/Pred	6	2	0.72
Insecta	Odonata	Coenagrionidae[b]	Pred	9	6	2.17
Insecta	Megaloptera	Corydalidae	Pred	0	4	1.45
Insecta	Trichoptera	Hydropsychidae	Filcol	4	231	83.70
Insecta	Coleoptera	Elmidae	Scrap	4	3	1.09
Insecta	Diptera	Chironomidae	Filcol/pred	6-8	2	0.72
Pelecypoda	Bivalvia	Corbiculidae[b]	Filcol	NA	28	10.14
			TOTALS		276	100
			Site 2			
Crustacea	Decapoda	Astacidae	Scav/Pred	6	1	0.12
Insecta	Ephemeroptera	Baetidae	Scrap	4	1	0.12
Insecta	Ephemeroptera	Oligonneuriidae	Filcol	2	1	0.12
Insecta	Megaloptera	Corydalidae	Pred	0	2	0.25
Insecta	Trichoptera	Hydropsychidae	Filcol	4	600	73.80
Insecta	Trichoptera	Philopotamidae	Filcol	3	1	0.12
Insecta	Coleoptera	Elmidae	Scrap	4	10	1.23
Insecta	Diptera	Tipulidae	Shred	3	2	0.25
Pelecypoda	Bivalvia	Corbiculidae	Filcol	NA	194	23.86
Gastropoda	Basommatophora	Ancylidae	Grazer	6	1	0.12
			TOTALS		813	100
			Site 3			
Crustacea	Decapoda	Astacidae	Scav/Pred	6	4	2.88
Insecta	Ephemeroptera	Baetidae	Scrap	4	5	3.60
Insecta	Ephemeroptera	Heptageniidae	Scrap	4	98	70.50
Insecta	Odonata	Coenagrionidae	Pred	9	1	0.72
Insecta	Megaloptera	Corydalidae	Pred	0	1	0.72
Insecta	Trichoptera	Hydropsychidae	Filcol	4	3	2.16
Insecta	Coleoptera	Elmidae	Scrap	4	18	12.95
Insecta	Diptera	Chironomidae	Filcol/Pred	6-8	1	0.72
Insecta	Diptera	Tabanidae[b]	Scrap	6	1	0.72
Pelecypoda	Bivalvia	Corbiculidae	Filcol	NA	7	5.04
			TOTALS		139	100

Table 2.4 (continued)

Class	Order	Family	Functional feeding group	Tolerance values[a]	Number of individuals per family	Relative abundance (%)
			Site 4			
Crustacea	Isopoda	Asellidae[b]		8	8	4.37
Insecta	Ephemeroptera	Baetidae	Scrap	4	9	4.92
Insecta	Ephemeroptera	Heptageniidae	Scrap	4	22	12.02
Insecta	Ephemeroptera	Tricorythidae[b]	Colgat	4	3	1.64
Insecta	Odonata	Coenagrionidae	Pred	9	2	1.09
Insecta	Odonata	Gomphidae[b]	Pred	1	1	0.55
Insecta	Trichoptera	Hydropsychidae	Filcol	4	105	57.38
Insecta	Coleoptera	Elmidae	Scrap	4	7	3.83
Insecta	Coleoptera	Psephenidae[b]	Scrap	4	1	0.55
Insecta	Diptera	Simulidae	Filcol	6	1	0.55
Insecta	Diptera	Tipulidae	Shred	3	1	0.55
Pelecypoda	Bivalvia	Corbiculidae	Filcol	NA	17	9.29
Gastropoda	Basommatophora	Ancylidae	Grazer	6	5	2.73
Gastropoda	Basommatophora	Physidae[b]	Grazer	8	1	0.55
			TOTALS		183	100
			Site 5			
Insecta	Ephemeroptera	Baetidae	Scrap	4	10	4.42
Insecta	Ephemeroptera	Heptageniidae	Scrap	4	78	34.51
Insecta	Ephemeroptera	Tricorythidae	Colgat	4	20	8.85
Insecta	Trichoptera	Hydropsychidae	Filcol	4	91	40.27
Insecta	Coleoptera	Elmidae	Scrap	4	1	0.44
Insecta	Diptera	Chironomidae	Filcol/Pred	6-8	8	3.54
Insecta	Diptera	Simuliiade	Filcol	6	5	2.21
Pelecypoda	Bivalvia	Corbiculidae	Filcol	NA	9	3.98
Gastropoda	Basommatophora	Ancylidae	Grazer	6	4	1.77
			TOTALS		226	100
			Site 6			
Crustacea	Isopoda	Asellidae		8	3	2.26
Insecta	Ephemeroptera	Heptageniidae	Scrap	4	4	3.01
Insecta	Ephemeroptera	Tricorythidae	Colgat	4	64	48.12
Insecta	Trichoptera	Hydropsychidae	Filcol	4	1	0.75
Insecta	Coleoptera	Elmidae	Scrap	4	1	0.75
Insecta	Coleoptera	Psephenidae	Scrap	4	1	0.75
Insecta	Diptera	Chironomidae	Filcol/Pred	6-8	11	8.27
Insecta	Diptera	Tipulidae	Shred	3	1	0.75
Pelecypoda	Bivalvia	Corbiculidae	Filcol	NA	40	30.08
Gastropoda	Basommatophora	Ancylidae	Grazer	6	1	0.75
Gastropoda	Basommatophora	Planorbidae[b]		6	1	0.75
Gastropoda	Mesogastropoda	Pleuroceridae	Grazer	NA	5	3.76
			TOTALS		133	100

Table 2.4 (continued)

Class	Order	Family	Functional feeding group	Tolerance values[a]	Number of individuals per family	Relative abundance (%)
			Site HC			
Crustacea	Decapoda	Astacidae	Scav/Pred	6	2	1.54
Insecta	Ephemeroptera	Baetidae	Scrap	4	12	9.23
Insecta	Ephemeroptera	Heptageniidae	Scrap	4	26	20.00
Insecta	Ephemeroptera	Oligoneuriidae	Filcol	2	6	4.62
Insecta	Megaloptera	Corydalidae	Pred	0	1	0.77
Insecta	Plecoptera	Taeniopterygidae	Shred/Scrap	2	1	0.77
Insecta	Trichoptera	Hydropsychidae	Filcol	4	32	24.62
Insecta	Trichoptera	Limnephilidae	Shred	4	1	0.77
Insecta	Trichoptera	Philopotamidae	Filcol	3	25	19.23
Insecta	Coleoptera	Elmidae	Scrap	4	5	3.85
Insecta	Diptera	Chironomidae	Filcol/Pred	6-8	8	6.15
Insecta	Diptera	Simuliidae	Filcol	6	3	2.31
Insecta	Diptera	Tipulidae	Shred	3	2	1.54
Gastropoda	Basommatophora	Ancylidae	Grazer	6	2	1.54
Gastropoda	Basommatophora	Pleuraceridae	Grazer	NA	4	3.08
			TOTALS		130	100

Scav=scavenger
Pred= predator
Filcol= filterer collector
Scrap= scraper
Colgat= collector-gatherer
Shred= shredder
NA=Tolerance value not available

[a]Tolerance values from Hilsenhoff [1988 (for arthropods)] and Bode [1988 (for non-arthropods)], as presented in EPA (1989c), where 0=most intolerant and 10=most tolerant of pollutants.
[b]Family not observed at the Hinds Creek reference site.

Table 2.5. Abundance index of small mammals along EFPC based on calculations of catch per effort

Parameter	Sampling site						
	1	2	3	4	5	6	Mill Branch
C_0[a]	13	4	5	9	11	1	3
C_{TL}[b]	54	25	10	13	40	1	8
Effort[c]	254.5	190	274	267	259	264	276
CE_0[d]	5.25	1.88	1.91	3.44	4.19	0.37	1.11
CE_{TL}[e]	21.57	13.82	3.78	4.98	15.57	0.37	2.96

[a]C_0 = original captures.
[b]C_{TL} = total captures (original + recapture).
[c]Effort [(Trapping Units (TU)] = trap nights. Effort corrected for sprung traps after Nelson and Clark (1973). Corrections were made for tripped traps and traps rendered inoperative because of disturbance (overturned, turned on side, turned on end, or stolen). Rarely, a trap would be intentionally left inoperative because a birthing female was using the trap as a nest or because an excessively trap-prone individual reentered a trap immediately upon release.
[d]CE_0 = catch/effort of original captures.
[e]CE_{TL} = catch/effort of total captures.

$CE = A \times 100 \div (TU - IS/2)$,
where
CE = catch effort,
A = no. of animals,
TU = P × I × N,
P = no. of trapping intervals,
I = length of trapping interval,
N = no. of traps,
S = total traps tripped.

Table 2.6. Total number of birds counted by sample plot method at Sites 2 through 6 at EFPC and Mill Branch, whose sum total for each site was greater than 25 birds

	Sampling location						
Species	Site 2	Site 3	Site 4	Site 5	Site 6	Mill Branch	Total
Red-bellied woodpecker	9	0	7	0	3	7	26
Downy woodpecker	7	0	7	5	5	6	30
Blue jay	16	23	6	6	4	5	60
Carolina chickadee	15	20	26	8	5	10	84
Tufted titmouse	9	0	12	7	2	1	31
Carolina wren	20	20	23	13	26	5	107
Northern cardinal	9	7	25	4	13	0	58
TOTAL	85	70	106	43	58	34	396

Table 2.7. Summary of adult aquatic and terrestrial arthropod sampling

Measurement	Sampling location						
	1 (n=5)	2 (n=5)	3 (n=5)	4 (n=5)	5 (n=5)	6 (n=5)	Hinds Creek (n=3)
Mean number of aquatic-origin individuals/sample	1000	1101	169	663	1044	2153	548
Mean number of terrestrial-origin individuals/sample	303	224	386	545	798	800	1248
Ratio (A:T)[a]	1:0.3	1:0.2	1:2.3	1:0.8	1:0.8	1:0.4	1:2.3
Taxonomic richness[b]	27	28	29	30	33	34	37
Diversity index[c] (A)	0.63	0.51	2.51	2.39	2.27	2.42	2.54
Diversity index (T)	3.77	4.21	3.90	3.83	4.02	3.85	3.33

[a]A = Aquatic; T = Terrestrial.
[b]Mean number of taxa collected in quantitative samples.
[c]Shannon-Wiener Diversity Index.

Table 2.8. Summary of dominant canopy species of terrestrial vegetation at EFPC and Mill Branch

Dominant canopy species	Relative cover	Percent cover	Relative abundance (tree species)
	Site 1		
Cercis canadensis	17.1	56	16.9
Platanus occidentalis	11.4	30	—
Fraxinus pennsylvanica	9.3	28	18.5
Ulmus rubra	6.4	20	4.6
Acer negundo	—	—	32.3
Prunus serotina	—	—	9.2
	Site 2		
Carpinus caroliniana	9.1	29	25.7
Acer negundo	9.1	29	4.4
Ulmus rubra	6.7	22	2.7
Platanus occidentalis	6.7	22	0.9
Fraxinus pennsylvanica	—	—	33.6
Prunus serotina	—	—	8.0
Acer saccharum	6.2	20	4.4
	Site 3A		
Acer negundo	40.3	96	73.3
Fraxinus pennsylvanica	6.0	14	26.7
Salix nigra	6.0	14	—
	Site 3B		
Aster sp.	29.6	64	
Glecoma hederacea	11.1	24	
Fescue	9.3	20	
Verbesina sp.	9.3	20	
Acer negundo	—	—	85.7
Salix nigra	—	—	8.6
Acer rubrum	—	—	5.7

Table 2.8 (continued)

Dominant canopy species	Relative cover	Percent cover	Relative abundance (tree species)
	Site 4		
Acer negundo	28.1	75	69.6
Platanus occidentalis	17.7	47	0.9
Ulmus rubra	7.3	19	0.9
Celtis occidentalis	—	—	15.2
Fraxinus pennsylvanica	—	—	9.8
	Site 5		
Acer negundo	32.2	88	70.0
Platanus occidentalis	12.6	34	10.0
Fraxinus pennsylvanica	9.2	25	—
Ulmus rubra	—	—	10.0
Celtis occidentalis	—	—	10.0
	Site 6		
Acer negundo	31.1	88	94.3
Platanus occidentalis	14.4	41	—
Fraxinus pennsylvanica	17.8	50	3.8
Celtis occidentalis	—	—	3.8
	Mill Branch		
Liquidambar styraciflua	17.2	66	1.3
Pinus virginana	14.8	56	0.9
Cornus florida	13.1	50	22.6
Acer saccharum	—	—	22.1
Acer rubrum	—	—	16.4
Corylus americana	—	—	16.8

Table 2.9. Potential jurisdictional wetlands in the EFPC floodplain

Wetland ID	Wetland location[a]	Land use	Wetland area (ha)	Wetland area (acres)
1	N 32,144 Right Bank	DOE	0.33	0.82
2[b]	N 32,812, Left Bank	Residential	0.01	0.02
3	N 33,468 Left Bank	Residential	0.23	0.57
4	N 33,796 Left Bank	Residential	0.23	0.56
5	N 34,452 Right Bank	Residential	0.35	0.85
6	N 58,069 Right Bank	Agricultural	0.04	0.09
7	E 54,460 Right Bank	Other	0.81	2.00
8	E 53,804/E 53,476 Left Bank	Residential	0.37	0.91
9	E 43,306 Right Bank	Open/ Agricultural	1.14	2.81
10	E 42,324 Left Bank	Other	0.05	0.12
11	E 40,024 Right Bank	Other	0.08	0.21
12	E 30,674 Left Bank	DOE	0.18	0.45
13	E 20,339 Right Bank	DOE	0.28	0.68
14	E 20,339 Right Bank	DOE	0.56	1.39
15	E 20,011 Left Bank	DOE	0.05	0.12
16	E 19,682 Left Bank	DOE	0.16	0.39
17	E 19,355 Right Bank	DOE	0.30	0.73
TOTAL			5.17	12.72

[a]Wetland locations are identified according to creek mile or Phase Ib soil sampling transects. Right or left bank refers to direction when facing downstream. Station numbers refer to soil sampling locations along Phase Ib soil sampling transects.
[b]Wetland 2 is not in the 500-year floodplain of EFPC.

Source: COE 1992

Table 2.10. Distribution of population by age cohort for areas around EFPC and SLB, Oak Ridge, Anderson and Roane counties, and the State of Tennessee

Age Cohort	Within —500 ft[a]— EFPC	SLB	Oak Ridge	Anderson County	Roane County	ROI[b]	Tennessee
Under 5	59	78	1,488	4,206	2,666	6,872	333,415
5-17	222	264	4,634	12,128	8,441	20,569	883,189
18-24	81	99	1,957	5,909	4,203	10,112	527,655
25-54	475	548	11,044	28,518	19,591	48,109	2,079,519
55-64	150	161	3,150	7,004	5,271	12,275	434,589
65 & over	201	284	5,037	10,485	7,055	17,540	618,818
TOTAL	1,188	1,434	27,310	68,250	47,227	115,477	4,877,185

[a]SAIC, *East Fork Poplar Creek/Sewer Line Beltway Remedial Investigation Report*, April 1993 draft, Chapter 2, Tables 2.3 and 2.5.
[b]Region of influence; defined as the sum of population in Anderson and Roane counties.

Source: U.S. Bureau of the Census 1991. *1990 Census of Population and Housing, Summary Population and Housing Characteristics, Tennessee*, 1990 CPH-1-44, August.

Table 2.11. Population trends in areas surrounding EFPC and SLB

Region	Population		Average annual growth 1980-90 (%)	1990 Average household size
	1980	1990		
Oak Ridge	27,662	27,310	-0.1%	2.35
Anderson County	67,346	68,250	0.1%	2.46
Roane County	48,425	47,227	-0.3%	2.62
ROI	115,771	115,477	-0.0%	2.53
Tennessee	4,591,120	4,877,185	0.6%	2.48

ROI = region of influence.

Sources: U.S. Bureau of the Census 1982. *1980 Census of Housing, Volume 1, Characteristics of Housing Units, Chapter A, General Housing Characteristics, Part 44, Tennessee,* HC80-1-A44, August; U.S. Bureau of the Census 1991. *1990 Census of Population and Housing, Summary Population and Housing Characteristics, Tennessee,* 1990 CPH-1.44, August.

Table 2.12. Growth in the number of housing units for regions surrounding EFPC

Region	Total housing units 1980	Total housing units 1990	Average annual change 1980-90 (%)
Oak Ridge	11,487	12,694	1.0%
Anderson County	25,849	29,323	1.3%
Roane County	18,732	20,334	0.8%
ROI	44,581	49,657	1.1%
Tennessee	1,747,422	2,026,067	1.5%

ROI = region of influence.

Sources: U.S. Bureau of the Census 1982. *1980 Census of Housing, Volume 1, Characteristics of Housing Units, Chapter A, General Housing Characteristics, Part 44, Tennessee*, HC80-1-A44, August; U.S. Bureau of the Census 1991. *1990 Census of Population and Housing, Summary Population and Housing Characteristics, Tennessee*, 1990 CPH-144, August.

Table 2.13. Housing characteristics for regions surrounding EFPC

Region	Single-family units	Multi-family units	Mobile homes	Total occupied units	Home vacancy rate	Renter vacancy rate
Oak Ridge	8,867	3,665	60	11,783	1.2%	14.5%
Anderson County	20,688	5,375	3,260	27,384	1.1%	9.3%
Roane County	15,174	2,119	3,041	18,453	1.4%	9.9%
ROI	35,862	7,494	6,301	45,837	1.2%	9.5%
Tennessee	1,413,523	405,100	207,444	1,853,725	2.1%	9.6%

ROI = region of influence.

Source: U.S Bureau of the Census 1991. *1990 Census of Population and Housing, Summary Population and Housing Characteristics, Tennessee*, 1990 CPH-1-44, August.

93-008P/080594

Table 2.14. Distribution of employment in EFPC region of influence, 1970, 1980, 1985, and 1990[a]

Employment sector	1970	1980	1985	1990	Average annual growth 1970-1980	1980-1990	1985-1990	1970-1990
FARMING	951	1,247	1,323	1,242	2.7%	-0.0%	-1.3%	1.3%
PRIVATE SECTOR	33,950	43,819	45,094	53,388	2.6%	2.0%	3.4%	2.3%
Agricultural services	84	119	167	229	3.5%	6.8%	6.5%	5.1%
Mining	759	726	567	313	-0.4%	-8.1%	-11.2%	-4.3%
Construction	930	1,632	1,635	2,554	5.8%	4.6%	9.3%	5.2%
Manufacturing	19,910	23,667	18,299	17,909	1.7%	-2.7%	-0.4%	-0.5%
Transportation and public utilities	852	1,071	1,111	1,461	2.3%	3.2%	5.6%	2.7%
Wholesale trade	515	1,093	730	898	7.8%	-1.9%	4.2%	2.8%
Retail trade	4,120	5,441	6,269	7,469[b]	2.8%	3.2%	3.6%	3.0%
Finance, insurance and real estate	944	1,677	1,796	1,936	5.9%	1.4%	1.5%	3.7%
Services	5,836	8,393	14,520	20,619[b]	3.7%	9.4%	7.3%	6.5%
GOVERNMENT SECTOR	6,773	9,081	8,182	8,687	3.0%	-0.4%	1.2%	1.3%
Federal, civilian	2,179	3,308	2,466	2,381	4.3%	-3.2%	-0.7%	0.4%
Military	671	561	494	512	-1.8%	-0.9%	0.7%	-1.3%
State and local	3,923	5,212	5,222	5,794	2.9%	1.1%	2.1%	2.0%
TOTAL	41,674	54,147	54,599	63,317	2.7%	1.6%	3.0%	2.1%

[a]Includes Anderson and Roane counties.
[b]Estimated. Not reported because of disclosure issues. Assumes that retail trade accounts for the same share of total private employment as 1987; services reflects the balance required to reach total for private employment

Source: Regional Economic Information System, Bureau of Economic Analysis, Table CA25 (on diskette), *Full-Time Employees by Major Industry for Counties and Metropolitan Areas (Numbers of Jobs)*, April 1992.

Table 2.15. Distribution of real average annual earnings in EFPC region of influence, 1970, 1980, 1985, and 1990[a] (Constant Dollars, 1987 = 100)[b]

Employment sector	1970	1980	1985	1990	Average annual growth 1970-1980	1980-1990	1985-1990	1970-1990
FARMING	2,814	3,411	4,503	4,494	1.9%	2.8%	-0.0%	2.4%
PRIVATE SECTOR	20,310	23,189	23,997	24,128	1.3%	0.4%	0.1%	0.9%
Agricultural Services	9,464	10,580	12,132	12,066	1.1%	1.3%	-0.1%	1.2%
Mining	27,300	43,344	31,935	28,511	4.7%	-4.1%	-2.2%	0.2%
Construction	18,033	20,047	18,853	20,322	1.1%	0.1%	1.5%	0.6%
Manufacturing	25,057	29,341	30,696	30,977	1.6%	0.5%	0.2%	1.1%
Transportation and public utilities	18,971	21,686	21,656	23,712	1.3%	0.9%	1.8%	1.1%
Wholesale trade	18,037	19,311	19,336	21,671	0.7%	1.2%	2.3%	0.9%
Retail trade	10,517	10,923	10,952	10,768[c]	0.4%	-0.1%	-0.3%	0.1%
Finance, insurance and real estate	15,993	12,516	10,581	11,720	-2.4%	-0.7%	2.1%	-1.5%
Services	11,735	15,667	23,667	24,860[c]	2.9%	4.7%	1.0%	3.8%
GOVERNMENT SECTOR	18,039	20,756	20,993	21,525	1.4%	0.4%	0.5%	0.9%
Federal, civilian	29,385	32,186	31,963	34,390	0.9%	0.7%	1.5%	0.8%
Military	3,137	4,068	5,628	5,607	2.6%	3.3%	-0.1%	2.9%
State and local	14,287	15,297	17,267	17,644	0.7%	1.4%	0.4%	1.1%
TOTAL	19,542	22,325	23,075	23,386	1.3%	0.5%	0.3%	0.9%

[a]Includes Anderson and Roane counties.

[b]Converted into constant dollars using the personal consumption expenditures deflator with a base year of 1987, as reported in U.S. Bureau of the Census, *Statistical Abstract of the United States, 1992*, 112th Edition, Table 750, p. 480.

[c]Estimated. Not reported because of disclosure issues. Assumes that retail trade accounts for the same share of total private employment as 1987; services reflects the balance required to reach total for private employment.

Sources: Regional Economic Information System, Bureau of Economic Analysis, Table CA25 (on diskette), *Full-Time Employees by Major Industry for Counties and Metropolitan Areas (Numbers of Jobs)*, April 1992; Regional Economic Information System, Bureau of Economic Analysis, Table CA5 (on diskette), *Personal Income by Major Source and Earnings by Industry for Counties and Metropolitan Areas (Thousands of Dollars)*, April 1992.

Table 2.16. Number of business establishments by county and sector in the EFPC region of influence, 1980 and 1990

Business sector	Anderson		Roane		ROI		Avg. annual ROI growth 1980-90
	1980	1990	1980	1990	1980	1990	
Agricultural services	6	14	3	4	9	18	7.2%
Mining	29	10	7	3	36	13	-9.7%
Construction	68	125	44	41	112	166	4.0%
Manufacturing	71	107	29	38	100	145	3.8%
Transportation and public utilities	40	56	20	17	60	73	2.0%
Wholesale trade	42	64	25	31	67	95	3.6%
Retail trade	339	388	215	219	554	607	0.9%
Finance, insurance, and real estate	85	122	43	48	128	170	2.9%
Services	332	608	167	233	499	841	5.4%
Nonclassifiable	54	51	36	31	90	82	-0.9%
TOTAL	1066	1545	589	665	1655	2210	2.9%

ROI = region of influence.

Sources: U.S. Bureau of the Census, *County Business Patterns*, 1980, Tennessee, CBP-80-44, May 1982; U.S. Bureau of the Census, *County Business Patterns*, 1990, Tennessee, CBP-90-44, September 1992.

Table 2.17. Trends in population and per capita income for EFPC region of influence, 1980 to 1990[a]

Year	Population	Per capita income ($)	Average annual growth (%)	Real per capita income (1987=100$)[b]	Average annual growth (%)
1980	115.8	8,463		11,657	
1981	115.9	9,325	10.2%	11,819	1.4%
1982	115.9	9,737	4.4%	11,703	-1.0%
1983	116.2	10,264	5.4%	11,839	1.2%
1984	116.2	10,984	7.0%	12,218	3.2%
1985	115.3	11,532	5.0%	12,360	1.2%
1986	114.8	12,264	6.3%	12,762	3.3%
1987	115.0	13,008	6.1%	13,008	1.9%
1988	115.3	14,122	8.6%	13,540	4.1%
1989	115.3	14,959	5.9%	13,686	1.1%
1990	115.5	15,997	6.9%	13,910	1.6%
Average annual growth 1980-1990	-0.0%	6.6%		1.8%	

[a]Includes Anderson and Roane counties.

[b]Converted into constant dollars using the personal consumption expenditures deflator with a base year of 1987, as reported in the U.S. Bureau of the Census, *Statistical Abstract of the United States, 1992*, 112th Edition, Table 750, p 480

Source Regional Economic Information System, Bureau of Economic Analysis, Table C45 (on diskette), *Personal Income by Major Source and Earnings by Industry for Counties and Metropolitan Areas (Thousands of Dollars)*, April 1992.

Table 2.18. Potentially affected local transportation routes

Route	Segment									
	1	2	3	4	5	6	7	8	9	Other[a]
Scarboro Road	X									X
South Illinois Avenue (State Route 62)	X	X								X
Inn Lane	X									
East Tulsa Road	X									
Wilberforce Avenue	X									
East Vanderbilt Drive		X								
Valparaiso Road		X								
Oak Ridge Turnpike (State Route 95)		X	X	X	X	X	X	X	X	
North Illinois Avenue (State Route 62)		X	X							
Ivanhoe Lane			X							
Adams Lane			X							
Robertsville Road			X							
Royce Circle			X							
West Vanderbilt Drive			X							
Jefferson Avenue			X	X						
Jefferson Terminal Road			X							
Wiltshire Drive						X				
Montery Road							X			
Gum Hollow Road							X			
Grandcove Lane								X		
Bear Creek Road										X
White Wing Road (State Route 95)										X
Blair Road										X
Bethel Valley Road										X

[a]Includes potentially affected routes to the borrow area(s), low-temperature thermal desorption treatment facility at the K-25 Site and a new disposal facility to be constructed on the ORR.

Table 2.19. Average daily traffic counts for potentially affected routes

Route	ADT[a]
South Illinois Avenue (south of Union Valley Road)	20,090
Scarboro Road (near Bear Creek Road)	10,390
Emory Valley Road (east of Briarcliff Avenue)	6,250
Fairbanks Road	3,650
East Tulsa Road	1,640
South Tulane Avenue	7,620
South Illinois Avenue (Days Inn)	25,480
Oak Ridge Turnpike (A.K. Bissell Park)	19,890
Oak Ridge Turnpike (Jefferson Tennis Courts)	27,610
Wiltshire Drive	117
Oak Ridge Turnpike (west of Big Turtle Park)	15,940
Gum Hollow Road	1,390

[a]1991 average daily traffic counts

Source: City of Oak Ridge.

Table 2.20. City of Oak Ridge performance standard for noise

The intensity level of sounds shall not exceed the following decibel levels when adjacent to the following types of uses:

Sound level (dB)	Adjacent uses	Where measured
50	All residential districts	Common lot line
55	Neighborhood business district	Common lot line
60	General business district	Common lot line
65	Industrial districts	Common lot line
75	Major street	At street lot line
60	Secondary residential street	At street lot line

The sound levels shall be measured with a type of audio output meter approved by the Bureau of Standards. Objectionable noises due to intermittence, beat frequency, or shrillness shall be muffled so as not to become a nuisance to adjacent uses.

Source: City of Oak Ridge Zoning Ordinance.

Table 2.21. Typical values of yearly day-night average sound levels (L_{dn})

Land use description	Population density (people/mile^2)	L_{dn} dB
Rural, undeveloped	20	35
Rural, partially developed	60	40
Quiet suburban	200	45
Normal suburban	600	50
Urban	2,000	55
Noisy urban	6,000	60
Very noisy urban	20,000	65

Source: National Academy of Sciences 1977.

Table 2.22. Chemicals of potential concern (COPCs)

Metals	VOCs	SVOCs	Pesticides/PCBs	Radionuclides
Antimony		Benzo(a)anthracene	Aroclor-1254	^{137}Cs
Arsenic		Benzo(a)pyrene	Aroclor-1260	^{60}Co
Barium		Benzo(b)fluoranthene		^{237}Np
Beryllium		Benzo(k)fluoranthene		^{233}Pa
Cadmium		Chrysene		^{228}Th
Chromium		Dibenzo(a,h)anthracene		^{230}Th
Copper		Indeno(1,2,3-cd)pyrene		^{232}Th
Lead				^{234}U
Manganese				^{235}U
Mercury				^{238}U
Nickel				
Selenium				
Silver				
Vanadium				
Arsenic		Benzo(a)anthracene	Dieldrin	
Beryllium		Benzo(a)pyrene	Aroclor-1254	
Cadmium		Benzo(b)fluoranthene	Aroclor-1260	
Chromium		Benzo(k)fluoranthene		
Copper		Chrysene		
Lead		Dibenzo(a,h)anthracene		
Manganese		Indeno(1,2,3-cd)pyrene		
Mercury				
Nickel				
Vanadium				
Zinc				

Table 2.22 (continued)

Metals	VOCs	SVOCs	Pesticides/PCBs	Radionuclides
Arsenic	Acetone			Ra (total)
Barium	Methylene chloride			^{234}U
Beryllium				^{238}U
Cadmium				
Chromium				
Copper				
Lead				
Manganese				
Mercury				
Vanadium				
Barium	Acetone	bis(2-Ethylhexyl)phthalate	Aldrin	^{234}U
Chromium	Chloroform		4,4'-DDT	^{238}U
Copper	Tetrachloroethene		Dieldrin	
Manganese			Endrin	
Mercury			Gamma-BHC	
Vanadium			Heptachlor epoxide	
Zinc				

Note: VOCs - volatile organic compounds
SVOCs - semivolatile organic compounds
PCBs - polychlorinated biphenyls

Table 2.23. EFPC RI—media sampling by location

	Sample type					
			Surface water			
	Soils	Sediments	Base flow	Storm flow	Groundwater	Geotechnical soils/ sediments
Tributaries[a]						
BC		X	X			
CC		X	X	X		
TA-TR		X	X[b]	X[c]		
Creek stations[d]						
LA		X	X	X		X
LB		X	X	X		X
LC		X	X			X
LE		X	X	X	X	
LR		X				
Study sites[e]						
NO	X	X			X	X
BR	X	X			X	X
WA	X	X	X		X	X
Stream segments[f]	X	X				
1	X	X				
2	X	X				
3	X	X				
4	X	X				
5	X	X				
6	X	X				
7	X	X				
8	X	X				
9						
SLB	X					
Reference site[g]						
HC2A	X	X	X			X
HC2B	X	X	X			X

[a]Tributaries: Major tributaries—Bear Creek (BC) and Civic Center (CC). Minor tributaries—TA to TR (18 total).
[b]At tributaries TF, TJ, and TO.
[c]At tributaries TF and TO.
[d]Permanent creek sampling stations: Lower East Fork LA, LB, LC, LE, and LR.
[e]Floodplain study sites: NOAA (NO), Bruner's Center (BR), and Sturm (WA) sites.
[f]Segments (transects): Segment 9 (transects 1-59), 8 (60-64), 7 (65-92), 6 (93-98), 5 (99-105), 4 (106-115), 3 (116-121), 2 (122-143), 1 (144-159).
[g]Hinds Creek reference site: HC2A and HC2B.

93-008P/080594

Table 2.24. Average mercury concentration in SLB

SLB areas	Length	
	Total	Average concentration (mg/kg Hg)
Tulane	91	29
Fairbanks	1,615	61
Emory Valley	2,438	49
Total (m)	4,144	
Total (ft)	13,596	

Table 2.25. Sediment material in the streambed by size class[a]

Mile	Silt (<62 μm)	VF sand (62 μm - 125 μm)	Fine sand (125 μm - 250 μm)	Medium sand (250 μm - 500 μm)	Coarse sand (500 μm - 1000 μm)	VC sand (1000 μm - 2000 μm)	Fine gravel (2000 μm - 4000 μm)
0.23	20.50	25.37	25.37	25.37	1.13	1.13	1.13
1.20	64.00	9.00	9.00	9.00	3.00	3.00	3.00
1.35	42.00	13.37	13.37	13.37	5.96	5.96	5.96
2.36	28.20	14.37	14.37	14.37	9.57	9.57	9.57
2.85	13.90	6.90	6.90	6.90	21.80	21.80	21.80
3.50	26.60	10.97	10.97	10.97	13.50	13.50	13.50
4.52	26.50	9.67	9.67	9.67	14.83	14.83	14.83
4.92	17.80	8.07	8.07	8.07	19.33	19.33	19.33
5.74	31.10	10.77	10.77	10.77	12.20	12.20	12.20
6.72	44.20	15.40	15.40	15.40	3.20	3.20	3.20
7.05	27.80	10.83	10.83	10.83	13.26	13.26	13.26
7.95	18.10	9.03	9.03	9.03	18.27	18.27	18.27
8.12	20.00	12.73	12.73	12.73	13.93	13.93	13.93
8.70	28.40	7.50	7.50	7.50	16.37	16.37	16.37
9.21	40.30	12.27	12.27	12.27	7.63	7.63	7.63
9.74	6.00	1.90	1.90	1.90	29.47	29.47	29.47
10.00	42.20	17.03	17.03	17.03	2.63	2.63	2.63
10.05	52.90	13.07	13.07	13.07	2.63	2.63	2.63
11.33	41.50	15.83	15.83	15.83	3.67	3.67	3.67
12.06	4.30	1.50	1.50	1.50	30.37	30.37	30.37
12.39	53.00	12.00	12.00	12.00	3.67	3.67	3.67
12.89	31.90	15.83	15.83	15.83	6.77	6.77	6.77
13.00	15.30	2.30	2.30	2.30	25.93	25.93	25.93
13.55	22.20	3.63	3.63	3.63	11.0	11.0	11.0
13.66	23.50	14.23	14.23	14.23	11.27	11.27	11.27
13.71	35.70	17.70	17.70	17.70	3.73	3.73	3.73
13.74	28.50	13.57	13.57	13.57	10.27	10.27	10.27
14.02	29.40	4.77	4.77	4.77	18.77	18.77	18.77
14.36	47.50	12.57	12.57	12.57	4.93	4.93	4.93

[a]Values of sediment material are in percentages.

Table 2.26. Chemical properties used in GLEAMS model simulations for COCs

Contaminant	Water solubility[a]	Soil half-life[b]	K_{oc}[a]
Mercury	69.0 ppm (based on chloride)[c]	Persistent	3,059,637.0 (based on K_d of 8.85e4)[d]
Arsenic	397.0 ppth (based on As_2O_5)[c]	Persistent	6,914.0 (based on K_d of 200)[e]
Cadmium	1500.0 ppth (based on chloride)[c]	Persistent	224.72 (based on K_d of 6.5)[e]
Chlordane	0.1 ppm	100[6]	1,000,000.0[6]
Benzo[a]pyrene	0.0012 ppm	57 - 530	398,107.2
Benzo[b]fluoranthene	0.014 ppm	360 - 610	549,540.9
Aroclor 1260	0.080 ppm	70 - 548	2,630,268.0

[a]Superfund Public Health Evaluation Manual - EPA540/1-86/060 and data from table in Sect.5 of the RI report.
[b]Handbook of Environmental Degradation Rates (Howard et al. 1991).
[c]CRC Handbook of Chemistry and Physics 1984.
[d]Site-specific study (SAIC 1993).
[e]Baes et al. 1984.

Table 2.27. Soil characteristics used in the GLEAMS model simulations[a]

Soil characteristic	Units	Newark series (silt loam)		Hamblen series (silt loam)	
Effective saturated conductivity	in./h	0.10		0.10	
Soil evaporation parameter		4.5		4.5	
Soil erodibility		0.43		0.32	
Max. effective rooting depth	in.	21.0		34.0	
Soil horizon		1	2	1	2
Soil horizon depths (from surface)	in.	8.0	21.0	8.0	34.0
Soil porosity	$in.^3/in.^3$	0.43	0.43	0.43	0.43
Field capacity	in./in.	0.19	0.21	0.19	0.19
Wilting point	in./in.	0.12	0.12	0.12	0.12
Organic matter	%	6.61	6.80	4.43	2.18
based on organic carbon	%	3.82	3.93	2.56	1.26
Fraction of:					
Clay	%	27.0	27.0	27.0	27.0
Silt	%	46.0	46.0	46.0	46.0
Sand	%	27.0	27.0	27.0	27.0

[a]Assumptions of characteristics based on information taken from Soil Survey of Anderson County, Tennessee (Moneymaker et al. 1981); GLEAMS Version 2.0, Part III: User Manual (Knisel, Davis, and Leonard 1992); and site-specific data presented in the RI report.

Table 2.28. Soil contaminant concentrations (ppm) used in the GLEAMS model

Creek segment	Mercury	Arsenic	Cadmium	Chlordane	Aroclor 1260	Benzo(a) pyrene	Benzo(b) fluoranthene
1	183.4	6.87	7.98	0.1162	1.52	1.05	1.42
2	33.26	9.77	7.08	0.0036	0.65	1.08	1.23
3	58.93	9.51	3.38	0.0540	0.33	1.20	1.18
4	193.20	10.75	20.88	0.0	2.23	0.70	1.24
5	57.59	9.42	7.01	0.0	0.37	0.94	1.80
6	27.14	7.40	2.79	0.61	0.14	0.23	0.25
7	15.71	7.93	5.43	0.0001	0.17	0.30	0.61
8	49.11	7.62	5.33	0.0016	0.02	0.20	0.22
9	12.25	6.92	2.49	0.0027	0.13	0.18	0.17

Table 2.29. Mercury concentrations in soil at the NOAA and Bruner sites found during the Vertical Integration Study

	NOAA site	Bruner site
Depth (in.)	Mercury (ppm)	Mercury (ppm)
0-1	0	451
1-2	25	593
2-3	2.1	642
3-4	32	647
4-5	40	R
5-6	492	R
6-7	1740	510
7-8	2450	1190
8-9	2440	1920
9-10	2740	2870
10-11	3420	1950
11-12	1870	R
12-13	292	R
13-14	374	318
14-15	295	306
15-16	168	436
16-17	140	495
17-18	R	717

R = rejected.

Table 2.30. Weighted-average concentrations of mercury for the NOAA and Bruner sites used as input in the GLEAMS model

Depth (in.)	NOAA site Hg weighted-average (ppm)	Depth (in.)	Bruner site Hg weighted-average (ppm)
0-6	99	0-7	569
6-12	2443	7-12	1983
12-18	253.8	12-18	454

Table 2.31. GLEAMS model predictions of contaminant loading into EFPC for Segment 1 after a 5-year 24-h rainfall event (short-term loading)

	Disturbed - Hambien soils		Disturbed - Newark soils		Undisturbed - Hambien soils (pasture)		Undisturbed - Hambien soils (woods)		Undisturbed - Newark soils (pasture)		Undisturbed - Newark soils (woods)	
Contaminant	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)
Mercury	1.76	1335 19	1 18	1338 04	0 655	110.01	0.496	21.36	0.441	110.34	0.335	21.43
Arsenic	26.90	46.12	18 54	47 46	9 83	3.73	7.434	0.723	6.84	3.87	5.18	0.750
Cadmium	177.08	9.87	192.56	16 02	38 76	0.478	27.28	0.086	50.08	0.921	36.13	0.170
Chlordane	0.031	0.759	0.021	0 762	0 011	0.062	0.009	0.012	0.008	0.063	0.006	0.012
Aroclor 1260	0.017	10.87	0 011	10 89	0 006	0.895	0.005	0.174	0.004	0.898	0.003	0.174
Benzo(a)pyrene	0.076	7.49	0.051	7 51	0 028	0.617	0.021	0.120	0.019	0.619	0.014	0.120
Benzo(b)fluoranthene	0.075	10.17	0.050	10.19	0.028	0.837	0.021	0.162	0.019	0.840	0.014	0.163

Table 2.32. GLEAMS model predictions of contaminant loading into EFPC for Segment 1 after 1 year of normal rainfall conditions (long-term loading)

	Disturbed - Hambien soils		Disturbed - Newark soils		Undisturbed - Hambien soils (pasture)		Undisturbed - Hambien soils (woods)		Undisturbed - Newark soils (pasture)		Undisturbed - Newark soils (woods)	
Contaminant	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)
Mercury	4.49	3161.08	2 96	3145 06	0 268	49.36	0.145	9.44	0.153	37.04	0.077	8.81
Arsenic	55.31	88 15	40 16	96 69	2 79	1.17	1.46	0.217	1.87	1.03	0.916	0.239
Cadmium	89.66	4 67	122 06	9 52	0 706	0 010	0.140	0.0007	1.26	0.026	0.370	0.003
Chlordane	0.031	0 718	0 021	0 720	0 001	0.004	0.0003	0.0006	0.0004	0.003	0.0001	0.0005
Aroclor 1260	0.034	20 86	0 023	20 77	0 002	0 282	0.0009	0.052	0.001	0.213	0.0005	0.049
Benzo(a)pyrene	0.155	14 23	0 102	14 19	0 008	0.191	0.004	0.035	0.005	0.145	0.0022	0.033
Benzo(b)fluoranthene	0.157	19 89	0 103	19 82	0 008	0 273	0.004	0.051	0.005	0.206	0.0023	0.048

Table 2.33. GLEAMS model predictions of contaminant loading into EFPC for Segment 2 after a 5-year 24-h rainfall event (short-term loading)

	Disturbed - Hamblen soils		Disturbed - Newark soils		Undisturbed - Hamblen soils (pasture)		Undisturbed - Hamblen soils (woods)		Undisturbed - Newark soils (pasture)		Undisturbed - Newark soils (woods)	
Contaminant	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)
Mercury	0.319	242.12	0.214	242.64	0 119	19.95	0.090	3.87	0.80	20.01	0.061	3.89
Arsenic	38.18	65.46	26.33	67 40	13.95	5.30	10.55	1.03	9.71	5.49	7.26	1.06
Cadmium	148.79	8.29	136.60	13.69	32.65	0.403	22.98	0.073	42.88	0.788	30.94	0.146
Chlordane	0.0001	0.023	0.0006	0.023	0.0003	0.002	0.0003	0.0004	0.0002	0.002	0.0002	0.0004
Aroclor 1260	0.007	4.64	0.005	4.65	0.003	0.382	0.002	0.074	0.002	0.384	0.001	0.075
Benzo(a)pyrene	0.078	7.70	0.0524	7.72	0.29	0.634	0.022	0.123	0.020	0.636	0.015	0.124
Benzo(b)fluoranthene	0.065	8.79	0.043	8.82	0.024	0.724	0.018	0.141	0.016	0.727	0.012	0.141

Table 2.34. GLEAMS model predictions of contaminant loading into EFPC for Segment 2 after 1 year of normal rainfall conditions (long-term loading)

	Disturbed - Hamblen soils		Disturbed - Newark soils		Undisturbed - Hamblen soils (pasture)		Undisturbed - Hamblen soils (woods)		Undisturbed - Newark soils (pasture)		Undisturbed - Newark soils (woods)	
Contaminant	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)
Mercury	0.815	573 23	0 536	570 32	0 049	8.95	0.026	1.71	0.028	6.72	0.014	1.60
Arsenic	78.51	125.12	57 04	137 32	3 67	1.66	2.08	0.308	2.65	1.46	1.30	0.339
Cadmium	76.72	4.00	105 67	8 24	0 613	0.009	0.125	0.0007	1.10	0.023	0.328	0.003
Chlordane	0.001	0 022	0 001	0 022	0 0	0.0001	0.0	0.0	0.0	0.0001	0.0	0.0
Aroclor 1260	0.015	8 91	0 010	8 87	0 0008	0.121	0.0004	0.022	0.0004	0.091	0.0002	0.021
Benzo(a)pyrene	0.159	14 62	0 105	14 58	0 008	0.196	0.004	0.036	0.005	0.148	0.002	0.034
Benzo(b)fluoranthene	0.136	17 21	0 090	17 15	0.007	0.236	0.004	0.044	0.004	0.178	0.002	0.041

Table 2.35. GLEAMS model predictions of contaminant loading into EFPC for Segment 3 after a 5-year 24-h rainfall event (short-term loading)

	Disturbed - Hamblen soils		Disturbed - Newark soils		Undisturbed - Hamblen soils (pasture)		Undisturbed - Hamblen soils (woods)		Undisturbed - Newark soils (pasture)		Undisturbed - Newark soils (woods)	
Contaminant	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)
Mercury	0.565	428.99	0.380	429 91	0 210	35 34	0.159	6.86	0.142	35.45	0.107	6.89
Arsenic	37.17	63.72	25.63	65.61	13.58	5.16	10.27	0.999	9.45	5.35	7.16	1.04
Cadmium	71.03	3.96	78.58	6 54	15.59	0.192	10.97	0.035	20.47	0.376	14.77	0.069
Chlordane	0.014	0.350	0.009	0.351	0.005	0.029	0.004	0.006	0.004	0.029	0.003	0.006
Aroclor 1260	0.004	2.36	0.002	2.36	0.001	0.194	0.001	0.038	0.0009	0.195	0.0007	0.038
Benzo(a)pyrene	0.087	8.55	0.058	8 59	0.032	0.705	0.024	0.137	0.022	0.707	0.016	0.137
Benzo(b)fluoranthene	0.062	8.43	0.042	8.46	0.023	0.695	0.017	0.135	0.016	0.697	0.012	0.135

Table 2.36. GLEAMS model predictions of contaminant loading into EFPC for Segment 3 after 1 year of normal rainfall conditions (long-term loading)

	Disturbed - Hamblen soils		Disturbed - Newark soils		Undisturbed - Hamblen soils (pasture)		Undisturbed - Hamblen soils (woods)		Undisturbed - Newark soils (pasture)		Undisturbed - Newark soils (woods)	
Contaminant	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)
Mercury	1.44	1015.64	0.950	1010.50	0.086	15.86	0.046	3.03	0.049	11.90	0.025	2.83
Arsenic	76.42	121.79	55.52	133.66	3.86	1.61	2.02	0.300	2.58	1.42	1.27	0.330
Cadmium	36.63	1.91	50.45	3 94	0 293	0.004	0.059	0.0003	0.527	0.11	0.157	0.001
Chlordane	0.014	0.331	0.010	0.332	0.0003	0.002	0.0001	0.0003	0.0002	0.002	0.0001	0.0003
Aroclor 1260	0.008	4.52	0.005	4 50	0.0004	0.061	0.002	0.011	0.0002	0.046	0.0001	0.011
Benzo(a)pyrene	0.177	16.25	0.117	16.20	0.009	0.218	.0005	0.40	0.0052	0.165	0.0025	0.38
Benzo(b)fluoranthene	0.130	16.51	0.086	16.45	0.007	0.226	0.004	0.42	0.0039	0.171	0.0019	0.039

Table 2.37. GLEAMS model predictions of contaminant loading into EFPC for Segment 4 after a 5-year 24-h rainfall event (short-term loading)

	Disturbed - Hamblen soils		Disturbed - Newark soils		Undisturbed - Hamblen soils (pasture)		Undisturbed - Hamblen soils (woods)		Undisturbed - Newark soils (pasture)		Undisturbed - Newark soils (woods)	
Contaminant	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)
Mercury	1.85	1406.43	1.24	1409.43	0.690	115.88	0.523	22.50	0.464	116.23	0.352	22.57
Arsenic	42.01	72.02	28.98	74 17	15.35	5.83	11.61	1.13	10.68	6.04	8.09	1.17
Cadmium	438.79	24.45	458 42	40 38	96.28	1.19	67.76	0.214	126.47	2.33	91.23	0.429
Chlordane	0.0	0.0	0 0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aroclor 1260	0.024	15 93	0 016	15.96	0.009	1.31	0.007	0.255	0.006	1.32	0.005	0.256
Benzo(a)pyrene	0.051	4 99	0.034	5 00	0.019	0.411	0.014	0.080	0.013	0.412	0.010	0.080
Benzo(b)fluoranthene	.065	8.87	0.044	8.89	0.024	0.730	0.018	0.142	0.016	0.733	0.012	0.142

Table 2.38. GLEAMS model predictions of contaminant loading into EFPC for Segment 4 after 1 year of normal rainfall conditions (long-term loading)

	Disturbed - Hamblen soils		Disturbed - Newark soils		Undisturbed - Hamblen soils (pasture)		Undisturbed - Hamblen soils (woods)		Undisturbed - Newark soils (pasture)		Undisturbed - Newark soils (woods)	
Contaminant	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)
Mercury	6.36	4576 08	3 12	3312 88	0 282	51.99	0.152	9.95	0.161	39.02	0.081	9.28
Arsenic	121.40	198 58	62 76	151.09	4.36	1.82	2.29	0.337	2.92	1.60	1.43	0.373
Cadmium	586.50	32 45	311 64	24 31	1.81	0.027	0.367	0.002	3.25	0.068	0.968	0.009
Chlordane	0.0	0.0	0 0	0 0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aroclor 1260	0 072	45 02	0 033	30 43	0.003	0.413	0.0014	0.077	0.002	0.312	0.0007	0.072
Benzo(a)pyrene	0.149	14 01	0 68	9 45	0.005	0.127	0.003	0.024	0.003	0.096	0.002	0.022
Benzo(b)fluoranthene	0.195	25 37	0 090	17 29	0.007	0.238	0.004	0.044	0.004	0.180	0.002	0.041

Table 2.39. GLEAMS model predictions of contaminant loading into EFPC for Segment 5 after a 5-year 24-h rainfall event (short-term loading)

	Disturbed - Hamblen soils		Disturbed - Newark soils		Undisturbed - Hamblen soils (pasture)		Undisturbed - Hamblen soils (woods)		Undisturbed - Newark soils (pasture)		Undisturbed - Newark soils (woods)	
Contaminant	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)
Mercury	0.553	419.24	0.371	420 13	0 206	34.54	0.156	6.71	0.138	34.65	0.105	6.73
Arsenic	36.82	63.11	25.39	64.99	13.46	5.11	10.17	0.989	9.36	5.30	7.09	1.03
Cadmium	147.32	8.21	162.97	13.56	32.32	0.399	22.75	0.72	42.46	0.781	30.63	0.144
Chlordane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aroclor 1260	0.004	2.64	0.003	2.65	0.002	0.218	0.001	0.042	0.001	0.218	0.0008	0.042
Benzo(a)pyrene	0.068	6.70	0.046	6.72	0.025	0.552	0.019	0.107	0.017	0.554	0.013	0.108
Benzo(b)fluoranthene	0.094	12.87	0.063	12.90	0.035	1.09	0.027	0.206	0.024	1.06	0.018	0.207

Table 2.40. GLEAMS model predictions of contaminant loading into EFPC for Segment 5 after 1 year of normal rainfall conditions (long-term loading)

	Disturbed - Hamblen soils		Disturbed - Newark soils		Undisturbed - Hamblen soils (pasture)		Undisturbed - Hamblen soils (woods)		Undisturbed - Newark soils (pasture)		Undisturbed - Newark soils (woods)	
Contaminant	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)
Mercury	1.41	992.55	0.929	987.52	0.084	15.50	0.045	2.96	0.048	11.63	0.024	2.77
Arsenic	75.69	120.64	55.00	132.40	3.82	1.60	2.00	0.298	2.56	1.41	1.25	0.327
Cadmium	75.96	3.96	104.63	8.16	0.607	0.009	0.123	0.0007	1.09	0.023	0.325	0.003
Chlordane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aroclor 1260	0.008	5.07	0.006	5.05	0.0004	0.069	0.0002	0.013	0.0002	0.052	0.0001	0.012
Benzo(a)pyrene	0.139	12.73	0 091	12 69	0.0071	0.171	0.004	0.032	0.004	0.129	0.002	0.030
Benzo(b)fluoranthene	0.199	25.18	0 131	25 09	0.010	0.345	0.006	0.064	0.006	0.261	0.003	0.060

Table 2.41. GLEAMS model predictions of contaminant loading into EFPC for Segment 6 after a 5-year 24-h rainfall event (short-term loading)

	Disturbed - Hamblen soils		Disturbed - Newark soils		Undisturbed - Hamblen soils (pasture)		Undisturbed - Hamblen soils (woods)		Undisturbed - Newark soils (pasture)		Undisturbed - Newark soils (woods)	
Contaminant	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)
Mercury	2.60	197.57	0.175	197.99	0.097	16.28	0.074	3.16	0.065	16.33	0.050	3.17
Arsenic	28.92	49.58	19.95	51 05	10.57	4.01	7.99	0.777	7.35	4.16	5.57	0.807
Cadmium	58.63	3.27	64.86	5.40	12.86	0.159	9.05	0.086	16.90	0.311	12.19	0.057
Chlordane	0.015	0 399	0.011	0.400	0.006	0.033	0.005	0.006	0.004	0.033	0.003	0.006
Aroclor 1260	0.002	1 00	0.001	1.00	0.006	0.082	0.0004	0.016	0.0004	0.083	0.0003	0.016
Benzo(a)pyrene	0.017	1.64	0.011	1 64	0.006	0.135	0.005	0.026	0.004	0.136	0.003	0.026
Benzo(b)fluoranthene	0.013	1.79	0.009	1.79	0.005	0.147	0.004	0.029	0.003	0.148	0.003	0.029

Table 2.42. GLEAMS model predictions of contaminant loading into EFPC for Segment 6 after 1 year of normal rainfall conditions (long-term loading)

	Disturbed - Hamblen soils		Disturbed - Newark soils		Undisturbed - Hamblen soils (pasture)		Undisturbed - Hamblen soils (woods)		Undisturbed - Newark soils (pasture)		Undisturbed - Newark soils (woods)	
Contaminant	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)
Mercury	0.665	467.75	0 438	465 38	0.040	7.30	0.021	1.40	0.023	5.48	0.011	1.30
Arsenic	59.46	94.77	43 20	10.401	3.00	1.25	1.57	0.233	20.10	1,10	0.985	0.257
Cadmium	30.23	1 58	41 64	3 25	0.242	0.004	0.049	0.0003	0.435	0.009	0.129	0.001
Chlordane	0.016	0.377	0 011	0 378	0.0004	0.002	0.0001	0.0003	0.0002	0.001	0.0001	0.0003
Aroclor 1260	0.003	1.92	0.002	1.91	0.0002	0.026	0.0001	0.005	0.0001	0.020	0.0	0.003
Benzo(a)pyrene	0.034	3 11	0.022	3.11	0.002	0.042	0.001	0.008	0.001	0.032	0.0005	0.007
Benzo(b)fluoranthene	0.028	3.50	0.018	1 49	0.001	0.048	0.001	0.009	0.0008	0.036	0.0004	0.008

Table 2.43. GLEAMS model predictions of contaminant loading into EFPC for Segment 7 after a 5-year 24-h rainfall event (short-term loading)

	Disturbed - Hamblen soils		Disturbed - Newark soils		Undisturbed - Hamblen soils (pasture)		Undisturbed - Hamblen soils (woods)		Undisturbed - Newark soils (pasture)		Undisturbed - Newark soils (woods)	
Contaminant	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)
Mercury	0.151	114.36	0 101	114 61	0 056	9.422	0.043	1.83	0.038	9.45	0.029	1.84
Arsenic	30.99	53.13	21.37	54.71	11 33	4.30	8.57	0.833	7.88	4.46	5.97	0.864
Cadmium	114.11	6.36	126.24	10.50	25.04	0.309	17.62	0.056	32.89	0.605	23.73	0.112
Chlordane	0.0003	0.001	0.00002	0.0001	0.00001	0.0001	0.00001	0.00001	0.00001	0.0006	0.00001	0.00001
Aroclor 1260	0.002	1.21	0.001	1.22	0.0007	0.100	0.0005	0.019	0.0005	0.100	0.0004	0.020
Benzo(a)pyrene	0.022	2.14	0.015	2.14	0.008	0.176	0.006	0.034	0.005	0.178	0.004	0.034
Benzo(b)fluoranthene	0.032	4.36	0.022	4.37	0.012	0.359	0.009	0.070	0.008	0.361	0.006	0.070

Table 2.44. GLEAMS model predictions of contaminant loading into EFPC for Segment 7 after 1 year of normal rainfall conditions (long-term loading)

	Disturbed - Hamblen soils		Disturbed - Newark soils		Undisturbed - Hamblen soils (pasture)		Undisturbed - Hamblen soils (woods)		Undisturbed - Newark soils (pasture)		Undisturbed - Newark soils (woods)	
Contaminant	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)
Mercury	0.385	270.76	0.253	269.39	0 023	4.23	0.012	0.809	0.013	3.17	0.007	0.755
Arsenic	63.72	101.56	46.30	111 46	3.21	1.34	1.69	0.250	2.15	1.18	1.06	0.275
Cadmium	58.84	3.07	81.04	6.32	0.470	0.007	0.095	0.001	0.846	0.018	0.252	0.002
Chlordane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aroclor 1260	0.004	2.33	0.003	2.32	0.0002	0.032	0.0001	0.006	0.0001	0.024	0.0001	0.006
Benzo(a)pyrene	0.044	4.06	0.029	4.05	0.002	0.055	0.001	0.010	0.001	0.041	0.001	0.009
Benzo(b)fluoranthene	0.067	8.53	0.044	8.50	0.004	0.117	0.002	0.022	0.002	0.088	0.001	0.020

Table 2.45. GLEAMS model predictions of contaminant loading into EFPC for Segment 8 after a 5-year 24-h rainfall event (short-term loading)

	Disturbed - Hamblen soils		Disturbed - Newark soils		Undisturbed - Hamblen soils (pasture)		Undisturbed - Hamblen soils (woods)		Undisturbed - Newark soils (pasture)		Undisturbed - Newark soils (woods)	
Contaminant	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)
Mercury	0.471	357.51	0.316	358.27	0.175	29.46	0.133	5.72	0.118	29.55	0.090	5.74
Arsenic	29.78	51.05	20.54	52.57	10.88	4.13	8.23	0.800	7.57	4.28	5.74	0.831
Cadmium	112.01	6.24	123 91	10.31	24.58	0.303	17.30	0.055	32.28	0.59	23.29	0.110
Chlordane	0.0004	0.010	0.0003	0.010	0.0002	0.0008	0.0001	0.0002	0.0001	0.001	0.0001	0.0002
Aroclor 1260	0.0002	0.14	0.0001	0.143	0 0008	0.012	0.00006	0.002	786.89	0.012	0.00004	0.002
Benzo(a)pyrene	0.014	1 43	0 010	1 43	0.005	0.117	0.004	0.023	0.00006	0.118	0.003	0.023
Benzo(b)fluoranthene	0.012	1.57	0.008	1.58	0.004	0.130	0.003	0.025	0.008	0.130	0.002	0.025

Table 2.46. GLEAMS model predictions of contaminant loading into EFPC for Segment 8 after 1 year of normal rainfall conditions (long-term loading)

	Disturbed - Hamblen soils		Disturbed - Newark soils		Undisturbed - Hamblen soils (pasture)		Undisturbed - Hamblen soils (woods)		Undisturbed - Newark soils (pasture)		Undisturbed - Newark soils (woods)	
Contaminant	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)
Mercury	1.20	846 40	0.792	842.11	0.072	13.22	0.039	2.53	0.041	9.92	0.021	2.36
Arsenic	61.23	97 59	44 49	107 10	3.09	1.29	1.62	0.240	2.07	1.14	1.01	0.265
Cadmium	57.76	3 01	79 55	6 21	0.461	0.007	0.094	0.0005	0.830	0.017	0.247	0.002
Chlordane	0.0004	0.010	0 0003	0 010	0.0	0.0001	0.0	0.0	0.0	0.0	0.0	0.0
Aroclor 1260	0.0005	0.274	0 0003	0 273	0 0	0.004	0.0	0.0007	0.0	0.003	0.0	0.0006
Benzo(a)pyrene	0.030	2 71	0 019	2 70	0 002	0.036	0.0008	0.007	0.0009	0.028	0.0004	0.006
Benzo(b)fluoranthene	0.024	3.08	0 016	3.07	0.001	0.042	0.0007	0.008	0.0007	0.032	0.0004	0.007

Table 2.47. GLEAMS model predictions of contaminant loading into EFPC for Segment 9 after a 5-year 24-h rainfall event (short-term loading)

	Disturbed - Hamblen soils		Disturbed - Newark soils		Undisturbed - Hamblen soils (pasture)		Undisturbed - Hamblen soils (woods)		Undisturbed - Newark soils (pasture)		Undisturbed - Newark soils (woods)	
Contaminant	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)
Mercury	0.118	89 18	0.079	89.37	0.044	7.35	0.033	1.43	0.029	7.37	0.022	1.43
Arsenic	27.05	46.36	18 65	47 74	9.88	3.75	7.47	0.727	6.88	3.89	5.21	0.754
Cadmium	52.33	2.92	57.89	4.82	11 48	0.142	8.08	0.026	15.08	0.277	10.88	0.051
Chlordane	0.0007	0.018	0.0005	0.018	0 003	0.001	0.0002	0.0003	0.0002	0.001	0.0001	0.0003
Aroclor 1260	0.001	0.928	0.0010	0.930	0.0005	0.076	0.0004	0.015	0.004	0.077	0.0003	0.015
Benzo(a)pyrene	0.013	1 28	0 009	1 29	0 005	0.106	0.004	0.021	0.003	0.106	0.002	0.021
Benzo(b)fluoranthene	0.009	1.22	0.006	1.22	0.003	0.100	0.003	0.019	0.002	0.100	0.002	0.020

Table 2.48. GLEAMS model predictions of contaminant loading into EFPC for Segment 9 after 1 year of normal rainfall conditions (long-term loading)

	Disturbed - Hamblen soils		Disturbed - Newark soils		Undisturbed - Hamblen soils (pasture)		Undisturbed - Hamblen soils (woods)		Undisturbed - Newark soils (pasture)		Undisturbed - Newark soils (woods)	
Contaminant	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)
Mercury	0.300	211.13	0.198	210.06	0.018	3.30	0.010	0.631	0.010	2.47	0.005	0.588
Arsenic	55.61	88.62	40.40	97.26	2.81	1.17	1.47	0.218	1.88	1.03	0.921	0.240
Cadmium	26.98	1.41	37.16	2.90	0.216	0.003	0.044	0.0002	0.388	0.008	0.115	0.001
Chlordane	0.0007	0.017	0.0005	0.017	0.0	0.0001	0.0	0.0	0.0	0.0001	0.0	0.0
Aroclor 1260	0.003	1.78	0 002	1 77	0.002	0.024	0.0001	0.005	0.0001	0.018	0.0	0.004
Benzo(a)pyrene	0.027	2.44	0.018	2.43	0.0014	0.033	0.0007	0.006	0.0008	0.025	0.0004	0.006
Benzo(b)fluoranthene	0.019	2.38	0.012	2.37	0.001	0.033	0.0005	0.006	0.0006	0.025	0.0003	0.006

Table 2.49. GLEAMS model predictions of contaminant loading of mercury into EFPC at the Bruner site after a 5-year 24-h rainfall event (short-term loading) and after 1 year of normal rainfall conditions (long-term loading)

Short-term loading of contaminant into EFPC (g/ha)				Long-term loading of contaminant into EFPC (g/ha)			
Disturbed - Newark soils		Undisturbed - Newark soils		Disturbed - Newark soils		Undisturbed - Newark soils	
Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)
3.66	4150.42	1.37	342.01	9.15	9739.72	0.484	121.68

Table 2.50. GLEAMS model predictions of contaminant loading of mercury into EFPC at the NOAA site after a 5-year 24-h rainfall event (short-term loading) and after 1 year of normal rainfall conditions (long-term loading)

Short-term loading of contaminant into EFPC (g/ha)				Long-term loading of contaminant into EFPC (g/ha)			
Disturbed - Newark soils		Undisturbed - Newark soils		Disturbed - Newark soils		Undisturbed - Newark soils	
Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)	Dissolved (g/ha)	Adsorbed (g/ha)
0.639	722.77	0.182	11.63	1.61	1701.09	0.048	4.94

Table 2.51. Mercury concentrations at EFPCM 3.3 as a result of runoff from a 20-ha disturbed area at the NOAA site and the Bruner site during a 5-year 24-h rainfall

NOAA site (mg/L)	Bruner site (mg/L)
2.57×10^{3}	1.48×10^{-2}

Table 2.52. Contaminant concentrations at EFPCM 3.3 as a result of runoff from a 20-ha site on disturbed Hamblen soil in each segment during a 5-year 24-h rainfall

Contaminant	Segment 1 (mg/L)	Segment 2 (mg/L)	Segment 3 (mg/L)	Segment 4 (mg/L)	Segment 5 (mg/L)	Segment 6 (mg/L)	Segment 7 (mg/L)	Segment 8 (mg/L)	Segment 9 (mg/L)
Mercury	4.75×10^{-1}	8.61×10^{-4}	1.53×10^{-3}	5.00×10^{-3}	1.49×10^{-3}	7.11×10^{-4}	4.07×10^{-4}	1.27×10^{-3}	3.17×10^{-4}
Arsenic	2.59×10^{-4}	3.68×10^{-4}	3.58×10^{-4}	4.05×10^{-4}	3.55×10^{-4}	2.79×10^{-4}	2.99×10^{-4}	2.87×10^{-4}	2.61×10^{-4}
Cadmium	6.64×10^{-4}	5.58×10^{-4}	2.66×10^{-4}	1.65×10^{-3}	5.52×10^{-4}	2.20×10^{-4}	4.28×10^{-4}	4.20×10^{-4}	1.96×10^{-4}
Chlordane	2.81×10^{-6}	8.21×10^{-6}	1.29×10^{-6}	0.0	0.0	1.47×10^{-6}	3.91×10^{-9}	3.69×10^{-6}	6.64×10^{-9}
Aroclor-1260	3.87×10^{-5}	1.65×10^{-5}	8.40×10^{-6}	5.67×10^{-6}	9.39×10^{-6}	3.56×10^{-6}	4.30×10^{-6}	4.98×10^{-7}	3.30×10^{-6}
Benzo(a)pyrene	2.69×10^{-5}	2.76×10^{-5}	3.07×10^{-5}	1.79×10^{-5}	2.40×10^{-5}	5.88×10^{-6}	7.68×10^{-6}	5.13×10^{-6}	4.59×10^{-6}
Benzo(b)fluoranthene	3.64×10^{-5}	3.15×10^{-5}	3.02×10^{-5}	3.17×10^{-5}	4.60×10^{-5}	6.40×10^{-6}	1.56×10^{-6}	5.62×10^{-6}	4.37×10^{-6}

Table 2.53. Risk measures and equations for risk

Contaminant type	Risk measure	Exposure measure	Toxicity measure	Individual contaminant risk equation	Total risk	EPA guidance on acceptable risk
Chemical carcinogens	Upper bound estimate of excess lifetime cancer risk to an individual	CDI - chronic daily dose averaged over a 70-year period (CDI = chronic daily intake)	CSF = 95% upper bound estimate of slope of dose-response relationship (CSF = cancer slope factor)	$Risk_i = CDI \times CSF$ i = chemical	$\sum_{i=1}^{n} \sum_{j=1}^{p} Risk_{ij}$ where i = chemical j = pathway	Risk < 10^{-4}
Chemical noncarcinogens	HQ = hazard quotient: potential for adverse noncarcinogenic effects	CDI = chronic daily dose averaged over the exposure period	RfD = acceptable daily intake for subchronic or chronic oral exposure or RfC = acceptable daily intake for subchronic or chronic inhalation exposure	HQ = CDI/RfD HQ = CDI/RfC	$HI = \sum_{i=1}^{n} \sum_{j=1}^{p} HQ_{ij}$ where i = chemical j = pathway (HI = hazard index)	HI < 1
Radionuclides (all carcinogens)	Excess lifetime cancer risk to an individual	IR = daily intake rate and EF = exposure days per year	SF = average risk per unit intake or exposure. (SF = slope factor)	$Risk_i =$ $C \times IR \times EF \times SF$ where C= concentration i = radionuclide	$\sum_{i=1}^{n} \sum_{j=1}^{p} Risk_{ij}$ where i = radionuclide j = pathway	Risk < 10^{-4}

Table 2.54. EFPC ecological risk assessment endpoints

Goals	Assessment endpoint	Measurement endpoint
1. Conservation of threatened, endangered, and rare species and their critical habitats	1a. No harm to any threatened and endangered species or their critical habitat of the EFPC floodplain	1a. Surveys of presence/absence of species and their habitats on the EFPC floodplain
	1b. Maintenance of plant community composition and/or structure required for rare plant/animal and support species	1b. Abundance and distribution of plant/animal species that would support threatened, endangered, and rare species
	1c. Exposure of threatened and endangered species to biomagnifiable contaminants through the food chain	1c. The body burdens of contaminants in selected species representative of lower trophic levels of aquatic and terrestrial food chains
2. Protection of migratory birds	2a. No killing or harming of migratory birds as a result of exposure to site-specific stressors	2a. Contaminant concentrations in selected migratory birds and weight-of-evidence data
3. Preservation of wetlands	3a. The presence and structure/function of wetlands in relation to contaminants	3a. Wetlands survey and their contaminant levels, if any, on the EFPC floodplain
4. Existence of a fish community indicative of undegraded conditions	4a. Fish community in which the proportion of species tolerant of degraded water quality is $<30\%$[a]	4a. Proportion of tolerant species at the site
5. No adverse effects from contaminants to aquatic indicator organisms and/or predators that feed on them	5a. Ratio of contaminant concentrations in surface water to water quality criteria for protection of aquatic life ≤ 1[b]	5a. Contaminants in surface water
	5b. Aquatic indicator organisms contaminant body burden ratio to toxicological effects levels ≤ 1[b]	5b. COPC concentrations in whole-body samples of aquatic indicator species
	5c. Fish contaminant body burden ratio to levels protective of piscivorous biota ≤ 1[b]	5c. COPC concentrations in whole-body samples of aquatic indicator prey species
6. Existence of terrestrial animal community indicative of undegraded conditions	6a. Terrestrial animals with diversity, abundance, and distributions indicative of undegraded conditions resulting in $\geq 20\%$ decrease compared to the reference[d]	6a. Population abundance and distribution by habitat

Table 2.54 (continued)

Goals	Assessment endpoint	Measurement endpoint
7. No adverse effects from contaminants to terrestrial indicator organisms and/or predators that feed on them	7a. Ratio of contaminant body burdens in terrestrial indicator species to toxicological effects levels ≤ 1[b]	7a. COPC concentrations in whole-body samples of terrestrial indicator species
	7b. Ratio of contaminant body burdens in terrestrial indicator species to levels protective of terrestrial predators ≤ 1[c]	7b. COPC concentrations in whole-body samples of terrestrial indicator prey species

[a] A value of 30% tolerant fish species at a site is the approximate value (conservative) associated with a change in Metric 6 of the Index of Biotic Integrity (percent abundance of tolerant species) that is "somewhat different than expected from a reference site" (Ohio EPA 1987). Interestingly, this value compares very closely to the observed value of 29% tolerant species at the Hinds Creek reference site that was used during the ecological risk assessment.

[b] Because threshold criteria values for effects associated with body burdens (quotient denominators) are concentrations "proposed protective against toxicological effects (Eisler 1987)" a quotient ≤ 1 is appropriate to indicate protection.

[c] Because threshold criteria values for protection of predators (quotient denominators) are concentrations "expected to protect their predators from toxicological effects (Eisler 1987)," a quotient ≤ 1 is appropriate to indicate protection.

[d] Suter et al. (1992) used the test concentration of a contaminant resulting in 20% reduction in population recruitment, growth, fecundity, or abundance parameters for aquatic biota as a lower screening threshold (benchmark) for potential COCs for effects on aquatic biota on the Oak Ridge Reservation. The 20% threshold has precedent in the regulatory practices associated with controlling effluents in water. Further, Suter et al. justified doing so saying, "The 20% figure was chosen as approximately the mean level of effect observed at CVs (chronic values) and as a minimum detectable difference in population characteristics in the field (Suter et al. 1987, Suter 1992)." Twenty percent reduction seems a reasonable assessment endpoint for terrestrial organisms for the same reasons.

Table 2.55. Measurements made for the EFPC ecological risk assessment

Matrix sampled	Population measures			Contaminant concentration	Colonization rate	Growth rate
	Relative abundance	Biomass	Diversity			
			Aquatic			
Fish	X	X	X	X		
Benthic macro-invertebrates	X		X	X		
Periphyton					X	X
Water				X		
Sediments				X		
			Terrestrial			
Small mammals	X	X	X	X		
Birds	X		X	X		
Insects	X	X	X	X		
Earthworms	X		X	X		
Vegetation	X		X	X		
Soil				X		

Table 2.56. Dominant mode of exposure of indicator organisms to contaminated source media in EFPC

	Medium				
Indicator biota	Surface water	Instream sediment	Groundwater	Soil	Biota
Fish	D	D/I	I	*	D
Benthic invertebrates	D	D	I	*	D
Aquatic insects	D	D	I	*	D
Crayfish	D	D	I	*	D
Periphyton	D	D	I	*	*
Small mammals	D	*	I	D	D
Birds	D	I	I	I	D
Terrestrial insects	*	*	I	D	D
Earthworms	*	*	I	D	*
Plants	D	D	I	D	*

D = Direct exposure
* = Incomplete pathway or considered negligible
I = Indirect exposure

Table 2.57. Summary table of trends for whole-body concentrations of contaminants in aquatic biota collected from EFPC and Hinds Creek, October 7-29, 1991

Taxon	Mercury	Other inorganics	PCBs		Pesticides	PAHs
			Aroclor 1260	Other		
Redbreast sunfish	• In samples from all six sites in EFPC and Hinds Creek. • Maximum at Site 3. • Decreasing body burdens downstream from Sites 3 to 6. • All samples in EFPC exceeded concentrations in sample from Hinds Creek.	• Uranium was below sample detection at all sites.	• In samples from all six sites in EFPC and Hinds Creek. • Maximum level at Site 3. • Decreasing body burdens. Downstream from Sites 3 to 6. • All samples in EFPC exceeded concentrations in sample from Hinds Creek.	• All other mixtures were below sample detection limits.	• Most were less than sample detection limit. • Chlordane, dieldrin, and heptachlor were in samples from all sites, including Hinds Creek. • Decreasing body burdens from Sites 1 to 2, then increasing to maximum at Sites 4 or 5. • Nearly all sites in EFPC exceeded Hinds Creek.	• All individual PAHs were below sample detection limits except for acenaphthene. • Acenaphthene body burden was greatest at Site 1, then nearly constant at remaining EFPC sites. • All samples in EFPC exceeded concentrations in samples from Hinds Creek.
Common stoneroller	• In all six samples from EFPC and Hinds Creek. • Maximum at Site 2. • Decreasing body burdens downstream from Sites 2 to 6. • All samples in EFPC except Site 6 exceeded Hinds Creek sample.	• Uranium in samples from all sites. • Maximum body burdens at Site 1. • Decreasing body burdens downstream from Sites 1 to 6. • Sites 1 to 4 exceeded Hinds Creek sample.	• Sufficient sample at Sites 1 to 5 and Hinds Creek. • Maximum at Site 1. • Decreasing body burdens downstream from Sites 1 to 4. • All samples in EFPC exceeded concentrations in samples from Hinds Creek.	• All the mixtures were below sample detection limit.	• Same sites as for PCBs. • Maximum at Site 1. • General trend of decreasing body burdens from Sites 1 to 4. • All samples in EFPC exceeded concentrations in samples from Hinds Creeks.	• Same sites as for PCBs. • Maximum at Site 1. • Same trend as for pesticides. • Nearly all sites in EFPC exceeded sample from Hinds Creek.

Table 2.57 (continued)

Taxon	Mercury	Other inorganics	PCBs		Pesticides	PAHs
			Aroclor 1260	Other		
Benthic macro-inverte-brates	• Sufficient sample only at 4 sites in EFPC and Hinds Creek. • Maximum at Site 2; other sites similar to each other. • All samples from EFPC exceeded sample from Hinds Creek.	• Same sites as for uranium and mercury. • Same trends as for mercury.	• Sufficient sample only at 2 sites in EFPC (Sites 1 and 2). • Maximum at Site 1 (6-fold greater than at Site 2).	• All other mixtures below sample detection limit.	• Same sites as for PCBs. • Nearly all were below sample detection limits.	• Same sites as for PCBs. • Most individual PAHs were similar to concentrations in samples from the two sites. • Fluoranthene was maximum at Site 1. • Benzo(a)pyrene was maximum at Site 2.
Crayfish	• Sufficient sample at 4 sites in EFPC and Hinds Creek. • Maximum at Site 1. • Decreasing body burdens downstream. • All samples from EFPC exceeded concentrations in samples from Hinds Creek.	• Same sites as for mercury. • Uranium was below sample detection limit at most sites. • Selenium body burdens were greatest in samples for Site 3, and all EFPC samples exceeded concentrations in samples from Hinds Creek.	• Same sites as for mercury. • Same trends as for mercury.	• All other mixtures below sample detection limit.	• Same sites as for mercury. • Nearly all were below sample detection limits.	• Sufficient sample only at Sites 1 to 3, and Hinds Creek. • Maximum at Site 3. • Most individual PAHs increased downstream from Sites 1 to 3. • Most PAHs at the 3 sites in EFPC exceeded concentrations in sample from Hinds Creek.

Table 2.58 Summary table of trends for whole-body contaminant concentrations in terrestrial biota collected from EFPC and reference site in late 1991

Taxon	Mercury	Other inorganics	PCBs		Pesticides	PAHs
			Aroclor 1260	Other		
White-footed mouse	• Levels below detection limit in 9 of 11 individuals. • Maximum value of 1.105 mg/kg at Site 2.	• Antimony, chromium, and selenium measured above detection limit in >50% of individuals.	• Above detection limits in all samples except reference. • Range from 0.051 mg/kg to 0.480 mg/kg, with highest at Site 1.	• All others below detection limit.	• Nearly all were below detection limits. • One value for DDT and one for heptachlor oxide above detection limits.	• All levels below detection limits or twice reference levels.
Short-tailed shrew	• Maximum of 7.9 mg/kg at Site 5.	• Uranium not detected. • Antimony, chromium, and selenium similar to mice.	• Maximum of 1.4 mg/kg at Site 5.	• Not detected.	• Nearly all were below detection limits.	• Not analyzed.
Woodland vole	• Less than detection limit.	• Chromium levels similar to mice. • Uranium not detected.	• Reported at 0.046 mg/kg.	• Aroclor 1016 at 0.073 mg/kg.	• All below detection limit.	• No unqualified levels above unqualified detection limits.
Great blue heron	• Breast feathers at 5.3 mg/kg • Liver sample at 9.0 mg/kg.	• Chromium, selenium, and zinc above detection limits in feathers. • Selenium and zinc above detection limits in liver.	• Liver sample at 1.4 mg/kg.	• All others below detection limit.	• Several reported but most below the detection limit.	• No unqualified levels above detection limit.

Table 2.58 (continued)

Taxon	Mercury	Other inorganics	PCBs		Pesticides	PAHs
			Aroclor 1260	Other		
Carolina wren	• Levels at 3.5 mg/kg in both samples.	• Antimony, selenium, and cadmium above levels in terrestrial insects.	• Average of 2.1 mg/kg is 10 times average in terrestrial insects.	• No others detected.	• Only DDE and heptachlor epoxide detected above detection limits.	• None above detection limit.
Flying insects	• Most samples below detection limit. • Maximum levels of 3.2 mg/kg at Site 3. • No correlation between measured concentrations in insects and soils.	• Uranium and cadmium not detected. • Antimony, chromium, zinc, arsenic and selenium noted above detection limits at 2 sites.	• Range of 0.02-0.35 mg/kg. • Maximum at Site 2 and decreased steadily with distance from Y-12 Plant.	• All levels below detection or reference site levels.	• DDE reported at Site 3, chlordanes at Site 4. • Others not identified above twice reference site levels.	• Few detected; highest value at Site 3.
Earthworms	• Range from 5 to 33 mg/kg. • Maximum observed at Site 2, with a steady decrease downstream. • No good correlation between earthworm composites and soil levels.	• Arsenic, cadmium, selenium, uranium, zinc, and chromium levels above reference site.	• Not sufficient sample for analysis.	• Not sufficient sample for analysis.	• Not sufficient sample for analysis.	• Not sufficient sample for analysis.

Table 2.58 (continued)

Taxon	Mercury	Other inorganics	PCBs		Pesticides	PAHs
			Aroclor 1260	Other		
Grass/ vegetables	• Geometric mean grass/browse concentration of 0.34 mg/kg, with maximum of 17 mg/kg. • Grasses near creek showed higher levels. • Levels in vegetables ranged from <0.03 to 3.2 mg/kg.	• Data not available.	• Not measured.	• Not measured.	• Not measured.	• Not measured.

Table 2.59. Summary table of media toxicity investigations conducted in EFPC

Media	Test type	Organism	Test endpoint(s)	Test dates	Test Results
Surface water (grab samples)[a]	Laboratory 7-d chronic (static with renewal)	*Pimephales promelas*	Survival, growth	March–July 1986	Reduced growth at sites close to the Y-12 Plant
Surface water (grab samples)[b]	Laboratory 7-d chronic (static with renewal)	*P. promelas*	Survival, growth	Sept. 1986–Oct. 1988	No pattern of longitudinal effects downstream from the Y-12 Plant
Surface water (grab samples)[b]	Laboratory 2-hour incubation (static)	*Haematococcus sp.*	Amount ^{14}C fixation (photosynthesis rate)	June–July 1987	No pattern of longitudinal effects downstream from the Y-12 Plant
Instream Surface water[b]	In situ 84-d exposure	*Sphaerium sp.*	Survival, growth	July–Oct. 1988	Reduced survival and growth; greatest impacts closest to the Y-12 Plant
Instream Surface water[b]	In situ 88-d exposure	*Sphaerium sp.*	Survival, growth	Oct. 1988–Jan. 1989	Reduced survival and growth; greatest impacts closest to the Y-12 Plant
Instream Surface water[c]	In situ 121-d exposure	*S. fabale*	Survival, growth, natality	1990	Reduced survival, growth, and natality at sites in EFPC; lowest survival and natality at site closest to the Y-12 Plant
Surface water and stream substrate (grab samples)[b]	Laboratory exposure, constant temperature	*H. depravata*	Growth, emergence	Sept.–Dec. 1988	No significant differences in endpoints using water from EFK 23.1, EFK 14.0, or tap water

[a]Loar 1992
[b]Hinzman 1992
[c]Kornegay 1991

Table 2.60. Classification of risk quotients for aquatic exposures by range and location[a]

Sample site	Quotient range[b]				
	Q>100	10≤Q<100	1≤Q<10	0.1≤Q<1	Q<0.1
1		WQC, Hg AI, pred. SR, PCB tox. SR, PCB pred.	CR, Hg tox. CR, PCB pred. RS, PCB tox. CR, PCB tox. RS, PCB pred.	WQC, Zn SR, Hg tox. RS, Hg tox.	
2		WQC, Hg SR, PCB tox. SR, PCB pred.	SR, Hg tox. CR, Hg tox. AI, pred. RS, PCB tox. RS, PCB pred.	WQC, Zn RS, Hg tox. CR, Hg tox. CR, PCB tox. CR, PCB pred.	
3		WQC, Hg	AI, pred. SR, PCB tox. RS, PCB tox. SR, PCB pred. RS, PCB pred.	WQC, Zn SR, Hg tox. RS, Hg tox. CR, Hg tox. CR, PCB tox. CR, PCB pred.	
4			AI, pred. SR, PCB tox. RS, PCB tox. SR, PCB pred. RS, PCB pred.	WQC, Zn SR, Hg tox. RS, Hg tox.	
5	HN, pred.	AI, pred.	HN, Hg tox. SR, PCB tox. RS, PCB tox. SR, PCB pred. RS, PCB pred.	WQC, Zn SR, Hg tox. RS, Hg tox. HN, PCB tox.	
6			SR, PCB tox. SR, PCB pred.	WQC, Zn CR, PCB tox. CR, PCB pred.	SR, Hg tox. RS, Hg tox. CR, Hg tox. CR, pred.
Reference				WQC, Zn SR, Hg pred. RS, Hg pred. CR, Hg pred. AI, Hg pred.	SR, Hg tox. RS, Hg tox. CR, Hg tox. SR, PCB tox. RS, PCB tox. CR, PCB tox. SR, PCB pred. RS, PCB pred. CR, PCB pred.

[a] Key: WQC = Water quality criteria; SR = Common stoneroller; RS = Redbreast sunfish; CR = Crayfish; AI = Aquatic insect; tox. = toxicity to indicator organism; pred. = toxicity to predators; HN = Great blue heron

[b] Quotients based on concentrations below detection limits were not included.

Table 2.61. Classification of risk quotients for terrestrial exposures by range and location[a]

	Quotient range[b]				
Sample site	Q>100	10≤Q<100	1≤Q<10	0.1≤Q<1	Q<0.1
1	EW, pred.			TI, PCB pred. MS, PCB pred.	TI, PCB tox. MS, PCB tox.
2	EW, pred.	MS, pred. WR, pred.	WR, Hg tox. TI, pred.	MS, Hg tox. TI, PCB pred.	TI, PCB tox. MS, PCB tox. WR, PCB tox. MS, PCB pred. WR, PCB pred.
3	EW, pred.	TI, pred.		TI, PCB pred.	TI, PCB tox. MS, PCB tox. MS, PCB pred.
4	EW, pred.	SH, pred. WR, pred.	SH, Hg tox. WR, Hg tox.	WR, PCB tox. MS, PCB pred. SH, PCB pred. WP, PCB, pred.	TI, PCB tox. PCB tox. SH, PCB tox. PCB pred.
5	EW, pred. SH, pred.		SH, Hg tox.	SH, PCB pred. HN, PCB pred.	TI, PCB tox. MS, PCB tox. SH, PCB tox. TI, PCB pred. MS, PCB pred.
6		EW, pred.			TI, PCB tox. TI, PCB pred.
Reference			MS, Hg pred. EW, Hg pred.	MS, Hg tox.	TI, Hg tox. MS, HG tox. TI, PCB pred. MS, PCB pred.

[a] Key: EW = Earthworm (undepurated for conservative modeling results)
TI = Terrestrial insect
MS = White-footed mouse
SH = Short-tailed shrew
WR = Carolina wren
tox. = toxicity to indicator organism
pred. = toxicity to predators

[b] Quotients based on concentrations below detection limits were not included.

Table 2.62. Patterns of measurement endpoints for the three ecological risk assessment segments

Media and measurement endpoints	Location in 23-km (14.5-mi) long floodplain		
	Upper reaches (Segments 1, 2, 3, and 4)	Middle reaches (Segments 5, 6, 7, and 8)	Lower reaches (Segment 9)
Abiotic media			
Water contaminants	Highest	Intermediate	Lowest
Soil contaminants	Highest	Intermediate	Lowest
Aquatic organisms			
Fish			
Tolerant species	Highest	Intermediate	Similar to reference
Species evenness	Lowest	Similar to highest	Highest
Contaminant body burdens	Highest	Intermediate	Lowest
Benthic macroinvertebrates			
Tolerant species	Highest	Intermediate	Similar to middle reaches
Species evenness	Lowest	Similar to highest	Highest
EPT richness	Lowest	Intermediate	Similar to middle reaches
Terrestrial organisms			
Arthropod mean abundance	Lowest	Intermediate	Highest
Contaminant body burdens for earthworms and mice	Highest	Intermediate	Lowest

Table 2.63. Comparison of ecological risk assessment results with assessment endpoints

Assessment endpoint	ERA result
1a. No harm to any threatened and endangered species and their critical habitat of the EFPC floodplain	1a. Literature and field surveys did not reveal threatened and endangered species living in EFPC floodplain. Habitat that could support an expansion of the range of a threatened and endangered species (e.g., Indiana and Gray bats) was found. However, a range expansion of such species is not likely.
1b. Maintenance of plant community composition and/or structure required for rare plant and animal and support species	1b. Literature and field surveys did not find that potential habitat—plant community—for rare animal or support species was harmed by EFPC contaminants. Wetlands may be an exception depending on the remediation goal option.
1c. No exposure to threatened and endangered species through biomagnifiable contaminants through the food chain	1c. Literature and field surveys and consultation with responsible agencies did not reveal threatened and endangered species living in the EFPC floodplain.
2a. No killing or harming of migratory birds as a result of exposure to site-specific stressors	2a. Field survey evidence provides names of more than 30 migrant bird species which are likely ingesting contaminated worms and arthropods and, therefore, likely being affected by EFPC contaminants.
3a. The presence and structure/function of wetlands in relation to contaminants	3a. Seventeen wetlands exist in the floodplain, some with mercury contamination, but each appears to exhibit undegraded structure and functions. (There is an ongoing contaminant sampling to establish this).
4a. Fish communities in which the proportion of species tolerant of degraded water quality is <30%	4a. Continual releases of water-borne contaminants impact fish community structure, resulting in communities dominated by species tolerant of degraded water quality conditions at the 4 sites closest to the Y-12 Plant.
5a. Ratio of contaminant concentration in surface water to water quality criteria for protection of aquatic life ≤1. These criteria are 0.012 μg Hg/L and 0.001 μg PCB/L.	5a. The quotient method indicated significant exceedances by factors up to 45 from mercury concentrations above water quality criteria of EFPC below Lake Reality.
5b. Aquatic indicator organisms contaminated body burden ratio to toxicological effects levels ≤1. These levels are 5 mg Hg/kg and 0.4 mg PCB/kg.	5b. Contaminant body burden measurements and quotients of 1 or less for mercury and up to 20 for PCBs were determined for common stonerollers, redbreast sunfish, and crayfish.
5c. Fish contaminant body burden ratio to protect piscivorous biota levels ≤1. These levels are 0.1 mg Hg/kg and 0.5 mg PCB/kg.	5c. The quotient method identified numerous exceedances by factors of 10 to >100 for mercury and up to 16 for PCBs for fish contaminant body burdens in a predator pathway.
6a. Terrestrial animals with diversity, abundance, and distributions indicative of undegraded conditions resulting in ≥20 or more percent decrease compared to the reference.	6a. Terrestrial insect abundance was more than 20% lower at all EFPC sites than at the reference site. Other findings suggest that no 20% decreases occur for other indicator organisms.
7a. Ratio of contaminant body burdens in terrestrial indicator species to toxicological effects levels ≤1. These levels are 1.1 mg Hg/kg and 16 mg PCB/kg.	7a. Body burdens of Great blue heron, Carolina wrens, and short-tailed shrews were found to exhibit quotient ranges between about 2 and 8 for mercury in the ERA sampling.
7b. Ratio of contaminant body burdens in terrestrial indicator species to levels protective of terrestrial predators ≤1. These levels are 0.05 mg Hg/kg and 3.0 mg PCB/kg.	7b. Contaminant body burden quotients in excess of 100 were determined for Great blue herons, earthworms, and short-tailed shrews for predator pathways. Quotients for mercury were as high as 19 for white-footed mice and 70 for Carolina wren predators.

Table 2.64. EFPC OU contaminants of concern for human health[a]

Pathway/medium	Human health	
Surface water	NA	
Sediments	NA	
Soil		
	Arsenic	
	Cadmium	
	Mercury	
Groundwater (incomplete pathway)	Arsenic	Lead
	Barium	Manganese
	Beryllium	Mercury
	Cadmium	Methylene chloride
	Chromium	Vanadium
	Copper	
Food chain		
Produce	Antimony	Chromium
	Aroclor-1254	Copper
	Aroclor-1260	Dibenzo(a,h)anthracene
	Arsenic	Manganese
	Benzo(a)anthracene	Mercury
	Benzo(a)pyrene	Nickel
	Benzo(b)fluoranthene	Selenium
	Beryllium	Silver
	Cadmium	Vanadium
Beef	Aroclor-1254	Chromium
	Aroclor-1260	Copper
	Arsenic	Indeno(1,2,3-cd)pyrene
	Benzo(a)anthracene	Manganese
	Benzo(a)pyrene	Mercury
	Benzo(b)fluoranthene	Selenium
	Benzo(k)fluoranthene	Vanadium
Dairy	Aroclor-1254	Chromium
	Aroclor-1260	Copper
	Barium	Indeno(1,2,3-cd)pyrene
	Benzo(a)anthracene	Manganese
	Benzo(a)pyrene	Mercury
	Benzo(b)fluoranthene	Selenium
	Benzo(k)fluoranthene	Silver
	Cadmium	Vanadium

NA = Pathway not applicable to receptors.

[a] This list is not the same as the list that appears in the RI due to a change in the definition of "contaminants of concern."

Table 2.65. EFPC soil remediation goal options (C_{soil}; mg of total mercury/kg soil) and assumptions

Indicator organism	Assessment endpoint (CD)	Scenario 1 Upper-bound exposure	Scenario 2 Intermediate exposure	Scenario 3 Lower exposure		
Top predators	mg MeHg[a]/kg diet[b]	100% diet from floodplain (Fl) 100% diet contaminated shrews; 100% absorption, methyl mercury (ABS); 0.04 = shrew BAF; 100% methyl mercury in prey (D_{Me})	100% diet from floodplain see RI addendum for diet %; 100% absorption of methyl mercury; see RI addendum for BAFs; 10% methyl mercury in prey	% diet from floodplain varies[c] see RI addendum for diet %; 100% absorption of methyl mercury; see RI addendum for BAFs; 10% methyl mercury in prey		
owl	0.1	3	94	2,337		
hawk	0.1	3	105	3,500		
fox	1.1	31	1,102	12,247		
Mid-level predators	mg MeHg/kg diet	100% diet from floodplain; 100% of diet earthworms[d]; 100% absorption of mercury; see RI addendum for BAFs; 100% methyl mercury in prey	100% diet from floodplain; see RI addendum for diet; 100% absorption of mercury; see RI addendum for BAFs; 40% methyl mercury in prey	100% diet from floodplain; see RI addendum for diet; 100% absorption of mercury; see RI addendum for BAFs; 10, 4, and 1% methyl mercury in prey		
wren	0.1[b]	1.6	15	61	153	612
wren	0.2[e]	3.3	30	122	306	1,225
shrew	0.4[f]	7	38	152	381	1,525
shrew	1.1[b]	18	105	419	1,048	4,193

Indicator organism	Assessment endpoint (CD)	Scenario 1 Upper-bound exposure	Scenario 2 Intermediate exposure	Scenario 3 Lower exposure
First-level Consumers	Miscellaneous (Inorg. mercury)	100% diet from floodplain; 100% soil ingestion (SI); 100% mercury absorbed from soil; 1 = worm BAF; 1.0 m^3/d inhalation rate; pore water in equil. with soil; 8.8E04 = K_D inorg. mercury[j]	100% diet from floodplain; % soil ingestion varies[g]; 50% mercury absorbed from soil; 0.06 = worm BAF[h]; 0.5 m^3/d inhalation rate; pore water in equil. with soil; 4.0E05 = K_D inorg. mercury	100% diet from floodplain; % soil ingestion varies[g]; 10% mercury absorbed from soil; 0.06 = worm BAF[h]; 0.026 m^3/d inhalation rate[i]; pore water in equil. with soil; 7.1E05 = K_D inorg. mercury[k]
earthworm	body burden 80 mg/kg worm[b]	80	2667	13,333
shrew	soil ingestion 87.7 $HgS^{a,c}$	87.7	8770	87,700
mice	soil-vapor inhalation 13.7 mg/kg/d	500	1000[l]	19,000
mice	soil ingestion 90.4 mg/kg diet[m]	90.4	18,080	301,333
crayfish	pore water LC_{50} of 0.2 mg $HgCl_2$[a]/L[n]	17	80	142
amphibian	pore water LC_{50} of 1.3 mg Inorg. mercury L[o]	114	520	923
Plants	Soil-Pore water Concentration[p] (mg Hg/L)	pore water in equil. with soil; 8.8E04 = K_D inorg. mercury[j]; 100% indicated form of mercury	pore water in equil. with soil; 4.0E05 = K_D inorg. mercury; 1.25% pore water methyl mercury[k]	pore water in equil. with soil; 7.1E05 = K_D inorg. mercury[k]; 1.25% pore water methyl mercury[k]
Coniferous evergreen [O_2/CO_2]	0.002 MeHg	176	64,000	113,600
Coniferous evergreen [chl a]	0.02 MeHg	1,760	640,000	NF[q]

Table 2.65 (continued)

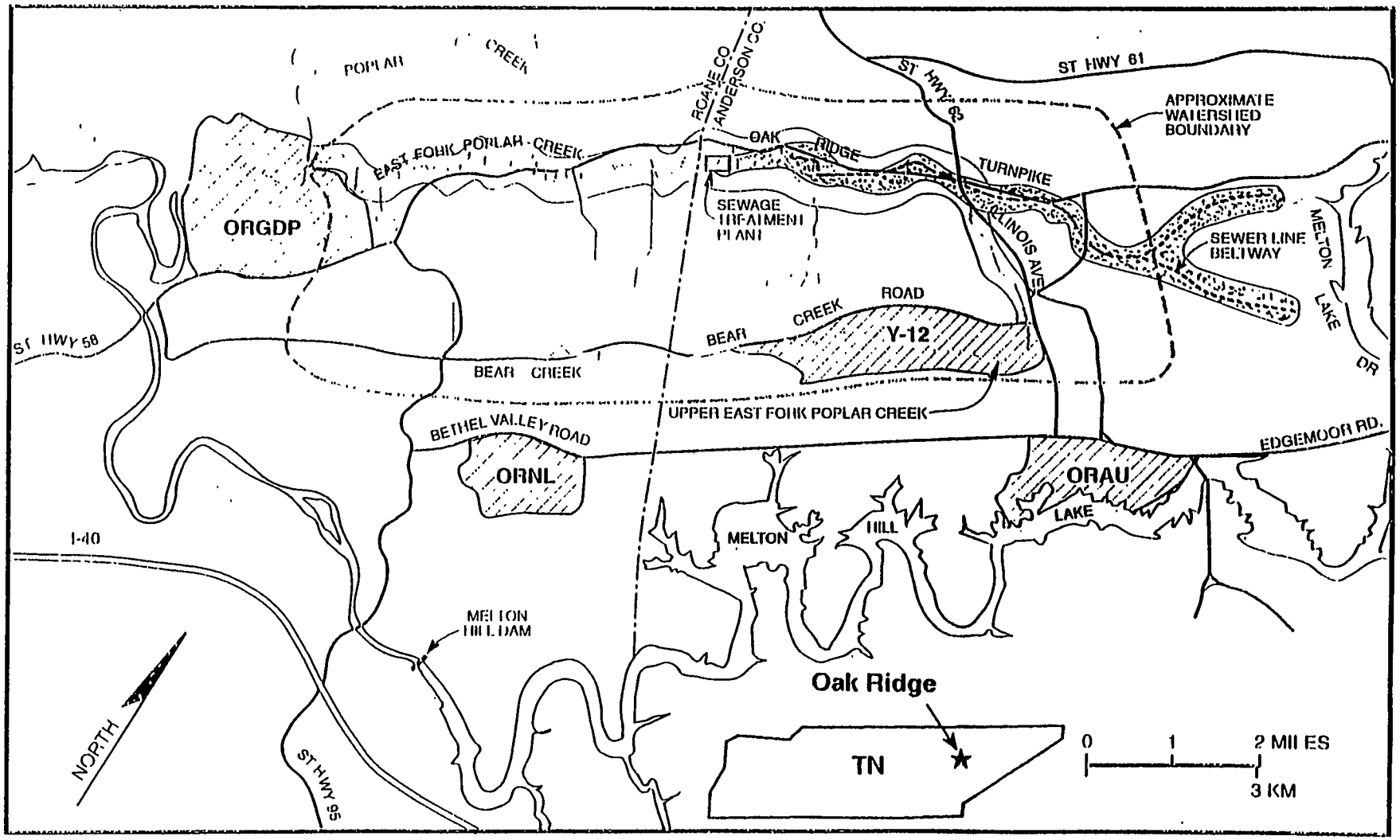
Indicator organism	Assessment endpoint (CD)	Scenario 1 Upper-bound exposure	Scenario 2 Intermediate exposure	Scenario 3 Lower exposure
Coniferous evergreen [chl a]	0.02 $HgCl_2$[a]	1,760	8,101	14,379
Grass [root/shoot]	5 $HgCl_2$[a]	440,000	NF[q]	NF[q]

[a] MeHg = methyl mercury, Inorg. = inorganic, HgS = mercuric sulfide; $HgCl_2$ = mercuric chloride.
[b] Eisler (1987), mercury toxicity to wildlife.
[c] For owl 4.0%; for hawk 3.0%, for fox 9.0%.
[d] Earthworms have highest BAF of potential wren and shrew prey items (0.06).
[e] Scheuhammer (1988), methyl mercury toxicity to finches.
[f] Opresko et al. (1993), wildlife benchmarks.
[g] For earthworms 100%; for mice 1.0% for Scenario 2, 0.3% for Scenario 3 (Beyer et al. 1991); for shrews 2.0% and 1.0%.
[h] EPA (1985b), earthworm BAF.
[i] EPA (1993), estimated using extrapolation equation.
[j] DOE (1994), EFPC Treatability Study, soil washing study results.
[k] Appendix Q (DOE 1994), EFPC mercury availability study.
[l] Lower value in range of RGOs based on inhalation in RI (DOE 1994) .
[m] Revis et al. (1989a), EFPC mouse soil-ingestion study results.
[n] Heit and Fingerman (1977), mercury toxicity for crayfish, *Procambrus clarki*.
[o] Birge et al. (1979), mercury toxicity for amphibian larvae.
[p] Suter et al. (1993), phytotoxicity data.
[q] NF = Not feasible because maximum possible pore water concentration is less than assessment endpoint, given indicated K_D and percent methyl mercury.
Source: DOE 1994b.

This page intentionally left blank.

SECTION 2
FIGURES

This page intentionally left blank.



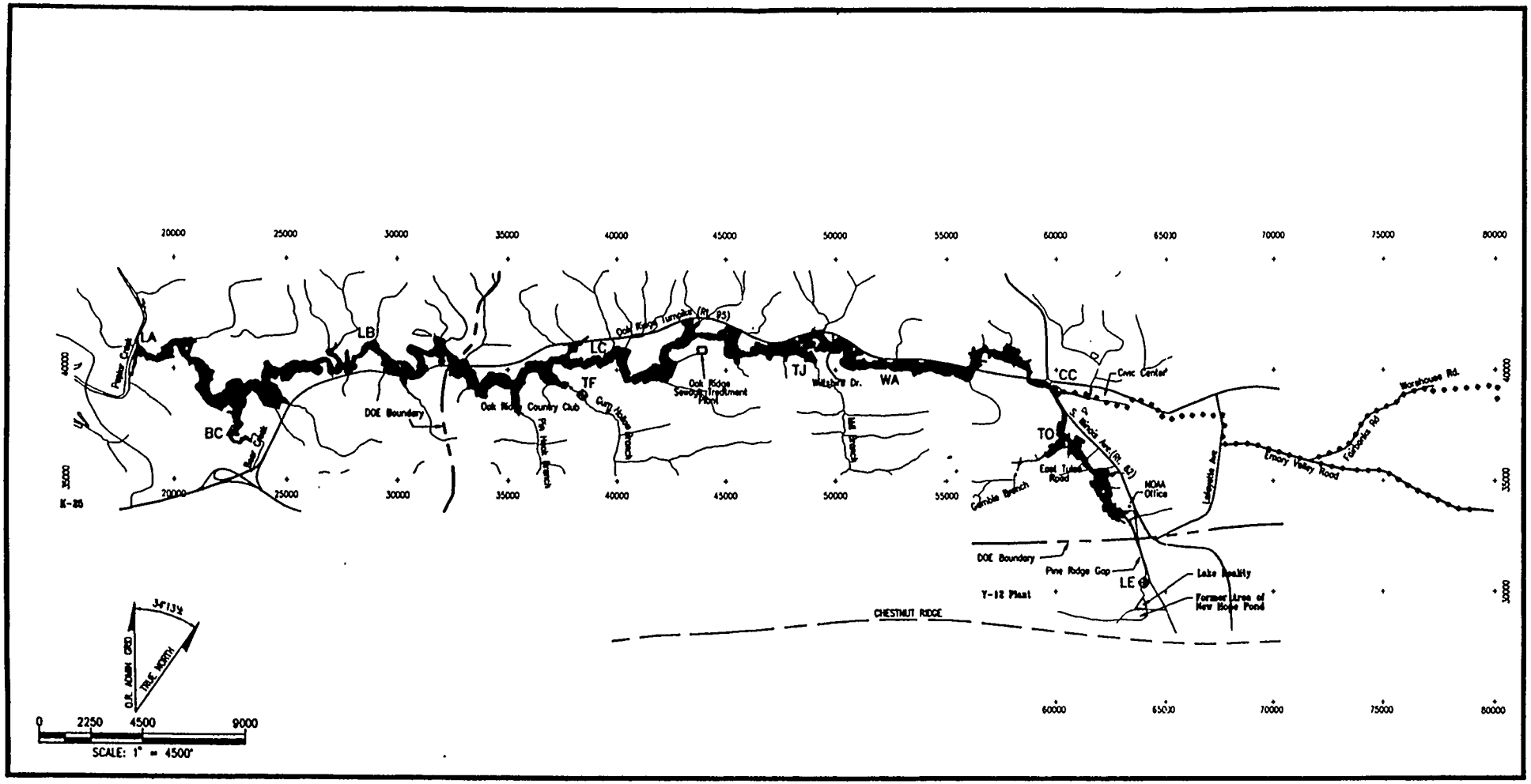
LEGEND

EFPC floodplain

Sewer Line Beltway

Fig. 2.1. Location map for EFPC and SLB.

This page intentionally left blank.



EAST FORK POPLAR CREEK

PLOTTING INFORMATION:		PEN CONFIGURATION
PROJECT NO: Z-0001	XREFS: Z-0001B/BW93, Z-0001B/FLOODPLN, Z-0001B/TRIBS	1
DWG FILE. \Z-0001\DWGS\ 486STRM.DWG		2
DATE: 09-20-93	PLOT FILES:\Z-0001P\ 486STRM.PLT	3
PLOTTED BY: J CHISMAN		4
SHEET 1 OF 1		5
		6
		7
		8

LEGEND:

- BASE FLOW SAMPLE
- STORM & BASE FLOW SAMPLE
- EXIST. ROADS
- CREEKS & TRIBUTARIES
- O. R. ADMIN. GRID TICK (IN FEET)
- FLOOD PLAIN
- SEWERLINE BELTWAY

TITLE

Fig. 2.2. EFPC and its tributaries.

Science Applications International Corporation

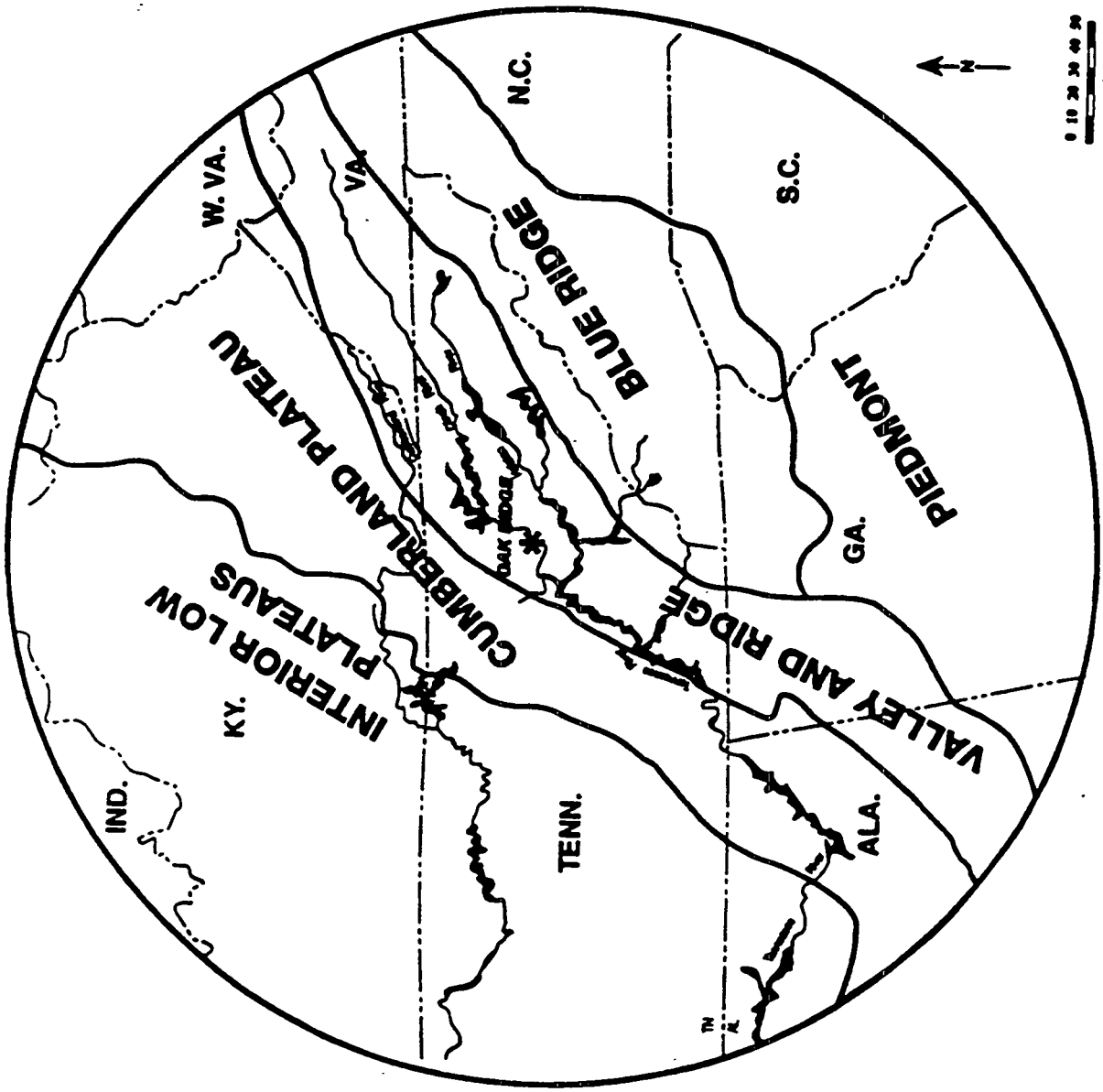


Fig. 2.3. Regional physiographic map

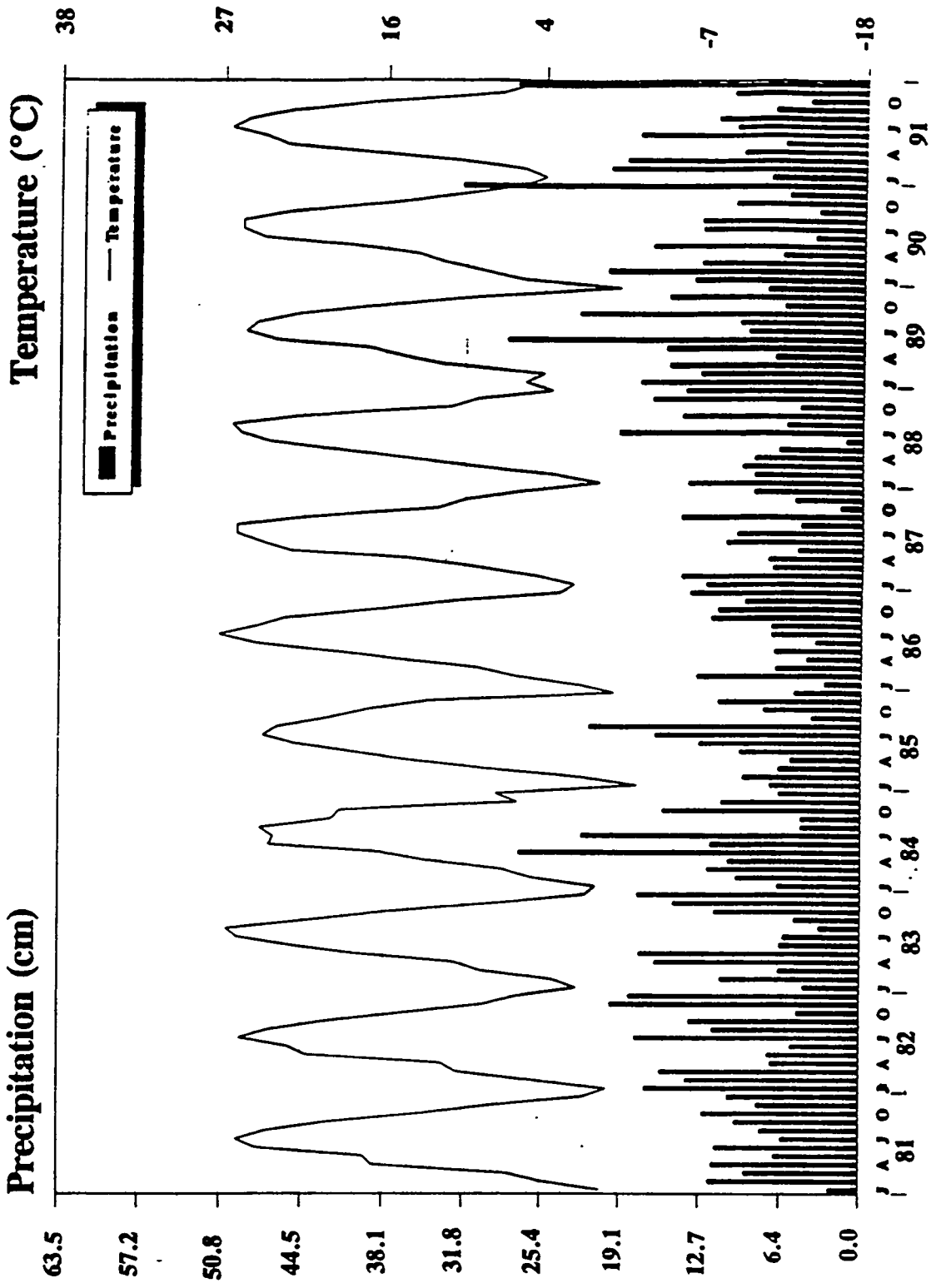


Fig. 2.4. Climatological data for EFPC and vicinity January 1981 - December 1991.
Source: NOAA.

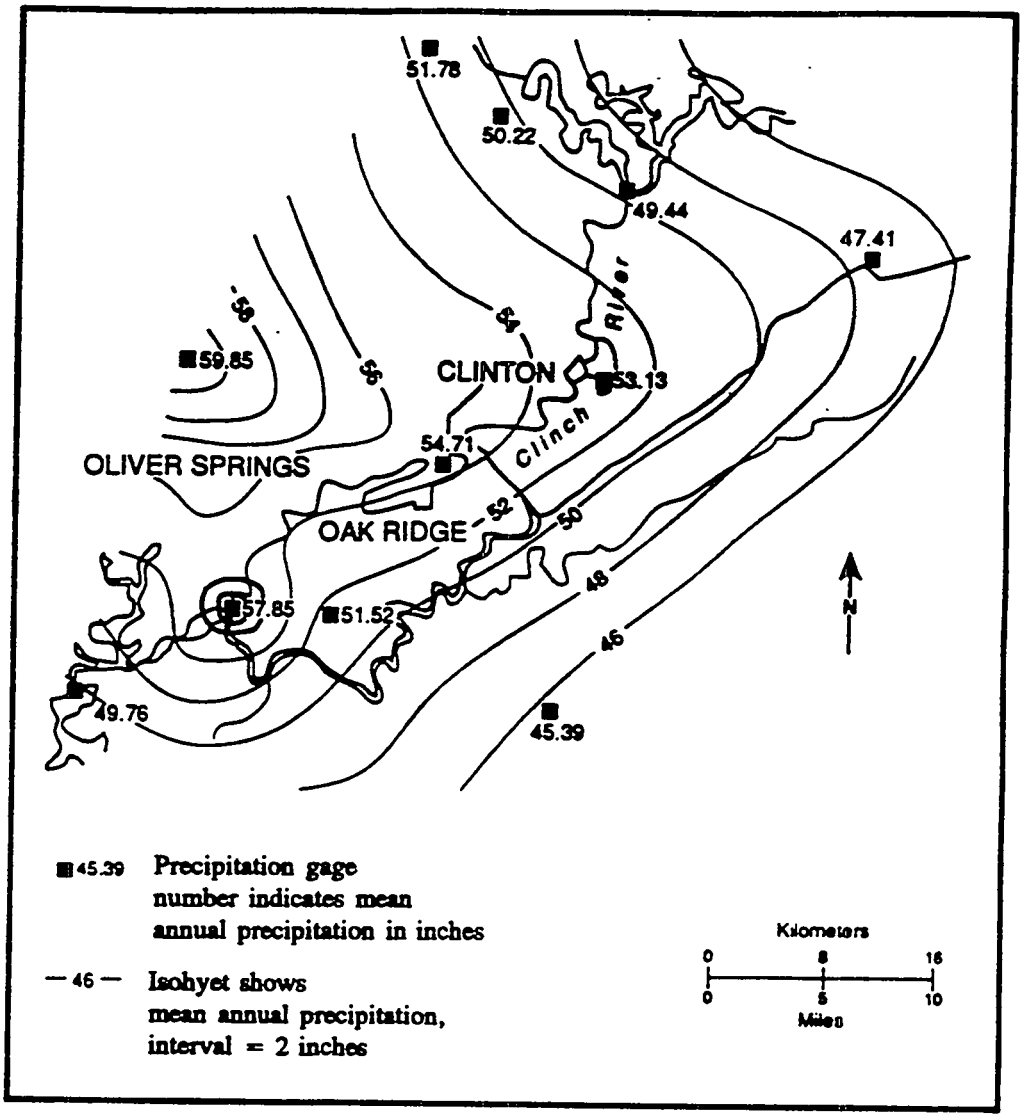


Fig. 2.5. Isohyetal map of the Oak Ridge, Tennessee area showing a northwest-to-southeast decline in average precipitation. Map based on mean annual precipitation data for 1936-1960 (McMaster 1967).

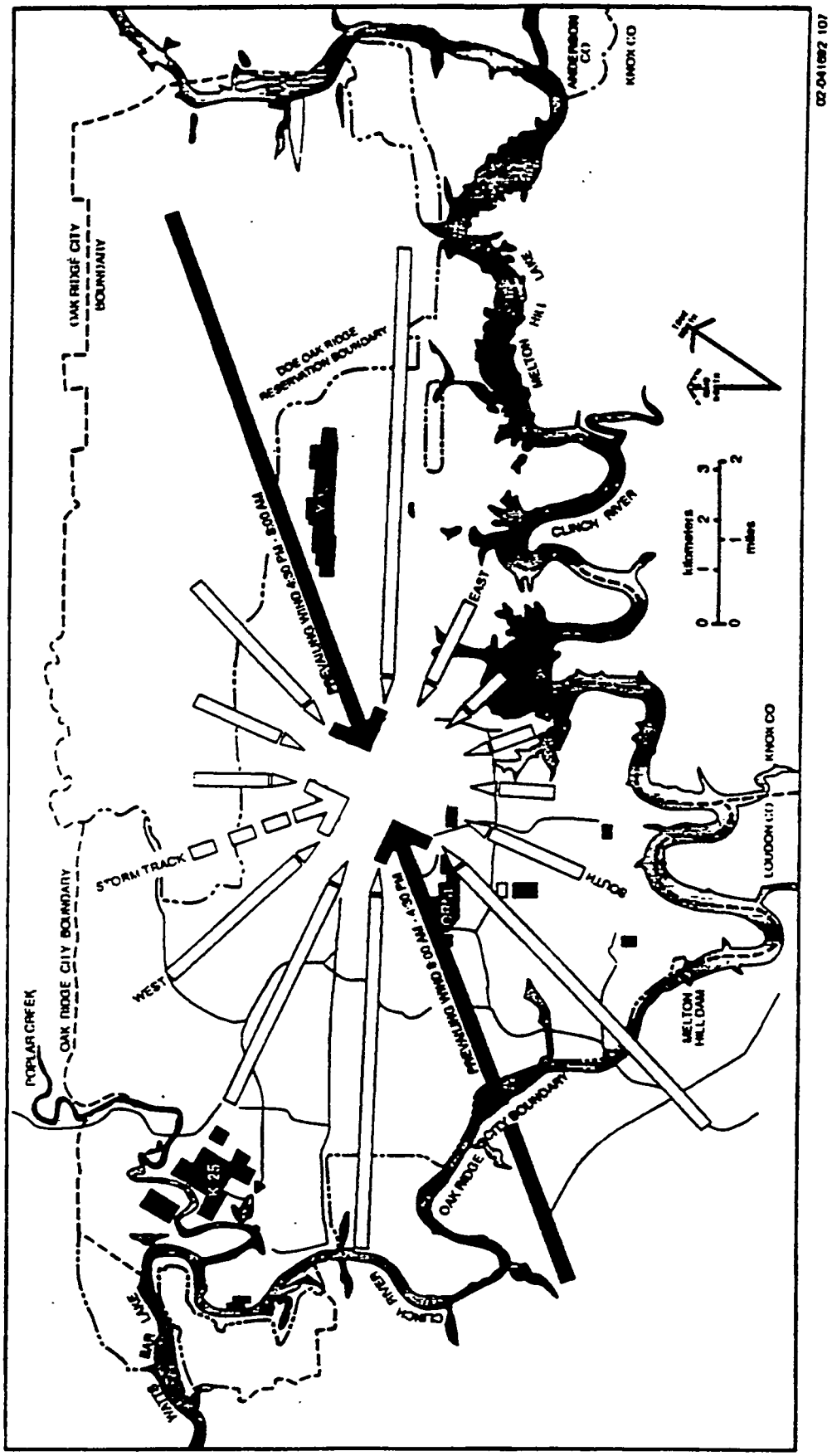


Fig. 2.6. Average wind frequency and direction for the DOE ORR vicinity.

This page intentionally left blank.

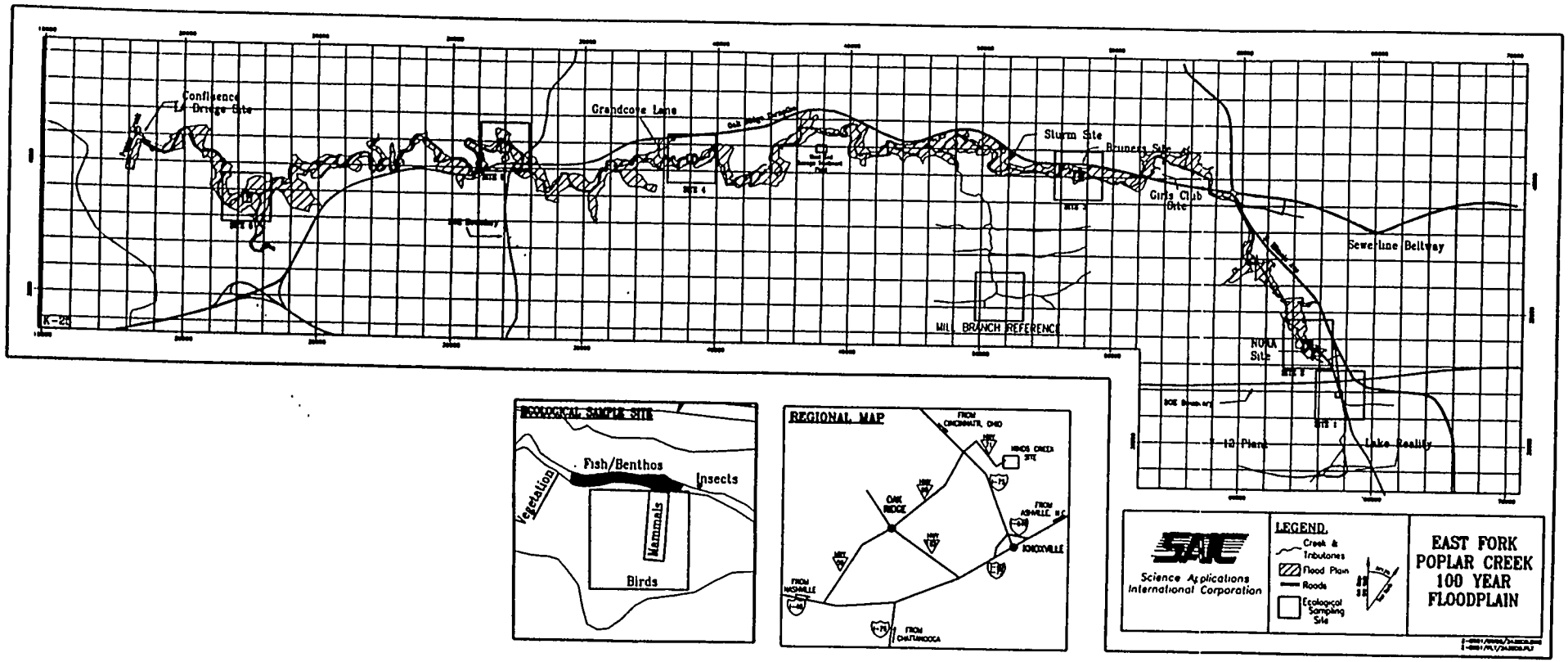


Fig 2.7. Map of EFPC and tributaries showing ecological sampling sites.

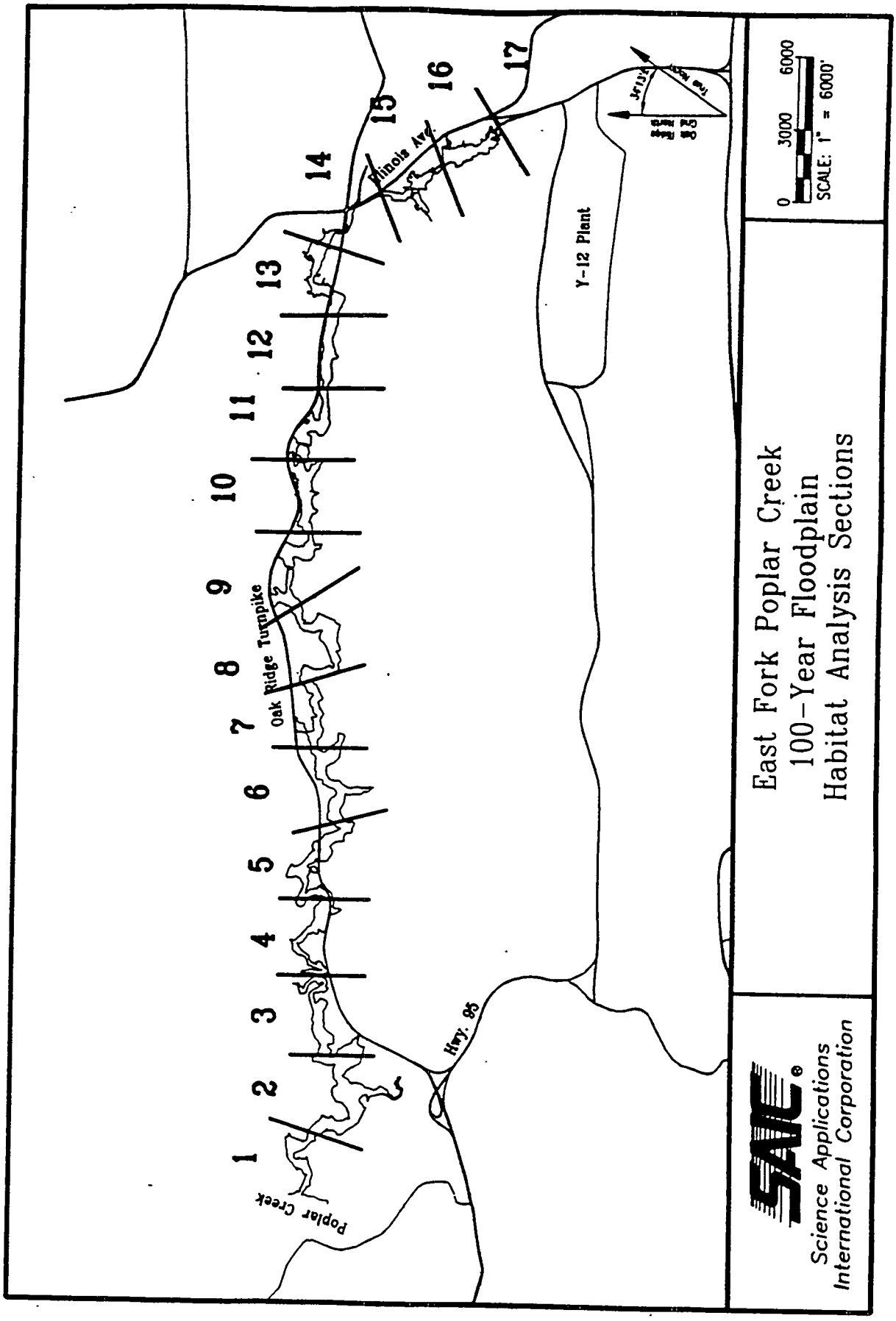


Fig. 2.8. Map of 17 sections for habitat analysis.

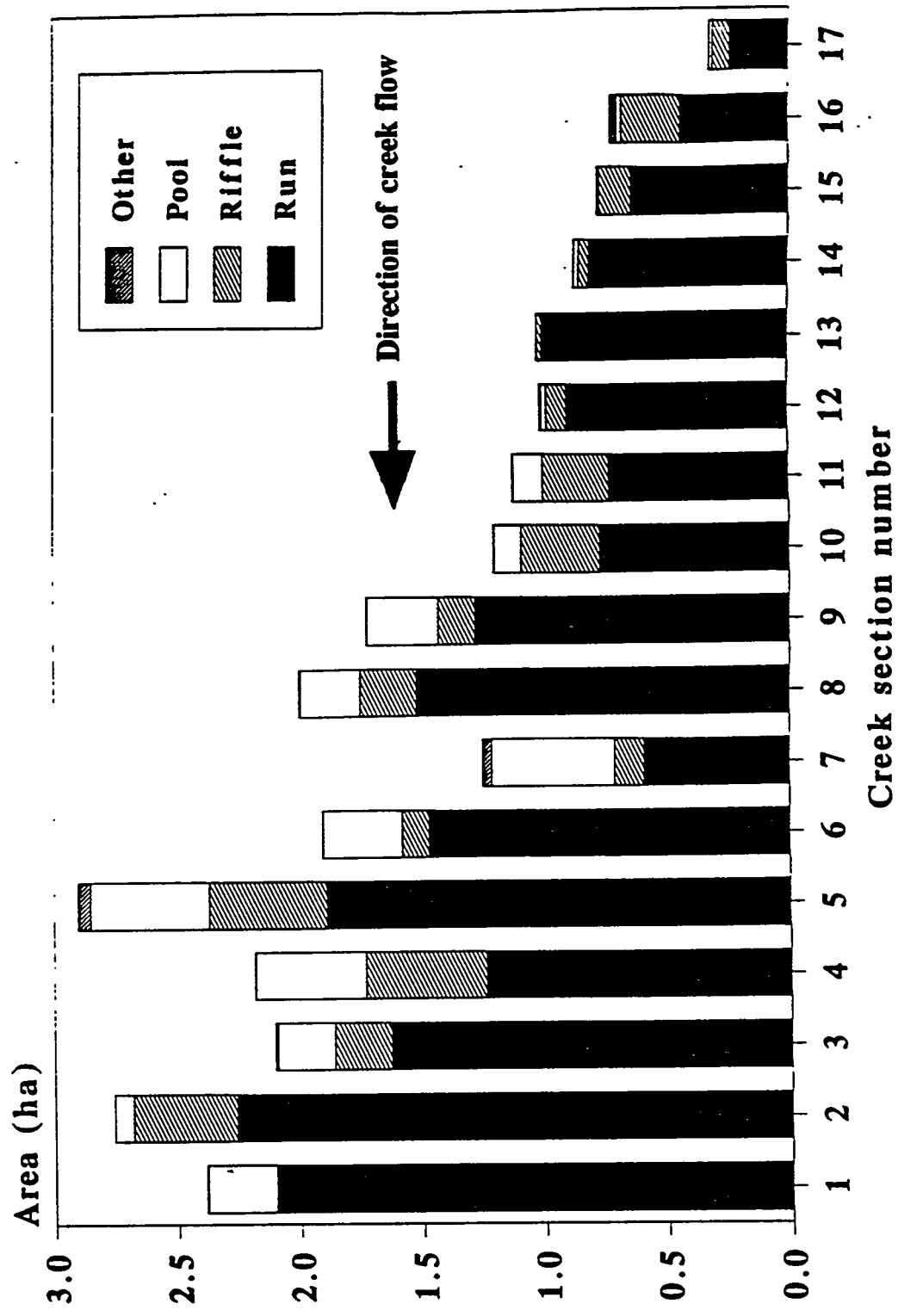


Fig. 2.9. Aquatic habitat areas by stream segment.

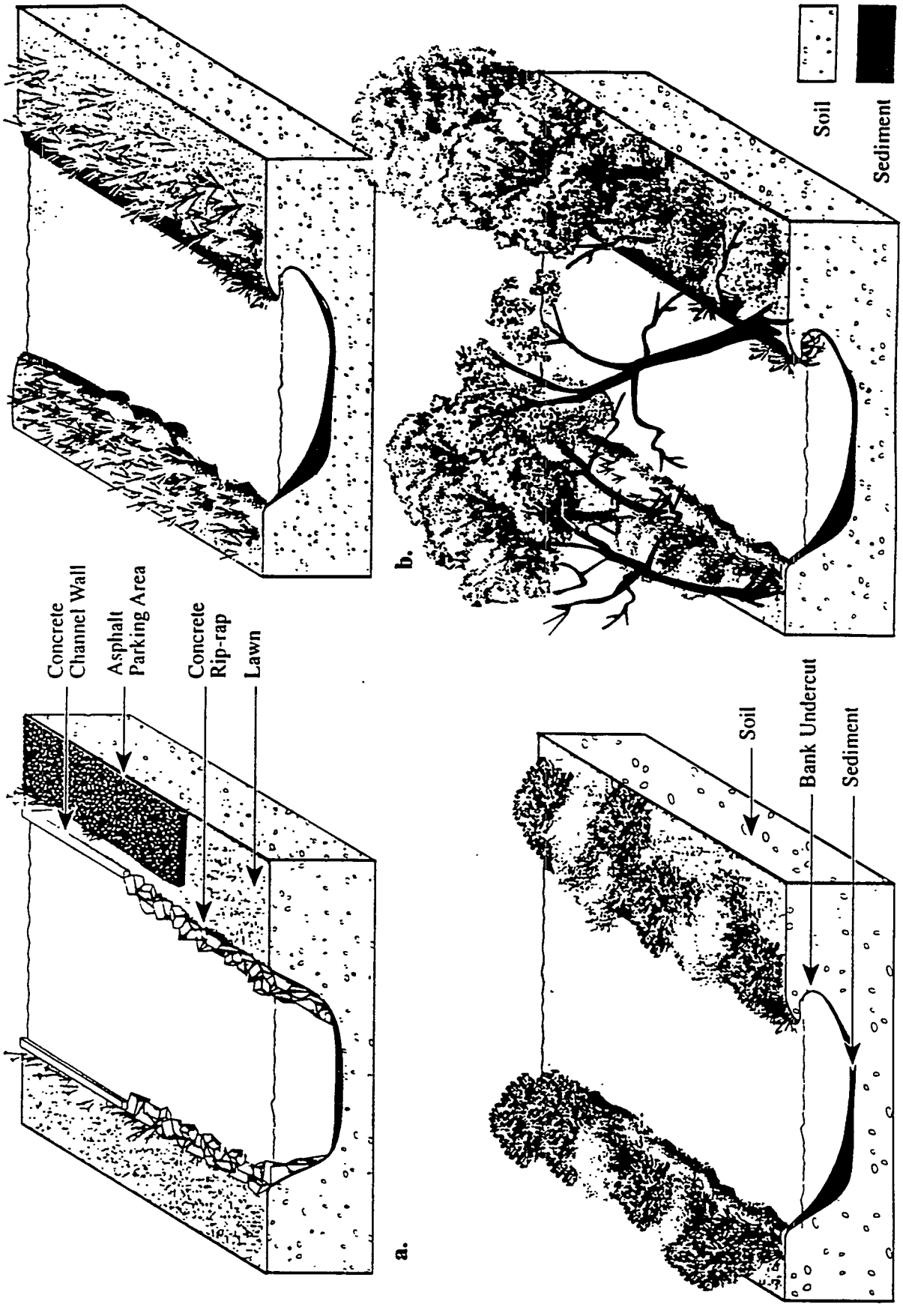


Fig. 2.10. Drawings of four riparian habitat types in Lower EFPC: (a) commercial/built-up; (b) pasture; (c) old field; (d) bottomland hardwood.

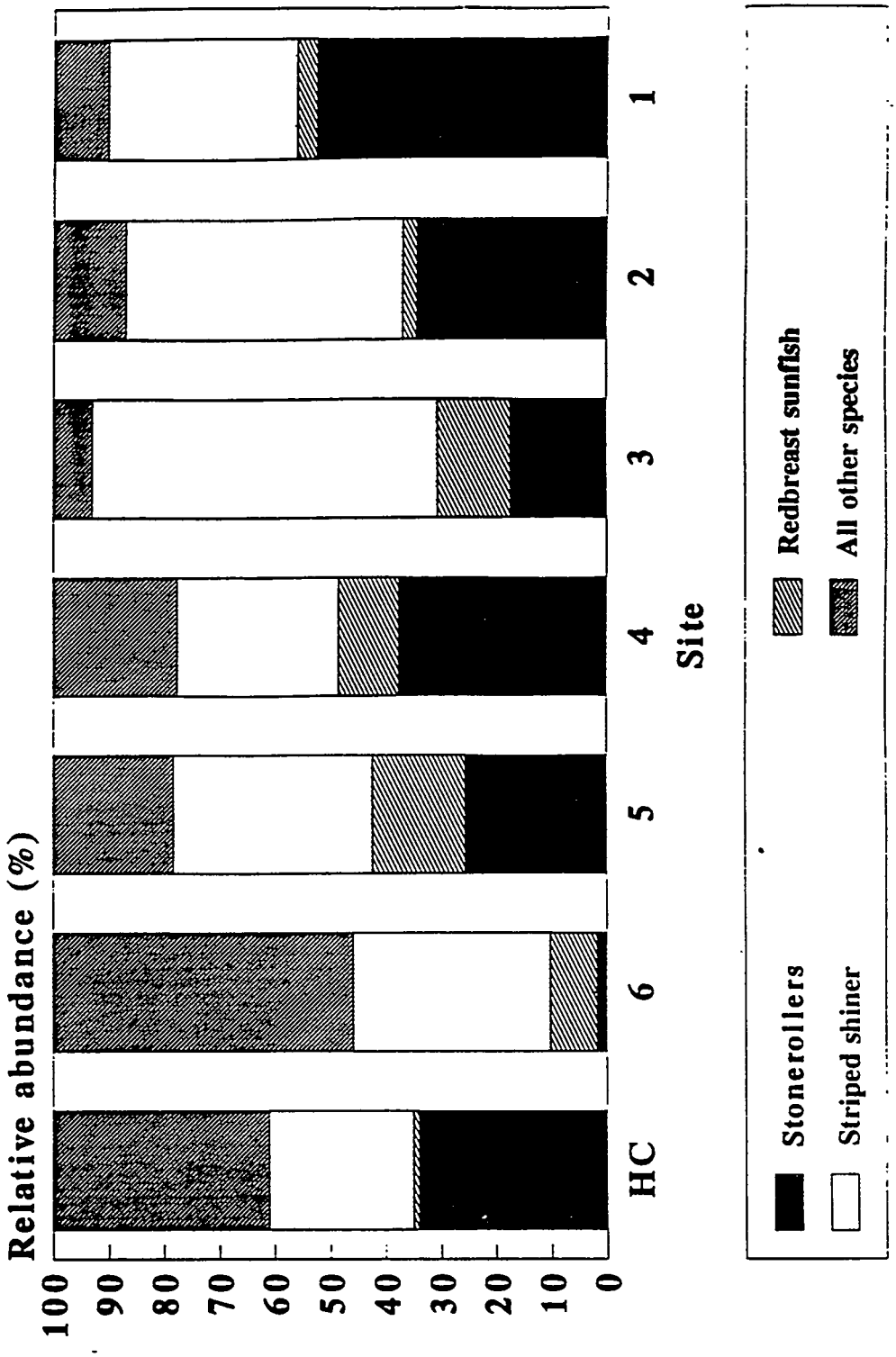


Fig. 2.11. Relative abundance of redbreast sunfish, stonerollers, striped shiners, and the collective remaining fish species captured at each site in EFPC and Hinds Creek.

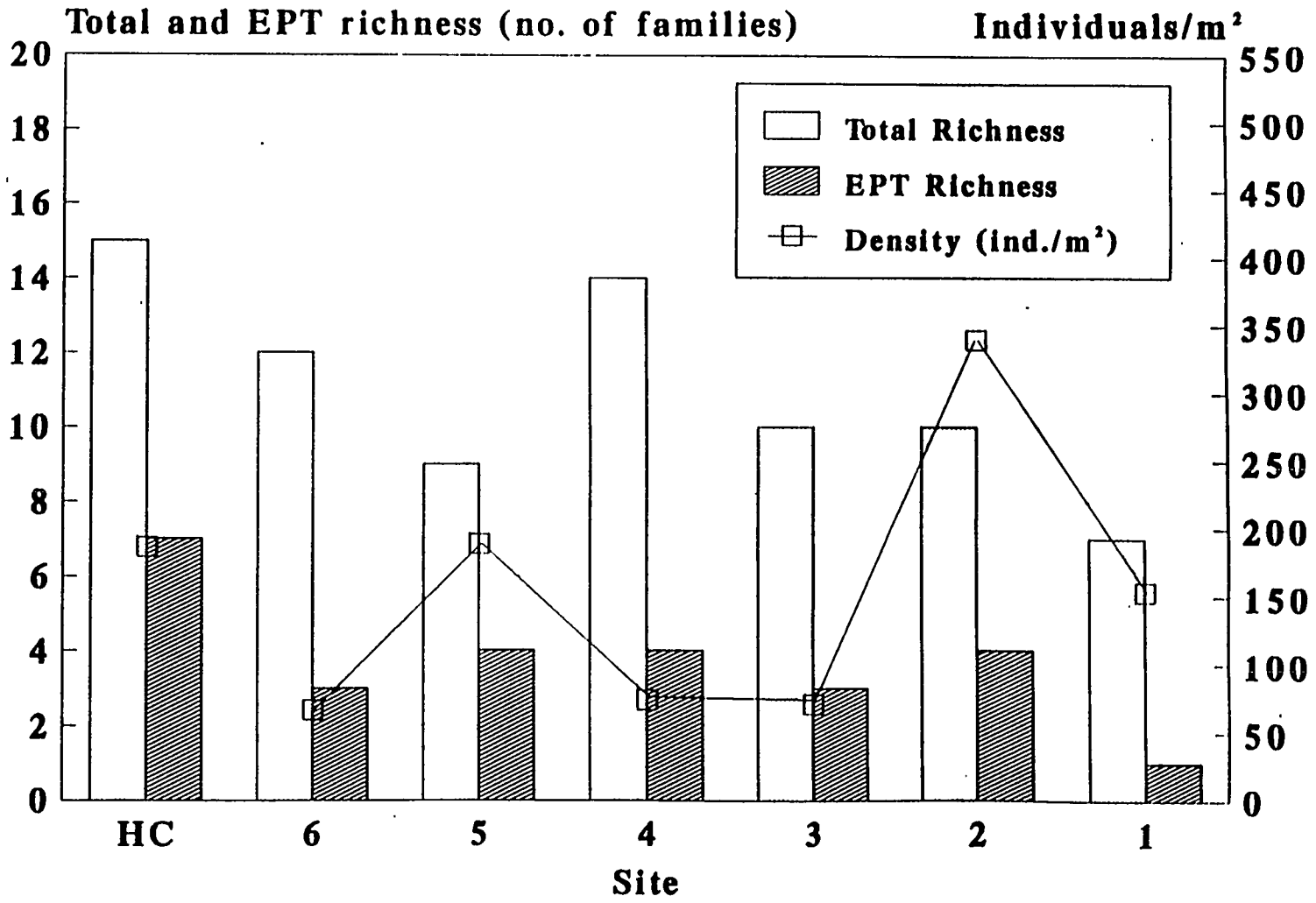


Fig. 2.12. Total family richness, EPT richness, and density (individuals per m²) of benthic macroinvertebrates collected from EFPC and Hinds Creek, October 22-29, 1991.

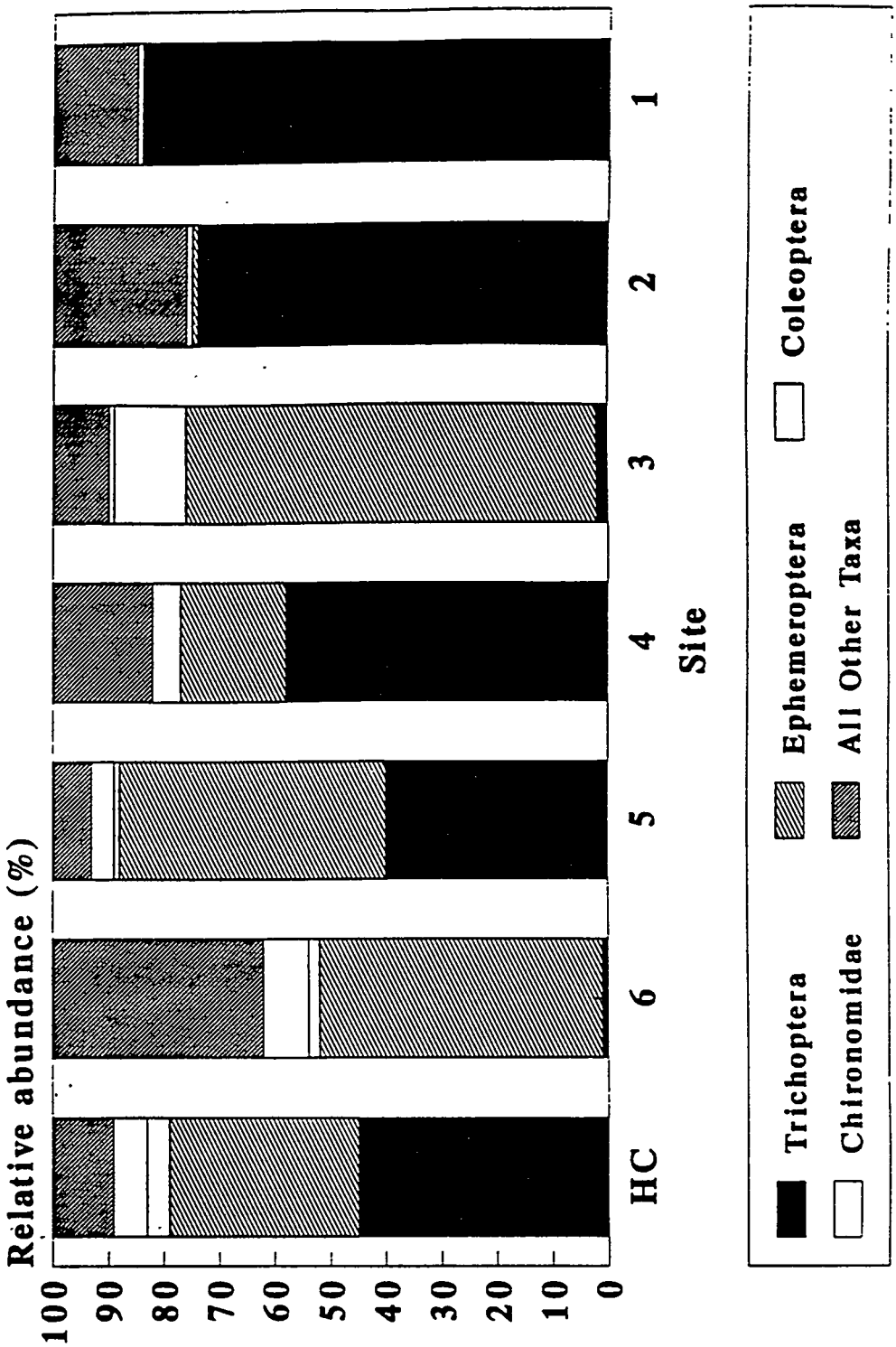


Fig. 2.13. Relative abundance of the dominant benthic macroinvertebrate taxa collected in EFPC and Hinds Creek, October 22-29, 1991.

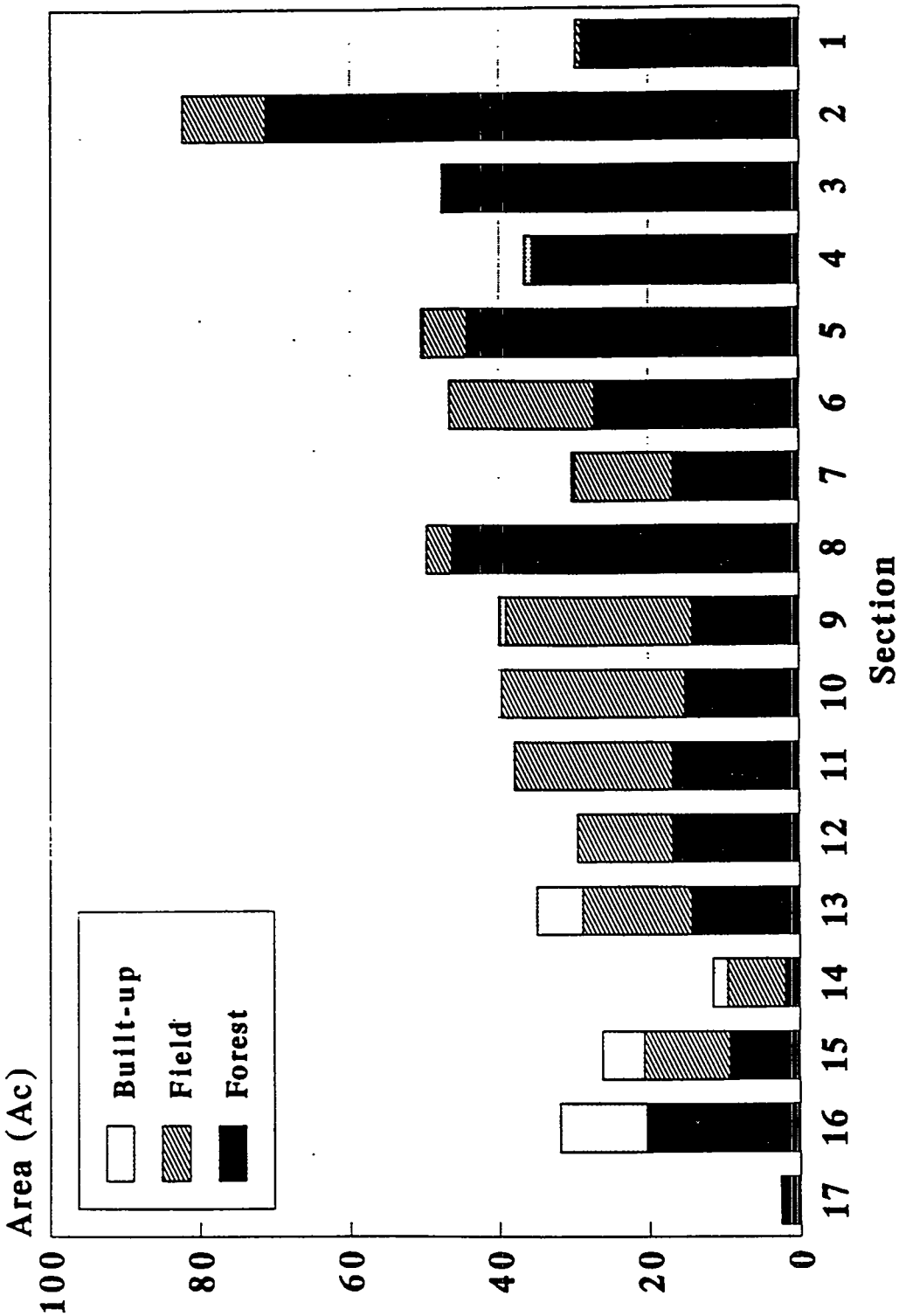


Fig. 2.14. Terrestrial habitats in the EFPC 100-year floodplain by stream section.

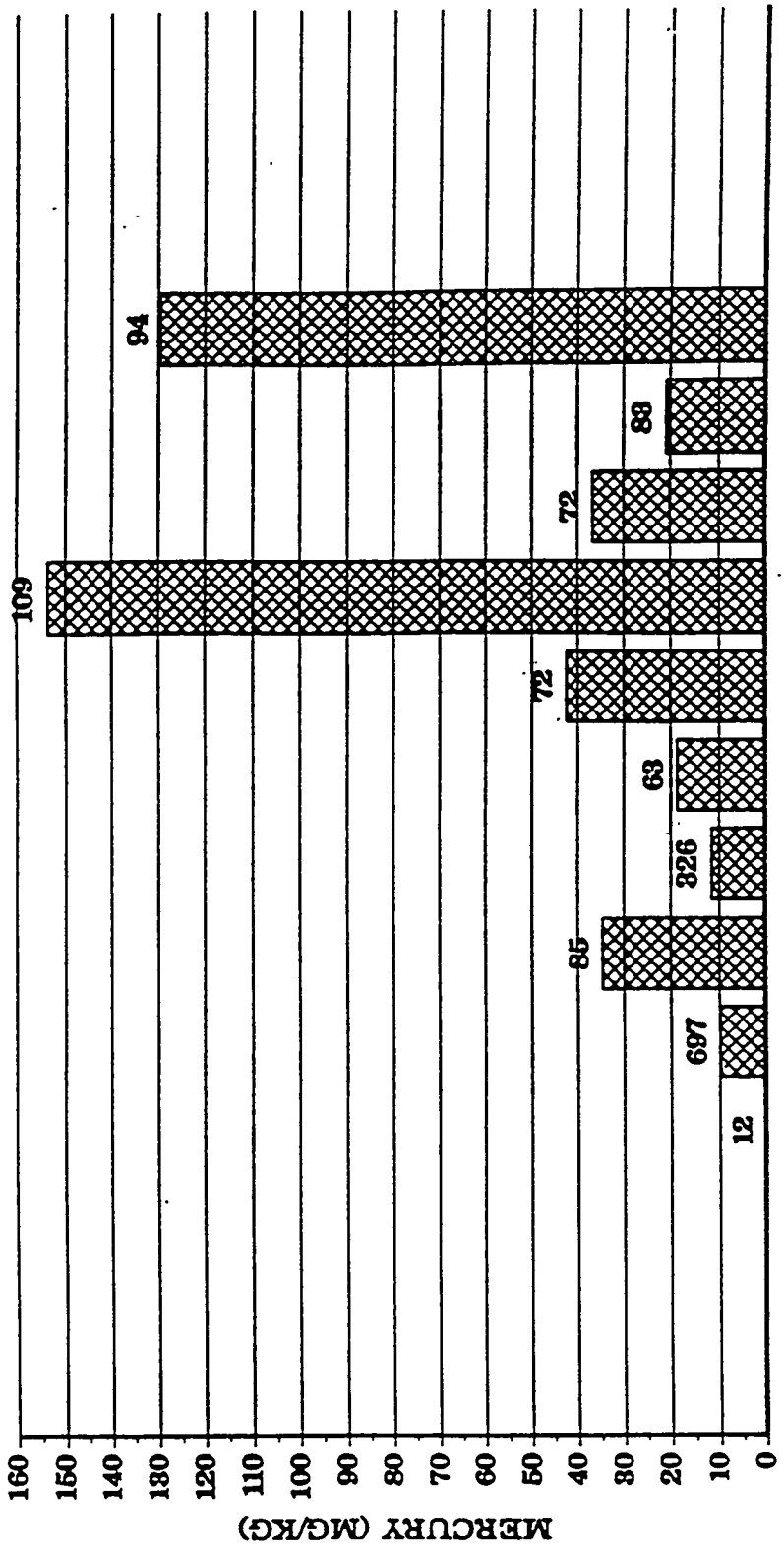


Fig. 2.15. Mean mercury concentrations (mg/kg) in the surface layer of EFPC floodplain soils. Values less than the detection limit were set to zero before averaging. The value above each bar is the number of samples taken. Floodplain segment numbers are plotted going upstream from left to right, and HC refers to the Hinds Creek reference site.

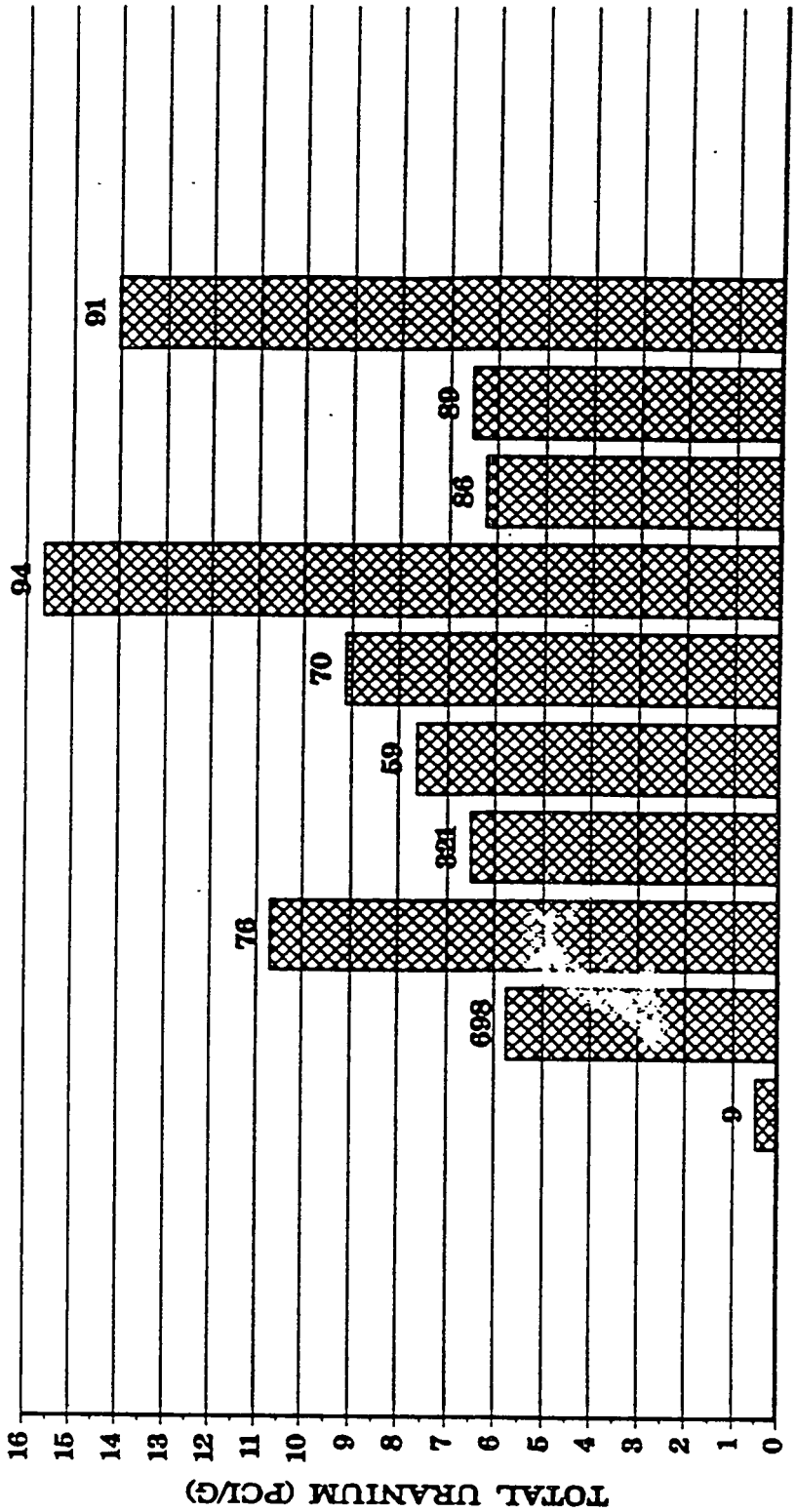


Fig. 2.16. Mean total uranium concentrations (pCi/g) in the surface layer of EFPC floodplain soils. Values less than the detection limit were set to zero before averaging. The value above each bar is the number of samples taken. Floodplain segment numbers are plotted going upstream from left to right, and HC refers to the Hinds Creek reference site.

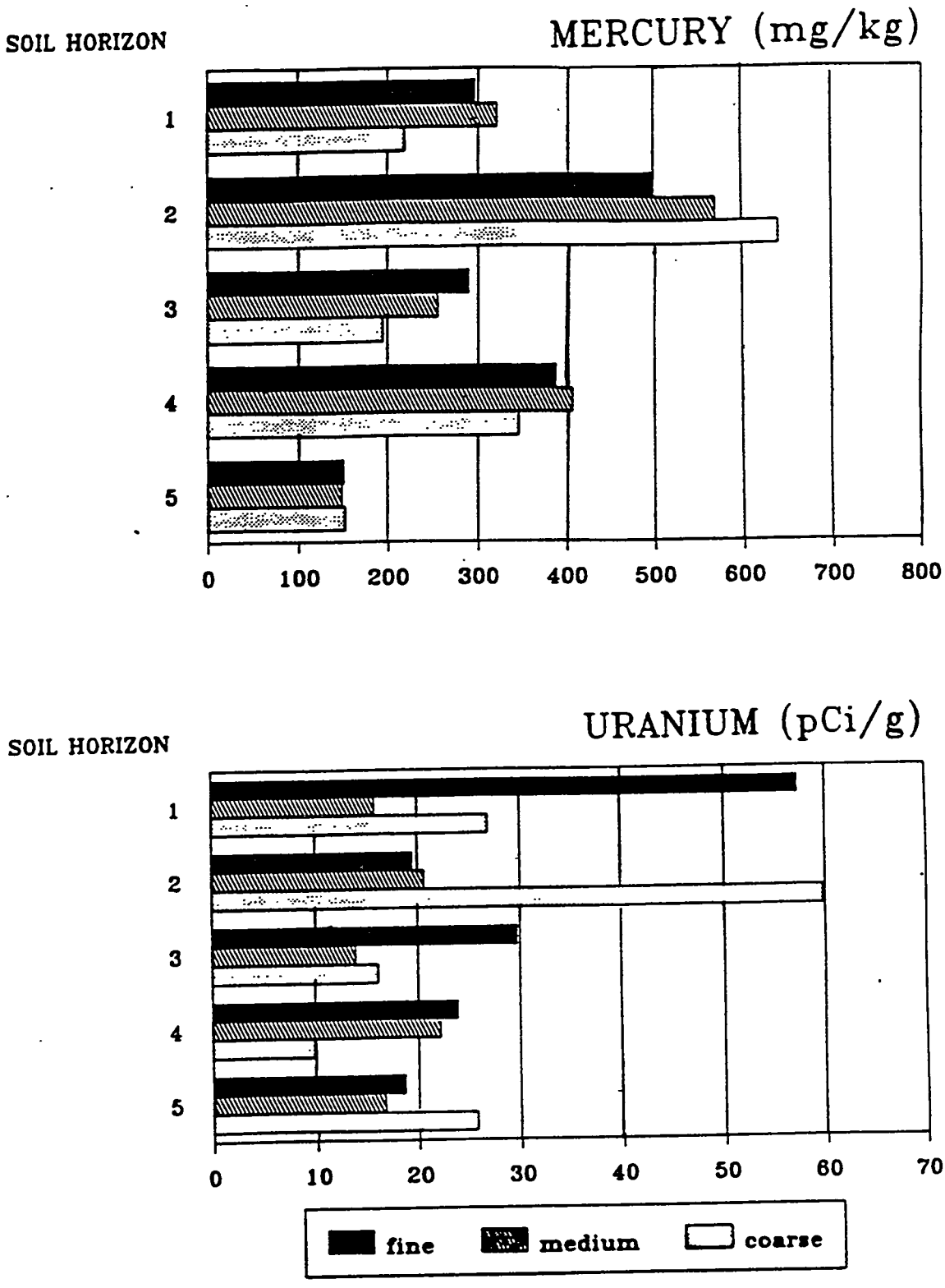


Fig. 2.17. Mean uranium activity and mercury concentrations in EFPC floodplain soils by horizon.

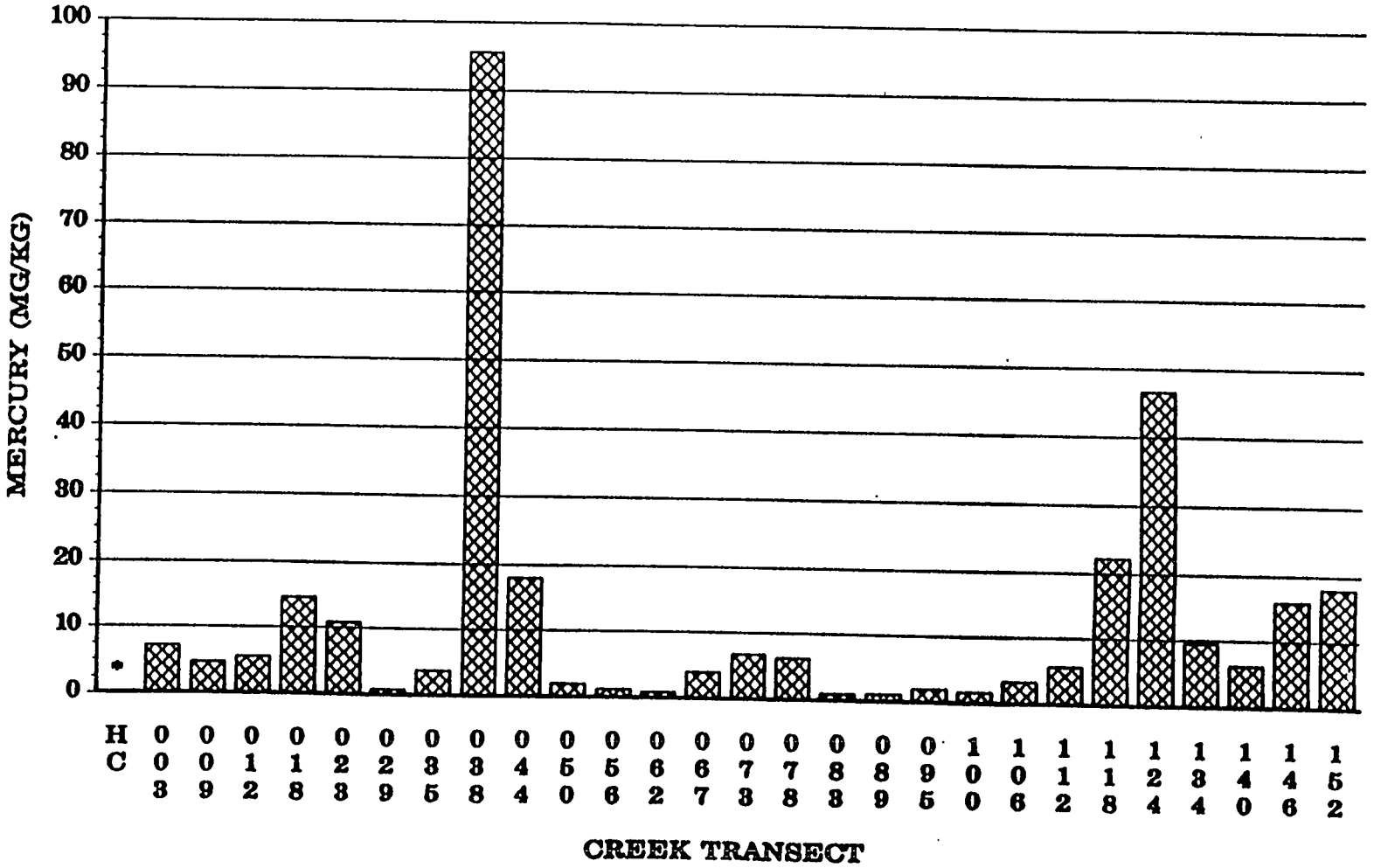


Fig. 2.18. Mercury concentrations (mg/kg) in EFPC sediments. Each bar represents a composite of three samples taken ~200 m apart. The bar is labeled with the transect number of the central sample of the composite. Transect numbers increase moving upstream. The average of two samples from the reference station is labeled "HC." Results less than the detection limit were set to zero and marked with an "*."

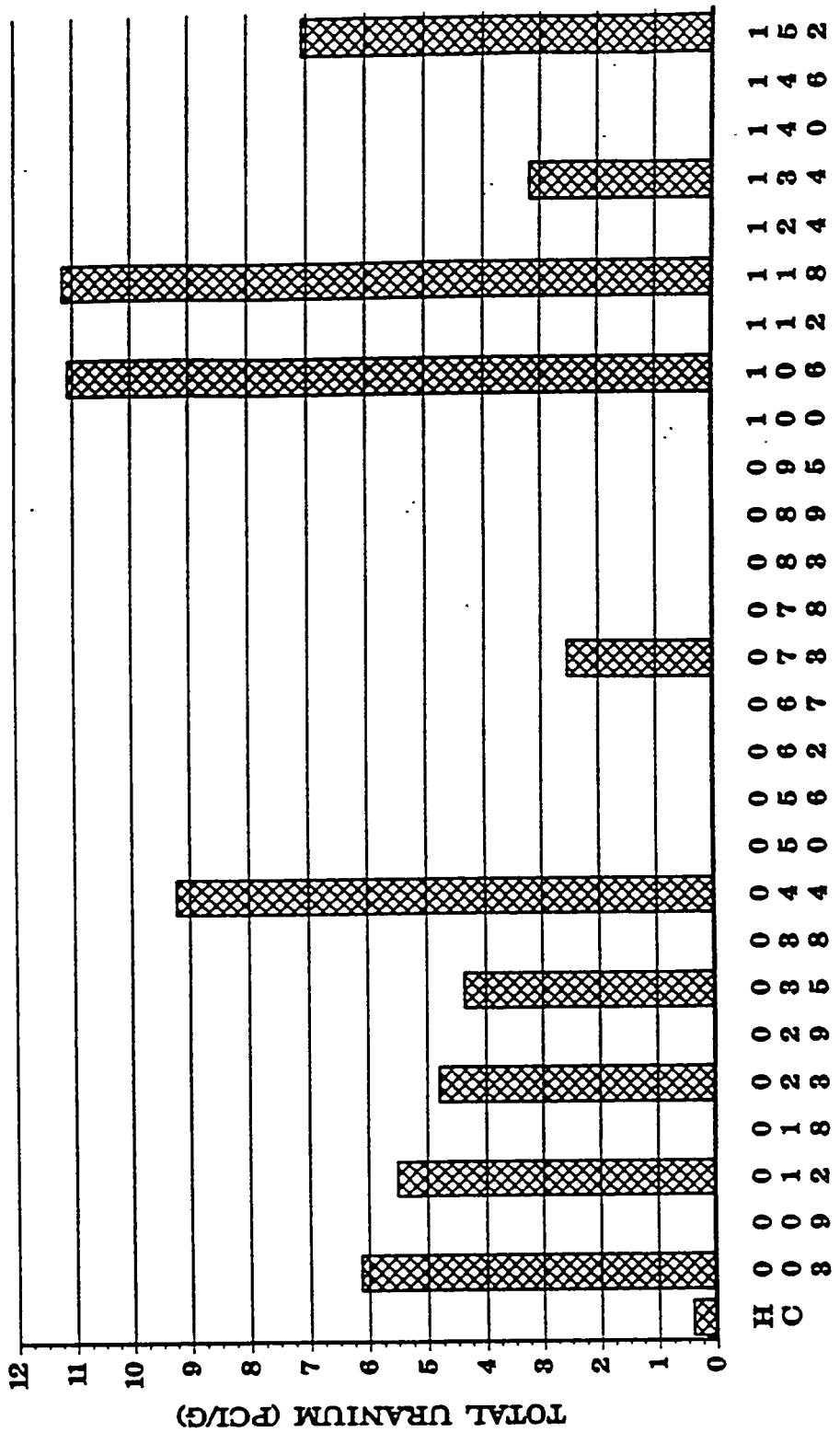


Fig. 2.19. Total uranium concentrations (pCi/g) in EFPC sediments. Each bar represents a composite of three samples taken ~200 m apart. The bar is labeled with the transect number of the central sample of the composite. Transect numbers increase moving upstream. The average of two samples from the reference station is labeled "HC." Results less than the detection limit were set to zero and marked with an "*."

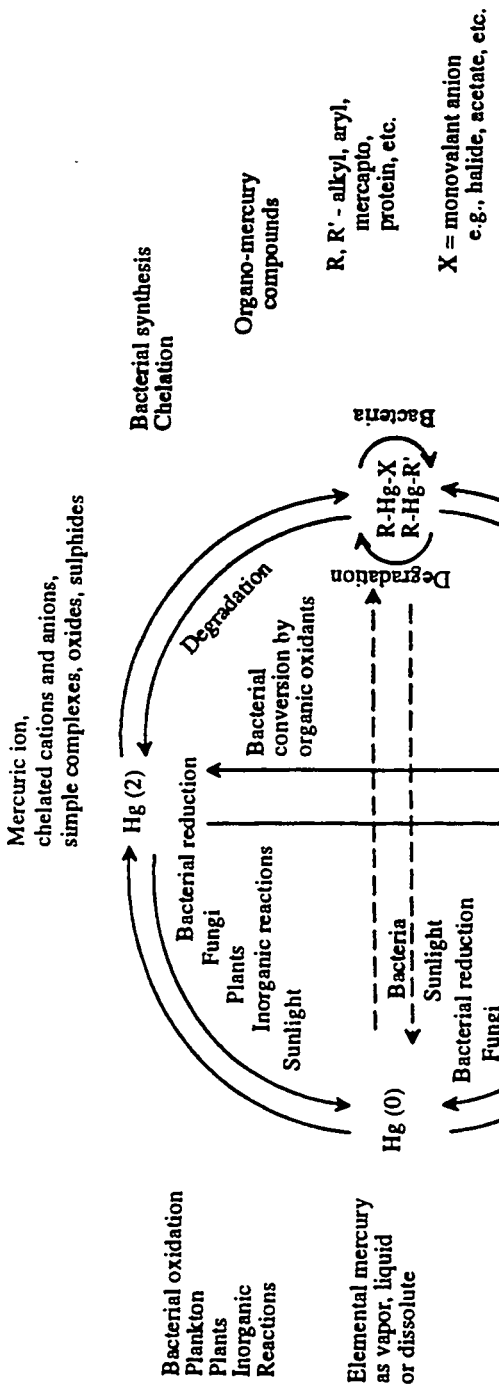


Fig. 2.20. Cycle of mercury conversions in nature. *Source:* Jonasson and Boyle 1972.

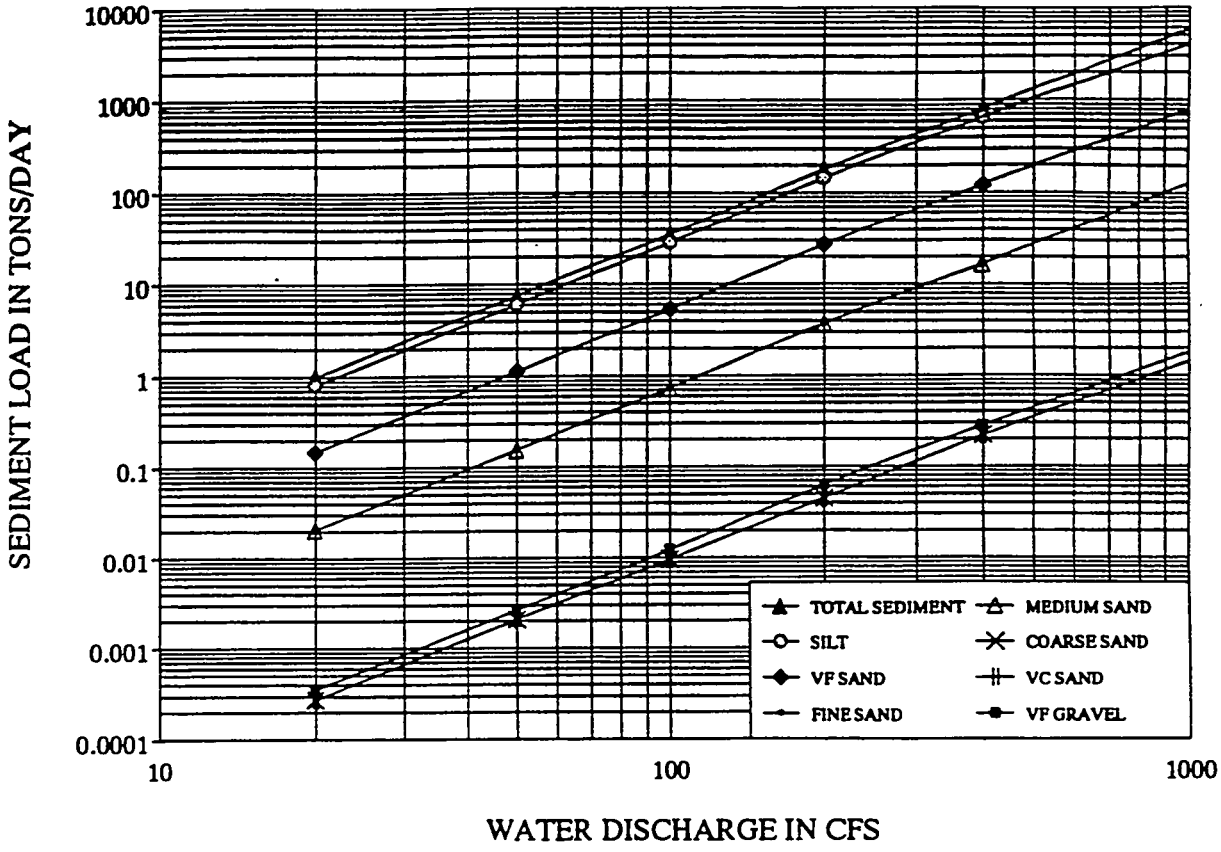


Fig. 2.21. Water-sediment inflow relationship, EFPCM 3.3.

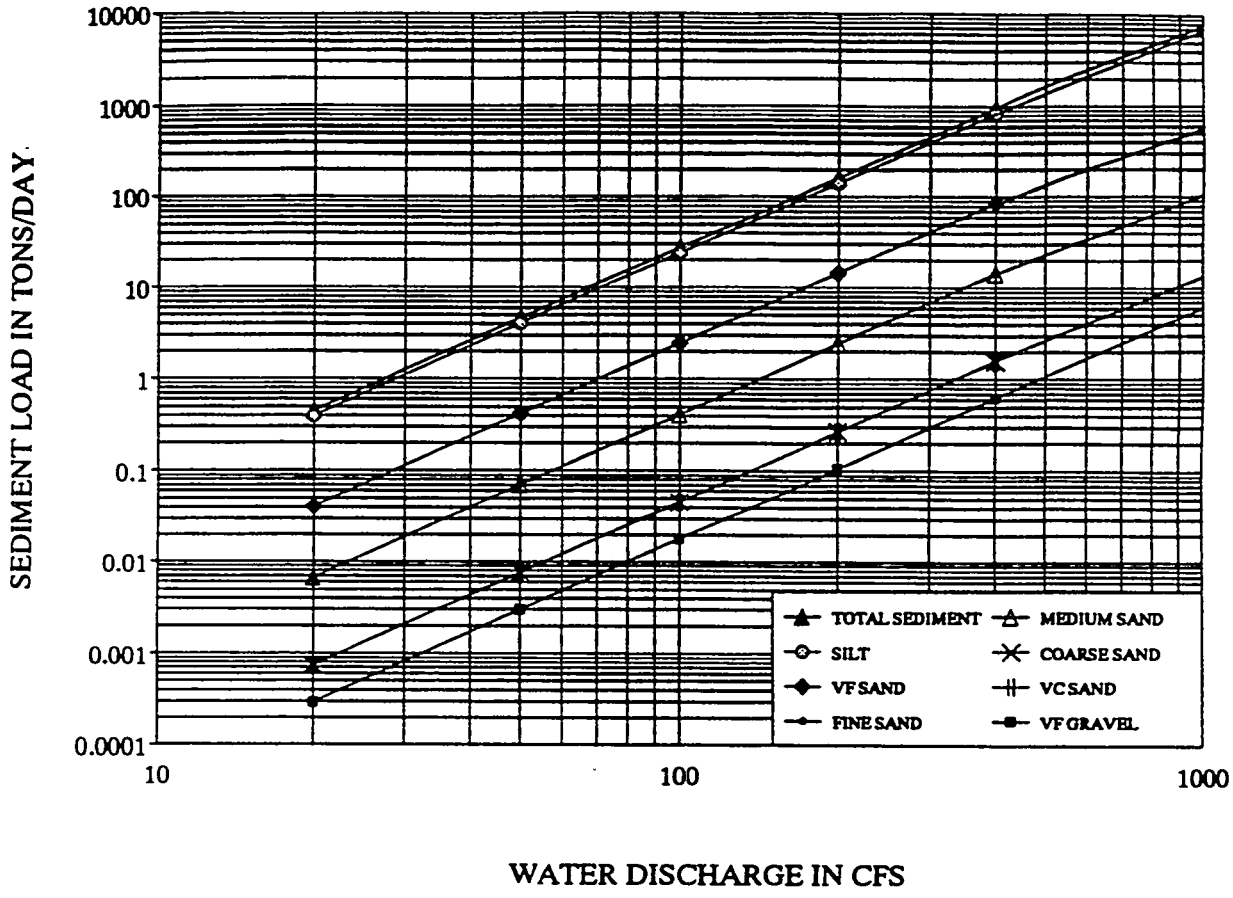


Fig. 2.22. Water-sediment inflow relationship, EFPCM 6.89.

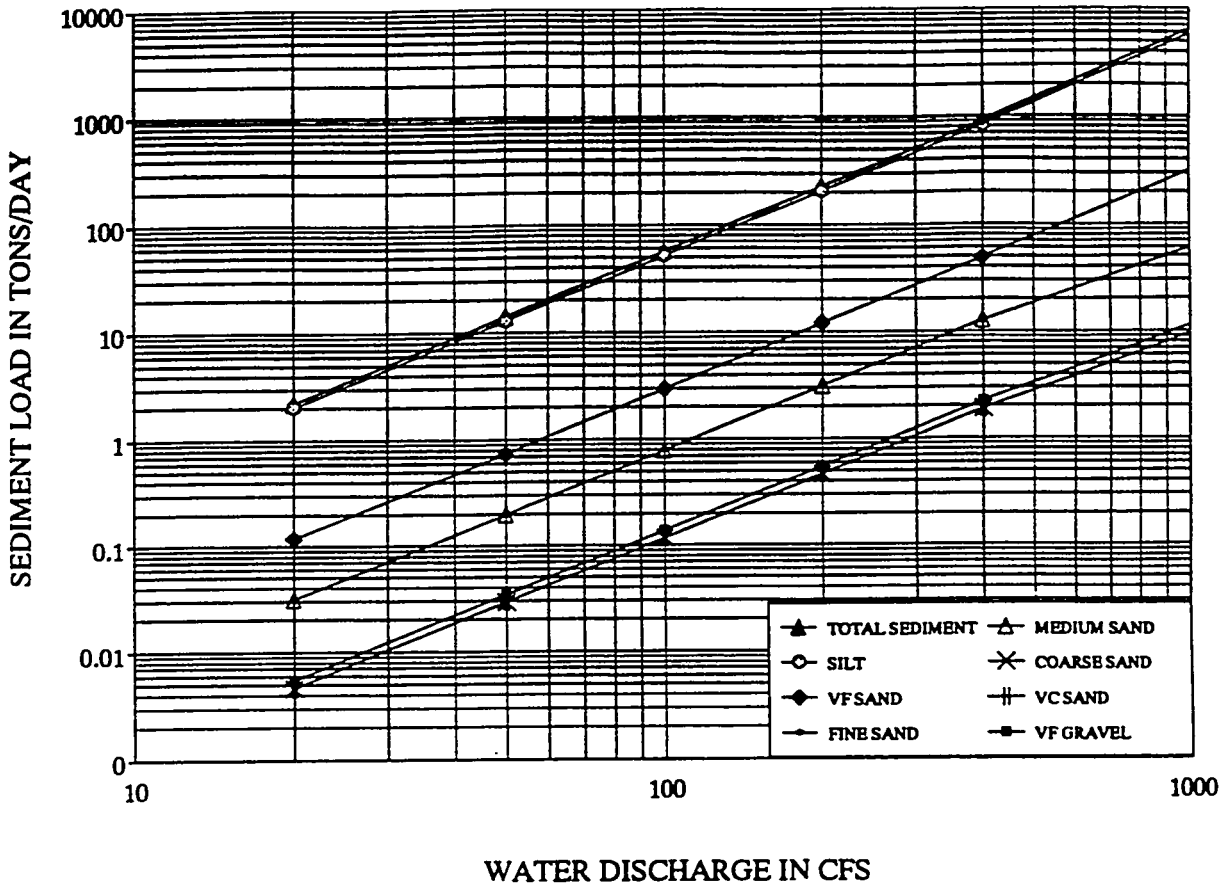


Fig. 2.23. Water-sediment inflow relationship, EFPCM 10.0.

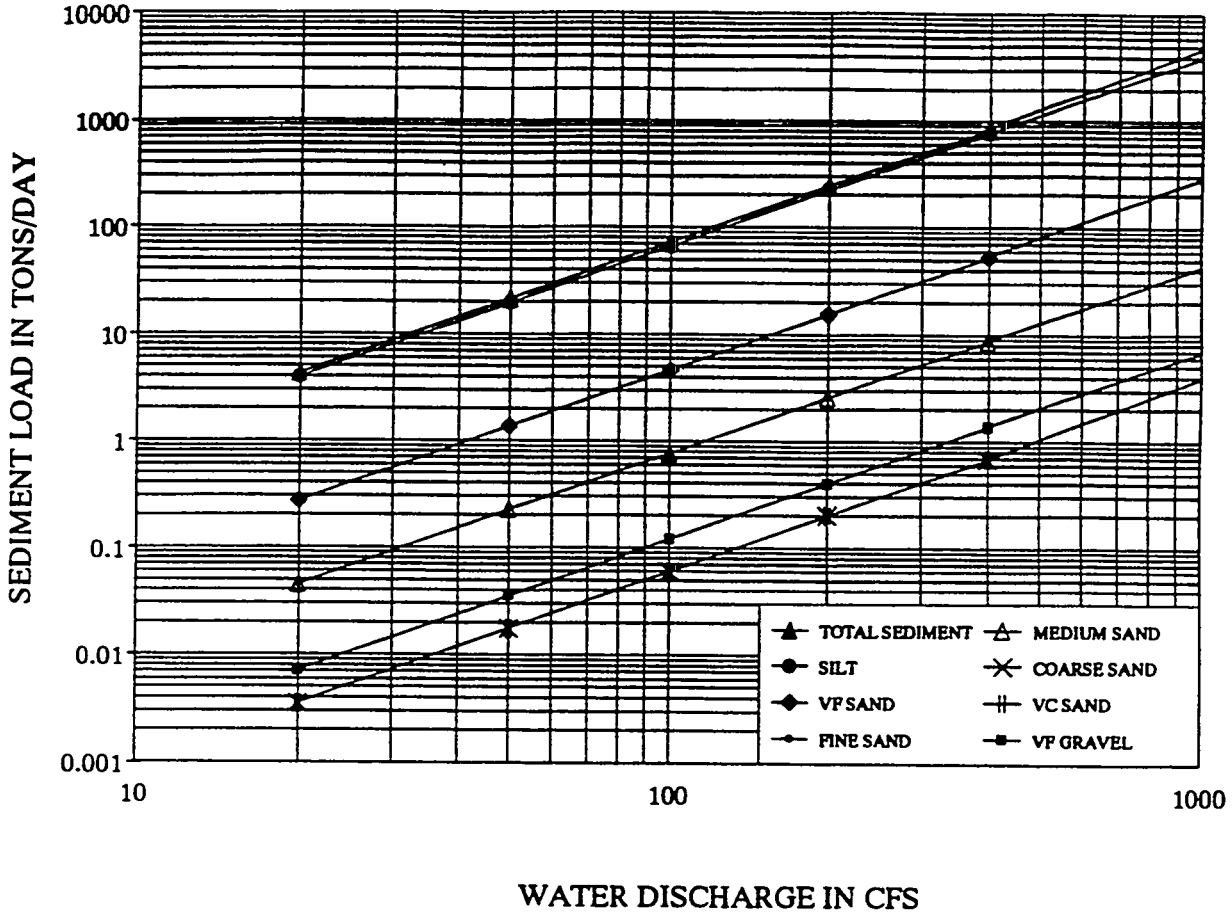


Fig. 2.24. Water-sediment inflow relationship, EFPCM 14.36.

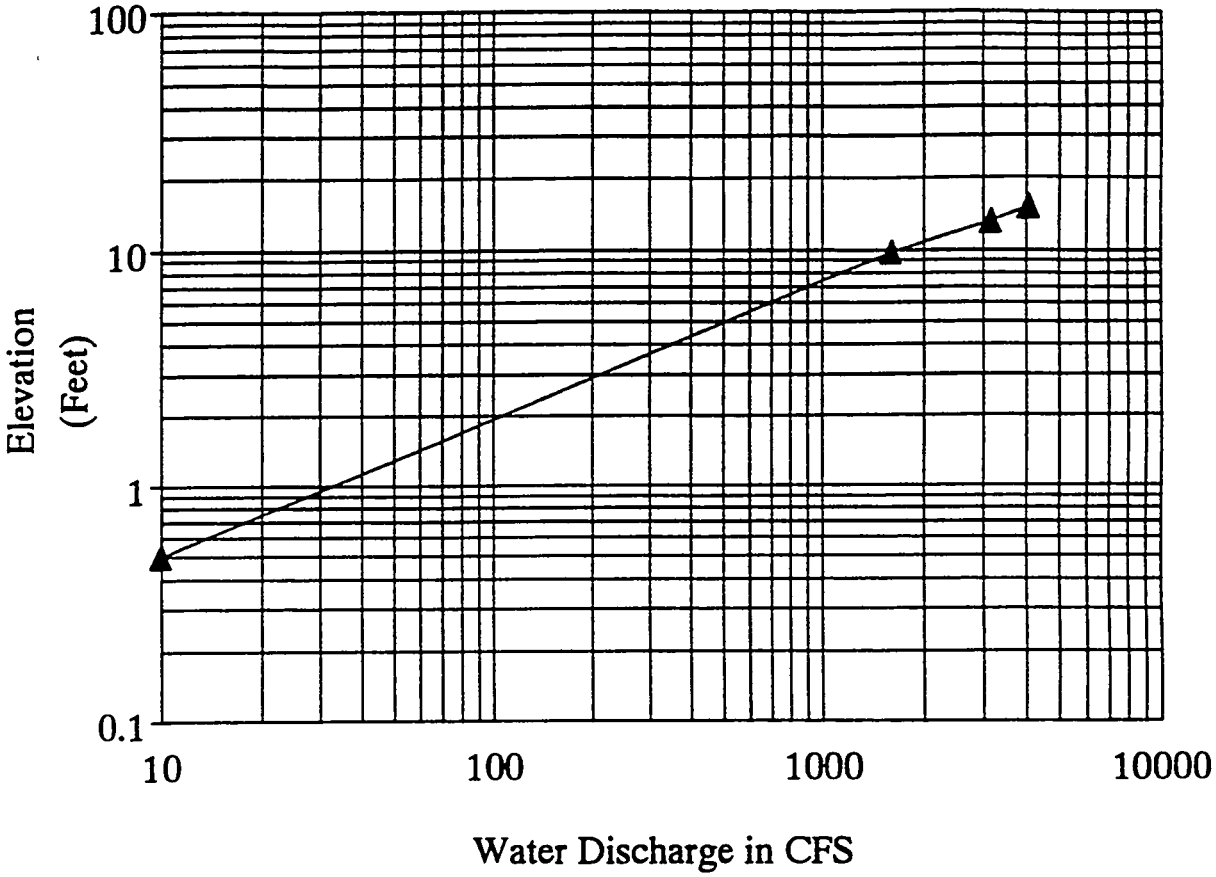


Fig. 2.25. Elevation/discharge rating curve, EFPCM 1.66.

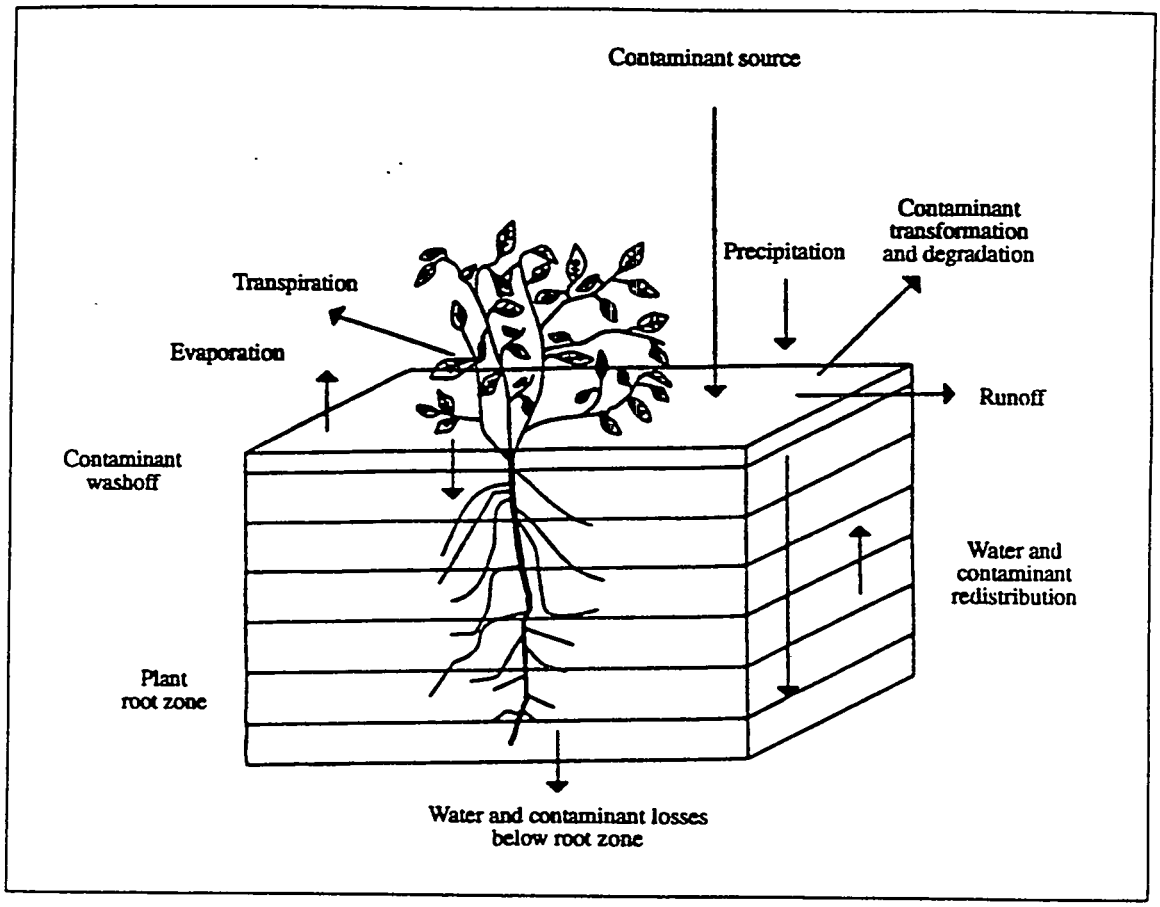


Fig. 2.26. The physical system and process represented in the GLEAMS model (after Leonard et al. 1987).

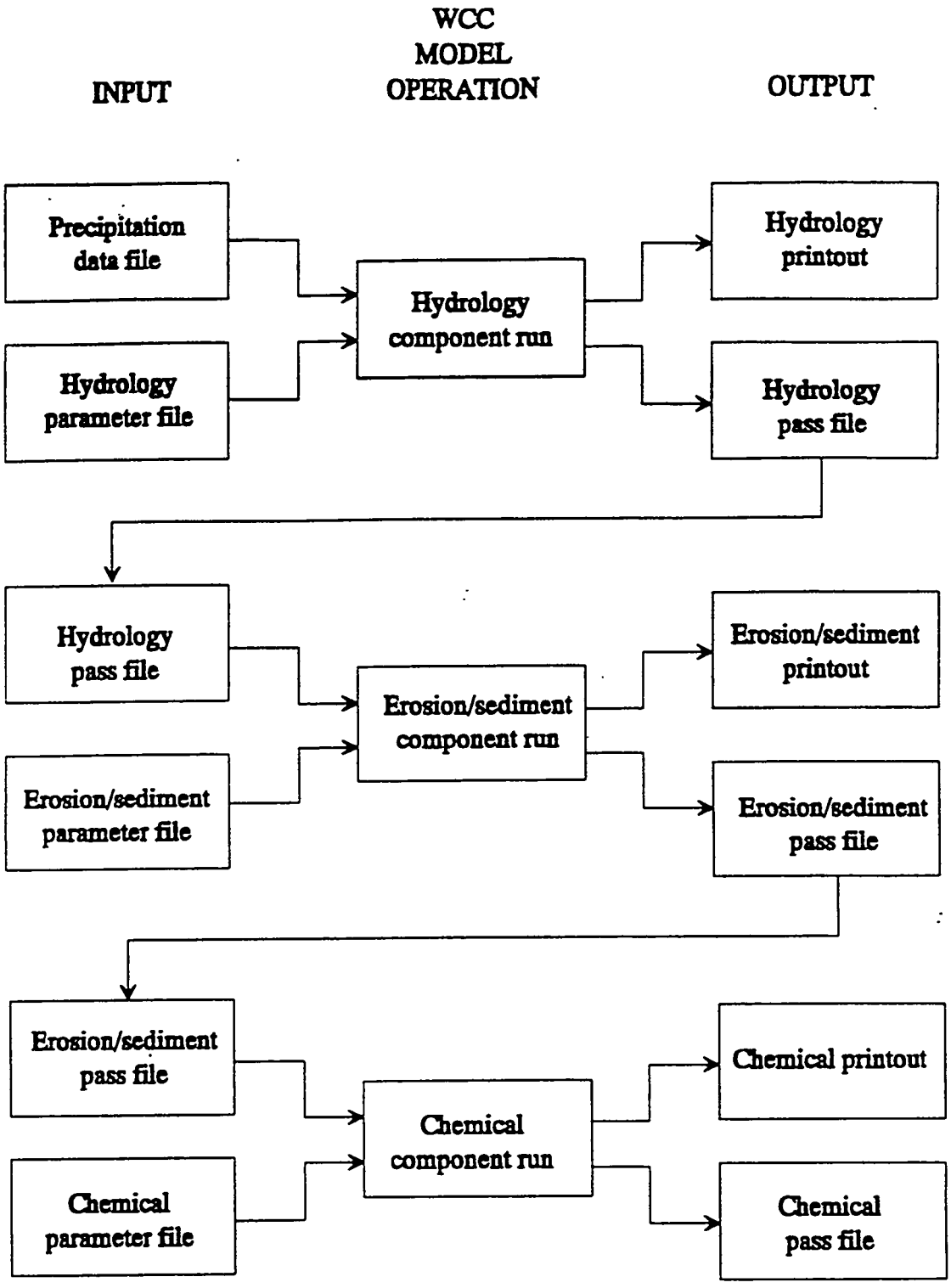


Fig. 2.27. Flow chart of CREAMS model operation (adapted from USDA 1984).

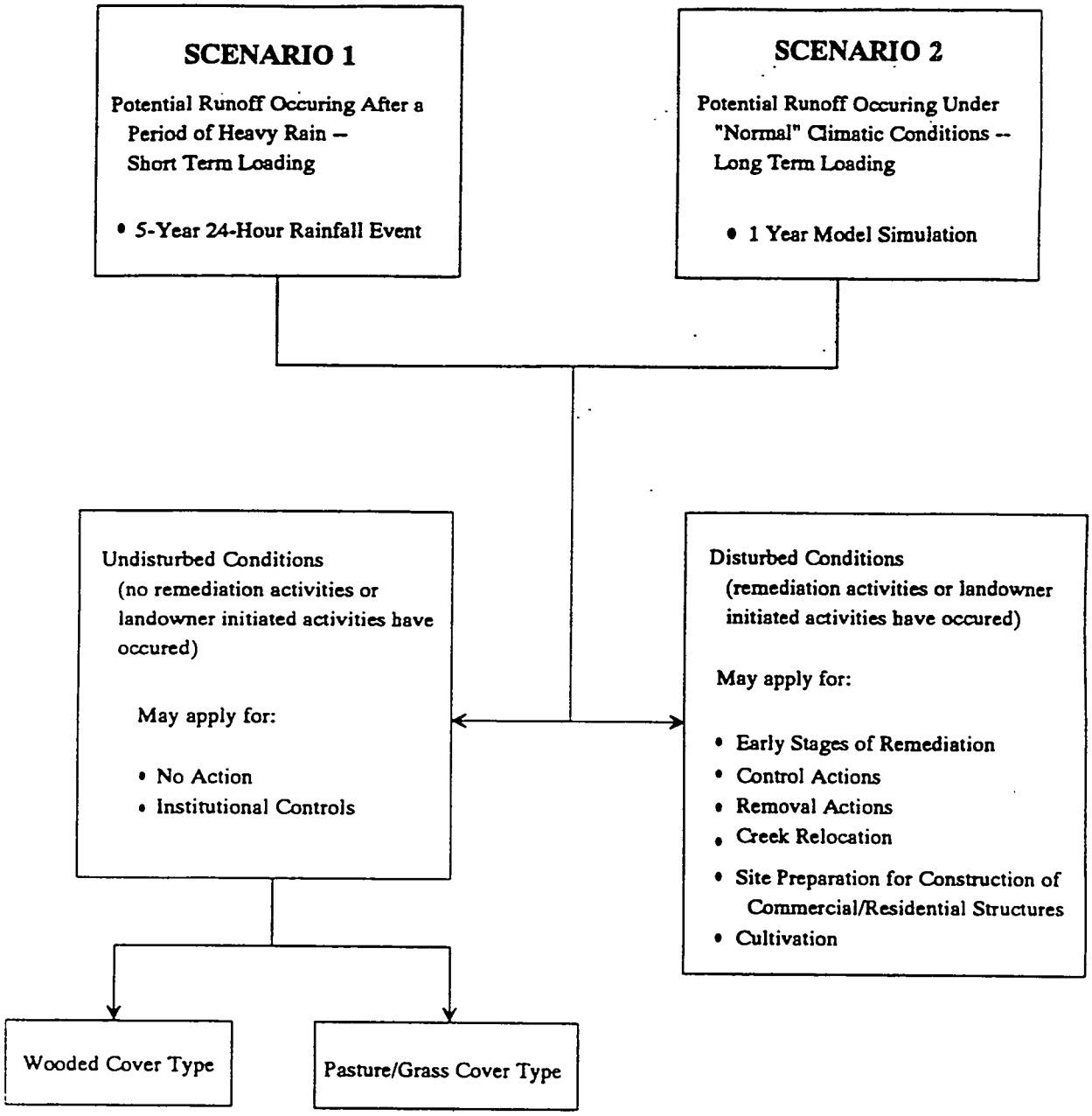


Fig. 2.28. GLEAMS modeling schematic.

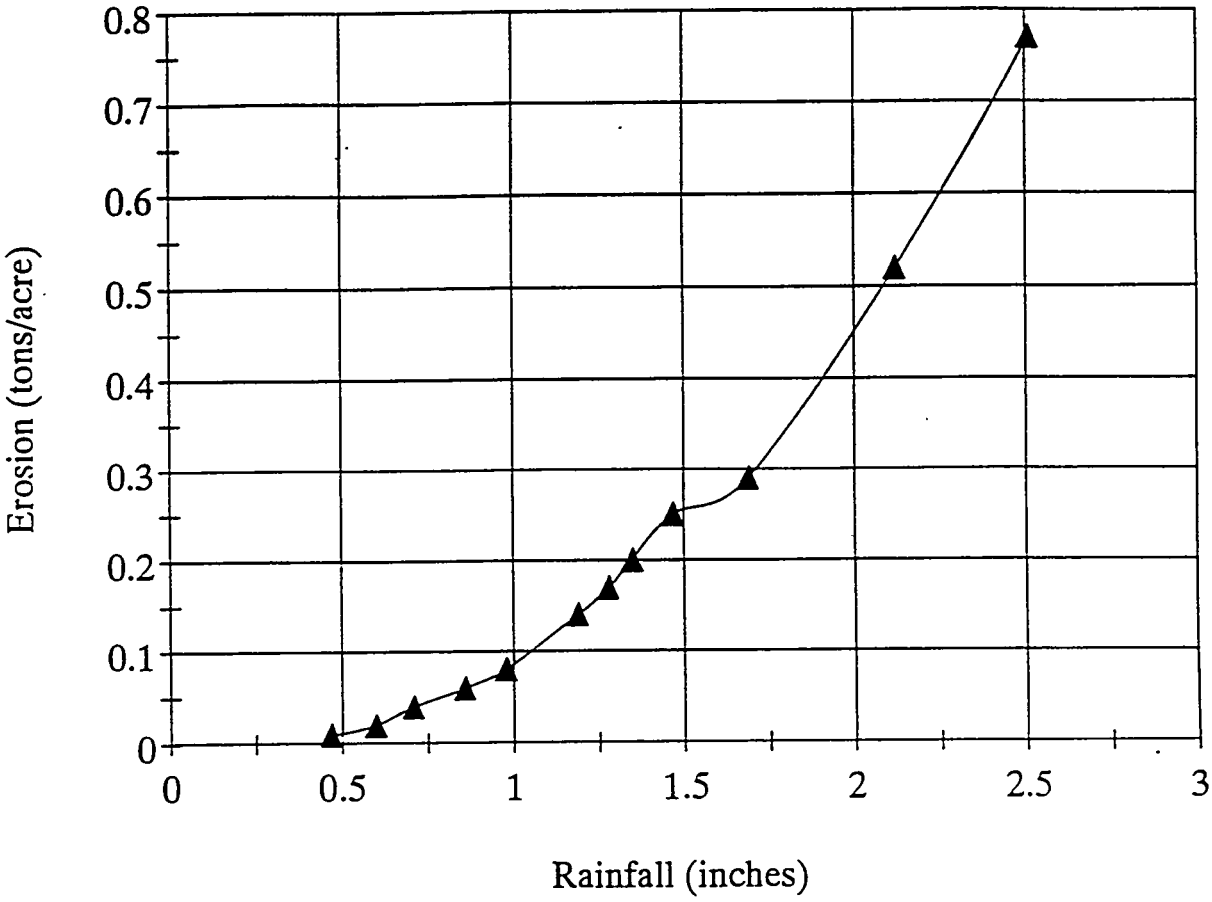


Fig. 2.29. Erosion loss from areas of disturbed Hamblen soil predicted by the GLEAMS model simulation during 24-h rainfall events.

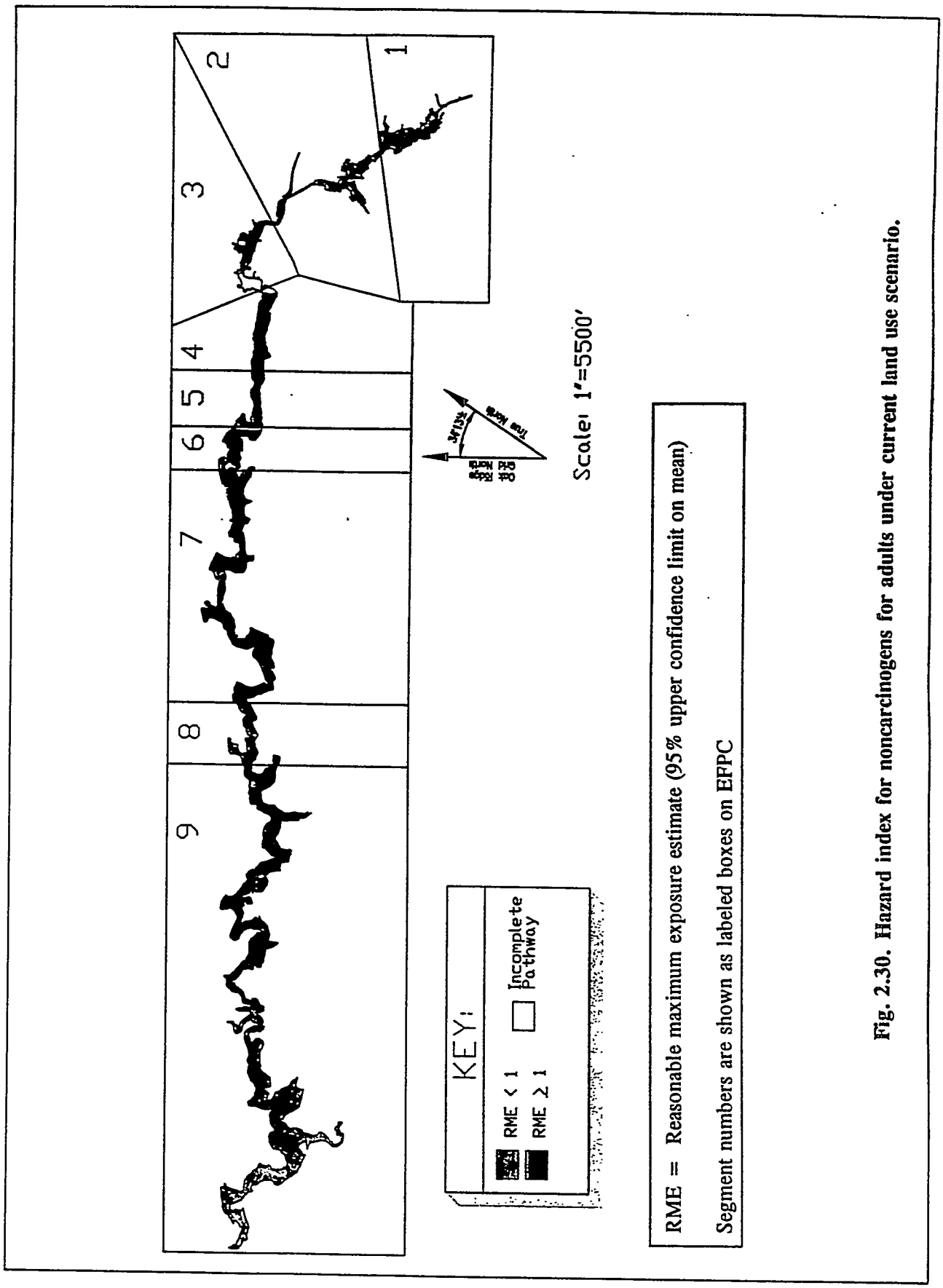


Fig. 2.30. Hazard index for noncarcinogens for adults under current land use scenario.

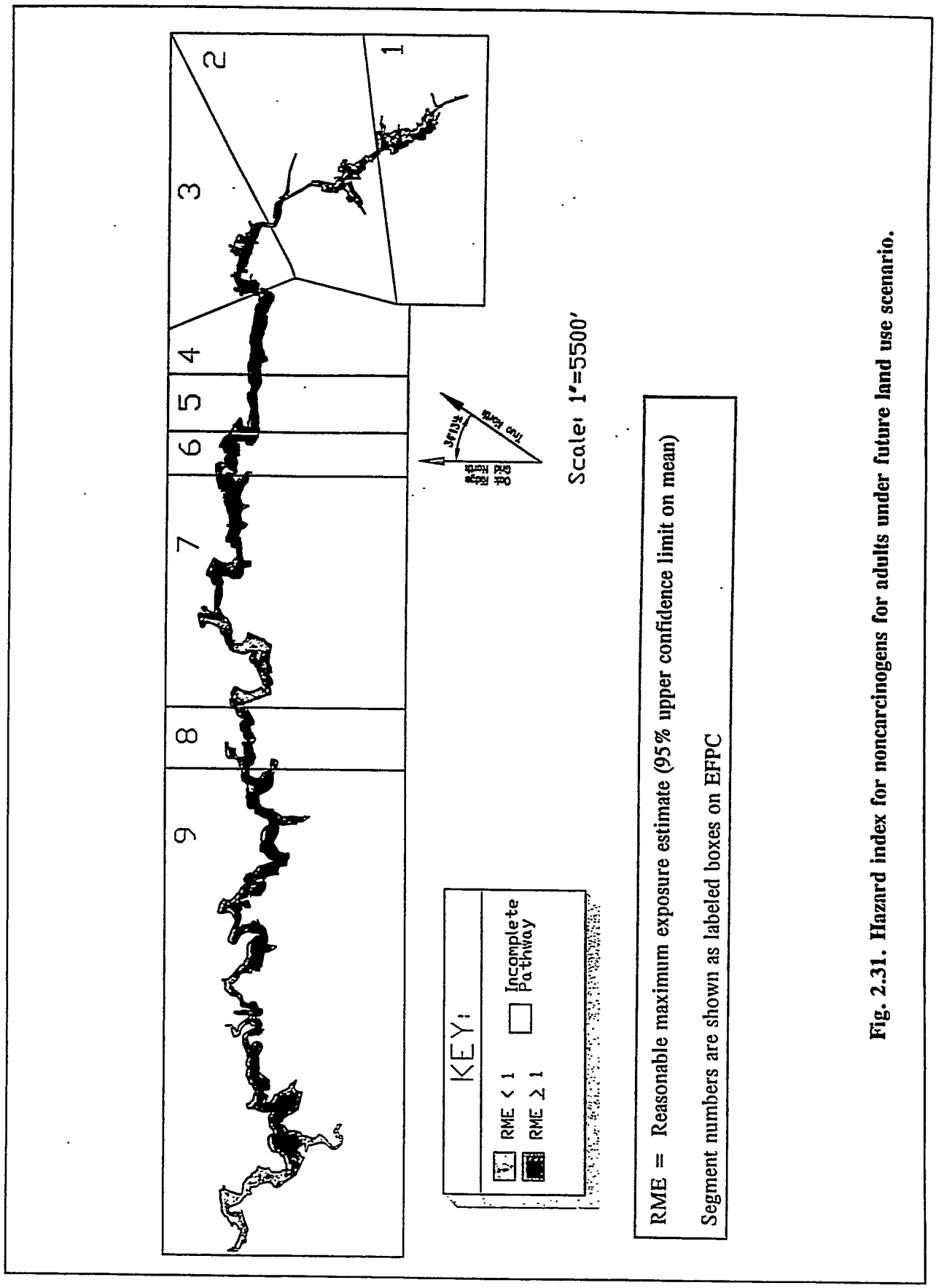


Fig. 2.31. Hazard index for noncarcinogens for adults under future land use scenario.

This page intentionally left blank.

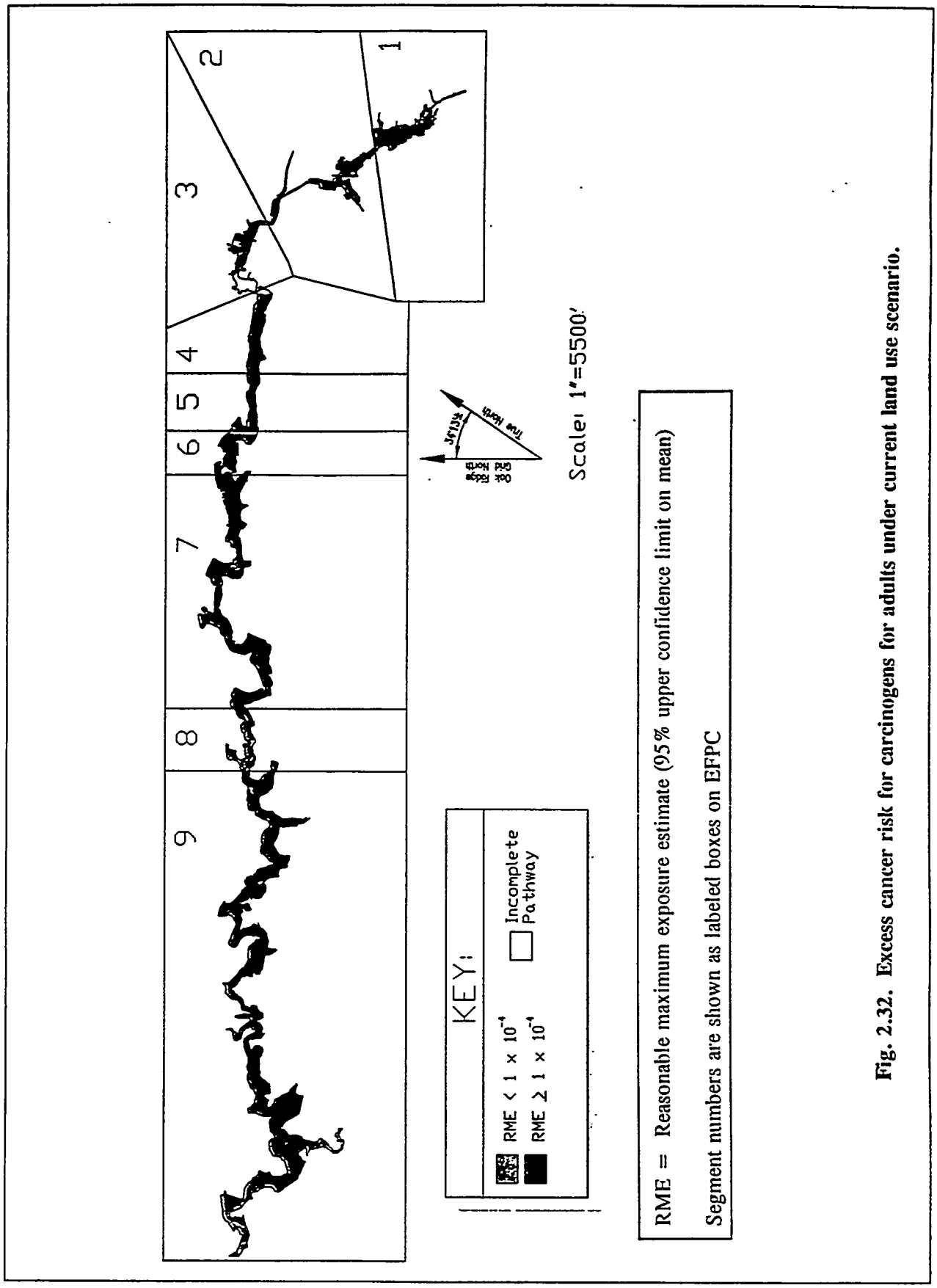


Fig. 2.32. Excess cancer risk for carcinogens for adults under current land use scenario.

This page intentionally left blank.

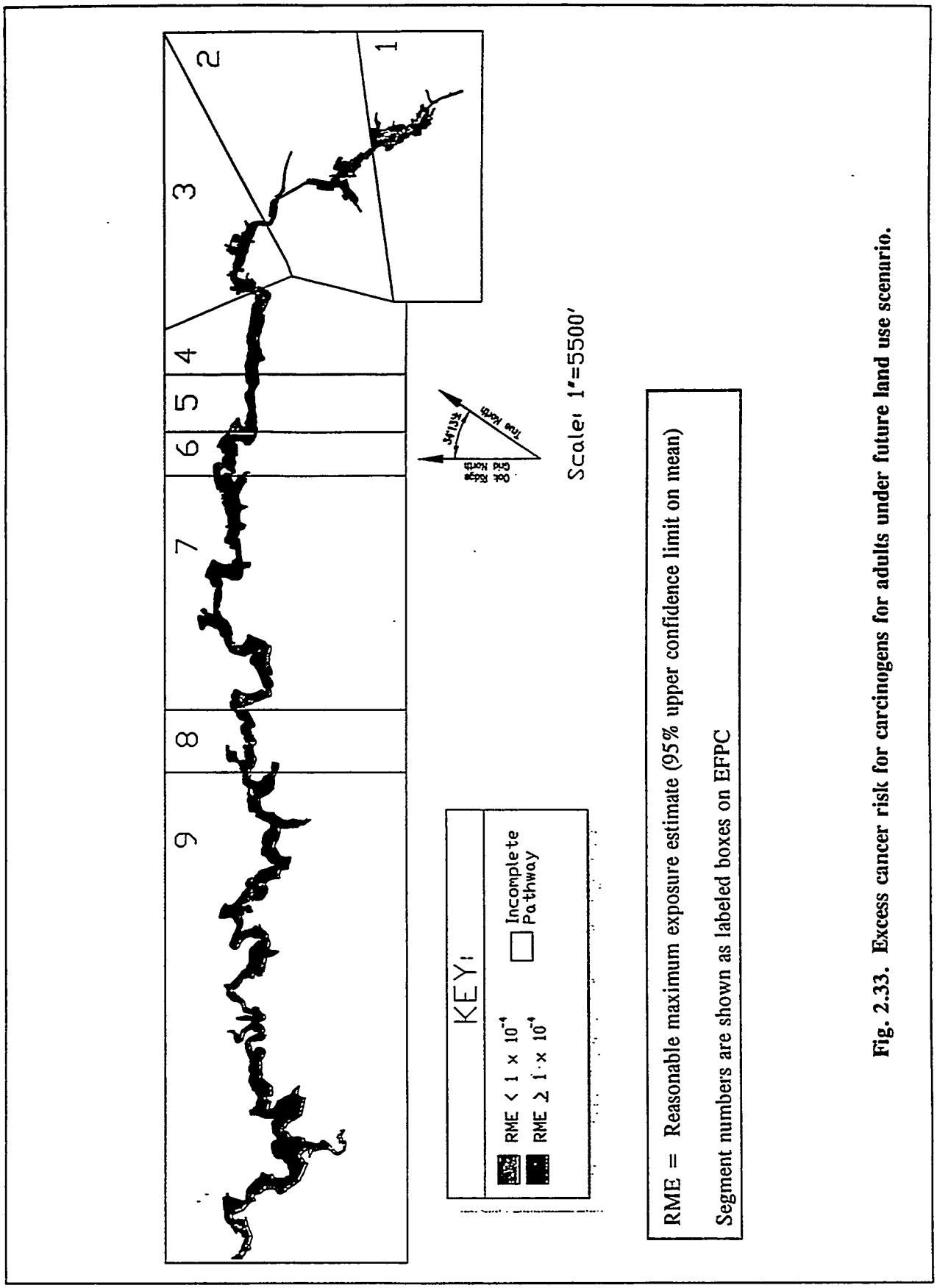


Fig. 2.33. Excess cancer risk for carcinogens for adults under future land use scenario.

This page intentionally left blank.

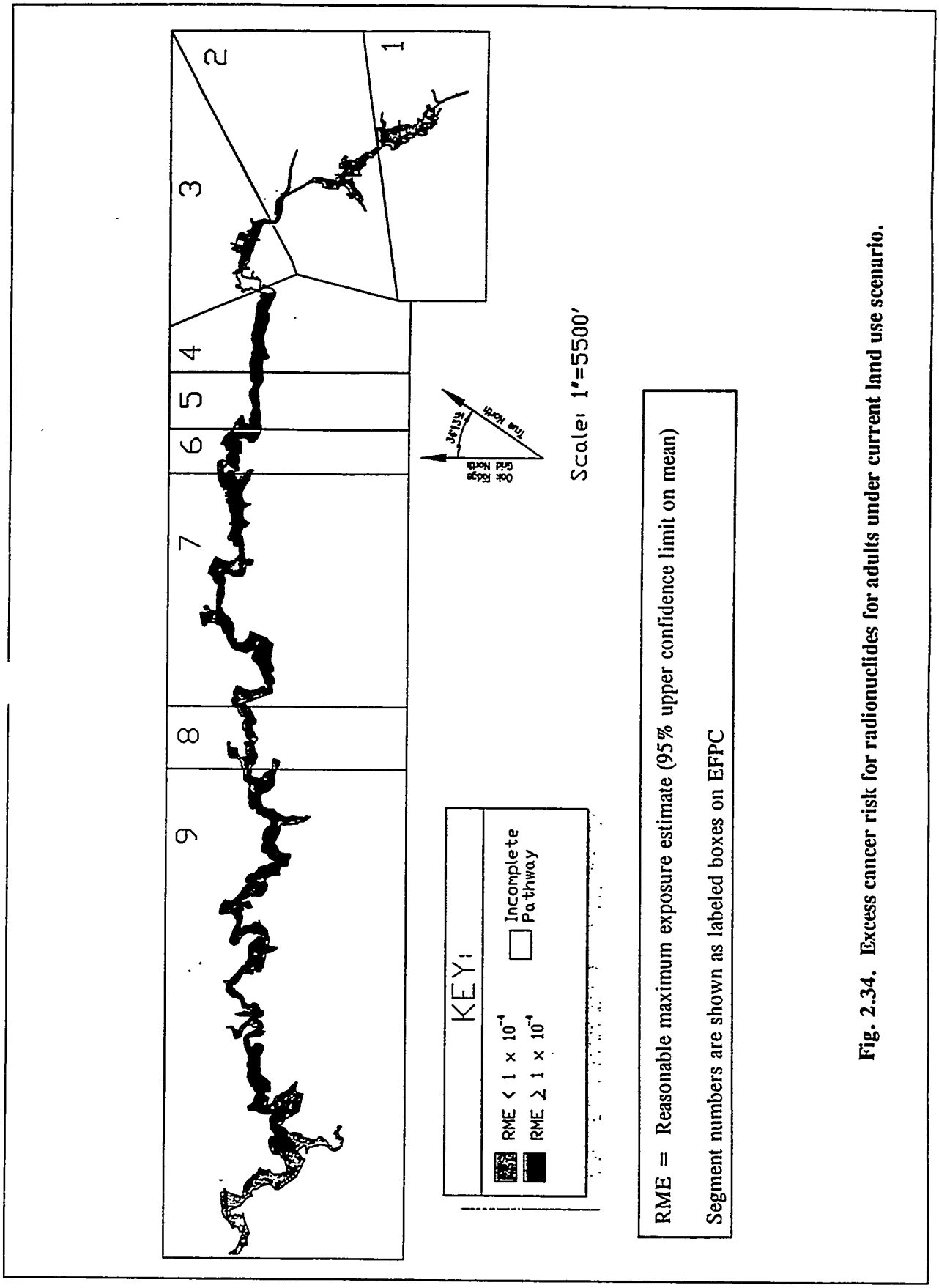


Fig. 2.34. Excess cancer risk for radionuclides for adults under current land use scenario.

This page intentionally left blank.

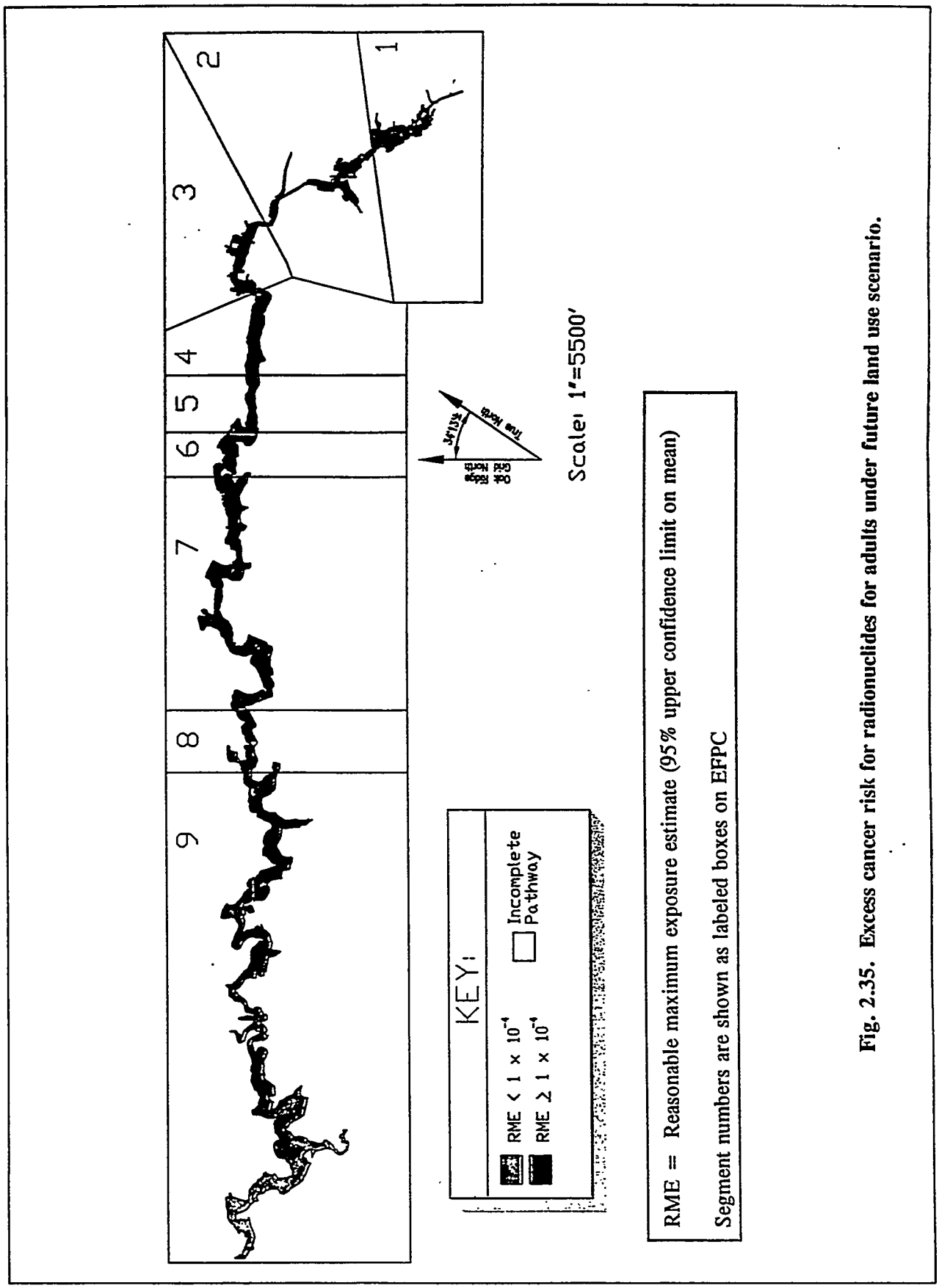


Fig. 2.35. Excess cancer risk for radionuclides for adults under future land use scenario.

This page intentionally left blank.

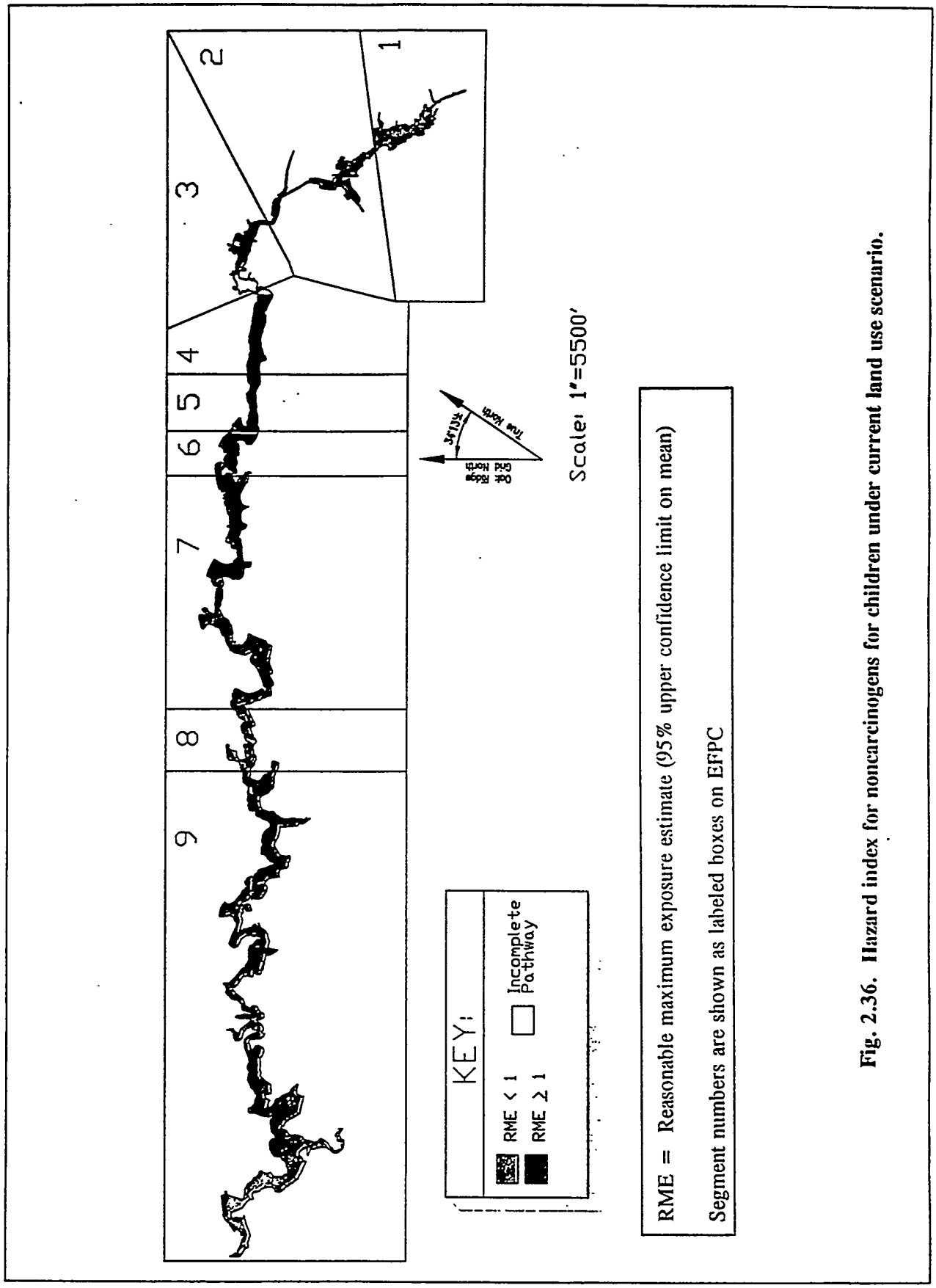


Fig. 2.36. Hazard index for noncarcinogens for children under current land use scenario.

This page intentionally left blank.

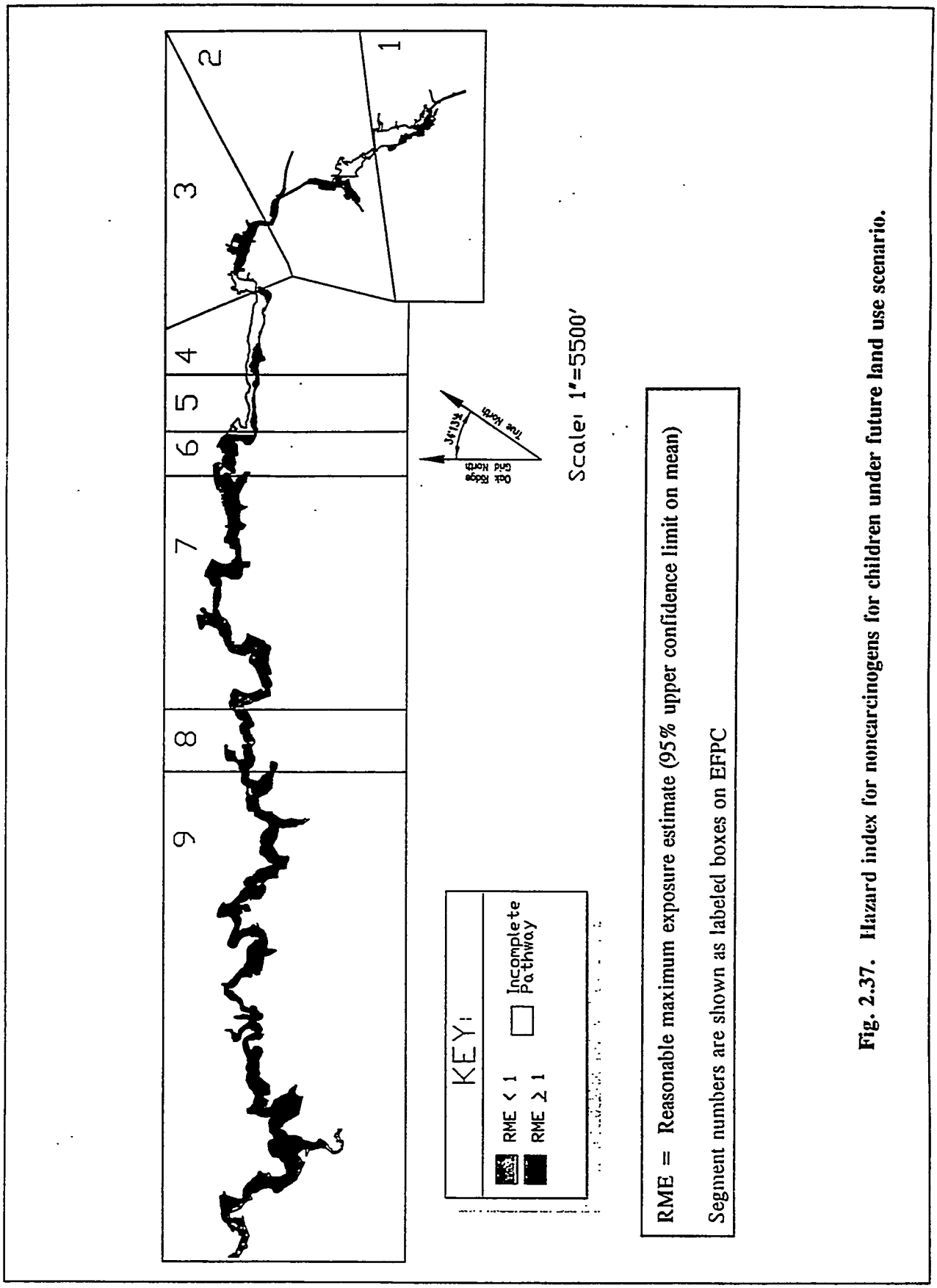


Fig. 2.37. Hazard index for noncarcinogens for children under future land use scenario.

This page intentionally left blank.

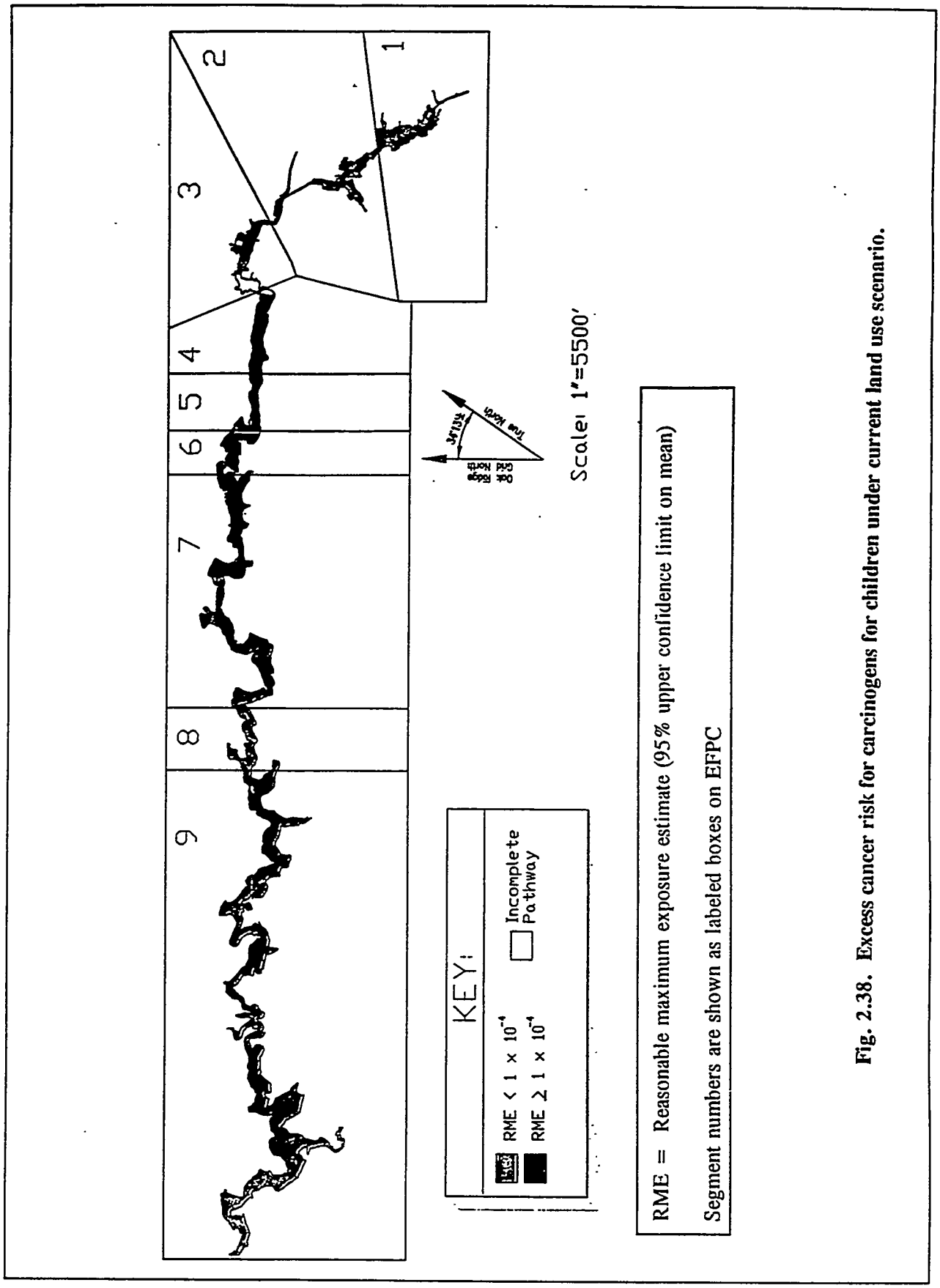


Fig. 2.38. Excess cancer risk for carcinogens for children under current land use scenario.

This page intentionally left blank.

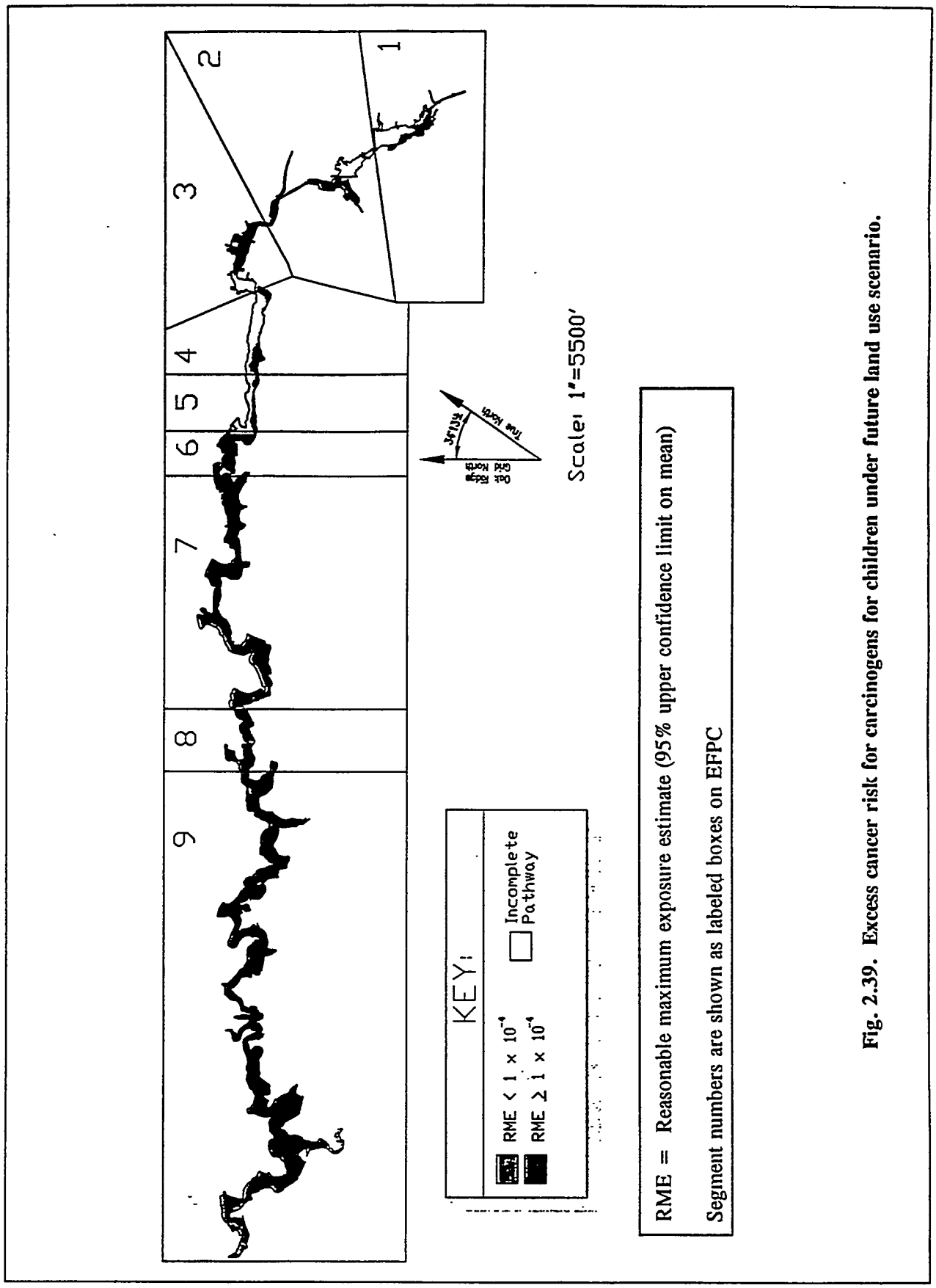


Fig. 2.39. Excess cancer risk for carcinogens for children under future land use scenario.

This page intentionally left blank.

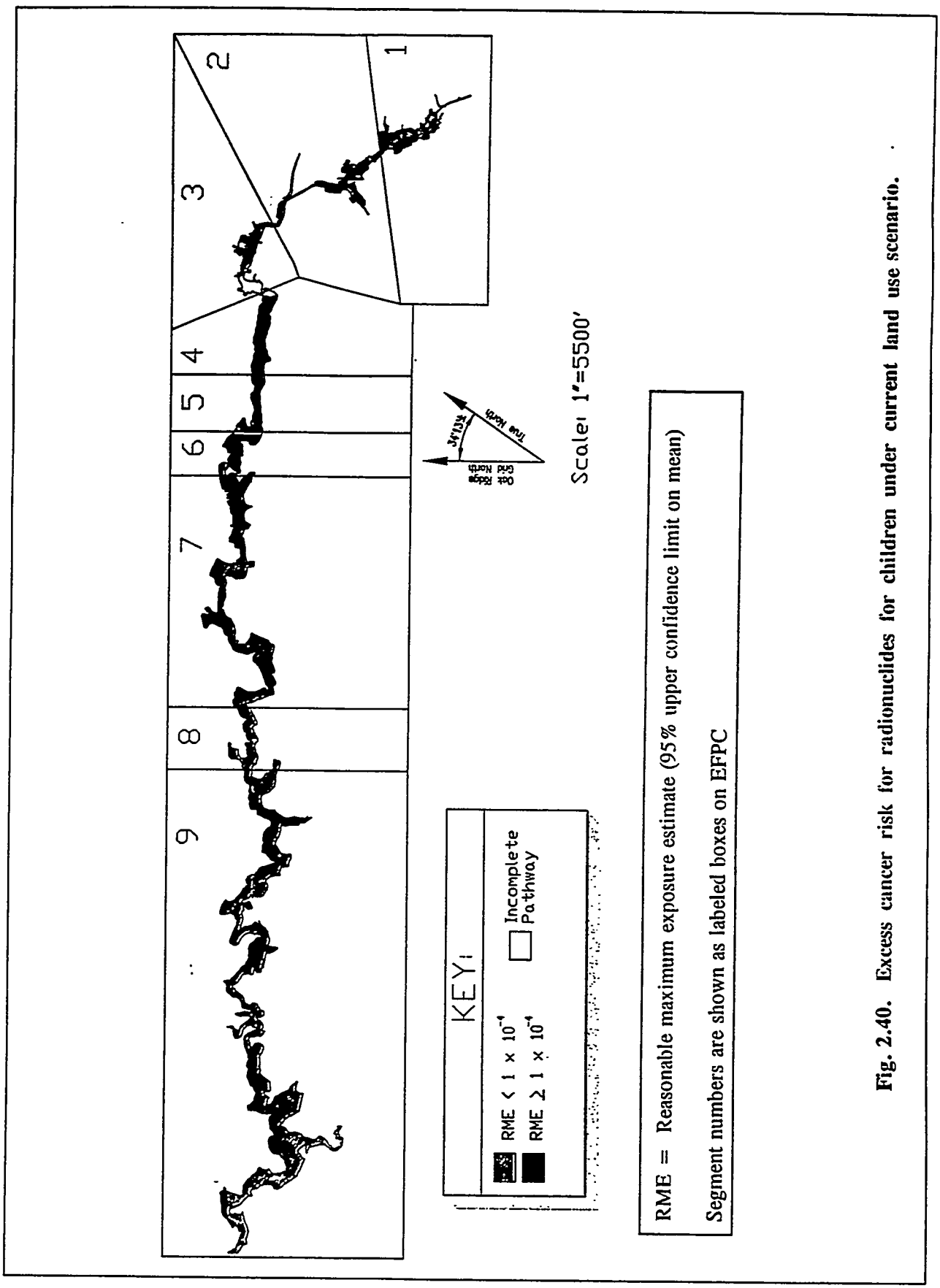


Fig. 2.40. Excess cancer risk for radionuclides for children under current land use scenario.

This page intentionally left blank.

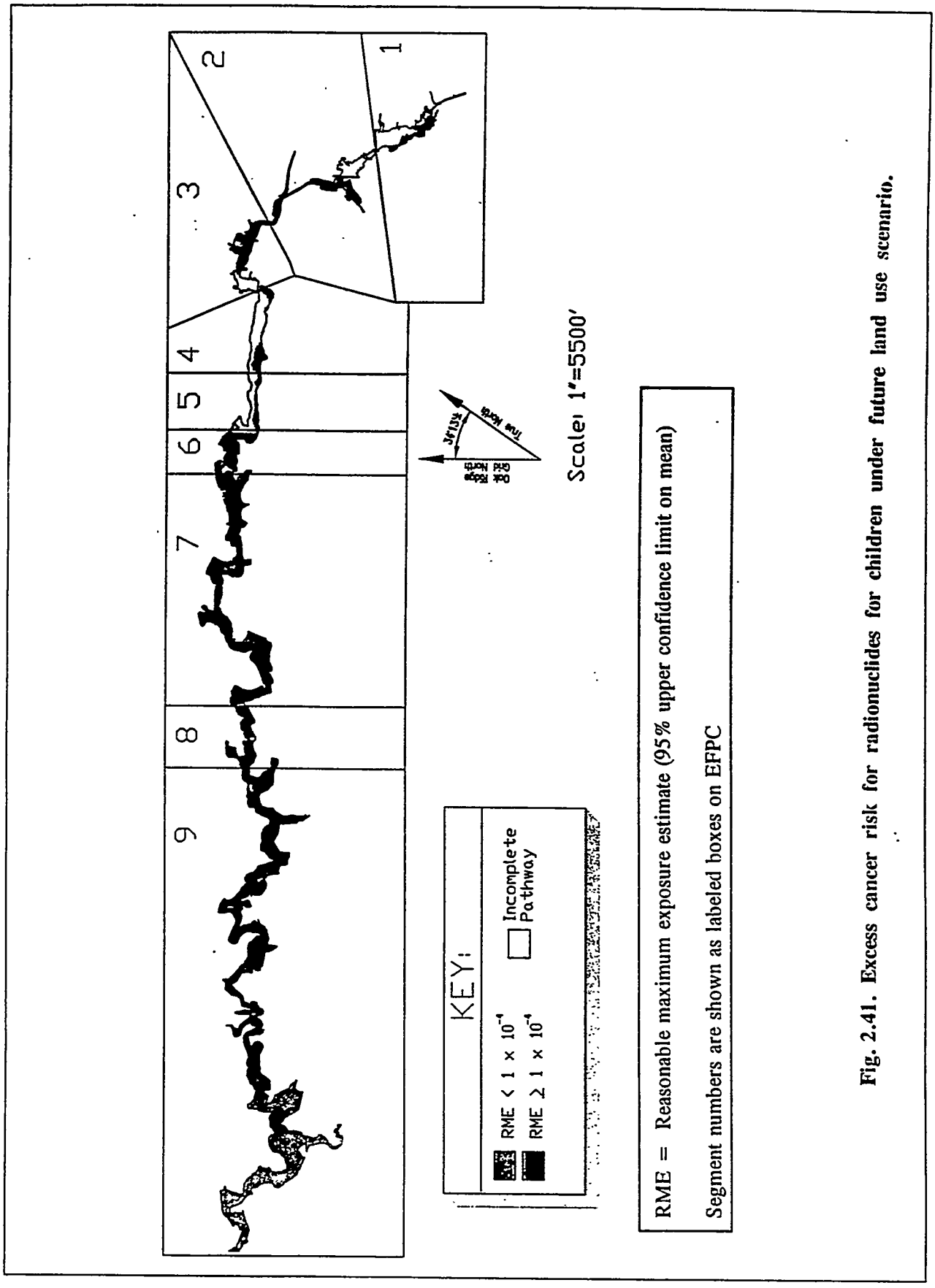


Fig. 2.41. Excess cancer risk for radionuclides for children under future land use scenario.

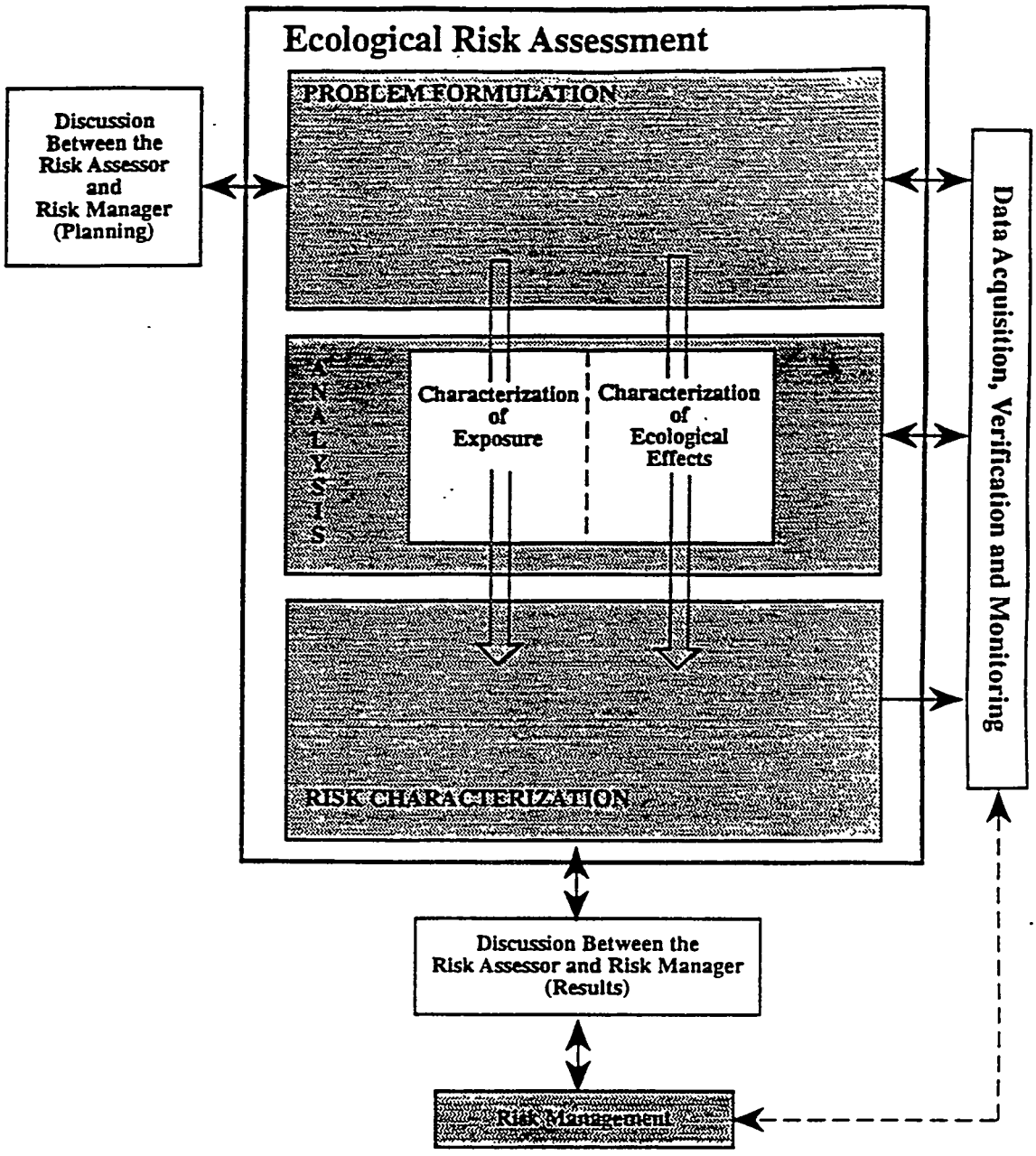


Fig. 2.42. Framework for ecological risk assessment. *Source*: EPA 1992c.

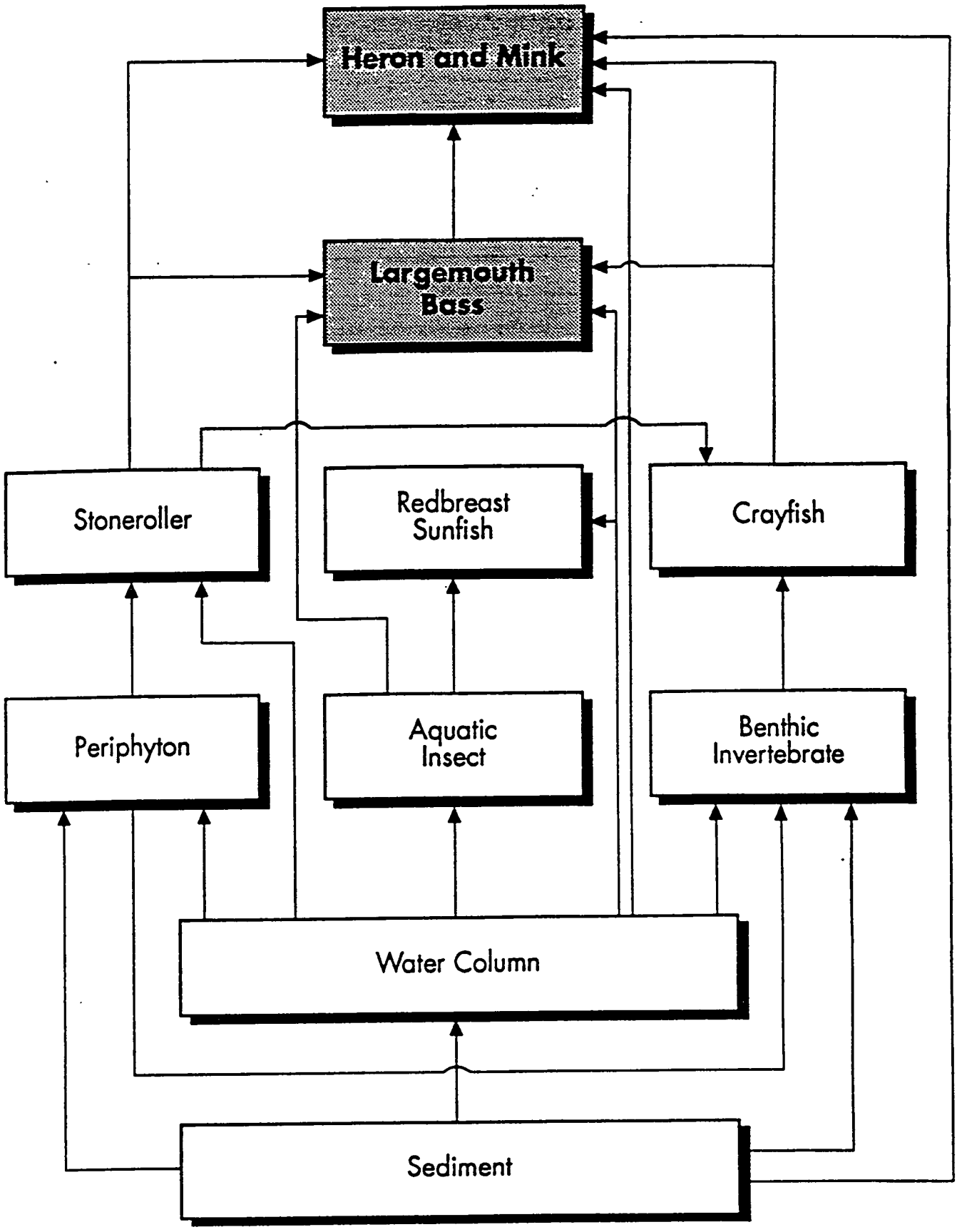


Fig. 2.43. Food web relationships of aquatic biota sampled (clear boxes) or modeled (shaded boxes) for EFPC ecological risk assessment.

9-122793-215

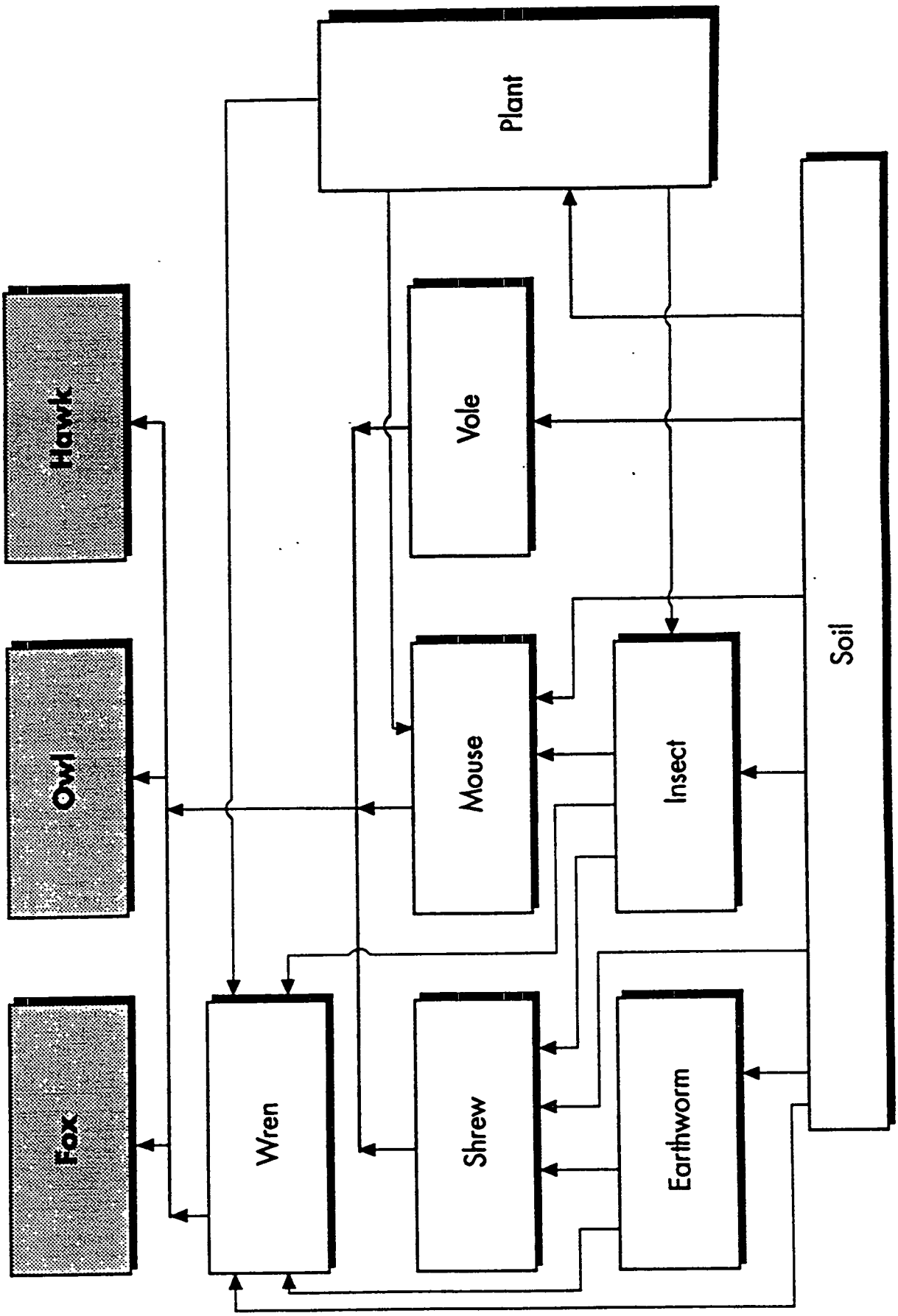


Fig. 2.44. Food web relationships of terrestrial biota sampled (clear boxes) or modeled (shaded boxes) for EFPC ecological risk assessment.

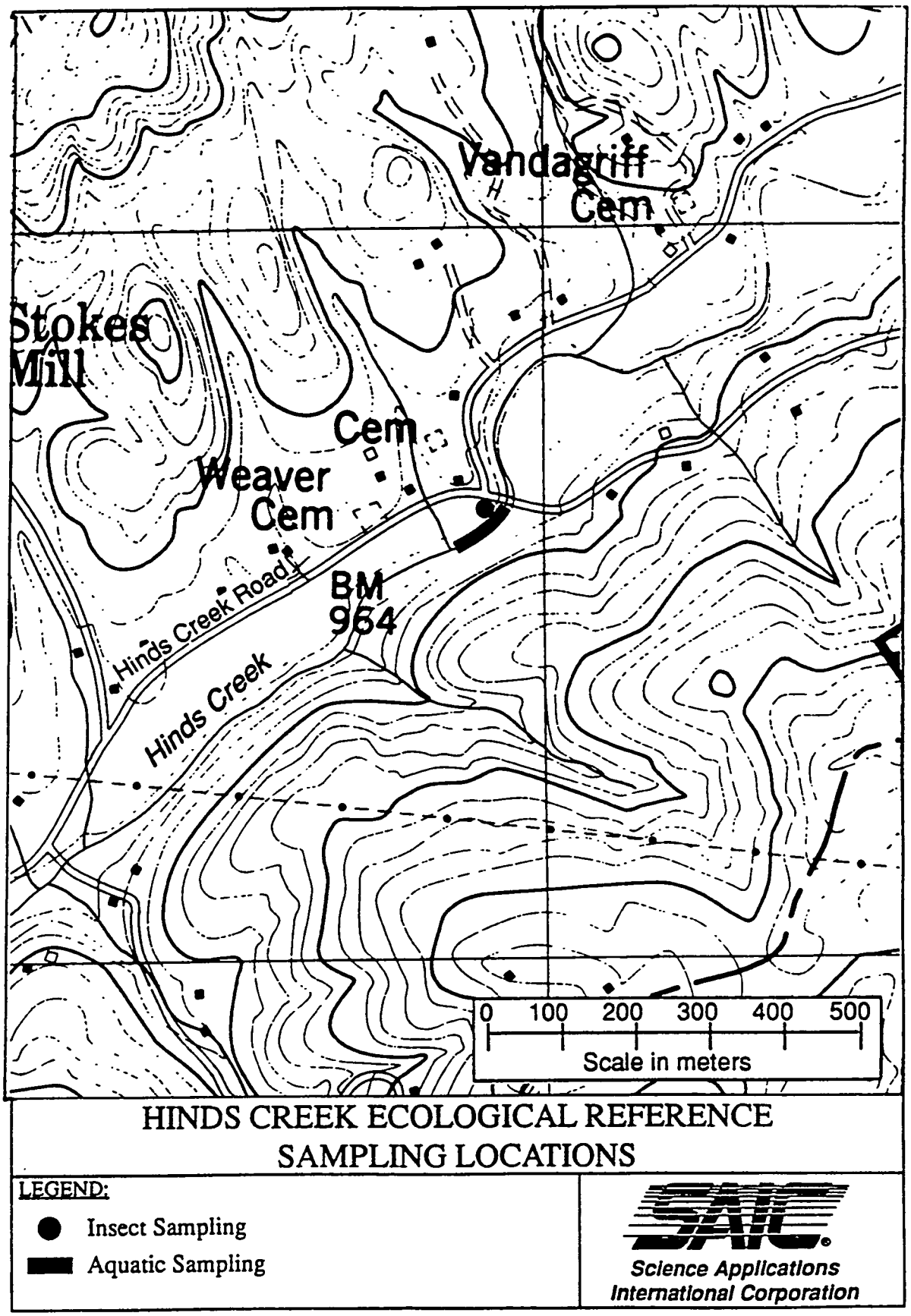


Fig. 2.45. Hinds Creek ecological reference sampling sites.

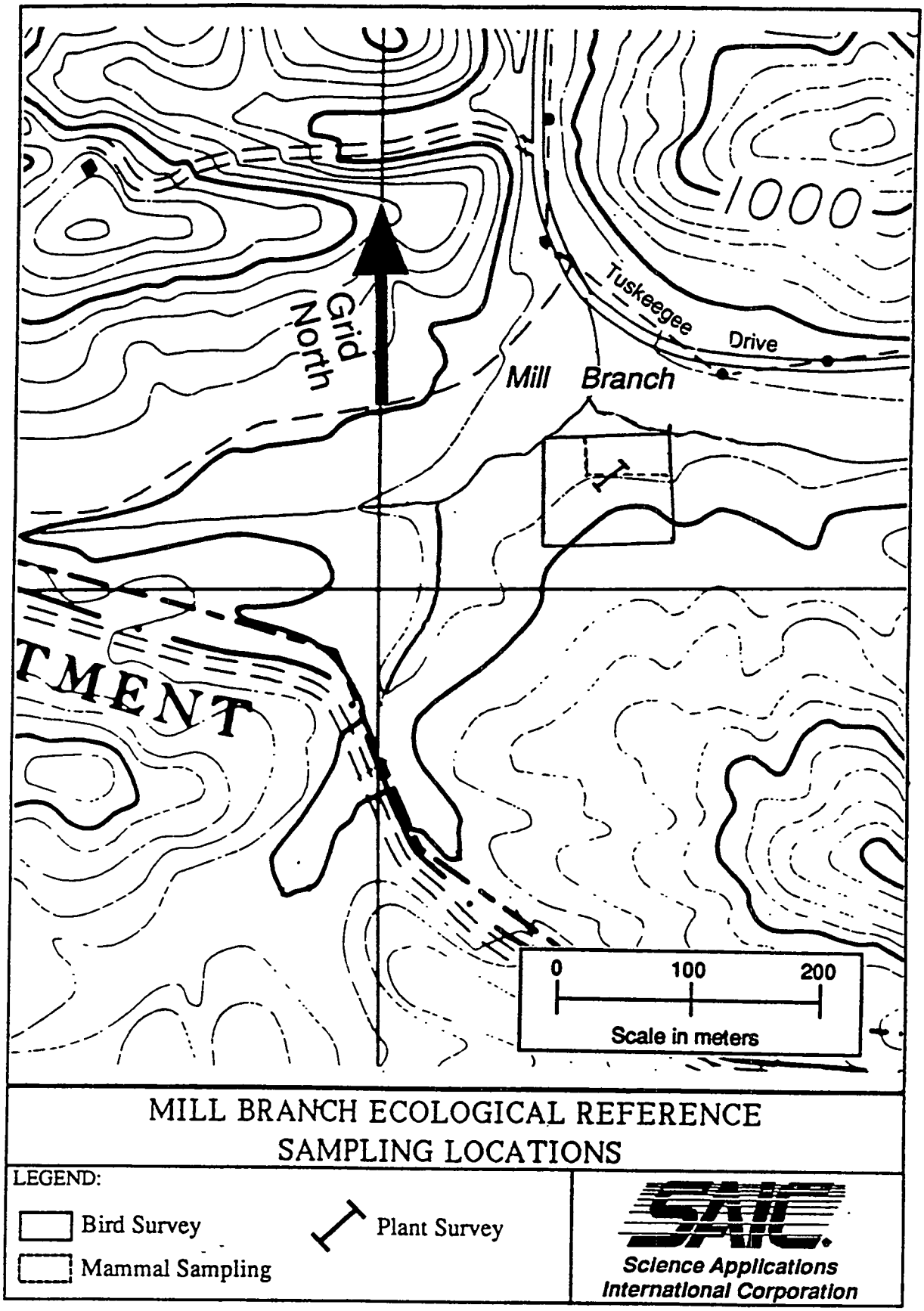


Fig. 2.46. Mill Branch ecological reference sampling sites.

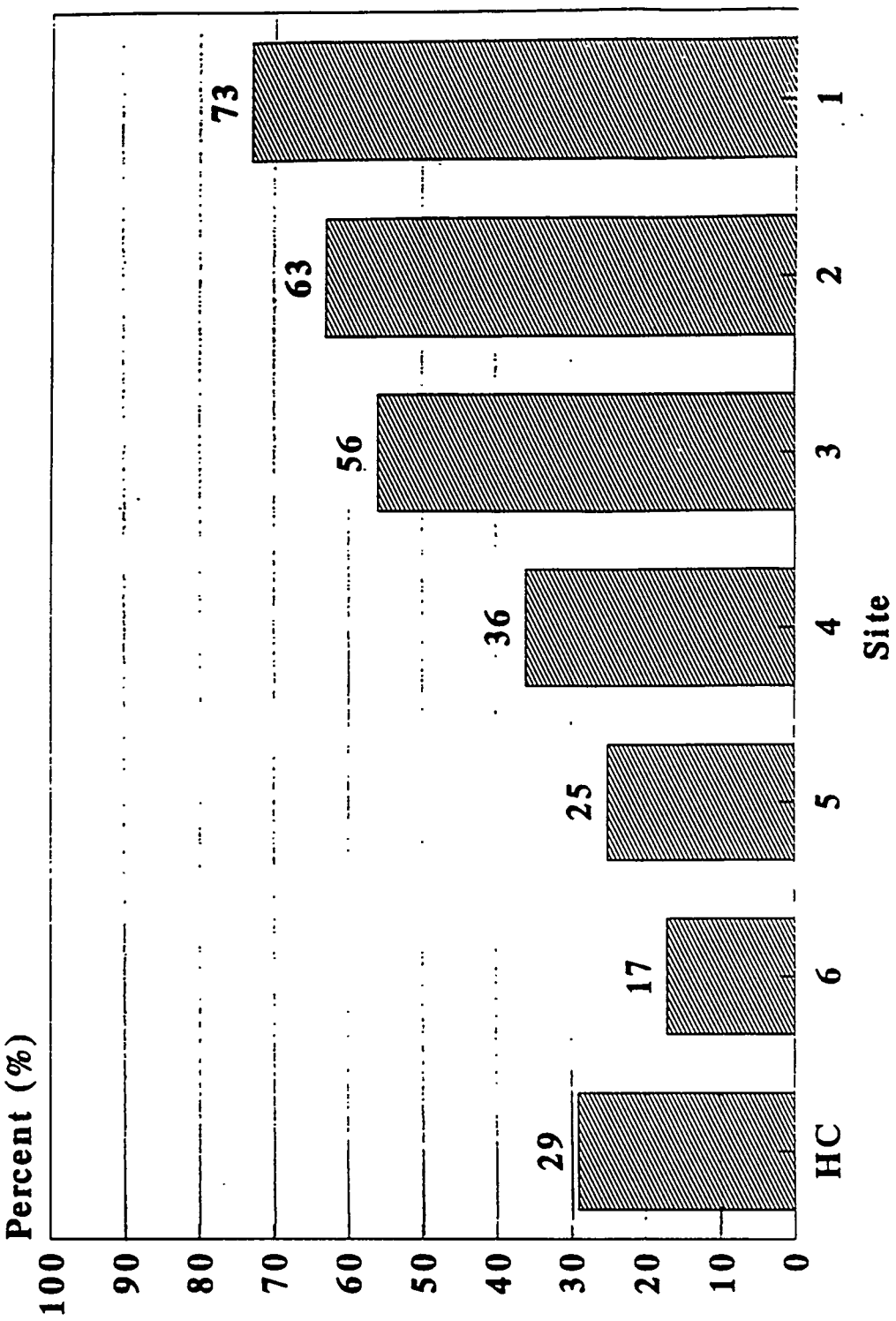


Fig. 2.47. Percentage of captured fish species from EFPC and Hinds Creek classified as tolerant of degraded water quality, October 7-12, 1991.

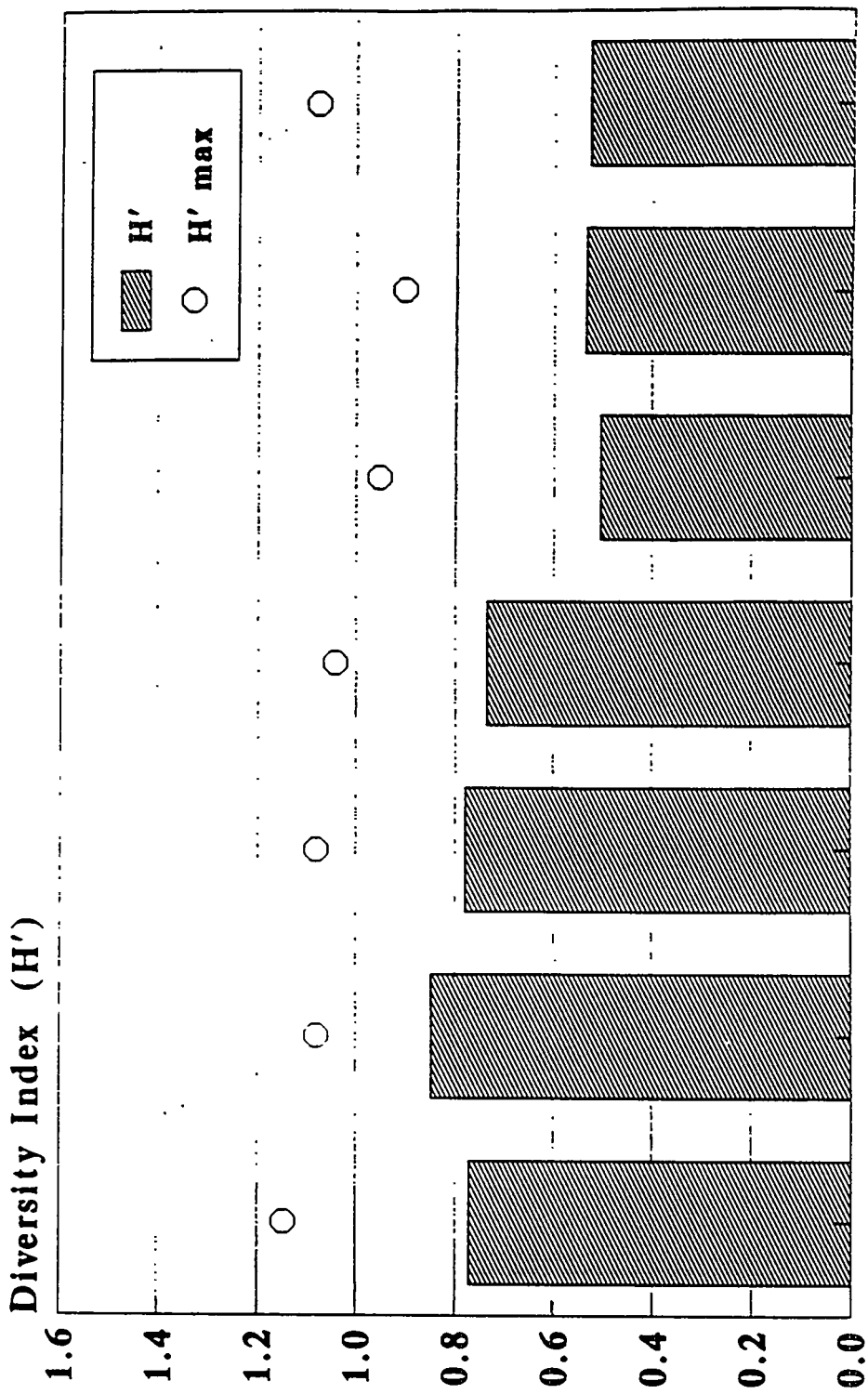


Fig. 2.48. Observed fish species diversity and maximum possible fish diversity at sites in EFPC and Hinds Creek, October 7-12, 1991.

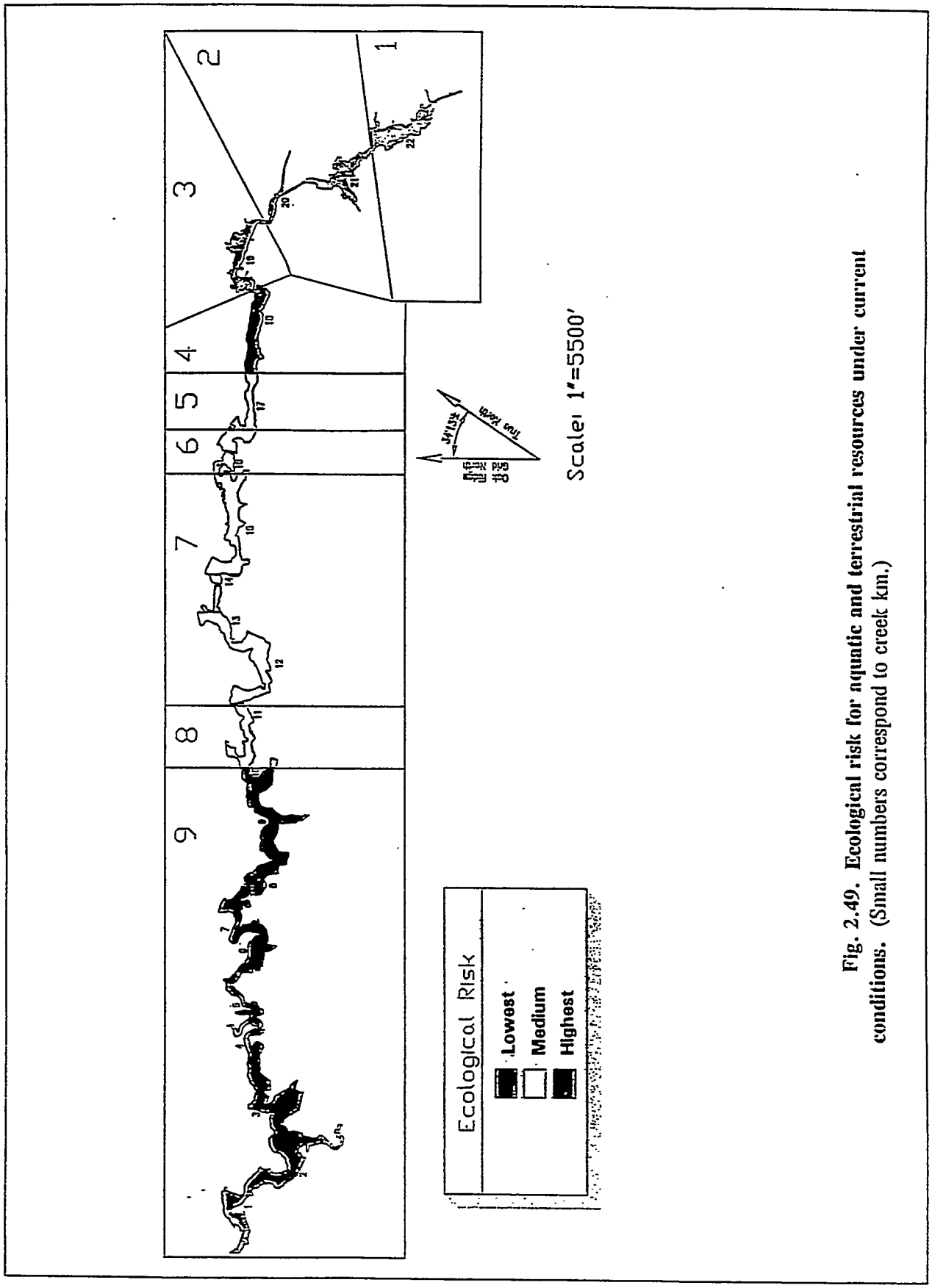


Fig. 2.49. Ecological risk for aquatic and terrestrial resources under current conditions. (Small numbers correspond to creek km.)

3. IDENTIFICATION AND SCREENING OF REMEDIAL ACTION TECHNOLOGIES

The baseline risk assessment for the EFPC OU addressed risks to human and ecological receptors on the basis of their potential exposure to the site-specific COPCs in various environmental media at the site. The results of these assessments were used to calculate remediation goal options specific to each contaminant and exposure pathway identified in the RI report (DOE 1994a). Additional studies were conducted on speciation of mercury in EFPC soil and on the fate of mercury in floodplain biota. These studies supported development of additional remediation goal options that were reported in the RI addendum (DOE 1994b).

In this section of the FS report, human health and ecological remediation goal options from the RI report and the RI addendum are evaluated on the basis of EPA threshold criteria and are incorporated in the remedial action objectives for the EFPC OU. All remedial alternatives developed under the FS process must focus on these remedial action objectives.

Once the remedial action objectives are established, the next step in the process is to identify and screen a range of general response actions and technologies that are potentially effective in achieving the remedial action objectives. Remedial action technologies and process options applicable to achieving the remedial action objectives for EFPC OU soil are identified and screened. Using the criteria of technical implementability, effectiveness, and cost, the screening process limits the number of remedial technology and process options to be carried forward. Representative remedial technologies are identified and carried forward for further consideration as site-specific remedial alternatives in Sect. 4. The ultimate goal of the remedy-selection process established by EPA is to select remedial actions that protect human health and the environment, maintain protection over time, and minimize untreated waste (EPA 1988b).

3.1 CRITERIA FOR DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES

The development of remedial action objectives includes consideration of site-specific COCs, the potential exposure routes for human and ecological receptors, and the remediation goal options for the site.

EPA has established two "threshold criteria" that must be satisfied before a remedial alternative is eligible for consideration and selection (40 CFR 300.430). These criteria are as follows:

- The remedial alternatives must afford overall protection of human health and the environment.
- The remedial alternatives must comply with federal and state ARARs.

The first criterion addresses potential effects of exposure to site contaminants; the second criterion addresses conformity to standards and guidelines. These "threshold criteria" serve as overall objectives for deriving target remediation levels for contaminated environmental media at waste sites (EPA 1988b, 1989a).

Chemical-specific requirements are usually health- or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in the establishment of numerical values. These values establish the acceptable amount or concentration of a chemical that may be found in or discharged to the environment.

Location-specific requirements are restrictions placed on the concentrations of hazardous substances or the conduct of activities solely because they occur in specific locations.

Action-specific requirements are technology- or activity-based requirements or limitations on actions taken with respect to hazardous substances.

To-be-considered criteria are nonpromulgated advisories or guidance issued by federal or state governments that are not legally binding and do not have the status of ARARs. These criteria are considered with ARARs in determining the necessary level of remediation for protection of health or the environment.

Site-specific factors that are used to identify ARARs include: (1) the characteristics of the remedial action, (2) the hazardous substances that are present, and (3) the physical characteristics of the site. These factors are considered for each requirement under evaluation to determine whether the requirement is directly applicable or whether it is relevant and appropriate. In some cases, only part of a requirement may be found to be relevant and appropriate. A determination that a requirement is relevant and appropriate will result in an ARAR that must be complied with to the same degree as an applicable requirement. A waiver of the ARARs may be invoked, where justification can be made, under the 1991 National Contingency Plan, Sect. 300.430(f)(1)(ii)(C). Appendix C lists the ARARs for the EFPC OU.

Risk assessment provides key input to determining site-specific protectiveness. EPA requires that the following factors be considered along with ARARs when establishing remedial action objectives [see 1991 National Contingency Plan, Sect. 300.430(e)(2)(i)]:

- For known or suspected carcinogens, acceptable exposure levels are those concentrations that represent an upper-bound excess lifetime cancer risk to an individual of 10^{-6} to 10^{-4} (1 in 1,000,000 to 1 in 10,000) as determined by the dose-response relationship. This range is intended to provide case-by-case flexibility, although the 10^{-6} (1 in 1,000,000) risk level is the point of departure for determining goals for alternatives when ARARs are not available or sufficiently protective.

- For systemic toxicants, acceptable exposure levels are those concentrations to which the most susceptible human population may be exposed over a lifetime without adverse effects, incorporating an adequate level of safety.

- Safe Drinking Water Act maximum contaminant level goals that are set at levels above zero will be attained by remedial action for current or potential sources of drinking water where the maximum contaminant level goals are relevant and appropriate. Safe Drinking Water Act maximum contaminant levels will be attained where the maximum contaminant level goals are not relevant and appropriate.

- Where the maximum contaminant level goal for a contaminant has been set at zero, the maximum contaminant level for that contaminant will be attained by remedial action for a current or potential source of drinking water.

- In the case of multiple contaminants, where the ARARs or risk projections will result in a cumulative risk in excess of 10^{-4} (1 in 10,000), acceptable exposure limits based on exposure to noncarcinogenic toxicants or cancer risk must be considered.

- Water quality criteria established under Sect. 303 or 304 of the Clean Water Act will be attained where relevant and appropriate.

- An alternate concentration limit for water may be established in accordance with CERCLA, Sect. 121(d)(2)(B)(ii).

- Assessments of threats to the environment will be considered, especially for sensitive habitats and critical habitats of species protected under the Endangered Species Act.

- Other factors related to technical limitations, uncertainty, and other pertinent information will be considered.

Acceptable exposure levels (EPA 1988a) are developed on the basis of the results of the site baseline risk assessment. The evaluation of expected exposures and associated risks for each alternative is also considered if an exposure level does not exist for the specific chemical or the specific pathway(s) of concern, or if multiple contaminants result in an unacceptable cumulative risk. Results of the baseline risk assessment for the EFPC OU are discussed in Sect. 2.5 of this report.

3.2 EVALUATION OF THE SURFACE WATER, SEDIMENT, AIR, AND DIRECT RADIATION PATHWAYS

The baseline risk assessment addressed several media of concern to human health and environmental receptors [e.g., soil, surface water (i.e., creek water), and the sediment within the creek] because COPCs (e.g., metals; PCBs, pesticides, and other organics; and radionuclides) were identified in these media. The site COCs for the EFPC OU were identified on the basis of ARARs and the results of the human health and ecological baseline risk assessment (see Table 2.64). The results of the baseline risk assessment show that mercury is the primary COC within each major exposure pathway in the EFPC OU. This section discusses surface water and sediment, the air pathway, direct radiation, and the basis for not developing final remedial action objectives in these areas.

3.2.1 Surface Water and Sediments

Remedial actions will be deferred for surface water and sediments at this time, although interim actions will be identified and evaluated. The NPDES permitted discharge from Lake Reality into Lower EFPC, which constitutes the largest source of flow for Lower EFPC, includes measurable concentrations of chemical constituents, including mercury. Present mercury loading to Upper EFPC is 15 g/d (0.48 oz./d); by 1998, the NPDES permit requires that the total loading

be reduced to 5 g/d (0.16 oz.) (Norris 1994). Average mercury levels in EFPC have already been reduced from 1.63 μg/L (1.98×10^{-7} oz./gal) in 1989 to 0.90 μg/L (1.095×10^{-7} oz./gal) in 1993 (Bunting 1994).

Currently, no excessive risk to human health is associated with contaminants in surface water or sediment in EFPC. The total mercury concentrations in surface water are below drinking water standards (maximum contaminant level of 2 μg/L), except on occasion in the upper reaches of the stream. For the creek sediment, the theoretical remediation goal option established for mercury for children (based on the baseline risk assessment for human health) was 61,000 mg/kg. Contamination at this level has not been detected in EFPC sediments. This value was based on occasional dermal exposure for humans and does not represent a more refined remediation goal option for sediment that would include ecological effects. However, as indicated in the baseline risk assessment, surface water and sediment at EFPC need not be remediated because of concerns for human health.

Risk to aquatic ecological resources was identified as a result of exposure to contaminants in surface water and sediment (DOE 1994a). The preponderance of risk identified for aquatic biota results from water-borne contaminants arising from continued releases from the Y-12 Plant and other sources into EFPC. In addition, additional risks also may result from resuspension of contaminated sediment, inputs of contaminated floodplain soil, and surface water runoff. The ecological impact of the contaminated sediment pathway, though only partially understood at this point, may also be significant. Contaminant body burdens of mercury in aquatic biota indicate bioaccumulation of contaminants in the ecological food chain. On the basis of uncertainties associated with these environmental pathways, an administrative decision was made to defer consideration of surface water and sediment for near-term corrective actions. These media will be reconsidered when the impacts of remediation of the floodplain and environmental restoration projects at the Y-12 Plant have been evaluated.

3.2.2 Air

Although there is a potential for inhalation exposure to organisms in burrows or other confined spaces in soil and sediment, no COPCs have been measured in air along EFPC or within the vicinity of the ORR that are of concern for human health or the ecological receptors. This pathway, therefore, will not be carried further into the alternatives screening process of the FS.

3.2.3 Direct Radiation

Direct radiation measurements made along the EFPC floodplain indicate that direct exposures resulting from natural and man-made radionuclides are indistinguishable from background levels. Therefore, risk assessment and derivation of remediation goal options were not conducted for irradiation exposure. A risk assessment for radionuclides was conducted to evaluate exposure by means of ingestion and inhalation. At background levels, no substantial human health nor ecological impacts were determined from the baseline human health or ecological studies (risks fell within the target ranges established by EPA).

3.3 REMEDIATION PLANNING EVALUATION OF HUMAN HEALTH AND ECOLOGICAL REMEDIATION GOAL OPTIONS

The surface water, sediment, air, and direct radiation pathways were eliminated from this FS screening process in Sect. 3.2. In this section, the remaining human health and ecological remediation goal options developed in the RI report, RI addendum, baseline risk assessment, and ecological risk assessment are evaluated for remediation planning. Section 3.3.1 discusses human health remediation goal options for: groundwater, food chain, and soil. Section 3.3.2 evaluates a range of ecological remediation goal options.

3.3.1 Remediation Goal Options for Human Health

This section discusses the remediation goal options for human health that were calculated in the RI report and the RI addendum and identifies those that are appropriate to serve as the basis for the remedial action objectives. In the RI report, remediation goal options were calculated for each appropriate environmental medium or exposure pathway, including soil, groundwater, food chain, and sediment. The sediment pathway has been eliminated from further consideration in this FS, as explained in Sect. 3.2. Section 3.3.1.1 discusses the human health remediation goal options for the remaining media and pathways addressed in the RI report. In the RI addendum, a second set of remediation goal options was developed only for mercury in soil and is discussed in Sect. 3.3.1.2.

3.3.1.1 Remediation goal options presented in the RI report

Many chemicals and exposure pathways were evaluated in the RI baseline risk assessment. Not all remediation goal options calculated for COCs defined in the RI report are applicable to the evaluation of alternatives in the FS; rather, remediation goal options for selected exposure pathways and chemicals were used as the basis for determining remedial action objectives. In Sect. 7 of the RI report (DOE 1994a), human health remediation goal options were calculated for COCs for the various pathways identified in the Tier II risk assessment. Remediation goal options were calculated for chemicals that contribute to a pathway that exceeds a 10^{-4} (1 in 10,000) risk or an HI of 1 or greater. They are derived from the EPA target risk values for carcinogens and noncarcinogens by back-calculating the corresponding concentrations in the appropriate environmental medium. The 10^{-6} (1 in 1,000,000) risk level was used as the EPA target risk value for carcinogens, and an HI of 1 was used for noncarcinogens.

The following medium-specific discussion identifies primary pathways and COCs, indicating which are appropriate for considering health effects in the FS. The intention is to focus the analysis of alternatives on the substances and pathways that most influence the purposes of the FS (i.e., protection of human health and the environment and compliance with ARARs).

Groundwater

Remediation goal options were presented in Sect. 7 of the RI report for groundwater ingestion and inhalation assumed to occur under residential and agricultural land uses. The groundwater pathway is an incomplete exposure pathway because the contamination cannot reach any receptors (groundwater currently is not being used as a drinking water source). No one is currently using groundwater as a source of drinking water because a municipal water supply is

available. Although risk estimates for the groundwater ingestion pathway exceed the target range established by EPA, this pathway does not represent a substantial or foreseeable risk to human health because it is an incomplete pathway. Risk assessment of hypothetical exposure to groundwater was conducted to comply with EPA requirements to provide an additional measure of the significance of the observed contamination. Should groundwater become a source of drinking water in the future, the risk estimates would be important in evaluating this pathway. For the sake of completeness, remediation goal options were calculated for chemicals in groundwater.

The risk assessment examined exposure to both unfiltered and filtered groundwater. Contaminant concentrations (primarily manganese and arsenic) were considerably reduced in the filtered samples. This is a useful indication of the lower particulate levels expected in an active drinking water well. Although COCs in the filtered groundwater are below federal maximum contaminant levels, the risks remain above target levels, primarily because arsenic and manganese are present. High levels of manganese are naturally found within the area, and levels observed in the soil of EFPC are indistinguishable from background. Arsenic is not thought to originate from the Y-12 Plant, and the chemical is suspected to come from a naturally occurring (i.e., background) area source.

The results of the Tier III analysis of groundwater indicate a range of uncertainty of less than an order of magnitude based on variability in exposure assumptions for groundwater. This reasonable level of uncertainty does not, however, reflect the fact that this is an incomplete pathway. The remediation goal options presented in the RI report are not carried over into the analysis of alternatives in the FS because they are based on hypothetical exposures that are unrealistic in the case of the EFPC floodplain. Should the usage status of groundwater change in the future, a reevaluation of the groundwater ingestion pathway would be required.

Food Chain

In Sect. 7 of the RI report, remediation goal options were developed for several COCs on the basis of potential exposure of humans ingesting contaminants in the food chain (e.g., produce, beef, and dairy). Note that estimates for these pathways relate to residential and agricultural land use and were above EPA targets. The remediation goal options for mercury are much lower (more stringent) based on the produce pathway than they are for direct soil contact; this reflects the conservative methods adopted when modeling chemical transport from soil to plant tissue. The RME risk estimates for food chain exposure are point estimates that fall in the upper tail of the probability distributions defined in the RI Tier III assessment. In some cases, the RME estimates exceed the 95th percentile values of these distributions.

Of particular concern in evaluating these risk estimates, are the conservative point estimates used for the food chain biotransfer factors. These factors predict the biotransfer of each contaminant from soil to plant tissue. Based on these data and the results of an experimental garden study (conducted at locations within the floodplain with the highest mercury contaminations), it has been concluded that the biotransfer factor for mercury that was obtained from the literature and recommended for use in the baseline risk assessment is likely to be one to two orders of magnitude too high.

To put the food chain pathway in perspective, risks also were estimated for the reference site at Hinds Creek using agricultural exposure assumptions. Despite the absence of substantial mercury contamination in the reference soil, risks for the produce, beef, and dairy ingestion pathways all exceeded EPA targets for both noncancer and cancer effects. As noted, the magnitude of the food chain risk estimates is primarily attributable to the very conservative biotransfer factors that were used to model contaminant uptake from soil into the food chain. This is why numerous COCs are identified with the food chain pathway.

It is important to reiterate that the human health risk estimates for the food chain pathways are based on modeled, not measured, data. There are no EPA-verified or recommended values for biotransfer factors to be used in the models. The Tier II and III results, the results of the garden uptake study, and the risk assessment of Hinds Creek all indicate that there is considerable conservatism and uncertainty in the risk estimates associated with the food chain pathways. Given this conclusion, the observation that limited agricultural or gardening activity is occurring along EFPC, and the assumption that these activities will not increase substantially in the future, the food chain pathways are not recommended as a basis for deriving remediation levels for soil. The remediation goal options for the food chain pathways that were presented in the RI report are not carried over into the development of remedial action objectives or the analysis of alternatives in the FS. Instead, they are considered hypothetical, extremely conservative, "bounding" estimates. Additional consideration of the food chain pathways as a basis for deriving remediation levels in soil would demand an expanded experimental analysis of mercury transport and speciation and the derivation of site-specific transfer factors.

Soil

The results of the baseline risk assessment indicate that soil ingestion is an exposure pathway of principal concern to human health. Risks from dermal contact with contaminants in EFPC floodplain soil did not exceed EPA targets. The RI identified three COCs for the soil pathway: mercury, arsenic, and cadmium. No promulgated standards exist for acceptable levels of these contaminants in soil. In the absence of such standards, the results of the baseline risk assessment were used to derive remediation goal options for soil.

For mercury in soil, the human health remediation goal options are based on ingestion and dermal contact; they were estimated using an RfD for mercury of 0.0003 mg/kg/d. The RfD is based on toxicity testing using soluble mercury species (mercuric chloride) in laboratory animals, and not the less soluble forms (mercuric sulfide and metallic mercury) predominantly found in EFPC floodplain soil. The RI derivation of these remediation goal options, therefore, assumed that mercury in floodplain soil was present in its most bioavailable form (i.e., mercuric chloride). The remediation goal options reported in the RI for the residential and agricultural settings were conservative at 58 mg/kg (or ppm) for children and 198 mg/kg for adults (these round to 50 mg/kg and 200 mg/kg, respectively). The remediation goal options reported in the RI report for commercial and open land use were 990 mg/kg for children and 461 mg/kg for adults. In addition, a remediation goal option of 938 mg/kg was calculated for an adult utility worker at the SLB.

Although risks from exposure to contaminated soil that were stated in the baseline risk assessment result primarily from mercury, cadmium and arsenic are also COCs for the soil medium. However, concentrations of arsenic in EFPC soil are only slightly above those found

in background samples from Hinds Creek. Furthermore, no excessive risk (above EPA targets) is associated with ingestion or dermal contact exposure to either arsenic or cadmium in floodplain soil. Arsenic and cadmium each have soil remediation goal options above actual contaminant levels found in the background reference soil from Hinds Creek. The highest concentration of cadmium in the floodplain soil is 41 mg/kg, which is several times less than the lowest remediation goal option for cadmium (i.e., 198 mg/kg for children). With the importance of arsenic and cadmium thus diminished, mercury in soil remains the primary contaminant pathway and is recommended as the only pathway for inclusion in the FS analysis of alternatives.

3.3.1.2 Remediation goal options for mercury incorporating reduced bioavailability factor

The second set of remediation goal options was presented in the RI addendum (DOE 1994b) and was developed only for mercury in soil. This second set was developed to account for speciation and leaching/availability studies, which indicate that less soluble and less bioavailable forms of mercury (mainly mercuric sulfide and metallic mercury) predominate in EFPC floodplain soil.

In the RI report, the bioavailability factor for mercury was set at 1.0 for the ingestion exposure route. This assumes that the bioavailability of mercury in EFPC soil is equivalent to that of mercuric chloride (a soluble species of inorganic mercury that is the basis of the chronic oral RfD). Considerable study was conducted on the species of mercury that exist in the EFPC soil. This work produced definitive evidence that the vast majority of mercury is in an insoluble inorganic form, primarily mercuric sulfide. EPA considered the data to be insufficient for developing an RfD specific for mercuric sulfide. However, because water solubility of substances has been shown to generally correlate with bioavailability in mammalian species, an adjustment in the 1.0 bioavailability factor seemed to be an appropriate means for making a mercury-species correction in obtaining remediation goal options. Previous experience in EPA Region IX was called on to derive an appropriate bioavailability factor. Decisions were made at three mercury-contaminated sites in California that support the use of an efficiency factor to account for the difference in the bioavailability of the various forms of mercury in soil. Two of the sites, Sulphur Bank and Carson River, are under EPA Region IX jurisdiction. At both of these sites, mercuric sulfide is one of the principal contaminants under investigation. In the risk assessments for these two sites (EPA 1994a and 1994b), a relative absorption factor of 3% was used to reflect the estimated five-fold difference in absorption between the chloride and sulfide forms.

At the third site, the Almaden Quicksilver County Park site in California, mercuric sulfide is also the principal contaminant under investigation. The State of California, Department of Health Services, has oversight responsibility for the RI/FS of the facility. In this risk assessment (CDM 1993), an availability factor of 0.3 (30%) was used for the soil ingestion pathway to reflect the differences in bioavailability between the sulfide and chloride species of mercury.

On the basis of the available scientific data and the work conducted under authorization of EPA Region IX and the State of California, an oral bioavailability factor of 30% for mercuric sulfide was incorporated into the calculation of the remediation goal options for the EFPC OU. This factor results in remediation goal options of 180 mg/kg for children (reported in the RI addendum) and 537 mg/kg for adults in the residential and agricultural settings. This factor is also applicable to the development of human health remediation goal options for other land uses.

For Commercial, DOE-owned, and Other land uses, the adjusted remediation goal options are 938 mg/kg for children and 1252 mg/kg for adults.

3.3.1.3 Uncertainty in bioavailability factor

Toxic substances taken into the body by ingestion must be in a bioavailable state before they are taken up by the body to manifest systemic toxicity. The bioavailability of a toxic element, such as mercury, is influenced by two major factors: (1) the chemical species of the element and (2) the medium or matrix by which the element enters a receptor (e.g., attached to soil particles). The data on the bioavailability of mercury are fairly limited regarding these two factors. Ideally, risk-based values like RfDs would be available for each stable chemical species, leaving only the matrix effect to be determined on a site-specific basis. Because this is not the case with mercury, the bioavailability value applied to mercury at this site does not distinguish between the two factors. It is also acknowledged that the bioavailability factor of 0.3 cannot be supported in an absolute sense by definitive data. There is considerable uncertainty in selecting any value. However, based on the limited laboratory and animal data, previous regulatory decisions, and the desire to have a high degree of confidence that remedial decisions are protective of human health and the environment, this value seems appropriate.

3.3.2 Remediation Goal Options for Ecological Receptors

Ecological remediation goal options are based on: (1) analytical data obtained during biota sampling, (2) media sampling (e.g., sediment, soil) carried out during Phases Ia and Ib, (3) published information about the toxicity of COCs, and (4) relationships among these findings. Because biota in the EFPC floodplain could potentially be exposed to these contaminants from four major sources—inhalation, surface water, instream sediment, and soil—each medium was considered separately in the derivation of ecological remediation goal options. Ecological remediation goal options were derived for physical media (surface water, sediment, and soil) as sources of contaminants to biota by direct ingestion, by direct contact, or through the food chain. As explained in Sect. 3.2, consideration of contamination of surface water and sediment has been deferred for near-term corrective actions. Although biota are a source of exposure through the food web, remedial goals for biota ultimately depend on uptake from abiotic media. Therefore, separate remediation goal options for biota were not derived.

There are four ecological remediation goal options for mercury in soil to protect ecological resources. The four soil remediation goal options are the results of several derivations from an ingestion or exposure equation for each of four trophic groups and three exposure scenarios. This is summarized in Sect. 2.5.3.2 of this FS and explained fully in the RI report (DOE 1994a) and RI addendum (DOE 1994b). Mid-level predators (e.g., wrens and shrews) require the lowest remediation goal options for protection because they have small home ranges and may ingest contaminated organisms which also live solely in their respective home ranges in contaminated portions on the floodplain. The proposed remediation goal options for mid-level predators are lower than those for other trophic groups and, therefore, as demonstrated in the RI report and RI addendum, automatically protect top predators (e.g., hawks and foxes), first-level terrestrial consumers (e.g., mice, insects, and earthworms), and plants. The four soil remediation goal

options, expressed in milligrams of total mercury per kilogram of EFPC soil, that protect ecological resources are:

- 3.3 mg/kg — upper-bound exposure (scenario 1)
- 30 mg/kg — intermediate exposure (scenario 2)
- 200 mg/kg — food chain scenario (DOE 1994a)
- 300 mg/kg — lower exposure (scenario 3)

The following paragraphs discuss each of the four remediation goal options with the objective of recommending one for subsequent use in this FS.

The high exposures resulting in remediation goal options of 3.3 mg/kg (rounded to 3 mg/kg) and 30 mg/kg are mathematically contrived. That is, the combination of exposures mathematically simulated in upper-bound and intermediate exposure scenarios has little to no basis in observed conditions on the EFPC floodplain. The ingestion or exposure equation contains seven variables, each of which can be mathematically expressed with a wide range of numerical values. High values — 100% in many cases — were selected to simulate "theoretical" or "very worst case" situations. As such, there is a great deal of unrealistic treatment of values that represent highly unlikely exposures and compounding of these effects that results in remediation goal options of 3 and 30 mg/kg.

The remediation goal option of 3 mg/kg from scenario 1 utilizes many 100% exposure parameters that are not likely to occur independently nor in combination, and thus may be overly protective. For example, the upper-bound exposure scenario assumes 100% of the diet is taken from the floodplain; 100% of the diet is contaminated earthworms or insects with high measured concentrations of mercury in their bodies; 100% of the mercury in the diet is absorbed by predators; and 100% of the total mercury in the diet is methyl mercury, which is relatively a very toxic form of mercury. Although a mid-level predator's range could be confined to the floodplain, it is not likely that any of the other conditions actually occurs, and it is even less likely that the combination actually can occur on the floodplain, given the scattered nature of the "hot spots" of the dominant mercury species. Thus, a remediation goal option of 3 is very conservative and probably overly protective; therefore, it is not recommended for further consideration.

The remediation goal option of 30 mg/kg from scenario 2 is also not likely to occur and may be overly protective. The intermediate exposure scenario assumes 100% diet is taken from the floodplain, 100% of the mercury in the diet is absorbed, and 40% of the total mercury in the diet is methyl mercury. The diet is less restrictive and includes combinations of foods that are likely eaten by EFPC predators. While this combination of assumptions is more likely to occur in EFPC than the combination of assumptions in the upper-bound scenario, the intermediate exposure combination is still not likely to be observed and is still overly protective; therefore, the remediation goal option of 30 is not recommended.

Furthermore, achievement of long-term reduction of ecotoxicological risk means that 15% or more of habitats in the floodplain may require alteration. The lower the remediation goal option, the larger the area of land requiring remediation at that concentration. For example, there are only a few acres where concentrations exceed 200 mg/kg but many acres where concentrations exceed 30 mg/kg and even more acres exceeding 3 mg/kg. Costs to remediate to

these levels would likely be very high, and given the highly conservative assumptions in deriving the remediation goal options, remediation to these levels would likely be excessive and, therefore, would not be cost effective. Remediation of more acreage means alteration of more habitats where organisms live. Any remediation involving excavation or containment would result in direct mortality of all plants and some animals living in the area. Since 70% of the floodplain is forests, much forest would be altered with remediation goal options of 3 and 30 mg/kg. The risk from remedial actions of this magnitude may even exceed the risk from no action.

Therefore, 3 mg/kg and 30 mg/kg are not reasonable remediation goal options because the conditions in the upper-bound and intermediate exposure scenarios being simulated are mathematically contrived. Each assumption in the ingestion equation is conservative, and when all the conservative assumptions are added one to another, this cumulative effect is to make the exposure, and therefore, the risk levels highly unlikely. Further, these unrealistically low remediation goal options would require habitat alteration (i.e., destruction followed by a slow recovery) of >15% of the floodplain [nearly 40 ha (100 acres)] for the 30 mg/kg remediation goal option alone and much more for the 3 mg/kg remediation goal option. In summary, the remediation goal options of 3 and 30 mg/kg represent ultraconservative exposures, would cost a great deal of money to implement, would result in direct mortality of plants and animals living in the area, and would cause so much habitat alteration that they should not be a serious consideration.

Exposures associated with remediation goal options of 200 and 300 mg/kg are more likely to actually occur. The exposure assumptions for the lower exposure scenario are based on fewer mathematically contrived values in the ingestion or exposure equation than are the variables in the upper-bound and intermediate exposures. For example, the percent of total mercury measured in prey bodies that is methyl mercury is mathematically reduced in the scenarios from 100% (upper-bound) to 40% (intermediate) to 10%, 4%, and 1% (lower). The latter three (lower exposure) values are believed to more realistically represent conditions in terrestrial organisms, as explained in the RI addendum (DOE 1994b). Other variables are held constant in this scenario and in each receptor. However, for top predators, the percent diet from the floodplain varies from 3% (hawks) to 9% (foxes), reduced from the assumed 100% in the more conservative scenarios. The lower values conform to more realistic home range sizes and hunting habits of these top predators. For first-level consumers such as mice, earthworms, and other invertebrates, it is assumed that 10% (not 100% as in the upper-bound exposure) of the mercury is absorbed from soil. Thus, the 200 and 300 mg/kg remediation goal options are more reasonable because their exposure assumptions are more reasonable.

Both the 200 and 300 mg/kg remediation goal options are protective of mid-level predators. One of the variables in the exposure equation is the assessment endpoint or the concentration (milligrams of methyl mercury in kilograms of food) that elicits a toxicological response. For the four toxicological values for wrens (0.1 and 0.2 mg/kg) and shrews (0.4 and 1.1 mg/kg), all four remediation goal options were computed, but 0.2 mg/kg is the most defensible conservative value because it is an estimated LOAEL for reproduction. Further, the LOAEL is for finches, which are small birds similar to wrens. By contrast, the lowest endpoint of 0.1 was a LOAEL for behavioral abnormalities in mallards, which represents a lesser effect than reproduction, and mallards are much larger birds than wrens. Thus, it is concluded that the 300 and the 200 mg/kg remediation goal options are protective because they are based on measured LOAELs, which

means that the toxicological assessment endpoint is supposedly low enough to protect all individuals in that population.

Both the 200 and 300 mg/kg remediation goal options automatically protect all other trophic groups. Protection of mid-level predators requires remediation goal options much lower than necessary to protect any other trophic group as computed in the lower exposure scenario. For example, remediation goal options for top predators range from 2300 mg/kg (owls) to 12,000 mg/kg (foxes). For protection of first-level terrestrial consumers, the remediation goal options are 920 mg/kg (amphibians) to >90,000 mg/kg (mice). For protection of plants, the remediation goal option is >10,000 mg/kg. All of these numbers exceed the 200 and 300 mg/kg remediation goal options for the mid-level predator. Thus, achieving a remediation goal option of 200 and 300 mg/kg would effectively protect all other terrestrial plants and animals in the EFPC floodplain ecosystem.

Remediation goal options of 200 and 300 mg/kg mean that ~3% and ~1.5%, respectively, of habitats may require alteration. The higher the remediation goal option, the smaller the area of land requiring remediation at that concentration. For example, there are ~7 ha (18 acres), 3% of 255 ha (630 acres), where soil concentrations exceed 200 mg/kg. For 300 mg/kg, around ~4 ha (9 acres) or 1.5% of the total acreage of the EFPC floodplain may require remediation. Lesser acreage means less alteration of habitats where organisms live and less direct mortality as a result of the remedial action itself. The higher the remediation goal option, the fewer acres of forest and/or field that must be disturbed. When the ecotoxicological risk is defined to size of habitat, then habitat alteration can be better justified (see balancing method in Appendix G). Remedial risk, as measured by habitat alteration, must be balanced against the benefits of remediating ecotoxicological risk. Generally, extent and magnitude of ecotoxicological risk increases with increasing sizes of habitats, so alteration of large habitats can be better justified than alteration of small habitats. Remediation goal options of 200 and 300 mg/kg require much less habitat disturbance than remediation goal options of 3 and 30 mg/kg and, therefore, when balancing the risks presented by remediation and the longer-term ecotoxicological risks, 200 and 300 mg/kg are more acceptable because much lower acreages of habitat would need to be disturbed.

The remediation goal option of 200 mg/kg is a conservative value that allows for some uncertainty in deriving the higher remediation goal option. One of the principal unknowns is the percent methyl mercury of total mercury in the bodies of various species of organisms. If there is more methyl mercury (the most toxic form) than the literature value for birds of 4%, then the exposure would be greater than computed, and the remediation goal option could reasonably need to be lower than 200 or 300 mg/kg. This unknown can be balanced by deliberately setting a remediation goal option that puts portions of populations (i.e., a small percentage of the total individuals) at risk. This would have the effect of raising the remediation goal option because the existing remediation goal options are protective of individuals. Another unknown is the relationship between methyl mercury in the soil and methyl mercury in animals. Bioaccumulation factors could be much higher than assumed or than is indicated by the limited sampling performed; this would result in a lower remediation goal option. However, measurements of methyl mercury in crayfish sampled in EFPC wetlands (DOE 1994b) seemed to show an upper limit to uptake rather than uptake proportional to concentrations in soil. Therefore, bioaccumulation factors may actually be lower than assumed. In addition, higher remediation goal options could result from a higher assessment endpoint or toxicological effect level. Indeed,

for most any condition that would lower the remediation goal option, there is a counter argument that would raise the remediation goal option. This technical counterbalancing of uncertainties and the tendency to be conservative because of such uncertainties argues for the selection of the lower of the two protective remediation goal options being discussed. Thus, 200 mg/kg is the recommended soil remediation goal option for protection of ecological resources.

3.4 SITE-SPECIFIC REMEDIAL ACTION OBJECTIVES

The overall objectives for remedial actions within the EFPC OU include eliminating or minimizing toxicity, mobility, and/or volume of mercury in soil, and the bioaccumulation or bioconcentration of mercury contaminants in sensitive ecological receptors. As specified in the National Contingency Plan (Sect. 300.430(e)(2)(i)(A)(2)), risk-based cleanup levels will be used in the absence of promulgated cleanup levels for soil in the EFPC floodplain. The remedial action objectives selected for developing remedial alternatives in the FS are based on the human health remediation goal options for soil ingestion and dermal contact with mercury in EFPC floodplain soil and on the lower exposure scenario for mid-level predators for ecological receptors.

- Residential and Agricultural land use
  - 180 mg/kg (protection of children)
  - 537 mg/kg (protection of adults)
  - 200 mg/kg (protection of ecological receptors)

- Commercial/DOE-owned and Other land use
  - 938 mg/kg (protection of children)
  - 1252 mg/kg (protection of adults)
  - 200 mg/kg (protection of ecological receptors)

- SLB
  - 990 mg/kg (protection of utility worker)
  - 938 mg/kg (protection of children)

The remedial action objectives for the EFPC OU are summarized in Table 3.1. The difference between the remedial action objectives for utility workers and children (as trespassers) in the SLB is minimal, and the 938 mg/kg objective affords protection to both groups of receptors. However, the mercury concentration in the SLB soil does not exceed the 990 mg/kg risk-based limit for exposure of utility workers; therefore, the SLB will not be considered further in this FS. Likewise, the mercury concentration in agricultural soil does not exceed the 180 mg/kg limit; therefore the agricultural soil will not be considered further in this FS. Surface water and sediment will be addressed by interim actions only.

3.5 GENERAL RESPONSE ACTIONS

The next step in the initial screening and development of alternatives is to identify general response actions and remedial technologies that address the remedial action objectives and are potentially applicable to the remediation of EFPC OU soil. The *Initial Screening of Alternatives*

for EFPC and SLB (Radian 1991) identified, evaluated, and retained a number of applicable remedial technologies. Since the publication of that document, more information and data have become available. For example, the media of concern have been revised, and the COPCs have been narrowed by the baseline risk assessment to applicable COCs, which are somewhat different. Therefore, some of the remedial technologies that were retained as applicable in the earlier document are no longer applicable.

General response actions involve activities (e.g., excavation and treatment) that directly affect the contaminated materials at the site to minimize the potential hazard to human health and the environment. Each general response action may include several technologies and process options. General response actions considered appropriate for the soil at the EFPC OU are listed in Table 3.2 and include the following:

- no action,
- institutional actions,
- containment actions,
- excavation actions,
- treatment actions, and
- disposal and beneficial reuse actions.

Although remedial action objectives will not be developed for the surface water and sediment at this time because of continued permitted discharges of contaminants to EFPC, interim general response actions are considered appropriate actions for the surface water and sediment at the EFPC OU and include the following:

- no action and
- institutional actions.

Interim actions for the EFPC OU are summarized in Table 3.3. The Reduction of Mercury in Plant Effluent Phase II (RMPE II) Program was established to mitigate current sources of mercury from the Y-12 Plant. The NPDES permit for the Y-12 Plant is currently being negotiated with the State of Tennessee with the goal of reducing mercury discharges to Upper EFPC by ~80% over the 5-year permit period. This reduction is based on achieving a site-specific criterion for mercury that has been presented to the State of Tennessee as part of the NPDES permitting process. For the purpose of this FS, the interim time frame extends from implementation of an action until the permitted discharges from the Y-12 Plant are eliminated or the levels of contaminants in the discharge are below levels of concern to ecological receptors. Interim actions for the surface water and sediment will be consistent with the NPDES permit (reissued 1994) and the associated schedule and timetable for bringing the Y-12 Plant effluent into compliance.

3.5.1 No Action

No Action is evaluated in compliance with CERCLA requirements and NEPA values and provides a baseline for comparison with other technologies and options. Under NEPA, evaluation of the No Action alternative should include a consideration of future land use. Remedial technologies, which reduce the potential hazards to human or ecological receptors, would not be implemented under the No Action alternative. Therefore, human health and

environmental risks of exposure to existing contamination would not change. No further action would be taken under this response, with the exception of environmental monitoring and periodic (5-year) reviews because contamination remains.

3.5.2 Institutional Actions

Institutional actions include institutional and legal controls, environmental monitoring, and 5-year reviews. Institutional and legal controls preclude or minimize exposure by limiting access to or use of contaminated areas by (1) restricting access to contaminated media by means of fencing, site security, and posting of signs; (2) federal real estate acquisitions of private property; and/or (3) deed or land-use restrictions. A DOE real estate acquisition could range from easement to right-of-way to property procurement. For example, DOE could purchase a portion of a privately owned parcel to secure a fenced area with soil cover following a containment action. Institutional controls do not reduce contaminant toxicity, mobility, or volume, but they can reduce the potential for exposure to contaminated material. In accordance with National Contingency Plan requirements, institutional controls may not be used as a substitute for active response measures as the sole remedy unless active measures are determined not to be practicable. Therefore, institutional controls are generally combined with other actions to reduce exposure to residual contaminants.

Environmental monitoring is included as an institutional action for the EFPC OU. Although monitoring alone does not prevent or minimize exposure, it does allow assessment of the migration of residual contaminants wherever contamination is left in place. A well survey would be conducted annually to confirm that groundwater was not being used as a drinking water source. Also included as institutional actions are 5-year reviews of site conditions and environmental data. Five-year reviews are required if residual contamination remains. These reviews would be repeated no less than every 5 years to confirm that residual risk levels remain acceptable.

3.5.3 Containment Actions

Containment actions consist of technologies that confine contaminated media at their current locations. These technologies reduce contaminant mobility and the associated potential for exposure; however, they do not reduce contaminant toxicity or volume. Containment actions include capping, vertical barriers, and horizontal barriers. Process options for capping include native soil, clay, synthetic membrane, multilayered media, asphalt, concrete, and chemical sealants and stabilizers. The capping technologies considered for the soil at the EFPC OU involve covering an area with soil or other cover material to reduce the migration of contaminants by free release to the atmosphere. A permeable high-density polyethylene intrusion barrier would be installed to deter burrowing animals from living in the contaminated areas. The cover material would also provide a barrier between the contaminated medium and human and some ecological receptors. The cover material could minimize the release into the atmosphere of contaminated surface soil, which could be redeposited onto another area. Vertical and horizontal barriers are used to prevent migration of mobile contaminants and include slurry walls, grout curtains or injections, and other processes listed in Table 3.2.

3.5.4 Excavation Actions

Contaminated materials may be removed from the area of contamination by soil excavation. Conventional earth-moving equipment (such as bulldozers, backhoes, front-end loaders, and excavators) can be used to excavate contaminated soil. The type of equipment to be used can be determined by the size of the area to be remediated, the area available to set up the equipment, the bucket size required for efficient removal of the soil, and the capability for moving the contaminated soil to a facility for treatment or disposal. Manual excavation techniques may be used in areas with limited access. Appropriate health and safety measures in accordance with OSHA are required for all excavation actions.

A site selection process was conducted to identify a reasonable site for a borrow area that has the capacity to supply backfill soil for excavation actions and soil for containment covers. Selection criteria for a borrow area included: minimize need for major road improvements; have adequate soil volume; minimize adjacent land disturbance; have compatible soil type (i.e., to match remediated areas); protect environment and preserve natural resources; require no new NEPA documentation; minimize impacts on public safety and convenience; minimize potential for accidental discharge of contaminants into surrounding streams; be compatible with existing land uses and future land-use plans; and consider public perception of the proposed activities. Twelve potential development areas (11 on the ORR and 1 outside the ORR) and an off-site vendor option were considered. Nine sites, including the one located outside the ORR and the off-site vendor option, were eliminated from further consideration based on the selection criteria. The three remaining candidates were evaluated and ranked by benefits and constraints. The borrow site best meeting the criteria used in this evaluation was the West End Borrow Area on the ORR. The site has the capacity to provide adequate soil volume for backfill and cover needs; has a stockpile of 22,937 m^3 (30,000 yd^3) of topsoil available on site; is already a designated borrow site with access roads; and has existing NEPA documentation. Figure 3.1 depicts the borrow site location.

3.5.5 Treatment Actions

Treatment involves the use of physical, chemical, biological, thermal, and dewatering technologies to reduce or eliminate the toxicity, volume, or mobility of the COCs. Some processes (e.g., incineration) require excavation of soil, whereas other processes (e.g., in situ vitrification) are performed in place. The following sections present an overview of available treatment technologies and their general applications. Table 3.4 lists process options under each type of technology.

Physical technologies reduce the volume of the contaminated materials by physical separation techniques and segregation or immobilize the contaminants in place (e.g., solidification). Mechanical soil washing, air stripping, soil flushing, and adsorption and absorption are all physical processes that separate the contaminants from the medium. Stabilization reduces the hazardous potential of a waste by converting each contaminant to a less mobile or reactive form. Stabilizers are used in conjunction with solidifiers to provide chemical and physical binding of contaminants in the soil. Solidification technologies that have been considered for EFPC soil include pozzolanic agents and portland cement. Additional physical processes are listed in Table 3.2.

Chemical technologies alter the chemical structure of the waste constituents to produce a waste residue that is less hazardous than the original waste. Chemical processes can separate the contaminants from solid waste media through chemical extraction or leaching techniques to reduce the volume or mobility of the contaminants. Other processes such as oxidation/reduction involve chemical reactions to change the form of the contaminant to be less toxic or mobile. Chemical fixation techniques can be used to form a bond with the waste material, resulting in solids or stable materials that are resistant to leaching of contaminants.

Biological technologies use microbial enzymatic processes to transform organic and inorganic compounds. Contaminated soil can be treated by solid-phase and slurry-phase processes. These processes have been developed and used to treat a wide range of contaminants such as pesticides, diesel fuel, gasoline, fuel oil, creosote, pentachlorophenol, and halogenated volatile organics. Microbial agents also can be used to transform, detoxify, or precipitate inorganic contaminants such as selenium and uranium.

Thermal treatment is associated with the use of elevated temperatures as the principal means of destroying, detoxifying, or physically stabilizing hazardous wastes. Thermal treatment includes such processing options as gaseous or rotary kiln incineration, infrared heating, wet air oxidation, pyrolysis, low-temperature thermal desorption, and vitrification.

In situ treatment involves various physical, chemical, biological, and thermal techniques used to treat contaminated soil in place.

Dewatering techniques are used on waste streams with high moisture contents to separate liquids from solids, often as a pretreatment step to reduce the volume of waste to be treated. Examples of dewatering process options include drying and dewatering beds and sludge dryers and kilns.

3.5.6 Disposal and Beneficial Reuse Actions

Disposal and beneficial reuse actions involve the permanent and final placement of waste materials in a manner that protects human health and the environment. Material can be disposed of on site or off site or can be beneficially reused. Both on-site and off-site disposal options could include moving the soil to staging areas prior to transport to the disposal facility. Both untreated and treated (low-temperature thermal desorption pilot study) samples of the floodplain soil meet RCRA TCLP limits. Disposal options for the soil are discussed below.

3.5.6.1 On-site disposal

The on-site disposal options include disposal at an existing, approved, lined disposal facility located on the ORR or through siting and construction of a new facility. The Y-12 Plant landfills, the only operating construction or industrial waste landfills on the ORR, are used to dispose of waste from the Y-12 Plant, K-25 Site, and ORNL. Existing facilities capable of accepting the waste material include Landfills II, V, VI, and VII, all located at the Y-12 Plant. These landfills meet the respective construction and operating requirements for Class II (sanitary) or Class IV (industrial or construction) landfills as defined by TDEC regulations. Disposal of EFPC soil in any Y-12 landfill would require discussions with and approval from TDEC and the State of Tennessee, Division of Solid Waste.

Class IV landfills are unlined bulk disposal cells with no leachate collection and limited cover requirements. They are used for disposal of waste such as construction and demolition debris. Landfill VI is a Class IV landfill that was completed in 1993 adjacent to Landfill II on Chestnut Ridge and is permitted. Landfill VII is also a Class IV landfill scheduled to be completed in late 1994 on Chestnut Ridge in conjunction with Landfill V and permitted. It is assumed that TDEC will not permit disposal of material with mercury concentrations > 180 ppm in Class IV landfills, such as Y-12 Landfills VI or VII, because of the lack of environmental protection provided by this type facility. However, environmental protection could be obtained by adding a liner and leachate collection/pretreatment system.

Class II landfills are lined bulk disposal cells with leachate collection systems and monitoring and daily cover requirements. Y-12 Landfill II is a Class II industrial waste landfill permitted by TDEC and located on Chestnut Ridge within the Y-12 Plant boundary. This facility has nearly reached its capacity and is scheduled to close in the near future. Because the Record of Decision for the EFPC remedial action is not scheduled to be signed until 1995, Landfill II was excluded from consideration.

Landfill V is a Class II industrial waste landfill to be located on another section of Chestnut Ridge within the Y-12 Plant boundary. Landfill V is designed in accordance with current Class II landfill requirements such as a lined disposal cell, leachate collection, environmental monitoring, and daily cover. If waste generation rates at the facilities are less than projected, and if approval is received from TDEC and the State of Tennessee, Division of Solid Waste to classify the excavated soil from EFPC as a "special waste," the waste could potentially be disposed of in Landfill V. Landfill V would provide a level of containment and environmental protectiveness consistent with the CERCLA requirements.

Any disposal facility selected would comply with all applicable federal, state, and local regulations and permits at the time of disposal. EFPC floodplain soil would not be considered a waste until it was excavated. Excavated floodplain soil would be managed as a low-level radioactive waste because man-made radionuclides (e.g., ^{237}Np) have been detected and quantified in floodplain soil but not in background samples.

In accordance with a DOE letter and the current TDEC permit, material accepted for disposal at the ORR landfills must have < 12 ppm total mercury and < 35 pCi/g total uranium, or written approval must be obtained prior to disposal. Other radionuclide concentrations are expected to be well below this limit. Mercury in the EFPC soil is significantly above (> 200 ppm) the DOE level but well below the levels that would necessitate handling this material as hazardous waste. If TDEC and the State of Tennessee, Division of Solid Waste approve, the material could be accepted at a permitted landfill as "special waste" under TDEC landfill regulations. Special waste can include any material not disposable in a landfill under a general operating permit. TDEC can approve disposal of special waste in the ORR landfills as currently designed and operated, or can allow the facility to accept the waste with design changes or additional facility operational requirements. At the levels expected for EFPC soil, and the proven minimal leachability characteristics of that soil matrix, it is anticipated that the Class II landfill design requirements for a bottom liner with leachate collection would provide adequate environmental protectiveness for long-term management of the waste materials.

On-site disposal could also be accomplished through the construction of a new facility specifically for EFPC soil. This facility would likely have to be constructed to standards similar to those for the Y-12 landfill: liner, leachate collection and treatment systems, and other design and operational requirements. Before accepting EFPC soil, a new disposal facility would have to go through an extensive process of siting, environmental impact assessment, regulatory approval, public review and comment, design, and ultimately, construction. This process could take many years. An area of 4 to 6 ha (11 to 15 acres) could accommodate the expected amount of excavated soil, assuming a soil depth of ~3 m (10 ft), and could include all engineering features such as runon/runoff controls, leachate collection and treatment systems, access roads, utility connections, and other requirements. Areas of this size are available on the ORR. However, because no investigations have been done to locate a suitable site, both the technical feasibility of these areas (soil types, slope stability, groundwater depth, availability of utilities, etc.) and the environmental and regulatory acceptability are uncertain.

3.5.6.2 Off-site disposal

Although DOE Order 5820.2A states that DOE low-level waste shall be disposed of on site or at another DOE facility, the precedent set when DOE's Formerly Utilized Sites Remedial Action Program waste was sent to the Envirocare Disposal Facility for disposal allows for further use of commercial disposal facilities. The off-site disposal options include a commercial sanitary landfill, an existing licensed low-level waste disposal facility, construction of a new low-level waste disposal facility, and ocean dumping.

Off-site disposal at a commercial sanitary landfill was eliminated as a disposal option because of DOE's "no-rad-added" policy. DOE policy stipulates that DOE facilities are not permitted to transport waste material with radioactive contamination generated by DOE operations for disposal at commercial disposal facilities unless they have a Nuclear Regulatory Commission license appropriate for the materials being disposed. There are no known commercial sanitary landfills with Nuclear Regulatory Commission licenses.

Off-site disposal at an existing, licensed low-level waste disposal facility involves consideration of the following disposal facilities: Nevada Test Site (Nevada), Envirocare (Clive, Utah), Chem-Nuclear (Barnwell, South Carolina), U.S. Ecology (Richland, Washington), and Texcor (Spofford, Texas).

The Nevada Test Site radioactive waste disposal operation has been designated for wastes generated through DOE Defense Program operations. The site has no specific restrictions that would preclude acceptance of EFPC wastes. Extensive certification and pre-shipment approval requirements are specified in the waste acceptance criteria.

The Clive, Utah, site was first chosen by DOE for the remediation of uranium mill tailings generated by Vitro Chemical Company. Factors that influenced the selection of the site included hydrogeology, location, flora and fauna, and overall site suitability. The Envirocare Disposal Facility of Utah was designed specifically for disposal of low-activity, high-volume remediation wastes, and was authorized for disposal of either bulk or containerized naturally occurring radioactive material. The site has no specific restrictions that would preclude acceptance of EFPC wastes. Extensive certification and pre-shipment approval requirements are specified in the waste acceptance criteria.

Chem-Nuclear Disposal Facility in Barnwell, South Carolina, has an agreement to provide disposal capacity for facilities within the Southeastern Regional Compact until January 1, 1996. After July 1, 1994, importation of out-of-compact waste must be specifically authorized. Any agreements to accept out-of-compact waste include a user's fee.

The disposal facility operated by U.S. Ecology in Richland, Washington, will only accept waste from states within the Northwest Compact and the Rocky Mountain Compact; therefore, EFPC wastes would be precluded. Texcor Industries, Inc. of Brackettsville, Texas, maintains a waste disposal facility located in Spofford, Texas. However, Texcor has a statutory restriction on accepting low-level waste generated out of state and, thus, is not a viable option for EFPC wastes.

Construction of a new off-site low-level waste disposal facility was eliminated as an option because of the availability of existing operating facilities with sufficient capacity to dispose of the EFPC soil. In addition, the cost of locating, permitting, designing, and constructing a new low-level waste disposal facility for the small volume of EFPC soil would be an order of magnitude higher than the cost of using an existing disposal facility.

Ocean dumping was also considered but was eliminated from further consideration. The disposal of materials in the ocean is regulated under 40 CFR 220 and 227 through 229. Ocean dumping is controlled by an extensive permitting system and was not considered to be appropriate for the EFPC mercury-contaminated soil.

3.5.6.3 Beneficial reuse

Beneficial reuse options include landfill cover, backfill in areas of excavation, roadway and runway fill, use as fill material on the ORR, land spreading, or reclamation and recycling of the concentrated contaminant. The reuse of soil as daily landfill cover is restricted to treated soil and to the volume of material that can be temporarily stored at the landfill site. Before backfilling excavated areas with treated soil, a performance assessment is necessary to study acceptable levels of residual contamination.

Beneficial reuse through roadbed dispersal involves using contaminated soil during the construction of airport runways, roads, and highways. Beneficial reuse also includes the use of contaminated soil as landfill cover or as fill material for a CERCLA action. To comply with the level of control specified in 40 CFR 192, only newly constructed interstate highways would be appropriate for such use. A site-specific performance assessment (to meet performance objectives of DOE Order 5820.2A, "Radioactive Waste Management") would be required for any disposal option, including beneficial reuse. Because Tennessee is a Nuclear Regulatory Commission "agreement state," the state must approve the performance assessment before excavated soil can be beneficially reused on the ORR or treated soil can be returned to the floodplain (or other Tennessee location) for beneficial reuse.

3.6 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

3.6.1 Identification of Applicable Technologies

Table 3.2 lists potential remedial technology types and technology process options that are applicable to the remediation of soil at the EFPC OU. The technology types are based, to the extent applicable, on the initial screening of alternatives (Radian 1991) and on the revised screening process performed and documented in this section of the FS report. Some of the selected representative technology process options are different from those initially proposed as representative in the initial screening of alternatives (Radian 1991) because the results of the baseline risk assessment eliminated some contaminants and media.

3.6.2 Initial Screening Criteria

The initial screening of technologies for the EFPC OU floodplain soil was based on technical implementability for mercury-contaminated soil:

- applicability to the affected medium and COC (mercury-contaminated soil),
- applicability to the contaminant fate,
- long-term reliability,
- volume and character of secondary wastes potentially generated by a process option,
- implementability within a reasonable period of time, and
- ability to identify and control process interferences.

3.6.3 Initial Screening of Technologies and Process Options

Table 3.4 lists the technology types and technology process options for each general response action, documents the technologies reviewed, and summarizes the revised initial screening of technologies and process options for soil. In accordance with EPA guidance (EPA 1988b), technology types and technology process options are eliminated from further consideration in this step on the basis of inapplicability to the contaminant or medium, or lack of technical implementability. Results of a preliminary treatability study (Radian 1993a) have been incorporated into this screening step. The technologies and process options correspond to the general response actions identified in Sect. 3.5 of this FS. Those process options not eliminated by the screening criteria identified in Sect. 3.6.2 are retained for further evaluation as "potentially applicable" technologies.

3.6.3.1 Retained technologies and process options for soil

The following technology types and process options were retained for further consideration for remediation of soil at the EFPC OU on the basis of the initial screening criteria identified in Sect. 3.6.2:

1. The institutional action technology types retained for soil were access control (i.e., site protection and security personnel); legal controls (i.e., federal acquisitions and deed and use restrictions); soil sampling as a monitoring process option; and 5-year reviews.

2. Native soil, clay, synthetic membrane, multilayered media, asphalt, and concrete caps were retained under containment technology.

3. Soil excavation using earth-moving equipment was retained as an excavation technology.

4. Several physical, chemical, thermal, and dewatering techniques were retained as treatment actions following excavation. The physical treatment technology process options retained include the crushing and grinding of solids, the shredding and chipping of solids, and screens and grizzlies. Chemical soil washing with potassium iodide/iodine (KI/I_2) was retained on the basis of treatability study results. The thermal treatment technology process options retained were fluidized-bed incineration, low-temperature thermal desorption, rotary kiln combustion, circulating-bed combustion, and multiple-hearth incineration. The dewatering treatment processes retained included drying and dewatering beds, confined disposal facility, and sludge dryers and kilns. As indicated in Table 3.4, biological treatment and in situ treatment technologies were not retained.

5. The retained on-site disposal process options include an approved, lined landfill with leachate collection, such as a modified Class IV construction debris landfill (Landfill VI or VII) or a Class II landfill (Landfill V). The off-site disposal process option that is retained is a licensed low-level waste disposal facility. Beneficial reuse options (Table 3.4) were retained.

3.7 EVALUATION OF RETAINED TECHNOLOGIES AND SELECTION OF REPRESENTATIVE TECHNOLOGIES AND TECHNOLOGY PROCESS OPTIONS

This section presents the results of further evaluation of the potentially applicable technology process options remaining after the initial screening conducted in Sect. 3.6. The criteria used for this second level of screening follow EPA guidance (EPA 1988b) and include an effectiveness, implementability, and cost analysis, which takes into account the volumes of waste material and site-specific constraints. This screening step results in the selection of one representative process option for each technology type, if practical. Selecting representative processes simplifies subsequent development and evaluation of remedial alternatives.

3.7.1 Evaluation Criteria

3.7.1.1 Effectiveness

The identified process options are evaluated as to their potential to protect human health and the environment and to satisfy the remedial action objectives for EFPC soil identified in Table 3.1. The potential of each process to reduce the contaminant concentrations or exposure levels is evaluated. The level of protection each option affords to human health and the environment, as well as any potential adverse environmental effects, is also considered.

The evaluation addresses site-specific performance (i.e., how effective and reliable the process option would be with respect to the contaminants and conditions at the site). Reliability is a major consideration in assessing effectiveness because of the operation and maintenance requirements of most process options and the importance of protecting human health and the environment during remediation activities. The effectiveness evaluation favors proven or

demonstrated technologies, although innovative technologies are also considered. An important measure of effectiveness is how quickly the process could achieve protection [National Contingency Plan 300.430(e)(7)(i)]. The long-term management of residual contamination or untreated waste reduces the effectiveness of a technology; therefore, the duration of long-term management is evaluated as part of the effectiveness of a technology.

3.7.1.2 Implementability

The implementability evaluation criteria include both technical and administrative considerations. Technical feasibility addresses the availability and constructability of the process option and the time required for construction and implementation. Both the implementation time and the period required for beneficial results to be realized are important to protection of human health and the environment.

The administrative considerations in evaluating implementability include the ability to obtain the necessary approvals from regulatory agencies; the availability of treatment, storage, and disposal facilities and associated capacities; and the availability of necessary equipment and skilled workers to implement the technology.

3.7.1.3 Cost

EPA guidance (EPA 1988b) suggests that viable process options be screened by relative capital costs and operation and maintenance costs rather than by detailed estimates. The complexity of the process options determines the detail required for the cost estimates. The cost analysis is based on engineering judgment, available vendor price quote, and costs reported from similar remedial actions implemented at other CERCLA sites.

3.7.2 Evaluation of Technology Process Options

The criteria described in Sect. 3.7.1 were used to evaluate the remedial technologies within each of the general response actions. Table 3.5 summarizes the evaluation of effectiveness, implementability, and costs for each technology process option retained in the initial screening. This information allows a review of the process options to facilitate the identification of those that are most feasible and representative of the applicable remedial technologies. The results of this screening are used to define representative process options for further consideration.

3.8 REPRESENTATIVE TECHNOLOGY PROCESS OPTIONS FOR SOIL

Representative technology process options for soil were selected from those retained in the second-level screening for further development and evaluation of remedial alternatives. Table 3.6 lists the representative technology process options that were judged to be the most effective, implementable, and cost-effective for each applicable technology type. In some cases, more than one technology process option was selected for a technology type because the options were different enough that the performance of one did not adequately represent the other. In addition, process options that can be used in combination with other processes were retained for evaluation as part of an action alternative.

The selection of a representative technology process option does not preclude the use of other potentially applicable technologies. Rather, the representative technology process option provides a basis for developing and evaluating remedial alternatives until such time as a final decision is made. In all cases, for this evaluation of the EFPC OU, the selected representative technology process option adequately represents the performance of the other potentially applicable technology processes.

Institutional actions for soil include institutional and legal controls (e.g., fences, signs, and berms; federal acquisitions; and deed and use restrictions) to provide a reliable containment action. Involvement of a federal agency (with cooperation of state and local agencies) would be required to maintain institutional actions. Long-term monitoring and 5-year reviews are also included.

Containment of contaminated soil by capping with native soil was chosen because of its effectiveness and relatively low cost. This option addresses the soil ingestion and dermal pathways. Because mercury is not mobile in the soil, it is not necessary to prevent infiltration of water through the cover.

Excavation of soil with conventional earth-moving equipment was chosen as an effective and reliable excavation action. Clean soil for replacement of excavated soil is available, if required, from the West End Borrow Area at the Y-12 Plant. Clean soil could also be obtained from excess soil at the Y-12 landfill site.

Treatment of soil is intended to reduce both the volume and toxicity of the medium. The dewatering process chosen for pretreatment was drying beds. The toxicity reduction treatment process chosen was low-temperature thermal desorption. Phase II treatability study results (Radian 1993b) have shown that low-temperature thermal desorption can remove mercury compounds from EFPC soil at temperatures as low as 350° C (662° F). KI/I_2 solution was demonstrated to be an effective trapping medium for mercury-containing vapors evolved during the process. Treatment residuals will be evaluated and sent to an approved disposal facility.

On-site disposal through the modification of a construction debris landfill (Landfill VII) was retained as the representative disposal option for evaluation. As discussed below, the on-site location has numerous advantages over potential off-site locations with respect to the technology process option screening criteria (i.e., effectiveness, implementability, and cost).

Modification of Landfill VII was chosen as the representative option for this evaluation only. Landfill V or Landfill VI modified include a liner and leachate collection, are also viable options. Y-12 Waste Management personnel have expressed a preference not to use Landfill V because it is an operational sanitary landfill with an active life of 43 years, which is fully dedicated to the mission of the ORR. Landfills VI and VII are both construction debris landfills; Landfill VII is larger and, therefore, was selected as the representative option. Landfill VII is a Class IV construction debris landfill located on a portion of the Chestnut Ridge within the Y-12 Plant boundary. Figure 3.1 identifies the locations of on-site landfill disposal areas in relation to the three plants. Figure 3.2 depicts the Landfill V and VII disposal locations.

Modification of the Landfill VII facility is recommended for disposal of the EFPC contaminated soil. The EFPC contaminated soil could potentially be accepted as a "special waste" under TDEC landfill regulations. Landfill VII modification would include leachate collection, a liner, leachate treatment (if required), construction of the new unit, cover material for the disposal cells and closure cap, and any additional monitoring or design costs TDEC may require for special waste. Modification of Landfill VII would require obtaining "special waste" approval and a modified permit from TDEC. Cost and schedule delays inherent in the permitting of a new facility would be eliminated by disposing of the EFPC material in Landfill VII. The cost to modify Landfill VII would be much less (on the order of 3 to 4 times less) than the cost of locating, designing, and operating another new facility. In addition, availability of potential suitable locations on the ORR is limited and finding another suitable disposal facility location would be expected to delay the completion of the EFPC OU remedial action by ~3 years. The identification and selection of the location of Landfill V was conducted over a period of ~5 years due to the required investigations and studies necessary to identify and select a suitable location on the ORR.

Disposal of the soil on site is not subject to Nuclear Regulatory Commission licensing, because DOE is self-regulating for on-site facilities operations. However, the design and performance of the landfill would be subject to DOE and TDEC oversight and regulation as a part of both the remedial action and the landfill permit, administered by TDEC. Currently, the amount of allowable radioactivity in the landfill is 35 pCi/g of total uranium and the allowable total mercury level is 12 ppm. Because the EFPC soil also contains trace quantities of other radionuclides (particularly ^{237}Np), acceptance of this soil in the landfill would be subject to "special waste" approval by TDEC.

Disposing of wastes generated by the remediation of EFPC on the ORR is consistent with DOE Order 5820.2A and allows control over the management and disposal of the waste. Use of the on-site Landfill VII is also consistent with the DOE-OR CERCLA waste management strategy of providing waste treatment, storage, and disposal within the area of contamination as part of an OU remediation activity. By maintaining control of the waste material within the area of contamination, the management of that waste remains under CERCLA authority, with its attendant emphasis on risk-based treatment, storage, and disposal options. As long as the excavated EFPC soil remains within the area of contamination (as defined by the boundaries of the ORR under the National Priorities List agreement), that material could potentially be handled as a special waste appropriate for disposal at Landfill VII. The disposal would, of course, be approved by EPA and the facility would be designed, constructed, and operated within the guidelines of DOE and TDEC. If the material is removed from the area of contamination and transported to other DOE or commercial treatment, storage, and disposal facilities, it must be packaged, transported, and subsequently managed by DOE, the Nuclear Regulatory Commission, EPA, and appropriate state regulations.

On-site disposal at a new disposal facility was not retained as the representative disposal option because of the increase in unit cost and the decreased implementability. The cost of locating and constructing a new disposal facility would be expected to be on the order of 2 to 3 times more than the cost of modifying an approved landfill facility. The approval process for a new facility would be long and costly. Locating and design periods of 4 to 6 years are not uncommon for similar landfill facilities. As an example, Landfill V required ~5 years of studies and investigations to identify a suitable location on the ORR. In addition, to operate properly,

a new facility would require all the necessary ancillary utilities and support buildings, which would not be required with the modification of an existing approved landfill. Construction of a new disposal facility for EFPC mercury-contaminated soil is not retained because the modification of an approved disposal facility (such as Landfill VI or VII) is considered to be equally effective and significantly more implementable and cost-effective than locating, designing, and constructing an entirely new disposal facility.

Off-site disposal at a licensed low-level waste disposal facility, which includes both commercial and DOE low-level waste disposal facilities, was not retained as the representative disposal option. The commercial low-level waste and DOE low-level waste disposal options were eliminated from further consideration because they are less implementable and are significantly more costly when compared with the retained representative disposal option, on-site disposal. Implementability issues considered during the evaluation as negative factors included the requirement to obtain approval to dispose of the EFPC soil from the EPA region where the disposal facility is located, potentially limited capacity at the existing disposal facilities, and public acceptance of the transportation and disposal of the waste materials. The costs of disposal and transportation for the commercial low-level waste facility ($\sim$\$300/yd^3) and for the DOE low-level waste disposal facility ($\sim$\$400/yd^3) are significantly more than the estimated disposal and transportation costs for the modification of Landfill VII ($\sim$\$100/yd^3). For the quantity of soil potentially requiring disposal, this cost differential would be $\sim$\$25 million for the commercial facility and up to $\sim$\$39 million for the DOE facility. The off-site disposal option would be retained for contaminated soil that does not meet the "special waste" provisions approved by TDEC and the State of Tennessee, Division of Solid Waste.

Beneficial reuse of treated soil was retained. The treated soil would be used as backfill in the excavated areas of the floodplain. Treated soil would be amended with fertilizers and replanted as needed to restore vegetation in those areas. Beneficial reuse of untreated soil was not retained because no reuse option is available at this time. However, if a CERCLA site becomes available and TDEC and EPA approve, beneficial reuse of untreated soil would be a viable option.

SECTION 3

TABLES

This page intentionally left blank.

Table 3.1. Remedial action objectives for EFPC OU soil

Potential exposure concerns	Remedial action objectives
Human health	Eliminate or minimize toxicity, mobility, and/or volume of mercury in soil.
	Eliminate or minimize exposures to mercury via the soil ingestion and dermal exposure pathways.
	Reduce exposure to mercury levels in soil to ≤ 180 mg/kg (ppm) for residential areas.
	Reduce exposure to mercury levels in soil to ≤ 938 mg/kg (ppm) for commercial/DOE-owned properties.
	Reduce exposure to mercury levels in soil to ≤ 938 mg/kg (ppm) for open (i.e., other) or undeveloped properties.
Environmental protection	Eliminate or minimize the bioaccumulation or bioconcentration of mercury contaminants in sensitive ecological receptors.
	Reduce exposures to mercury levels in soil to ≤ 200 mg/kg (or ppm) for commercial/DOE-owned, open (i.e., Other), or undeveloped properties.

Table 3.2. EFPC OU general response actions, remedial technologies, and process options considered prior to screening

Environmental medium	General response actions	Remedial technologies	Process options
Soils	No Action	—	—
	Institutional Actions	Access controls	Site protection, security personnel, fencing (institutional actions only)
		Legal controls	Federal acquisitions, deed/use restrictions, construction permit restrictions
		Monitoring	Soil sampling/analysis (No Action and institutional actions); sampling/analysis of biota
		5-year review	Documented reviews conducted every 5 years until results indicate residual risk levels are acceptable
	Containment	Capping	Native soil, clay, synthetic membrane, multi-layered media, asphalt, concrete, chemical sealants/stabilizers
		Vertical barriers	Slurry walls, sheet piling, grout curtain, ground freezing, vibrating beam
		Horizontal barriers	Liners, grout injection, block displacement, ground freezing
	Excavation	Soil excavation	Earth-moving equipment
	Treatment	Physical	Thermoplastic solidification, water/solids leaching, mechanical soil washing, air stripping, soil flushing, adsorption/desorption, solids crushing/grinding, solids shredding and chipping, magnetic separation, Portland cement solidification, land aeration, screens/grizzlies, pozzolanic agents solidification, liquid gas extraction
		Chemical	Electrolytic oxidation, chemical oxidation/reduction, oxidation by hypochlorite, fixation/immobilization, chemical soil washing, chemical/acid leaching
		Biological	Biological processes. Aerobic and anaerobic degradation of organics; transformation or precipitation of inorganics.
		Thermal	Fluidized-bed incineration, pyrolysis, gaseous incineration, radio frequency/infrared incineration, retorting, low-temperature thermal desorption, rotary kiln incineration, circulating beds, advanced electric fluid wall reactor, permitted/approved low-level waste incinerator
		In situ	Subsurface biodegradation, radio frequency heating, soil flushing, steam extraction, vacuum extraction, in situ vitrification, surface bioreclamation, surface micro-encapsulation, acid leaching, nutrient/microbial injection, in situ stabilization/solidification, hydrolysis, in situ chemical treatment (detoxifier), chemical flushing, electrokinetics, engineered wetlands

Table 3.2 (continued)

Environmental medium	General response actions	Remedial technologies	Process options
		Dewatering	Drying/dewatering bed, confined disposal facility, sludge dryers/kilns
	Disposal	On-site disposal	Existing and new disposal facilities
		Off-site disposal	Sanitary landfill, licensed low-level waste facility, new low-level disposal facility
	Beneficial reuse	Beneficial reuse	Land cover, backfill, roadway/runway fill, land spreading, reclamation

Table 3.3. Interim actions for surface water and sediments at the EFPC OU

Environmental medium	Interim general response actions	Remedial technologies	Process options
Sediments/ surface water	No action	—	—
	Institutional actions	Institutional controls	Digging restrictions; fish consumption warnings; fencing; public advisories
		Monitoring	Environmental monitoring, studies
		5-year review	Documented reviews conducted every 5 years

Table 3.4. Initial screening of process options for soils at EFPC OU

Soils general response action	Remedial technology	Process options	Description	Screening comments
No Action	None	N/A	No action to be taken to implement remedial technologies to reduce the hazard to potential human or ecological receptors.	Required for consideration by CERCLA and NEPA.
Institutional Actions	Access controls	Site protection	Fencing, barriers, signs, etc.	Potentially applicable. Easily implementable in the ORR area. In other areas, careful consideration will be warranted.
		Security personnel	Guards used to restrict and monitor site access.	Potentially applicable. Implementable on the ORR. Difficult to enforce in other areas.
	Legal controls	Deed/use restrictions	Deeds and titles for property in the area of influence would include restrictions on wells and/or property use.	Potentially applicable.
		Federal acquisitions	Acquisition ranges from easement to right-of-way to property procurement.	Potentially applicable.
	Monitoring	Sampling/ analysis	Monitoring of soil before, during, and after site remediation.	Potentially applicable.
	5-Year review	Documented reviews	A review performed to evaluate the protectiveness of the response action. Required if residual contamination remains.	Potentially applicable.
Containment Actions	Capping	Native soil	Areas of contamination covered with a layer of clean soil.	Potentially applicable. Would reduce contact with contaminated soils.

Table 3.4 (continued)

Soils general response action	Remedial technology	Process options	Description	Screening comments
Containment (cont.)	Capping (cont.)	Clay	Compacted clay covered with soil over areas of contamination.	Potentially applicable in reducing direct contact exposure.
		Synthetic membrane	Synthetic liner installed over contaminated areas.	Potentially applicable, but typically requires cover material to hold it in place.
		Multi-layered media	Multiple layers of synthetic liner and clay over areas of contamination.	Potentially applicable.
		Asphalt	Layer of asphalt applied over areas of contamination.	Potentially applicable.
		Concrete	Concrete placed over contaminated areas.	Potentially applicable.
		Chemical sealants/ stabilizers	Chemicals mixed with surface soils to form an impermeable boundary.	Not applicable. Organic and other unknown constituents in the soil may interfere with the process. Side reactions producing unwelcome off-gas and other products may occur.

Indicates technologies determined to be not applicable.

Table 3.4 (continued)

Soils general response action	Remedial technology	Process options	Description	Screening comments
Containment (cont.)	Vertical barriers	Slurry walls, sheet piling, etc.	Various methods to construct vertical barriers, such as slurry walls, sheet piling, grout curtains, and ground freezing.	Not applicable. Mercury is tightly bound in soil and is therefore not migrating horizontally through soil matrix.
	Horizontal barriers	Grout injection, block displacement, etc.	Various methods to construct horizontal barriers, such as grout injection, block displacement, ground freezing, and liners.	Not applicable. Mercury is tightly bound in soil and is therefore not migrating vertically through soil matrix.
Excavation	Soil excavation	Earth moving equipment	Conventional earth moving equipment such as bulldozers, backhoes, excavators, and scrapers.	Potentially applicable. Site has limited access at various locations.
Treatment Actions	Physical	Thermoplastic solidification	Waste sealed in asphalt bitumen, paraffin, or polyethylene matrix.	Not applicable. Organic and other unknown constituents (solvents, greases, and salts) can interfere with the solidification process.
		Water/solids leaching	Water is used to dissolve solids in a matrix and subsequently allowed to leach out where it can be further treated.	Not applicable. The COCs in the soils are not readily leached by water. They associate strongly with the soil.

Indicates technologies determined to be not applicable.

Table 3.4 (continued)

Soils general response action	Remedial technology	Process options	Description	Screening comments
Treatment (cont.)	Physical (cont.)	Soil washing	Excavated soil enters a series of highly aggressive waste washing phases to remove and concentrate contaminants.	Not applicable. The treatability report indicated that this process is ineffective as a volume reduction technique because the contamination is spread throughout the soil.
		* Solids crushing/ grinding	Soils/sediments/solids are processed through mechanical devices to reduce large solids to smaller particles.	Potentially applicable. The process can be used as a pretreatment process prior to other treatment processes such as thermal desorption.
		* Solids shredding and chipping	Less dense solids, such as wood, paper, and plastic are processed through a shredder or wood chipper.	Potentially applicable. This process can be used as a pretreatment process to chip tree roots prior to further treatment processes.

Indicates technologies determined to be not applicable

* Will be retained only in combination with other options.

93-022MS/081294

Table 3.4 (continued)

Soils general response action	Remedial technology	Process options	Description	Screening comments
Treatment (cont.)	Physical (cont.)	Magnetic separation	Magnets or electromagnets are used to separate ferrous from non-ferrous material.	Not applicable. Ferrous particles are not COCs.
		Portland cement solidification	Immobilize contaminants by adding Portland cement to form a solid matrix.	Not applicable. There is no observable benefit for immobilizing the contaminated soil. Mercury is strongly bound to soil.
		Land aeration	Spreading of soil on land surface to facilitate natural volatilization of volatile organic compounds. Also referred to as landfarming.	Not applicable. Volatile organic compounds are not the primary COCs.
		* Screens/grizzlies	Vibrating units operated by selectively allowing particles to pass through them and oversized material removed.	Potentially applicable. Primarily a pretreatment or volume reduction process.
		Pozzolanic agents solidification	Contaminated soil solidified by the addition of large amounts of siliceous (pozzolanic) materials combined with a setting agent.	Not applicable. Results of treatability study indicated that the low strengths and high additive loading rates were undesirable.

Indicates technologies determined to be not applicable.

* Will be retained only in combination with other options.

Table 3.4 (continued)

Soils general response action	Remedial technology	Process options	Description	Screening comments
Treatment (cont.)	Physical (cont.)	Liquid gas extraction	Uses gases (CO_2, propane) to alter properties of solvents to make extraction of organics more rapid and efficient.	Not applicable. Organics are not COCs.
		Vitrification	A process in which the physical characteristics of a waste are immobilized in a vitreous mass.	Not applicable for the COCs. The presence of mercury is considered undesirable for treatment of soils by this process..
	Chemical	Electrolytic oxidation	Cathodes and anodes are immersed in a tank containing waste to be oxidized as a result of a direct current imposed on the system.	Not applicable. Extensive pretreatment is required to dissolve metal waste contained in soil into a solution for the electrolytic oxidation process to take place.
		Chemical oxidation/ reduction	Appropriate chemicals added to raise the oxidation state of the reactant.	Not applicable. Extensive pretreatment is required to dissolve waste into solution for the redox process to take place. Reactions can be explosive and inadvertent production of a more hazardous waste could result from unknown constituents in the soil.
		Oxidation by hypochlorite	Appropriate chemicals added to lower the oxidation state of the reactant.	Not applicable. This method can produce toxic chlorinated organic by-products and it must be conducted under controlled conditions. In addition, it is a nonspecific reactant.

Indicates technologies determined to be not applicable.

Table 3.4 (continued)

Soils general response action	Remedial technology	Process options	Description	Screening comments
Treatment (cont.)	Chemical (cont.)	Fixation/ immobilization	Chemicals added to bind waste into a form that is resistant to leaching of contaminants.	Not applicable. Results of treatability study indicate that very little mercury is extractable; therefore, no need to immobilize.
		Chemical soil wash	Similar to physical soil washing; however, chemicals are used as the wash fluid.	Potentially applicable. The KI/I_2 process could be used to extract mercury from the soil.
		Chemical/ acid leaching	Addition of strong acids or bases to extract metals from the solid matrix.	Not applicable. Requires additional treatment of leachate and the addition of chemicals may cause undesirable reactions with unknown constituents in the soil.
	Biological	Biological processes	Various aerobic/anaerobic biological processes used mainly to degrade organic contaminants.	Not applicable. No proven biological technology applicable to transformation/precipitation of mercury from soil has been identified.

Indicates technologies determined to be not applicable.

Table 3.4 (continued)

Soils general response action	Remedial technology	Process options	Description	Screening comments
Treatment (cont.)	Thermal	Fluidized bed incineration	Waste injected into hot agitated bed of sand where combustion occurs.	Potentially applicable. Mercury would be volatilized. Emissions controls required in the off-gas system to collect mercury and arsenic.
		Pyrolysis	Destruction of organic material in the absence of oxygen at a high temperature to reduce toxic organic constituents to gas and water	Not applicable. Organics are not COCs.
		Gaseous incineration	The incinerating of incomplete combustion, volatile, or off-gases in a device commonly referred to as an after-burner.	Not applicable. Primarily for the treatment of off-gases. Off-gas treatment for a thermal treatment system will be evaluated as part of that system.
		Radio frequency/ infrared incineration	Process units use silicon carbide elements to generate thermal radiation beyond the red end of the visible spectrum.	Not applicable. Process is new and unproven.
		Retorting	Used primarily as a recovery process where waste is heated to volatilize the metal constituents, then collected in a condenser.	Not applicable. Retorting is only applicable for waste that has a low total organic content (i.e., below 1 %). A majority of the EFPC soil samples exceed this value.

Indicates technologies determined to be not applicable

Table 3.4 (continued)

Soils general response action	Remedial technology	Process options	Description	Screening comments
Treatment (cont.)	Thermal (cont.)	Low-temperature thermal desorption	Moderate temperature (200-600°C) vaporization using rotary drums or pug mill to separate volatile metals from the soil media.	Potentially applicable. Mercury would be volatilized. Off-gases require collection/treatment.
		Rotary kiln incineration	Combustion in a horizontally rotating cylinder designed for uniform heat transfer.	Potentially applicable. Mercury would be volatilized. Special consideration should be given for the collection/ treatment of mercury in the off-gas system.
		Circulating bed combustion	High turbulence in the combuster allows volatile metals such as mercury to be driven off.	Potentially applicable.
		Advanced electric fluid wall reactor	Electrically heated fluid walls are used to pyrolyze waste contaminants.	Not applicable. Primarily for very hazardous waste or high activity radioactive waste. Not as cost effective as other thermal processes that can treat the COCs.
		Permitted/ approved low-level waste incinerator	Contaminated materials transported to facility permitted for low-level waste incineration.	Potentially applicable. Mercury would be volatized.

Indicates technologies determined to be not applicable.

Table 3.4 (continued)

Soils general response action	Remedial technology	Process options	Description	Screening comments
Treatment (cont.)	In situ	Subsurface biodegradation	Addition of nutrients and moisture, possibly enzymes, and microorganisms to enhance the ability of natural degradation of organic contaminants.	Not applicable. Unproven technology. Inorganic contaminants can inhibit microbial metabolism. Will not address mercury contamination in the soils.
		Radio frequency heating	A system of electrodes used to heat soil and volatilize trapped hydrocarbons so they may escape for ex situ treatment.	Not applicable. Treatment efficiency can be reduced by utilities and buried metals that can interfere with radio-frequency path. Also, a relative new and unproven technology.
		Soil flushing	Injection of a solvent or surfactant solution (or water) to enhance the contaminant solubility.	Not applicable. Considered an emerging technology that is suited for permeable soils. In addition, the remediation time is considered too lengthy due to the slowness of diffusion processes in the liquid phase.
		Steam extraction	Steam and hot air are injected into the soil to promote the removal of petroleum and chlorinated hydrocarbons.	Not applicable. Principally applicable for volatile organics. Will not address mercury in soils.
		Vacuum extraction	Vacuum pumps are connected via a pipe system to a series of production wells to remove volatile organic compounds from the soil.	Not applicable. Principally applicable for volatile organics. Will not address mercury in the soils.

Indicates technologies determined to be not applicable.

Table 3.4 (continued)

Soils general response action	Remedial technology	Process options	Description	Screening comments
Treatment (cont.)	In Situ (cont.)	In situ vitrification	A process of melting wastes and soils or sludges in place to bind the waste in a glassy, solid matrix resistant to leaching.	Not applicable. Not feasible in saturated soil. Off-gases require collection/ treatment.
		Surface bioreclamation	The addition of nutrients and possibly microorganisms to surface soils to enhance the natural degradation of organic contaminants.	Not applicable. Inorganic and metal contaminants can inhibit microbial metabolism.
		Surface micro-encapsulation	Physical microencapsulation of wastes in an organic binder or resin.	Not applicable. High organic content of surface soils can impede the solidification process.
		Acid leaching	Acid solution (pH 1.5-2.0) is added to waste in place to mobilize and leach out toxic metals.	Not applicable. Addition of acids may cause uncontrolled reactions with non-target contaminants such as organics or radioactive materials in the soil.
		Nutrient/ microbial injection	System of injection/extraction wells to introduce oxygen, nutrients, and specialized bacteria to degrade COCs.	Not applicable. No biological technology applicable to transformation of mercury has been identified.
		In situ solidification	Solidification agent (e.g., cement) is added directly into contaminated soils.	Not applicable. Difficult to implement in situ solidification.

Indicates technologies determined to be not applicable.

Table 3.4 (continued)

Soils general response action	Remedial technology	Process options	Description	Screening comments
Treatment (cont.)	In situ (cont.)	Hydrolysis	Involves a reaction with an organic chemical and water or hydroxide ions to break the chemical down to a simpler, less toxic form.	Not applicable for inorganic and metal contaminants.
		In situ chemical treatment (detoxifier)	A mobile unit capable of neutralization, solidification/ stabilization, or nutrient/microbial injection of soils in place.	Not applicable. Severe caustic or acidic conditions do not exist.
		Chemical flushing	A process similar to soil flushing; however, chemicals are added to the flushing liquid to enhance the recovery of contaminants.	Not applicable. Process is similar to soil flushing. See explanation under soil flushing.
		Electrokinetics	Water, ions, and charged colloids transferred relative to one another under the action of an applied direct current in the ground.	Not applicable. The process requires conversion of inorganics into ionic or soluble forms. Other soil contaminants may react with the strong pretreatment solutions required, with unpredictable results and potential for groundwater contamination. Also, there is considerable uncertainty about the rates of migration of ions in a soil matrix.
		Engineered wetlands	Area developed into a wetland where appropriate biota and aquatic species will be cultivated to provide uptake of contaminants.	Not applicable. The process would require long-term cultivation of biota and would be difficult to manage.

Indicates technologies determined to be not applicable.

* Will be retained only in combination with other options

93-022MS/081294

Table 3.4 (continued)

Soils general response action	Remedial technology	Process options	Description	Screening comments
Treatment (cont.)	* Dewatering	* Drying/ dewatering bed	Dewatering technique by which the moisture is removed by natural evaporation and gravity or by induced drainage.	Potentially applicable as a pretreatment process or for volume reduction. For example, could be used as pretreatment to thermal desorption.
		* Confined disposal facility	An engineered structure designed to retain soils and provide storage time for gravity drainage, consolidation, and evaporation.	Potentially applicable as a pretreatment process or for volume reduction.
		* Sludge dryers/kilns	Water heated to remove moisture by evaporation, allowing suspended solids to be concentrated.	Potentially applicable as a pretreatment step or for volume reduction.
Disposal Actions	On-site disposal	Approved lined landfill with leachate collection	Use of Landfill V or modification of a Class IV landfill to include a liner and leachate collection/pretreatment such as Landfill VI or VII for disposal of the untreated soil.	Potentially applicable if facility can meet the DOE and TDEC requirements.
		Site and construct new landfill	Site, design, construct and operate new landfill.	Not feasible due to cost and time required to implement.

* Will be retained only in combination with other options.

Table 3.4 (continued)

Soils general response action	Remedial technology	Process options	Description	Screening comments
Disposal (cont.)	Off-site disposal	Sanitary landfill	Transport untreated soils to an off-site sanitary landfill for disposal.	Not applicable because of DOE "no-rad-added" policy.
		Licensed low-level waste disposal facility	Transport of untreated soil to existing licensed low-level waste disposal facility for disposal.	Potentially applicable to untreated soil.
		New low-level waste disposal facility	Design and construct a new low-level waste disposal facility.	Not applicable. Not required because of availability of existing licensed facilities.
		Ocean dumping	An offshore disposal facility that is permitted to receive low-level radioactive wastes.	The extensive permitting system required would preclude this disposal option.

Indicates technologies determined to be not applicable.

Table 3.4 (continued)

Soils general response action	Remedial technology	Process options	Description	Screening comments
Beneficial Reuse	Beneficial reuse	* Landfill cover	Treated soils used as cover material at a controlled landfill.	Potentially applicable if soils treated to acceptable levels.
		* Backfill	Treated soils used as backfill material in areas of excavation.	Potentially applicable if soils treated to acceptable levels.
		* Roadway/ runway fill	Excavated soils or treated residuals used as roadway/runway fill material.	Potentially applicable. Only newly constructed interstate highways would be appropriate for this use.
		* Reclamation/ recycle	Concentrated contaminants are reclaimed as commercial products by recycling.	Potentially applicable.

* Will be retained only in combination with other options.

Table 3.5. Evaluation of process options for the EFPC OU – soils response technologies

Soil general response actions	Remedial technology	Process options	Effectiveness	Implementability	Cost
No Action	None	Not applicable	Does not achieve remedial action objectives	Easily implemented.	No capital, low monitoring costs only.
Institutional Actions	Access controls	Site protection/ security	Effective for controlling site access and reducing public exposure. No contaminant reduction.	Easily implemented on some properties.	Low capital, low O&M [a].
		Security personnel	Effective for controlling site access and reducing public exposure. No contaminant reduction.	Easily implemented on some properties.	Low capital, low O&M.
	Legal controls	Deed/use restrictions	Effectiveness depends on continued future implementation. Does not reduce contaminant toxicity, mobility, or volume.	Potentially difficult to implement due to legal requirements.	Low capital, low legal costs, low O&M costs.
		Federal acquisition	Effective for controlling land use. Does not reduce contaminant toxicity, mobility, or volume.	Implementable.	High capital, moderate-high O&M.
	* Monitoring	* Soil sampling/ analysis	Useful for documenting conditions. Does not reduce risk by itself.	Easily implemented.	Low capital, low O&M.
	* 5-Year review	* Documented review	Effective in evaluating protectiveness of response action.	Implementable.	Low capital, moderate-high O&M.
Containment Actions	Capping	Native soil	Effective in restricting direct human contact and minimizing migration caused by wind or surface water erosion. Not effective against infiltration of rain.	Easily implemented but requires land use restrictions.	Moderate capital, low O&M.
		Clay	Effective in restricting direct human contact and minimizing migration caused by wind or surface water erosion. Effective against infiltration. Requires maintenance.	Easily implemented but requires land use restrictions. Prevention of rain infiltration not required because mercury contaminants not mobile in soil.	Moderate capital, low O&M.

* Will be retained only in combination with other options.
[a] Operation and maintenance costs.

93-022MS/081294

Table 3.5 (continued)

Soil general response actions	Remedial technology	Process options	Effectiveness	Implementability	Cost
Containment Actions (cont.)	Capping (cont.)	Synthetic membrane	Effective, but requires continued maintenance. Highly susceptible to damage.	Easily implemented but requires land use restrictions.	Moderate capital, high O&M.
		Multi-layered media	Effective, least susceptible to cracking.	Easily implemented but requires land use restrictions.	Moderate capital, moderate O&M.
		Asphalt	Effective in restricting direct human contact and minimizing migration caused by wind or surface water erosion. Requires maintenance.	Easily implemented but requires land use restrictions.	Moderate capital, low O&M.
		Concrete	Effective in restricting direct human contact and minimizing migration caused by wind or surface water erosion. Requires maintenance.	Easily implemented, but requires land use restrictions.	Moderate capital, low O&M.
Excavation	Soil Excavation	Earth-moving equipment	Conventional earth-moving equipment is effective for either complete or partial excavation of contaminated soil.	Implementable; conventional dust controls and runoff control would be necessary.	High capital, low O&M.
Treatment Actions	Physical	* Solids crushing/ grinding	Effective for volume reduction. Also effective for pretreatment.	Implementable using conventional equipment.	Moderate to high capital, moderate O&M.
		* Solids shredding & chipping	Effective for volume reduction. Also effective for pretreatment.	Implementable using conventional equipment.	Moderate to high capital, moderate O&M.
		* Screens/ grizzlies	Effective for separating insoluble contaminants but not dissolved contaminants.	Implementable; commercial vendor units available.	Moderate capital, moderate O&M.

☒ Indicates technologies/process options eliminated from further consideration.
* Will be retained only in combination with other options.

Table 3.5 (continued)

Soil general response actions	Remedial technology	Process options	Effectiveness	Implementability	Cost
Treatment Actions (cont.)	Chemical	Chemical soil washing (KI/I_2)	Effective in extracting mercury but large volume secondary wastestream would be generated.	Implementable. Would require a pilot test.	Moderate capital; high O&M.
	Thermal	Fluidized bed incineration	Effective for volatilizing arsenic and mercury. Off-gas requires collection and treatment. KI/I_2 impinger to be tested at pilot scale.	Implementable; commercially available.	High capital cost, moderate O&M.
		Low-temperature thermal desorption	Effective for volatilizing arsenic and mercury. Off-gas requires collection and treatment. KI/I_2 impinger to be included in pilot-scale test.	Implementable; commercially available.	Moderate capital cost, low O&M.
		Rotary kiln incineration	Effective for volatilizing arsenic and mercury. Off-gas requires collection/treatment.	Implementable; however, more energy-intensive than other thermal processes.	High capital cost; moderate O&M.
		Circulating bed combustion	Effective for volatilizing mercury. Off-gas requires collection/treatment.	Implementable; however, more energy-intensive than other thermal processes.	High capital cost; moderate O&M.
		Permitted, approved low-level waste incinerator	Effective for volatilizing arsenic and mercury. Off-gas requires collection/treatment.	Implementable; however, more energy-intensive than other thermal processes.	High capital cost; moderate O&M.
	Dewatering	* Drying/ dewatering Bed	Effective for pretreatment or volume reduction, but does not reduce toxicity or mobility.	Easily implemented.	Low capital, moderate O&M.
		* Confined disposal facility	Effective for pretreatment or volume reduction, but does not reduce toxicity or mobility.	Easily implemented.	Moderate capital cost, low O&M.
		* Sludge dryers/ kilns	Effective for pretreatment or volume reduction, but does not reduce toxicity or mobility.	Easily implemented.	Moderate capital cost, moderate O&M.

Indicates technologies/process options eliminated from further consideration.
* Will be retained only in combination with other options.

93-022MS/081294

Table 3.5 (continued)

Source media response media	Remedial technology	Process options	Effectiveness	Implementability	Cost
Disposal Actions	On-site disposal	Approved lined landfill with leachate collection	Effective. Reliability based on design to include liner and leachate collection.	Implementable, but would have to comply with waste acceptance criteria and TDEC approval.	Low capital cost, low O&M.
		Site and construct new landfill	Effective. Reliability based on design to include liner and leachate collection.	Lengthy approval process anticipated for a new landfill	Moderate capital cost related to new ancillary utilities and support buildings, low to moderate O&M.
	Off-site disposal	Licensed low level waste disposal facility	Effective for untreated soil.	Implementable, extensive certification and preshipment approval requirements to meet waste acceptance criteria.	High capital cost, negligible O&M.

▨ Indicates technologies/process options eliminated from further consideration.
* Will be retained in combination with other options.

Table 3.5 (continued)

Source media response media	Remedial technology	Process options	Effectiveness	Implementability	Cost
Beneficial Reuse	Beneficial reuse	* Landfill cover	Effective use for treated soils. Replaces excavated soils.	Implementable if treated waste can meet the waste acceptance criteria.	Very low capital and O&M cost.
		* Backfill	Effective use for treated soils. Replaces excavated soils.	Implementable if treated waste can meet the land disposal restrictions.	Very low capital, negligible O&M.
		* Roadway/ runway fill	Effective use for treated soils.	Implementable if treated waste can meet the land disposal restrictions.	Very low capital, negligible O&M.
		* Reclamation/ recycle	Effectiveness is uncertain.	Implementable if the concentration of contaminant is high enough to be reclaimed.	Moderate capital, moderate O&M.

* Will be retained in combination with other options.

Table 3.6. Representative remedial technologies and process options for EFPC OU general response actions

General response action	Remedial technology	Technology process option(s)
No Action	None	NA
Institutional[a]	Access control	Site protection
	Legal control	Deed/use restriction, federal acquisitions
	Monitoring	Soil sampling/analysis
	5-year review	Documented review
Containment[b]	Capping[c]	Native soil cover
Excavation	Soil excavation	Earth-moving equipment
Treatment	Thermal	Low-temperature thermal desorption
	Dewatering	Dewatering/drying beds[d]
Disposal	On-site disposal	Modification of Landfill VII
Beneficial reuse	Beneficial reuse	Replacement in floodplain excavation

NA = not applicable.

[a] This response action alone does not remove or remediate the source contamination.

[b] This response action must be used in combination with institutional actions.

[c] Existing concrete slabs and asphalt pavement will be assumed to provide adequate containment.

[d] These process options are volume reduction treatment processes to be used only in combination with other technologies.

This page intentionally left blank.

SECTION 3

FIGURES

This page intentionally left blank.

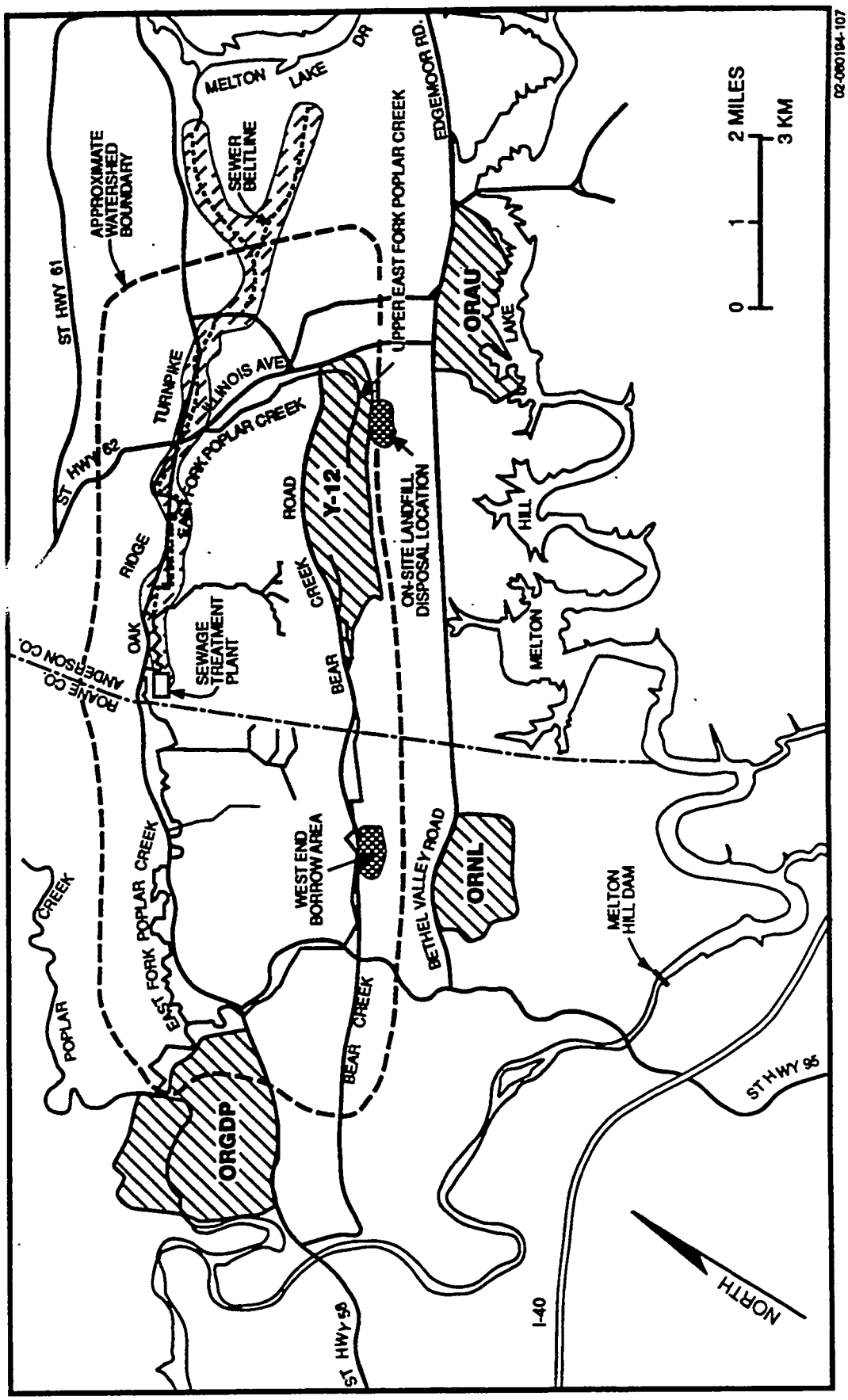


Fig.3.1. Location map for borrow and disposal locations.

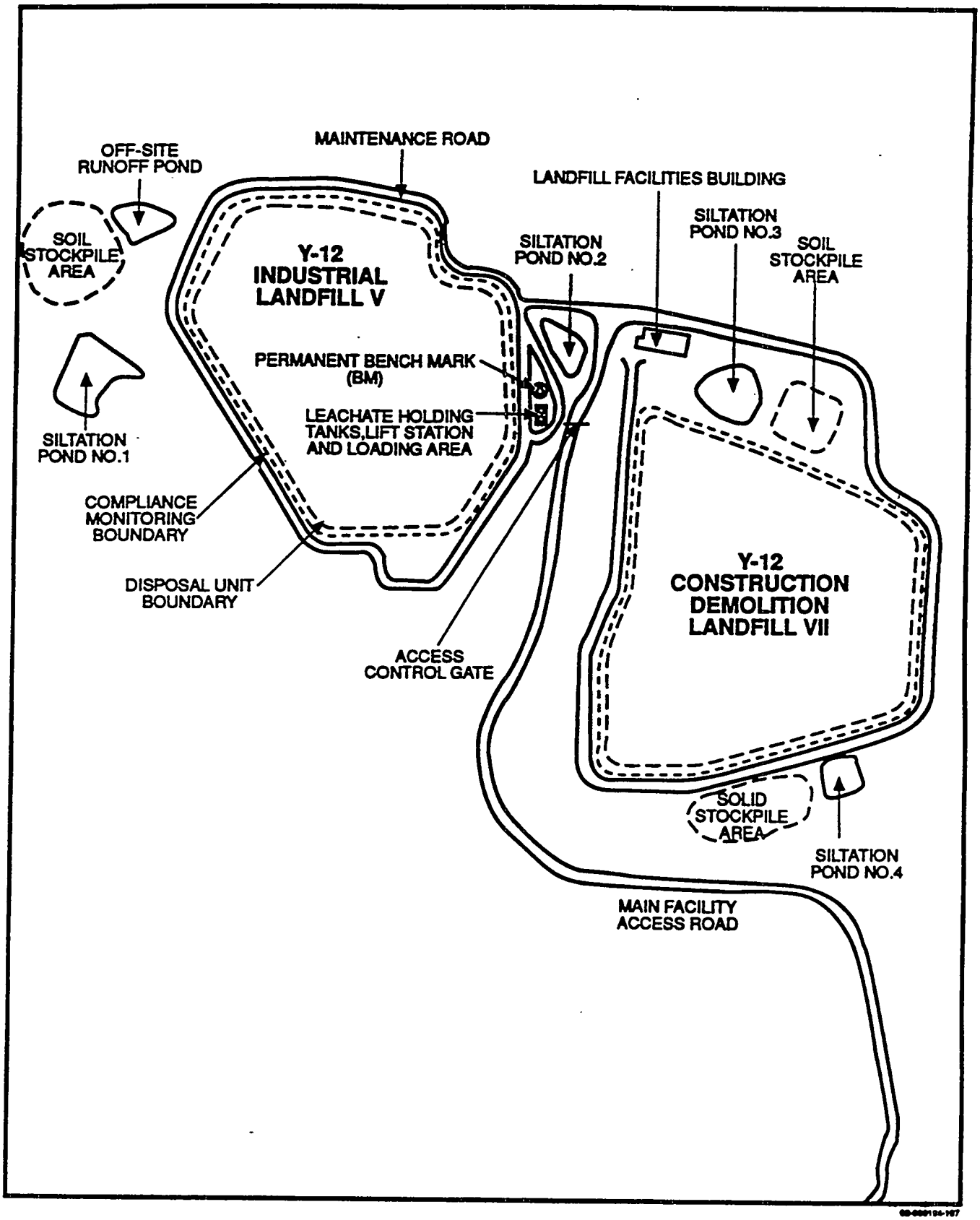


Fig. 3.2. On-site landfill disposal location.

4. DEVELOPMENT AND SCREENING OF ALTERNATIVES

Section 3 of this FS describes three steps preliminary to the screening of sitewide remedial alternatives: (1) the development of quantitative remedial action objectives, (2) the identification of general response actions that have the potential to achieve the remedial action objectives, and (3) the screening of technologies and process options and the subsequent selection of representative process options.

This section focuses on the ultimate goal in the screening process: developing and screening sitewide alternatives (i.e., alternatives for the entire EFPC OU). The remedial actions (representative process options) that passed the screening steps described in Sect. 3 are initially combined into RU alternatives representing a range of containment, treatment, excavation, and disposal options for specific land-use types within the EFPC OU. These RU alternatives are defined for the initial screening of alternatives because of the complexity of the EFPC OU and the large number of possible sitewide alternatives. Remedial actions undergo an effectiveness, implementability, and cost screening for each RU. Retained RU alternatives are combined into seven sitewide alternatives (SWAs 1 through 7) for the EFPC OU, including the No Action alternative. The sitewide alternatives for the EFPC OU undergo a detailed analysis per CERCLA criteria, which is addressed in Sect. 5.

4.1 INTRODUCTION

Because of the magnitude and complexity of the EFPC OU and its varied characteristics, the site was divided into six subsites, or RUs, for the development of alternatives. The development and initial screening of alternatives by RU provides a means of addressing remedial action objectives specific to certain land uses and exposure pathways within the EFPC OU. Remedial action objectives for the site include (1) limiting human exposure to mercury in soil to ≤ 180 ppm on properties in the Residential and Agricultural RUs and ≤ 938 ppm on properties in the remaining RUs and (2) reducing exposures to mercury in soil on all RU properties to ≤ 200 ppm for protection of ecological receptors. Figure 4.1 illustrates the RU delineations. Section 4.2 defines and characterizes the six RUs within the EFPC OU.

The categories of general response actions for which representative process options were selected in Sect. 3 include no action, institutional actions, containment actions, excavation actions, treatment actions, on-site disposal actions, and beneficial reuse actions. Section 4.3 presents the CERCLA criteria and site-specific assumptions applicable to the screening of remedial actions appropriate for each RU. The results of the screening are explained in Sect. 4.4. The remedial actions remaining as options for each RU after this screening are developed into RU alternatives in Sect. 4.5. Rationale for assembling these RU alternatives into sitewide remedial alternatives for the EFPC OU and descriptions of the seven sitewide remedial alternatives are presented in Sect. 4.6.

4.2 DESCRIPTION OF EFPC RUs

The Lower EFPC OU includes Lower EFPC, the 100-year floodplain, and the SLB (outside the floodplain). To facilitate the baseline human health risk assessment in the RI, EFPC and the associated 100-year floodplain were sectioned into nine land segments on the basis of geography, uniformity of land use types, and/or similar contaminant concentrations. The FS has retained the delineation of EFPC and the floodplain into these nine land segments (Table 4.1). Present land use for the nine segments was estimated in the RI to be 7% residential, 2% commercial, 52% agricultural, and 31% open land; the remaining 8% (including the creek itself, the roads, and the rights-of-way) was unclassified in the RI (DOE 1994a). Environmental resources include 17 wetland areas, comprising ~5.2 ha (12.7 acres). To identify remedial alternatives applicable for the entire OU, the site was divided into six RUs for the FS process. The six RUs for EFPC OU are as follows:

- Surface Water/Sediments RU (EFPC)
- SLB RU (soil)
- Commercial/DOE RU (soil)
- Residential RU (soil)
- Agricultural RU(soil)
- Other RU (soil)

The delineation of these RUs was based on differing land uses, potential exposure pathways and associated risks, media (to some extent), and public accessibility. There are various RUs within the nine land segments; Figs. 4.1 through 4.3 illustrate the relationship between the nine land segments and the RUs. In these figures, there are no contaminated areas above the RGOs identified within the SLB, Agricultural, and Surface Water/Sediments RUs because the SLB and Agricultural RUs do not require remediation and the Surface Water/Sediments RU will be addressed only by interim institutional actions.

The RI report (DOE 1994a) categorized land use as either current or future, and the human health risk analysis incorporates land use scenarios that are most conservative (i.e., residential or agricultural) in order to be most protective. Similar conservative assumptions were applied when individual properties were assigned to RUs for the development of remedial alternatives for the EFPC OU. The preliminary land use assumptions were based on the land use scenario (either current or future) that was most protective of human health. Figures 4.1 and 4.2 reflect these conservative land-use designations for SWAs 1 through 5 and 6, respectively. For example, property that is currently undeveloped could be developed in the future as residential property. Therefore, the undeveloped property is evaluated in light of the most conservative potential land use, residential.

Three exceptions were made to the RI future land use designations illustrated in Figs. 4.1 and 4.2: (1) DOE property would remain DOE-owned in the future; (2) a business area along West Tulsa Road would remain commercial in the future; and (3) a vacant parcel near Jefferson Avenue adjacent to an apartment building would be used as residential rather than commercial. [Note: A small strip of land between a commercial area and South Illinois Avenue was identified as open and residential (more conservative) rather than commercial.] Figure 4.3 reflects the land-use assumptions that were applied to the remaining sitewide alternative, SWA 7.

4.2.1 Surface Water/Sediments RU

For the purposes of this FS, surface water and sediment are combined into a single RU because the media are commingled. Lower EFPC begins at the Lake Reality outfall and meanders through DOE-owned property, City of Oak Ridge property, and private property, flowing adjacent to various types of land uses before reaching confluence with Poplar Creek. EFPC is considered a perennial stream with a length of 23.3 km (14.5 miles) and stream depths averaging 1 to 3 m (3 to 10 ft). Sediment thickness in EFPC ranges from 0.15 to 1.7 m (0.5 to 5.5 ft) and is intermittent. The approximate total volume of the sediment within EFPC is 55,400 m^3 (72,500 yd^3). The EFPC 100-year floodplain encompasses ~270 ha (670 acres), which also includes roads and rights-of-way.

Only interim remedial alternatives are developed for EFPC surface water and sediment in this document. As discussed in Sect. 3, the relationship between long-term impacts to the aquatic community and the source(s) of continuing contaminant exposures (including resuspension of sediment, inputs of floodplain soil, and continuous controlled releases from the Y-12 Plant) are not well understood. Though preliminary human health and ecological remediation goal options have been developed for sediment, the technical bases for remediation decisions are not yet well ounded, and additional ecological pathway studies and monitoring will need to be conducted oefore final decisions are made on the timing or extent of surface water/sediment remedial actions. Hence, an administrative decision was made to defer final action on the Surface Water/Sediments RU. Interim measures will be implemented to provide continued monitoring of the aquatic community and to further reduce the contaminant levels in water-borne releases from the Y-12 Plant in accordance with the schedule and timetable of the NPDES permit, as reissued in 1994. Upon completion of the proposed action for the EFPC floodplain soil, the Surface Water/Sediments RU will be reevaluated and appropriate administrative actions taken to reach a Record of Decision for that portion of the watershed OU.

4.2.2 SLB RU (Soil)

The SLB was constructed during 1982-1983 as part of a three-phase upgrade of the city water pollution control facilities. During construction, the top of the sewer line was buried a minimum of 75 cm (30 in.) below ground surface. The trench was then backfilled with a layer of crushed stone, and the remaining portion of the trench was backfilled with regular fill material. In certain instances, soil was transported from the EFPC floodplain to the SLB and used as topsoil or fill material. The total length of the SLB is ~16 km (10 miles). The SLB area consists of rights-of-way and easements, is well developed, and includes mostly commercial properties. The concentrations of contaminants in SLB soil are below levels of concern for utility workers, trespassers (children and adults), and the ecological receptors. Therefore, no further action is required for the SLB RU.

4.2.3 Commercial/DOE RU (Soil)

Commercial and DOE-owned properties were grouped together within a single RU. Remedial actions appropriate for commercial properties also would be appropriate for DOE-owned property because both types of property have similar scenarios for exposure to contaminants.

The Commercial portion of the Commercial/DOE RU is defined as areas used and zoned for commercial purposes, such as offices, retail stores, restaurants, shopping centers, and other commercial establishments. This RU encompasses ~13.3 ha (32.8 acres) of commercial property within the EFPC 100-year floodplain. Table 4.1 provides a breakdown by RU of the total surface areas in each of the nine segments of the EFPC floodplain. The Commercial parcels in which contamination exceeds the 200-ppm ecological remediation goal option encompass ~0.05 ha (0.12 acre). Table 4.2 presents the surface areas that exceed the remediation goal options.

The estimated total volume of contaminated soil that exceeds the 200-ppm remediation goal option within the Commercial portion of the Commercial/DOE RU is ~400 m^3 (500 yd^3). See Table 4.3 for delineation of contaminated soil volumes within the commercial properties in each of the nine land segments. The majority of the Commercial portion of this RU is easily accessible to the heavy equipment that would be required for some remedial actions.

The DOE portion of the RU is defined as all properties owned by DOE. This portion of the Commercial/DOE RU encompasses ~90 ha (223 acres) within the EFPC 100-year floodplain. Soil contaminated above the 200-ppm ecological remediation goal option for this land use is found in EFPC Segments 1 and 9 and includes ~0.81 ha (2.02 acres). The contaminated area in Segment 1 includes smaller areas with contamination above the 938-ppm human health remediation goal option for this land use.

The volume of contaminated soil that exceeds the 200-ppm remediation goal option within the DOE portion of the RU is ~6500 m^3 (8500 yd^3). See Table 4.3 for estimates of contaminated soil volumes within each of the land segments. The accessibility of this RU to the use of heavy equipment for remediation is varied. DOE properties are densely wooded; therefore, they are less accessible than most commercial properties.

4.2.4 Other RU (Soil)

The Other RU consists of land classified as open land use (except DOE-owned property, which has been considered as part of the Commercial/DOE RU), as defined in the RI report (DOE 1994a). The Other RU includes non-SLB areas that may have only incidental use (e.g., recreation or trespass). This RU comprises ~43 ha (107 acres) within the EFPC 100-year floodplain. See Table 4.1 for an estimation of the total areas included in the Other RU within each of the nine segments of the EFPC floodplain.

The levels of mercury identified by the RI within the Other RU did not exceed the human health remediation goal option of 938 ppm. The volume of contaminated soil that exceeds the 200-ppm remediation goal option for ecological receptors within the Other RU is ~9400 m^3 (12,200 yd^3) (see Table 4.3). Contaminated soil in the Other RU is limited to Segments 4 and 5 of the EFPC floodplain (see Table 4.2) and includes ~1.64 ha (4.05 acres). Although these areas are accessible by way of Oak Ridge Turnpike [see Fig. 4.1(d) and (e)], the use of heavy equipment for remediation would necessitate additional engineering measures (see Appendix J) because of the wet soil conditions within these segments of the floodplain.

4.2.5 Residential RU (Soil)

This RU consists of existing residential areas (primarily single-family and multifamily units), vacant parcels zoned for residential use in the future, and areas that have potential for future residential development. Also included are public educational and recreational facilities. This RU encompasses ~78 ha (192 acres) in the EFPC 100-year floodplain. See Table 4.1 for a breakdown of Residential RU areas within each of the nine land segments. Contaminated soil within the Residential RU includes ~4.85 ha (11.97 acres) and is limited to Segments 1, 3, 4, 5, 8, and 9 (see Table 4.2).

The volume of contaminated soil that exceeds the 180-ppm remediation goal option within the Residential RU is ~25,100 m^3 (32,800 yd^3). See Table 4.3 for the distribution and volumes of contaminated soil within the nine segments of the EFPC floodplain. The accessibility of this RU for the use of heavy equipment for remediation purposes is relatively good in the currently developed areas because of the numerous roads. However, some vacant parcels could require road construction and vegetation removal to allow access to the contaminated areas.

4.2.6 Agricultural RU (Soil)

The Agricultural RU consists of those areas used for agricultural purposes (e.g., pasture land for livestock grazing, horse ranches, etc.). Currently, no crops or family gardens are being grown within the floodplain proper. The Agricultural RU comprises ~29 ha (71 acres) within the EFPC 100-year floodplain. Agricultural RU areas are found in Segments 3, 6, and 7 of the EFPC floodplain (see Table 4.1). No further action would be required for the Agricultural RU because the identified areas of mercury contamination are below the remediation goal option [180 mg/kg (ppm)] for this RU.

4.3 DEVELOPMENT OF RU ALTERNATIVES

The RU alternatives developed in this section are evaluated on the basis of the screening criteria in Sect. 4.4 and are summarized in Sect. 4.5.

Because the EFPC OU is diverse and complex, a preliminary screening of the remedial actions defined in Sect. 3 was performed for each of the EFPC RUs. This evaluation of the alternatives was based on the effectiveness, implementability, and cost criteria described in the National Contingency Plan [300.430(e)(7)].

Assumptions made before evaluating the site-specific remedial actions for each of the RUs include: (1) long-term maintenance of containment and institutional actions could be controlled only if a federal entity is responsible, (2) the SLB and Agricultural RUs need not be included in the screening because no further action is required for these RUs, and (3) the Surface Water/Sediments RU is unique among the RUs in that only interim institutional actions would be applied. The interim institutional actions proposed for this RU include periodic environmental monitoring and 5-year reviews.

4.4 SCREENING OF RU ALTERNATIVES

The site-specific remedial actions as defined in Sect. 3.3 were evaluated as to their ability to satisfy short- and long-term effectiveness, implementability, and cost criteria for each RU to be remediated. The process of evaluation and the results are reported in this section. Table 4.4 summarizes the results of the screening process.

The first remedial action evaluated was "No Action." This remedial "action" does not satisfy the effectiveness criterion but must be considered in accordance with CERCLA requirements.

The next remedial actions evaluated were institutional actions. Institutional actions include environmental monitoring, 5-year reviews, and various institutional controls. Institutional actions alone were not retained as a final action appropriate for the RUs to be actively remediated. Independent of other remedial actions, institutional actions provide limited protection of human health (for minimizing exposures) but do not protect the environment; do not provide long-term protection; and would not be effective in reducing the toxicity or volume of mercury in soil (a criterion of effectiveness). However, institutional actions have been retained in combination with other remedial actions.

Containment (soil cover) was retained for the Commercial/DOE and Other RUs. However, containment would be ineffective without the use of institutional actions. Institutional actions are needed to maintain the integrity of the soil cover by limiting access and restricting and eliminating potentially destructive activities. Containment (with institutional actions) was eliminated for the Residential RU based on long-term effectiveness criteria. It would be difficult to ensure the long-term maintenance and integrity of the soil cover in these RUs if the property remains privately owned.

Other remedial actions such as excavation of contaminated soil followed by disposal or treatment and beneficial reuse of that soil, or combinations thereof, satisfied the screening criteria and have been included as RU alternatives. These alternatives are summarized in the next section.

4.5 SUMMARY OF RU ALTERNATIVES

Based on the assumptions presented in Sect. 4.3 and the site-specific remedial actions that satisfied the screening criteria for effectiveness, implementability, and cost, the RU alternatives were developed. The following is a summary of the alternatives retained for each RU to be remediated. As discussed above and in Sect. 4.2.2 and 4.2.6, no further action is necessary for the SLB and Agricultural RUs because soil in those RUs are not contaminated above human health or ecological risk-based levels. Therefore, these RUs are not evaluated in the remaining sections of this document.

4.5.1 Surface Water/Sediments RU Interim Actions

Alternative A - No Action
Alternative B - Interim Institutional Actions

4.5.2 Commercial/DOE RU (Soil) Alternatives

Alternative A - No Action
Alternative B - Containment and Institutional Actions
Alternative C - Excavation and Disposal
Alternative D - Excavation, Treatment, and Beneficial Reuse

4.5.3 Other RU (Soil) Alternatives

Alternative A - No Action
Alternative B - Containment and Institutional Actions
Alternative C - Excavation and Disposal
Alternative D - Excavation, Treatment, and Beneficial Reuse

4.5.4 Residential RU (Soil) Alternatives

Alternative A - No Action
Alternative B - Excavation and Disposal
Alternative C - Excavation, Treatment, and Beneficial Reuse

4.6 DEVELOPMENT OF SITEWIDE ALTERNATIVES

The RU alternatives identified in Sect. 4.5 are developed into seven sitewide alternatives in this section. The incorporation of RU alternatives into sitewide alternatives provides a means of identifying remedial alternatives appropriate for all remedial action objectives and land uses of the site. The sitewide alternatives for the EFPC OU are illustrated in Fig. 4.4.

4.6.1 Development Criteria for Sitewide Alternatives

The RU alternatives were assembled to form all reasonable combinations to create a full range of remedial options for the site as a single entity. The assembly of the RU alternatives into sitewide alternatives was governed by the criteria listed below, which address a range of sitewide remedial alternatives while avoiding redundant combinations. Criteria applicable to SWAs 2 through 6 are more conservative than SWA 7, which was developed using a different approach that addresses remedial actions on an area-specific basis.

SWAs 2 through 6 were established on the principle that all contaminated soil exceeding remedial action objectives require action and that the same action would be taken for all properties within an RU, regardless of other considerations. This approach reflects a conservative view of protectiveness and minimizes the number of sitewide alternatives that would be necessary if scenarios for individual properties were combined in a matrix for all RUs. In contrast, and to provide a range of options in the remediation of the EFPC floodplain, SWA 7 was developed based on less conservative assumptions across all RUs and fewer environmentally adverse impacts from remedial actions. SWA 7 also differs from the other sitewide alternatives in that it considers remedial actions on an area-specific basis; this allows remedial actions to be considered for individual properties within an RU.

The following criteria apply to the development of sitewide alternatives from RU alternatives:

- The No Action alternative does not satisfy the remedial action objectives identified in Sect. 3 and is included to comply with CERCLA requirements and NEPA values. The No Action alternative (SWA 1) offers a basis for comparison with the other alternatives.

- Interim institutional actions for the Surface Water/Sediments RU are constants and are a component of all sitewide alternatives except the No Action alternative (SWA 1).

- Because of similarities in exposure to contaminant scenarios and remedial action objectives, remedial alternatives are the same for the Commercial/DOE RU and the Other RU within SWAs 2 through 6; therefore, the same actions are proposed for these RUs within each sitewide alternative. The retained RU alternatives for Commercial/DOE and Other RUs that are incorporated into sitewide alternatives include No Action (SWA 1), excavation and disposal (SWA 3); excavation, treatment, and beneficial reuse (SWA 5); and containment and institutional actions (SWAs 2, 4, and 6). SWA 7 includes—on a site-specific basis—the alternative of institutional actions alone where land use restrictions can be ensured.

- Similarly, remedial alternatives for the Residential RU are the same within SWAs 2 through 6. The retained RU alternatives for the Residential RU that are incorporated into sitewide alternatives include No Action (SWA 1), excavation/disposal (SWAs 2, 3, and 7), and excavation/treatment/beneficial reuse (SWAs 4 and 5). Consistent with the criteria for the Residential RU presented in Sect. 4.4, containment with institutional actions is excluded from remedial actions for this RU in SWAs 2 through 5. However, the addition of acquisition of realty interests (federal acquisition of some residential properties) in SWA 6 allows the containment and institutional actions alternative to be feasible for properties in this RU.

- If treatment is considered in an alternative, then all excavated soil would be treated. Residuals from the treatment process would be stored prior to transport to an approved disposal facility.

- SWA 7 provides for a balancing of ecological and human health risk. In all segments, except Segment 1, the Residential RU remedial alternative includes excavation and disposal of soil exceeding the 180-ppm mercury remediation goal option. To prevent adverse short-term impacts to sensitive ecological receptors that would result from excavation or containment, no active remediation would be implemented in Commercial/DOE or Other RU parcels where mercury contamination is above the 200-ppm ecological remediation goal option but below the 938-ppm human health remediation goal option. In Segment 1, the area of contamination that exceeds the 180-ppm remediation goal option for the Residential parcel and the 200-ppm remediation goal option for the Commercial/DOE parcel would be fenced to restrict human access. The area of fencing would encompass both Wetlands 3 and 4 for a total area of 5.53 ha (13.67 acres) and could be maintained as a DOE study area. Fencing the area in Segment 1 establishes physical access controls to those areas with >938 ppm mercury.

- For this evaluation, the representative disposal option for the untreated soil is Landfill VII, modified to include a liner and leachate collection/pretreatment. This does not preclude the modification of Landfill VI or the use of Landfill V for disposal of the untreated soil. In addition, off-site disposal at an approved low-level waste disposal facility would be appropriate for contaminated soil that does not meet the "special waste" criteria approved by TDEC.

- As defined in the National Contingency Plan, EPA has certain expectations in developing appropriate remedial alternatives. Treatment should be considered for remediating a site, whenever practicable, to address principal threats such as liquid media, high concentrations of toxic compounds, and highly mobile materials. SWAs 4 and 5 include treatment of the contaminated soil. However, SWA 7 does not include treatment due to the small volume of contaminated soil to be excavated. It would be more cost effective to dispose of the untreated soil than to treat it. In addition, the medium of concern is soil, not liquids, the areas of the floodplain are not contaminated with high concentrations of mercury, and the contamination in the soil is not highly mobile. Therefore, the EFPC OU does not satisfy the criteria posed by EPA as principal threats that would necessitate a preference for treatment.

Based on these criteria, and by eliminating unnecessary or redundant combinations, the RU alternatives have been assembled into seven sitewide alternatives. Figure 4.1 shows the locations of mercury contamination within each RU and identifies the current land use and the anticipated future land use of parcels that are addressed in SWAs 1 through 5. For example, the Hopkins-Strang Ball Park (Segment 1, parcel 408) is marked with the term, "C=Other," which is the current land use; the parcel is also color-shaded as Residential RU to reflect its potential for future use. Figure 4.2 reflects these same land use assumptions and also shows the locations of contaminated areas to be acquired and fenced under SWA 6. Figure 4.3 illustrates the property-specific land use assumptions of SWA 7 and delineates areas proposed for land use restrictions unique to that alternative. The following section describes the assembled sitewide alternatives.

4.6.2 Sitewide Alternative 1 (SWA 1): No Action

The No Action alternative is considered and defined according to CERCLA regulations and NEPA values and provides a baseline for comparison with other alternatives. This alternative would provide for no further remedial action at the EFPC OU. Although some institutional controls are in place at the site, these would not be maintained under this alternative. Environmental monitoring of groundwater, surface water, sediment, soil, and ambient air and biomonitoring to determine contaminant migration would be conducted periodically at all RUs except the SLB and Agricultural RUs. Because the contamination would remain on site, 5-year reviews would be conducted to confirm that the residual risk levels remain acceptable.

4.6.3 Sitewide Alternative 2 (SWA 2): Interim Institutional Actions for Surface Water/Sediments RU; Containment and Institutional Actions for Commercial/DOE and Other RU Soil; Excavation and Disposal of Residential RU Soil

This alternative includes interim institutional actions (construction permit restrictions, fish consumption warning signs, and periodic environmental monitoring) for the Surface Water/Sediments RU.

This alternative also involves the use of containment and institutional actions for soil with mercury concentrations >200 ppm in the Commercial/DOE and Other RUs. The installation of a 30- to 45-cm (12- to 18-in.) soil cover on the Commercial/DOE and Other RU contaminated soil would be supplemented by institutional controls (e.g., construction permit restrictions) to preclude the inadvertent excavation of the contaminated soil. A long-term maintenance program would be implemented to maintain the soil cover, and periodic environmental monitoring would be conducted. Five-year reviews would be conducted to evaluate the protectiveness of the soil cover and associated institutional actions and to confirm that residual risk levels remain acceptable.

Soil with mercury concentrations >180 ppm in the Residential RU would be excavated and disposed of in an approved lined disposal facility with leachate collection, such as Landfill V or Landfills VI or VII modified to include a liner and leachate collection. The contaminated soil would be excavated by conventional excavation techniques. Borrow soil from the West End Borrow Facility would be transported by truck for backfill. The locations of the proposed disposal and borrow sites are illustrated in Fig. 3.1.

4.6.4 Sitewide Alternative 3 (SWA 3): Interim Institutional Actions for Surface Water/Sediments RU; Excavation and Disposal of Commercial/DOE, Other, and Residential RU Soil

This alternative includes interim institutional actions (construction permit restrictions, fish consumption warning signs, and periodic environmental monitoring) for the Surface Water/Sediments RU.

Soil contaminated with >180 ppm mercury in the Residential RU as well as soil contaminated with >200 ppm mercury on the Commercial/DOE and Other RUs would be excavated and disposed of in an approved lined disposal facility with leachate collection, such as Landfill V or Landfills VI or VII modified to include a liner and leachate collection. Borrow soil from the Y-12 West End Borrow Facility would be transported by truck for backfill. The disposal site and borrow locations are illustrated in Fig. 3.1.

4.6.5 Sitewide Alternative 4 (SWA 4): Interim Institutional Actions for Surface Water/Sediments RU; Containment and Institutional Actions for Commercial/DOE and Other RU Soil; Excavation, Treatment, and Beneficial Reuse of Residential RU Soil

This alternative includes interim institutional actions (construction permit restrictions, fish consumption warning signs, and periodic environmental monitoring) for the Surface Water/Sediments RU.

Soil with mercury concentrations >180 ppm in the Residential RU would be excavated, treated, and beneficially reused under this alternative. The contaminated soil would be excavated by conventional excavation techniques. To remove the mercury contamination, the excavated soil would be transported to the K-25 Site for treatment by low-temperature thermal desorption. Following a performance assessment and approval by the State of Tennessee, the treated soil would be enhanced with organic matter, nutrients, and water as necessary to enable replacement in the excavated areas within the EFPC floodplain. The treatment residuals, concentrated material from the treatment process, would be packaged in preparation for shipment to a licensed disposal facility. Treatment residuals would be managed in accordance with applicable federal, state, and local regulations and the waste acceptance criteria of the licensed off-site disposal facility.

The containment and institutional actions for Commercial/DOE and Other RU soil under this alternative are similar to the containment and institutional actions discussed for Commercial/DOE and Other RU soil under SWA 2 in Sect. 4.6.3.

4.6.6 Sitewide Alternative 5 (SWA 5): Interim Institutional Actions for Surface Water/Sediments RU; Excavation, Treatment, and Beneficial Reuse of Commercial/DOE, Other, and Residential RU Soil

This alternative involves interim institutional actions (construction permit restrictions, fish consumption warning signs, and periodic environmental monitoring) for the Surface Water/Sediments RU.

This alternative involves the excavation and treatment of soil contaminated with >180 ppm mercury on the Residential RU as well as soil contaminated with >200 ppm of mercury from the Commercial/DOE and Other RUs, and the beneficial reuse of the treated soil as backfill material for the areas of excavation within the floodplain with State approval as described in Sect. 4.6.5. Low-temperature thermal desorption would be used to treat the soil and the treatment residuals would be transported for disposal at a licensed off-site disposal facility.

4.6.7 Sitewide Alternative 6 (SWA 6): Interim Institutional Actions for Surface Water/Sediments RU; Containment and Institutional Actions for Commercial/DOE and Other RU Soil; Containment and Institutional Actions for DOE-Acquired (Previously Residential) RU Soil

This alternative involves interim institutional actions (construction permit restrictions, fish consumption warning signs, and periodic environmental monitoring) for the Surface Water/Sediments RU.

Containment and institutional actions would be implemented where soil contamination is >200 ppm mercury on the Commercial/DOE and Other RUs. Furthermore, to maintain the protectiveness of containment and institutional actions on the Residential RU soil, DOE would acquire the portion(s) of the residential parcels with mercury contamination >180 ppm. The DOE real estate acquisition could range from easement to right-of-way to property procurement. Following real estate acquisition of the contaminated portion(s), a 45-cm (18-in.) soil cover would be installed over the soil in the acquired areas of the Residential RU that have mercury concentrations >200 ppm. Institutional actions (including installation of a fence around the area

with mercury concentrations > 180 ppm to restrict access) would be implemented. Also included in institutional actions would be environmental monitoring and 5-year reviews as described for containment actions and institutional actions for SWA 2 in Sect. 4.6.3.

4.6.8 Sitewide Alternative 7 (SWA 7): Interim Institutional Actions for Surface Water/Sediments RU; Institutional Actions for Commercial/DOE and Other RU Soil; Excavation and Disposal of Residential RU Soil

This alternative is similar to SWAs 2 through 6 in that interim institutional actions (construction permit restrictions, fish consumption warning signs, and periodic environmental monitoring) would be implemented for the Surface Water/Sediments RU.

Given the presence of the wetland habitat, special consideration was given under SWA 7 to the feasibility of institutional actions (acquisition, fencing, and zoning restrictions) to restrict human access and future land use in Segment 1 while protecting ecological receptors. DOE would acquire a small portion of commercial parcel #58 [0.01 ha (0.03 acre)], which is the Commercial/DOE RU, and also a portion of parcel #571 [1.32 ha (3.27 acres)], which is privately owned, undeveloped land in the Residential RU. The acquired properties would be fenced along with DOE parcel #461 [0.53 ha (1.30 acres)] in a manner that would preserve the wetlands (COE #3 and #4). The fenced area includes a total area of 5.53 ha (13.67 acres) [shown in Fig. 4.3(a)] could be maintained by DOE as a future study area for the fate of mercury in the environment. Additional institutional actions, including public information (e.g., posting of signs), periodic environmental monitoring, well restrictions and survey, and 5-year reviews would be implemented.

For the remaining areas of the Residential RU [3.5 ha (8.7 acres)], the remedial action includes excavation of contaminated soil exceeding the 180-ppm mercury remediation goal option for human health. Disposal of excavated soil would be in an approved lined disposal facility with leachate collection, such as Landfill V or Landfills VI or VII modified to include a liner and leachate collection.

No active remediation would be implemented in Commercial/DOE and Other RU parcels where mercury contamination of soil is above the 200-ppm ecological remediation goal option but below the 938-ppm human health remediation goal option. However, because the mercury contamination would be left in place, monitoring and 5-year reviews would be conducted in these areas to confirm that the residual risk levels remain acceptable. Institutional actions (e.g., future land use restrictions, well restrictions and survey, construction permit restrictions, public education programs) would be implemented to restrict residential or agricultural use of these contaminated areas.

SECTION 4

TABLES

This page intentionally left blank.

Table 4.1. Summary of EFPC remedial unit areas by segment

	Remedial unit									
	Commercial		DOE		Other		Residential		Agricultural	
Segment	(ha)	(acres)	(ha)	(acres)	(ha)	(acres)	(ha)	(acres)	(ha)	(acres)
1	8.51	21.02	0.84	2.07	0.64	1.59	6.05	14.94	0	0
2	1.77	4.37	0	0	4.71	11.64	6.66	16.45	0	0
3	2.84	7.02	0	0	0.09	0.21	8.52	21.04	0.45	1.11
4	0.04	0.10	0	0	8.48	20.94	4.94	12.21	0	0
5	0.13	0.33	0	0	5.31	13.12	2.50	6.17	0	0
6	0	0	0	0	0.68	1.68	9.46	23.37	0.03	0.07
7	0	0	0	0	23.24	57.41	0.29	0.71	28.31	69.92
8	0	0	0	0	0	0	10.65	26.31	0	0
9	0	0	89.24	220.43	0	0	28.73	70.96	0	0
Total	13.30	32.84	90.08	222.50	43.15	106.59	77.80	192.16	28.79	71.1

Table 4.2. Estimated surface areas of EFPC floodplain soil contaminated above the mercury remediation goal options[a]

	Remedial unit									
	Commercial (>200 ppm)		DOE (>200 ppm)		Other (>200 ppm)		Residential (>180 ppm)		Agricultural (>180 ppm)	
Segment	(acres)	(ha)	(acres)	(ha)	(acres)	(ha)	(acres)	(ha)	(acres)	(ha)
1	0.03	0.01	1.49	0.60	0	0	3.38	1.37	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0.09	0.04	0	0	0	0	0.62	0.25	0	0
4	0	0	0	0	3.34	1.35	6.32	2.56	0	0
5	0	0	0	0	0.71	0.29	0.55	0.22	0	0
6	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0.83	0.34	0	0
9	0	0	0.53	0.21	0	0	0.27	0.11	0	0
TOTAL	0.12	0.05	2.02	0.81	4.05	1.64	11.97	4.85	0	0

[a] Values for acres converted from yd^2; values for hectares converted from acres. All values rounded to two decimal places after conversion.

Table 4.3. Estimated in situ volumes of EFPC soil contaminated above the mercury remediation goal option levels[a]

EFPC floodplain segment	Remedial unit									
	Commercial (>200 ppm)[b]		DOE (>200 ppm)[b]		Other (>200 ppm)[b]		Residential (>180 ppm)[c]		Agricultural (>180 ppm)[c]	
	(yd^3)	(m^3)	(yd^3)	(m^3)	(yd^3)	(m^3)	(yd^3)	(m^3)	(yd^3)	(m^3)
1	100	100	6,200	4,700	0	0	8,500	6,500	0	0
3	400	300	0	0	0	0	2,700	2,000	0	0
4	0	0	0	0	10,700	8,200	17,200	13,200	0	0
5	0	0	0	0	1,500	1,200	1,400	1,100	0	0
6	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	1,800	1,400	0	0
9	0	0	2,300	1,800	0	0	1,200	900	0	0
Total	500	400	8,500	6,500	12,200	9,400	32,800	25,100	0	0

[a] All values have been rounded to the nearest 100 m^3.
[b] Remediation goal option for ecological receptors; human health remediation goal option for this land use if 938 ppm mercury in soil.
[c] Human health remediation goal option for this land use; ecological remediation goal option for this land use is 200 ppm mercury in soil.

Table 4.4. Screening of representative remedial actions by RU

RU	Remedial actions						
	No action	Institutional actions	Containment actions	Excavation actions	Treatment actions	Disposal actions	Beneficial reuse actions
EFPC surface water/sediments	No-1	No-2	No-2	No-2	No-2	No-2	No-2
SLB	NFA	NFA	NFA	NFA	NFA	NFA	NFA
Commercial/DOE	No-1	No-3	Yes-4	Yes	Yes	Yes	Yes-5
Other	No-1	No-3	Yes-4	Yes	Yes	Yes	Yes-5
Residential	No-1	No-3	No-6	Yes	Yes	Yes	Yes-5
Agricultural	NFA	NFA	NFA	NFA	NFA	NFA	NFA

1. Does not meet effectiveness criteria.
2. Only interim institutional actions.
3. Does not meet long-term protectiveness criteria, or reduce toxicity, mobility, or volume.
4. Does meet criteria if combined with institutional actions.
5. Does meet criteria if combined with treatment actions.
6. Does not meet long-term protectiveness criteria.

NFA = No Further Action is necessary because there was no contamination measured above human health or ecological remediation goal option levels.
No = Does not meet criteria.
Yes = Does meet criteria.

5. DETAILED ANALYSIS OF ALTERNATIVES

5.1 INTRODUCTION

In this section, sitewide alternatives capable of addressing contamination at the EFPC OU, developed and screened in Sect. 4, are described and evaluated using CERCLA criteria and other NEPA values (Sect. 5.3). A description of actions common to several sitewide alternatives is provided in Sect. 5.2. Individual discussions of monitoring and mitigative measures, cumulative impacts, and impacts of potential loss of institutional controls are provided in Sects. 5.4, 5.5, and 5.6, respectively.

The statutory requirements (42 USC § 9621) and the regulatory requirements (40 CFR 300) that guide the evaluation of alternatives in an FS are that a remedial action should:

- protect human health and the environment;
- attain ARARs or define criteria for invoking a waiver;
- be cost effective;
- use permanent solutions and alternative treatment technologies to the maximum extent practicable; and
- satisfy the preference for treatment that reduces toxicity, mobility, or volume as a principal element (or explain why this is not obtainable).

EPA has established the following nine evaluation criteria to address these regulatory requirements:

- overall protection of human health and the environment;
- compliance with ARARs;
- long-term effectiveness and permanence;
- short-term effectiveness;
- reduction of toxicity, mobility, or volume through treatment;
- implementability;
- cost;
- state or support agency acceptance; and
- community acceptance.

Section 5.3 presents an evaluation of each potential remedial action alternative based on these nine criteria and other NEPA values [40 CFR 300.430(b)(1-9)]. Table 5.1 presents the integration of NEPA values with CERCLA criteria.

With respect to **overall protection of human health and the environment**, each alternative is evaluated as to its ability to reduce the risk from potential exposure pathways by using treatment, engineering measures, or institutional controls. The evaluation also examines whether alternatives pose any unacceptable short-term or cross-media impacts.

The federal environmental laws that are determined to be either applicable or relevant and appropriate to each alternative are identified. State laws that are more stringent than the federal requirements, or for which there are no federal counterparts, are also identified. The ability of each alternative to meet all of its respective **ARARs** and any need to justify a waiver are noted and discussed. Regulations and guidance that were screened for relevance to the remedial actions are presented in Appendix C.

Long-term effectiveness and permanence are evaluated on the basis of the magnitude of residual risk and the adequacy and reliability of the controls used to manage the remaining waste (untreated waste and treatment residuals) over the long term (i.e., after remedial objectives are met). Alternatives that afford the highest degree of long-term effectiveness and permanence are those that leave little or no waste at the site, making long-term maintenance and monitoring unnecessary and minimizing the need for institutional controls.

Evaluation of alternatives for **short-term effectiveness** takes into account the protection of remediation workers and the community during the remedial action and before remedial action objectives are met. Environmental impacts from implementing the action, as well as the time required to achieve remediation goals, are also considered.

The statutory preference is to select a remedial action that employs **treatment to reduce the toxicity, mobility, or volume** of hazardous substances. This criterion addresses the anticipated performance of the technologies that may be employed to achieve these treatment goals. This criterion considers the amount of waste treated or destroyed; the reduction in toxicity, mobility, or volume; the irreversibility of the treatment process; and the type and quantity of residuals resulting from the treatment process.

The evaluation of **implementability** deals with the technical and administrative feasibility of implementing the alternatives as well as the availability of necessary goods and services. This criterion considers such factors as the ability to construct and operate components of the alternatives; the ability to obtain services, capacities, equipment, and specialists; the ability to monitor the performance and effectiveness of technologies; and the ability to obtain necessary approvals from other agencies.

The bases for the **costs** presented in this report are defined in Appendix D. The costs are based on a variety of information, including quotes from suppliers, generic unit costs, vendor information, conventional cost estimating guides, and prior experience (EPA 1987d). The feasibility-study-level cost estimates were prepared from the information available at the time of the estimate using guidance in project evaluation and implementation. The actual costs of the project will depend on true labor and material costs, actual site conditions, competitive market conditions, final project scope, the implementation schedule, and other variables. An uncertainty that may affect the cost is the actual volume of contaminated soil. Most of these uncertainties would affect the costs similarly. A sensitivity cost analysis, presented in Appendix D, describes potential cost analysis impacts based on the variation of certain factors. No escalation or discount factors were used in these estimates.

Legal costs, siting studies, treatability testing, and the documentation of environmental impacts (including the NEPA public review process) could affect the cost estimates provided in this FS by causing significant delays in obtaining approvals. The actual costs could also be

higher than those estimated for these actions as the result of unexpected site conditions and potential delays in the action. The cost estimate for new disposal facilities that involve other sites on the ORR would vary depending on the percentage of cost sharing between this remedial action and other remedial actions on the ORR.

State and community acceptance of various remedial action alternatives being evaluated is factored into this analysis, to the extent possible, based on information available to date. The concerns of the community should be considered in formulating alternatives that will be acceptable to it. See Appendix I for a description of the Community and Public Involvement Program for EFPC. These two criteria will be formally evaluated following public comment on the FS report and will be addressed in making a final decision on the remedy to be selected.

5.2 DESCRIPTION OF GENERAL RESPONSE ACTIONS

This section describes the general response actions which, alone or in combination, are used in sitewide alternatives (e.g., excavation, transportation, treatment, and disposal). Descriptions of these general actions will not be repeated in the detailed descriptions of each sitewide alternative.

5.2.1 Institutional Actions

Institutional actions help to protect human health and the environment when implemented in combination with other remedial actions. Institutional controls, a subset of institutional actions, include access controls and legal controls. According to 40 CFR 300.430, institutional controls "should not substitute for active response measures as the sole remedy unless active response measures are not practicable..." (55 *FR* 8706). Access and legal controls minimize potential exposures resulting from inadvertent access to the site and direct contact with contaminated media, but they do not reduce contamination toxicity, mobility, or volume. Institutional actions, described in EPA's *Guidance for Conducting Remedial Investigation and Feasibility Studies under CERCLA* (1988b), include not only institutional controls but also environmental monitoring and 5-year reviews.

Access controls are implemented by restricting access to the area of remediation through physical controls. Physical controls include fencing, construction of berms, posting of warning signs, and site security to help prevent unauthorized access to the site. Security personnel can be used to allow only authorized access to the site during active remediation.

Legal controls place restrictions on land use to limit future development and site use. The municipality may accomplish this by placing zoning restrictions on land use or activities on the contaminated properties within the municipal boundary. Another option is for the federal government to acquire appropriate realty interests from the landowners, which could result in total acquisition of the land or in a lesser interest estate, which could be restrictive in nature.

Any remedial action would require some form of acquisition of appropriate realty interests, except on DOE-owned property. A Final Real Estate Planning Report would be prepared upon approval of the Record of Decision. This report would identify the affected properties and ownership through map delineation; establish an acquisition line based on the minimum amount

of land needed to satisfy the remediation requirements; select the appropriate realty estate or combination of estates necessary to accomplish the action; address the highest and best use of the land and its current monetary value; determine the subsequent retention, use, or disposal of any land acquired; and analyze and recommend a real estate alternative that would best achieve the mandates of federal real estate policy and law. The realty estates or interests to be considered would include fee title, permanent or temporary easements, licenses, permits, and leases. Methods of acquisition to be used may include purchase, condemnation, or donation.

Although environmental monitoring is included as an institutional action, it does not prevent or minimize exposure. The objective of environmental monitoring is to observe changes in contaminant levels and determine whether contaminants are migrating off site. Monitoring allows assessment of contaminant migration and is thus an important part of preventing potential unacceptable exposures. Environmental monitoring would involve routine, periodic sampling of potentially affected media. Contaminant levels above maximum contaminant levels for metal, organic, or radioactive contaminants in groundwater or levels above risk-based standards for surface water and sediments would potentially trigger a reevaluation of the response action. An additional trigger would be evidence of a trend toward increased contaminant migration. In biological sampling, reevaluation could be triggered by body burdens exceeding levels predicted to be protective of species and their predators. In addition, a well survey would be conducted annually to confirm that the groundwater is not being used as a drinking water source.

Because some alternatives leave contaminants above risk-based levels, 5-year reviews are included as an institutional action. The purpose of 5-year reviews is to confirm that the response action remains protective of public health and the environment. The more specific objectives of the reviews are to confirm that the remedy, as reflected in the Record of Decision and/or remedial design, remains effective in protecting human health and the environment and to evaluate whether the original remediation levels remain protective of human health and the environment. The first objective can be accomplished primarily through a review of documented operation and maintenance of the site, a site visit, and limited analysis of site conditions. The second objective necessitates an analysis of newly promulgated or modified requirements of federal and state environmental laws to determine whether they are ARARs and whether they call into question the protectiveness of the remedy. A further objective of the review is to consider the scope of operation and maintenance, the frequency of repairs, changes in monitoring indicators, costs at a site, and how these factors relate to protectiveness. The reviews are to be conducted no less often than each 5 years after the initiation of the remedial action.

The focus of a 5-year review depends on the original goal of the response action. For example, if protectiveness is being provided through exposure protection and institutional controls, the review would focus on whether the action remains effective and the controls remain in place. EPA retains final review and approval authority for the 5-year reviews but may enter into contracts and/or agreements to authorize other parties to perform portions of the reviews.

There are three levels of reviews: Level I, the lowest level of evaluation of protectiveness; Level II, an intermediate level of evaluation of protectiveness; and Level III, the highest level of evaluation of protectiveness. The appropriate level of evaluation needed to complete a 5-year review is determined based on the risk remaining after remedial action and will be described in the Proposed Plan.

5.2.2 Containment Actions

Containment would involve the installation of a soil cover for contaminated areas with a mercury concentration >200 ppm. A 45-cm (18-in.) soil cover, consisting of 15 cm (6 in.) of topsoil placed on 30 cm (12 in.) of borrow soil, would be installed to reduce the potential for direct human or ecological receptor contact with contaminated surface soil and to minimize the potential for airborne migration of surface contamination to human and ecological receptors. A high-density polyethylene intrusion barrier would be used for ecological protection. A soil cover would minimize exposure pathways.

Surface preparation prior to cover installation would include removal of all vegetation to within 5 cm (2-in.) of the ground surface level. Trees would be cut into transportable sizes [2.4- to 3-m (8- to 10-ft) lengths] and transported to a construction landfill for disposal. Small trees, vegetation, brush, tree branches, and leaves would be chipped to be spread on the ground surface in the postremediation restoration of the site. A permeable high-density polyethylene intrusion barrier would be installed to deter burrowing animals from living in the contaminated areas. Cover soil would be obtained from the West End Borrow Area on the ORR and would be transported by truck. Borrow soil would cover the liner to a depth of 30 cm (12 in.), and 15 cm (6 in.) of topsoil would be placed on top of the borrow soil. The soil cover and liner would extend ~3 m (10 ft) beyond the area of contamination. Shallow-rooted vegetation (i.e., grass) would be planted over the soil cover by hydroseeding, a technique that mechanically disperses grass seeds, nutrients, and straw over the surface to be vegetated. Construction and maintenance of access roads would be necessary in some areas for installation and maintenance of the soil cover.

Runon/runoff controls (e.g., berms, silt fences, and hay bales) would be implemented and maintained to reduce the potential of surface water from off site impacting the soil cover or vegetation, or for the release of contaminants during the remedial action. These controls would be removed when the area had been stabilized and the vegetation was well established. Where the soil cover extends to the creek bank, or as necessary, additional surface control measures (e.g., bank stabilization by gabions) would be taken to minimize or eliminate contaminant migration into the surface water and to prevent encroachment of the creek into the remedial area. The gabions would become a permanent component of the creek bank.

Unrestricted access to the covered areas could lead to removal of the cover and/or excavation of contaminated soil by individuals having no knowledge of the presence or nature of the contamination; therefore, institutional controls would be required to maintain the integrity of containment. Institutional actions that could be implemented include legal controls to limit future development and site use (e.g., land-use or construction-permit restrictions); annual environmental monitoring (including groundwater, surface water, sediment, soil, air, and biological monitoring) and a well survey; 5-year reviews, which include reviews of the environmental monitoring data to confirm whether the containment option was and is protective of human health and the environment; and public education programs.

A long-term maintenance program for upkeep of containment actions and institutional actions would be established. Upkeep would include, at a minimum, repairs of the cover (such as repair of erosion damage). Mowing would be included to maintain the shallow-rooted vegetative cover (grass) where required.

5.2.3 Excavation Actions

Excavations would be performed in accordance with federal, state, and local construction, grading, and transport permits. Temporary access roads would be installed to allow access to the excavation areas. Central staging areas would minimize the impacts to the environment.

Runon/runoff control measures such as silt fences, diversion ditches, culverts, berms, and riprap would be installed in compliance with state and local construction regulations. Where remediation extends to the creek bank, or as necessary, additional temporary surface control measures (e.g., bank stabilization) would be employed to minimize and/or eliminate contaminant migration into surface water and to prevent encroachment of the creek into the remedial area.

Other technologies such as size classification and crushing and grinding would be implemented at the treatment and disposal facility to make the soil matrix more workable.

5.2.3.1 Excavation

Clearing equipment and specially equipped bulldozers would be used to remove vegetation and to clear and grub. Trees would be cut into transportable sizes [2.4- to 3-m (8- to 10-ft) lengths] and transported to a construction landfill for disposal. Small trees, vegetation, brush, tree branches, and leaves would be chipped to mulch and stockpiled for use in the postremediation restoration of the site. Access and haul roads would be installed to allow access to the excavation areas.

The disposition of plant materials should not be limited by contaminant content. The regulatory limit for toxicity characteristic is 0.2 mg mercury/L of TCLP extract, which corresponds to 4 mg extractable mercury/kg solid waste. Mercury levels in plant materials were determined as part of the RI (DOE 1994a,b). The maximum mercury levels in tree cores sampled in the wetland investigation (DOE 1994b) and in plant foliage and garden vegetation samples analyzed in the RI Phase Ib investigation (DOE 1994a) were all below 4 mg/kg. One of the 16 plant foliage samples analyzed in the wetland study (DOE 1994b) was above 4 mg/kg. It is likely that it was contaminated with surficial soil or sediment, which has been shown not to contain extractable mercury (DOE 1994a). All samples of plant materials contained less than the 12-mg/kg limit set by DOE for mercury disposal in landfills at the Y-12 Plant.

Contaminated soil would be excavated with conventional heavy construction equipment such as hoes. The specific equipment to be used would be determined by site conditions such as the size of the area to be excavated, available area for setup and operation, depth of excavation, and the rate for treatment or disposal. (See Appendix J for a discussion of issues related to use of heavy equipment in wetlands and high-water-table floodplains.) In general, contaminated subsurface soil would be removed with equipment such as hoes. Manual excavation could be required due to conditions such as underground utilities or a crowded site. The contaminated areas would be remediated in a systematic manner, using Best Management Practices to prevent recontamination. Confirmatory sampling would be performed during each excavation to verify that cleanup levels are met.

The term "hoe" applies to any excavating machine of the power-shovel type (e.g., hoe, backhoe, back shovel, or pull shovel). Hoes are used primarily to excavate below the natural

surface of the ground on which they rest and are best suited to excavating trenches and pits and to general grading work that requires precise control of excavation depth. They are superior to drag lines for close-range work and for loading excavated material into dump trucks. Hoes can work from a clean area, contaminating only their buckets. The actual excavation techniques would be specified to avoid the cross contamination of clean soil as the hoe excavates the contaminated soil. Confirmatory sampling would be used to detect cross-contamination. For excavations deeper than 0.3 to 0.6 m (1 to 2 ft), the hoe is generally the most effective piece of equipment.

Bulldozers are effective for moving earth for distances up to 90 m (300 ft), spreading earth fill, clearing and grubbing sites, and pushing earth and debris into stockpiles or loading areas. Bulldozers with the appropriate tooling can be used effectively for compacting general fill (not underlying a civil structure such as a road or building) by several passes with the tracks.

Front-end loaders can have either tracks or rubber tires and are effective for handling and loading bulk material such as soil, rocks, and rubble. They are also useful in moving material from stockpiles to dumptrucks for hauling to backfill areas and in hauling for short distances. Front-end loaders have a limited use as excavating equipment.

All excavated areas would be backfilled with clean material from a borrow area or with treated soil. The borrow site that meets the evaluation criteria is the West End Borrow Area on the ORR. The site has the capacity to provide adequate soil volume for backfill and cover needs; has a stockpile of 23,000 m^3 (30,000 yd^3) of topsoil available on site; is already a designated borrow site with access roads; and has existing NEPA documentation. For stability, the backfill material would be compacted using a compactor or the tracks of a heavy bulldozer. Compaction helps prevent settling of the backfill soil, limits erosion, and provides support for construction vehicles. The disturbed areas would be regraded to original or higher-than-original contours and covered with a topsoil layer capable of sustaining vegetative growth. The topsoil may be augmented by adding the chipped trees and brush removed from the floodplain. This additional organic content would act as a soil amendment and would also serve as a means for disposing of the brush.

Haul roads would be removed and returned to their original condition when they were no longer needed. This would include regrading, spreading a layer of topsoil, and stabilizing with vegetation. Silt and erosion control measures also would be removed when they were no longer necessary. The disturbed areas would be seeded with an annual grass (for rapid stabilization) and planted with tree species that occur naturally in the floodplain, if these are commercially available.

5.2.3.2 Transportation

Transportation for the remediation of the EFPC OU includes transport by dump truck of excavated soil from the excavation location to a treatment and/or disposal area and transport of borrow or treated soil back to the remediation site.

Dump trucks are useful for hauling soil, rock, aggregate, and other material. Because of their speed on suitable roads, they provide high earth-moving capacity at relatively low hauling cost. They also provide a high degree of flexibility, as the number of trucks in service may

easily be increased or decreased to modify the total hauling capacity of a fleet. Dump truck models should be selected for their ability to prevent spillage of contaminated material, size efficiency, and minimal ecological impacts.

The transportation of contaminated materials would comply strictly with applicable federal, state, and local regulations. The U.S. Department of Transportation (DOT) Regulations for Hazardous Materials list general requirements for shipping and packaging in 49 CFR 172 and 173 and requirements for carriage by public highway in 49 CFR 177.

Transport would follow predesignated routes, for which an emergency response program would be developed. Transport vehicles would be inspected before use and surveyed for radioactive contamination following transport. Because the trucks may haul saturated soil, watertight liners would be used to prevent water from leaking out during transportation. Tarpaulins would be used to prevent spillage and dust release during transport. Vehicles would be decontaminated as required.

5.2.4 Treatment Actions

Three types of remedial treatment technologies were identified in Sects. 3 and 4: physical, thermal, and dewatering. Physical technologies achieve either volume reduction or stabilization/immobilization of the contaminants. Thermal technologies separate volatiles from the soil by either desorption or destruction. Dewatering technologies reduce the soil volume or prepare it for additional treatment process options. Through the screening process, the low-temperature thermal desorption process was retained as the representative treatment technology process option. Physical treatment to achieve size reduction and dewatering were retained as pretreatment steps.

The objective of the treatment action is to separate mercury from the soil. The thermal desorption unit dissociates volatiles from the soil, including certain metals such as mercury. The treated soil may be suitable for beneficial reuse as backfill in the floodplain, and the concentrated contaminants, treatment residuals, would be managed and disposed of in an appropriate disposal facility. Identification of the residuals disposal location prior to treatment is important because the disposal facility could impose waste acceptance limitations or conditions. A pilot study was conducted and provides additional operating information for the design of the unit.

5.2.4.1 Dewatering technologies

Dewatering would primarily be used as a pretreatment step with thermal desorption. Dewatering may be required for some soil in the EFPC floodplain prior to processing. Dewatering would involve the use of dewatering beds. The dewatering beds, if required, would be centrally located. Impermeable liners or containers would be used to prevent the uncontrolled release of untested fluids to the environment. Effluents from the dewatering process would be collected, analyzed, and disposed of in compliance with ARARs. The dewatered soil would be loaded into dump trucks for transport to the treatment or disposal facility.

5.2.4.2 Low-temperature thermal desorption

The thermal desorption process uses heat to dissociate volatiles, including certain metals such as mercury, from the soil. Thermal desorption, particularly low-temperature thermal desorption, typically does not reach the temperatures necessary to break down organic compounds. In addition to mercury (and other volatile or semivolatile metals), PCBs and other organic compounds would be present in the off-gas if they were present in the soil. The air pollution control system would be designed to keep air emissions within the limits specified in the air permit for the low-temperature thermal desorption unit. Preliminary results indicate that removal efficiencies approaching 99.99% can be readily achieved using conventional air pollution control methods. Nonvolatiles and radionuclides are not treated by low-temperature thermal desorption. Therefore, additional treatment steps may be necessary to treat the nonvolatiles in the waste stream to meet specific criteria for beneficial reuse in backfilling as well as for the concentrated contaminants from the off-gas collection and treatment system.

Preliminary results of a treatability study of EFPC-SLB soil indicate that >95% of the mercury could be removed using temperatures as low as 350° C (662° F) and residence times on the order of 15 min (Energy Systems 1994). Low-temperature thermal desorption processing appeared to have no significant impact on the levels of uranium in the soil and sediment, confirming its ineffectiveness in treating nonvolatiles. An observation concerning total organic carbon and PAH emissions suggested that minimizing the organic emissions through temperature control would generate less waste in the off-gas.

A permanent low-temperature thermal desorption unit could be built on site, or a mobile unit could be brought on site by a commercial vendor. Commercial suppliers and operators of low-temperature thermal desorption equipment are available. The proposed location for installation and operation of the low-temperature thermal desorption unit is at the K-25 Site where space and utilities are readily available. The unit could be constructed and operated through contract with one of the commercial suppliers of the technology.

Developing low-temperature thermal desorption capabilities on the K-25 Site would begin by establishing a specific location to install the process unit. Natural gas, electricity, process water, and dry instrument air would be required for the operation of the low-temperature thermal desorption equipment. These utilities are available on site; piping modifications may be required to route them to the low-temperature thermal desorption unit.

The contaminated soil would be excavated at approximately the same rate as the daily burn rate of the low-temperature thermal desorption unit, 500 tons/d. Tree stumps and roots (or other material excavated with the soil) would be separated from the soil and would pass through a materials processing stage to achieve size reduction. Excavated soil would undergo a separate size-reduction process. These materials would be reduced to a size of ≤6.3 cm (2.5 in.) before passing through the low-temperature thermal desorption treatment. It is estimated that low-temperature thermal desorption would reduce the volume of the treated soil by ≤10%. Volume reduction occurs when mercury, moisture, and organics are driven off during treatment.

Preliminary results from the pilot-scale treatability study demonstrated that residual waste quantities generated during treatment approach 0.45 kg (1 lb) of waste generated for each pound of soil treated in the pilot test. The preliminary waste stream of concern is from the wet

scrubbers, which use large amounts of water to remove contamination from the off-gases. This water contains elevated concentrations of contaminants. Management of the residuals could involve pretreatment, transportation, and disposal and may affect the desirability of using thermal treatment. Therefore, the actual configuration of the low-temperature thermal desorption unit and its air pollution control equipment must be carefully thought out, particularly with respect to residual waste generation. The residual or concentrated material from the treatment process would be placed in containers, sampled, and tested for TCLP and radionuclides. Residues would then be transported to an appropriate disposal facility. Preliminary treatment study results suggest that the largest portion of mercury recovered in the off-gases is found in the scrubber solids (63% of the mercury was measured in the air pollution control system); the remaining mercury is found throughout the air pollution control system in both liquid and solid media.

Treated soil would be enhanced with nutrients and water while at the treatment unit site and would be transported by truck to a staging area on the floodplain. At the staging area, wood chipped during the removal action would be added to the soil for beneficial reuse as backfill into the floodplain excavation. Enough nutrients, water, and wood chips would be added to return the soil to approximately its original volume and contour and to return nutrients and organic matter to the soil.

5.2.5 Disposal and Beneficial Reuse Actions

The disposal options for mercury-contaminated soil excavated from the EFPC OU include disposal at an approved lined landfill with leachate collection, such as Landfill V or modification of Landfills VI or VII at the Y-12 Plant, or beneficial reuse of the treated soil as fill in the area of excavation from the EFPC OU. All disposal and beneficial reuse actions would require regulatory approval.

5.2.5.1 On-site disposal

This on-site disposal option involves the use of an approved lined landfill with leachate collection, such as Landfill V, or the design and construction of a modified Class IV construction debris landfill. For this evaluation, the proposed disposal unit would be a Class IV landfill located at the Y-12 Plant, modified to include a liner and leachate collection (see Fig. 3.1). An environmental assessment for Landfill VII was approved by the Office of Environment, Safety, and Health with a Finding of No Significant Impact (Ziemer 1992). The potential environmental consequences of operating this disposal facility are described in Sect. 5.3.2.5, short-term effectiveness and environmental impacts.

The setting of the proposed disposal facility is on the ORR at the East Chestnut Ridge site. The site is underlain by carbonate rocks of the Cambro-Ordovician Knox Group. Detailed descriptions of the rock groups may be found in the studies by Ketelle and Huff (1984) and Lee and Ketelle (1989). If unweathered, the Knox Group typically has low permeability and porosity; however, the Knox dolostones are susceptible to the formation of solutional features, primarily along bedding planes and fractures caused by folding and faulting. Karst features such as dolines, disappearing streams, and sinkholes have been observed at the West Chestnut Ridge site (Ketelle and Huff 1984).

Because there is a karst feature with surface expression (sinkhole) in the vicinity of the proposed site (ORNL 1992a), test borings would be required to confirm that no karst features are in the area being developed as a disposal area or, if there are, that the disposal area is engineered to avoid such features.

Overburden on the site is substantial. Residual soil materials, derived from weathering of the bedrock, blanket the bedrock to depths generally ranging from 12 to 37 m (40 to 120 ft). The soil consists primarily of clay and silty clay of low to high plasticity [CL to CH, according to the Unified Soil Classification System (ORNL 1992a)].

The thickness of the soils developed on the Knox Group on Chestnut Ridge is variable. In general, the thicker soil development is found at the higher ground surface elevations, whereas thinner soil development is common at the lower ground surface elevations. At the East Chestnut Ridge site, soil thickness varies between 23 m (74 ft) and 42 m (138 ft) (ORNL 1992a).

The hydrogeologic setting of the area is complicated. Weathered Knox bedrock and its overlying residual soils are hydraulically connected and are generally considered a single aquifer. The results of field studies at the East Chestnut Ridge and West Chestnut Ridge sites indicate that the Chestnut Ridge area is underlain by a network of developed karst (i.e., sinkholes and other solution features) (Woodward-Clyde Consultants 1984; Ketelle and Huff 1984; Golder Associates 1989). Although the complexity and extent of this network is not currently known, it is generally believed that groundwater flow on Chestnut Ridge is controlled by the fractures and solution cavities within the rock (ORNL 1992a). Additional groundwater data were reported in *Environmental Assessment: Steam Plant Ash Disposal Facility and Industrial Landfill at the Y-12 Plant, Anderson County, Tennessee* (ORNL 1992a).

Private water supply wells near the proposed disposal areas are located south of the Clinch River, and no known public or private water supply wells are located along the groundwater pathway between the proposed site or the alternative sites and the Clinch River. It is not expected (see above) that groundwater flowing from the site would flow beneath the river (ORNL 1992a).

Several bodies of water exist within the East Chestnut Ridge site, including two small ponds and one small unnamed stream. However, because the stream is intermittent, flowing primarily during periods of rainfall, TDEC does not consider that either "Water of the State" (i.e., perennial streams) or jurisdictional "wetlands" exist within the boundaries of the site as defined in the Tennessee Water Quality Control Act (ORNL 1992a).

The candidate disposal area within the East Chestnut Ridge site consists of old field and pine plantation, with second-growth hardwood communities (primarily white oak, northern red oak, hickory, and yellow poplar) common to the region along the edge of the area to be disturbed. As a result, terrestrial animals present on the site are also likely to be common and widespread on the ORR and in the region. Although several unusual or sensitive communities and plant species are present along the East Chestnut Ridge area, none occurs in the candidate waste disposal areas (ORNL 1988).

The two ponds present on the site support some common emergent aquatic vegetation and provide habitat for common waterfowl. No rare or sensitive plant species are present. No reported studies have been published on the aquatic biota of the ponds or the stream on the East Chestnut Ridge site. Intermittent streams, such as that on the site, are typically colonized by numerous invertebrate taxa that are adapted to living in periodically dry conditions (Williams 1987).

No plants or terrestrial mammals listed by the FWS as endangered or threatened are known to occur on the East Chestnut Ridge site. The site consists of habitat that might be used for foraging by the Cooper's hawk, a species listed by the state as threatened. This species is believed to be scarce on the ORR. It is unlikely that the species nests on the site, but it may occasionally forage there. Similarly, the site provides potential foraging and nesting habitat for species listed by the state as in need of management, the black vulture and the red-shouldered hawk (ORNL 1992a).

No threatened or endangered fish or invertebrates listed by either the State of Tennessee or the FWS have been found or are known to occur on the ORR. One species of fish, the Tennessee dace *(Phoxinus tennesseensis)*, listed by the State of Tennessee as a species in need of management, occurs in several streams on the ORR, but there is no record of its occurrence in either of the streams on the proposed site and it has not been found in any stream draining the south side of Chestnut Ridge that has been recently sampled (ORNL 1989). Fielder (1974) did not designate any archaeological sites in the proposed area.

The disposal facility would be designed with the appropriate engineering controls. Design capacity would be for the amount of material generated during remediation of the EFPC OU. The disposal facility for EFPC would be a modified Class IV landfill constructed at the Y-12 Plant. The design of the cell would be similar to that of Landfill V at the Y-12 Plant. This disposal unit would be single-lined and equipped with a leachate collection system. The liner, consisting of natural and/or synthetic materials, would be designed to (1) achieve a maximum hydraulic conductivity of 1×10^{-7} cm/s and (2) last the life of the site (expected to be from 15 to 25 years depending primarily on waste volumes) plus 30 years (the postclosure period). As required, the liner would be underlain by at least 3 m (10 ft) of soil (geologic buffer) between the bottom of the liner to the top of the seasonally high water table, which will be verified and monitored by construction and observation of piezometers on the site. As described in the environmental assessment, it is not anticipated that groundwater would rise into or above the liner of the landfill. A leachate collection and removal system would be installed above the liner. A treatment unit to treat the leachate collected from the landfill is proposed. Treated leachate would be discharged to the City of Oak Ridge Public-Owned Treatment Works permit station. The landfill would be constructed and operated under solid waste disposal regulations of the TDEC.

Requirements for landfill operation would include a groundwater monitoring program. The program would include a conventional approach of one upgradient and four downgradient wells and a comparison of both site groundwater and leachate to the regional background water quality as determined by a well remote from the landfill. This dual system is intended to reveal whether other activities on the ORR affect the water beneath the landfill. A detailed description of the groundwater monitoring wells placement is provided in the environmental assessment (Energy Systems 1992).

5.2.5.2 Beneficial reuse

This option would involve the beneficial reuse of treated soil as fill material in the EFPC floodplain and restoration of the site including grading to original contour, replacing pavement, sowing grass, and planting shrubs and tree seedlings as needed. Beneficial reuses of the treated material would require regulatory approval from the State of Tennessee prior to implementation. This use may be applicable to all or some of the treated soil and could result in a borrow material cost saving as well as minimization of the environmental impacts from borrow soil areas.

5.3 INDIVIDUAL ANALYSIS OF SITEWIDE ALTERNATIVES

Alternatives capable of addressing contamination at the Lower EFPC OU are evaluated in detail in this section. The evaluation of alternatives for remediation of the entire site is conducted using a process that ensures that values and environmental consequences considered under NEPA are addressed within the framework of the CERCLA evaluation of alternatives. Table 5.1 shows the integration of NEPA values with CERCLA evaluation criteria. In general, the NEPA values have been grouped under the criterion "short-term effectiveness." Many of the environmental issues addressed under this criterion may have impacts at the site beyond the short-term period of the implementation of the alternative; however, to avoid repetition of issues and to facilitate review of the document, these NEPA values are evaluated under the "short-term effectiveness" criterion.

The total area for each RU and the corresponding area of contamination based on the human health and ecological remedial action objectives is presented in Table 5.2. The total area affected would be 7.35 ha (18.16 acres) of contaminated area for SWAs 1 through 5. For the actions proposed for SWAs 6 and 7 to be effective, additional acreage beyond the 7.35 ha (18.16 acres) of contaminated areas must be included. Because of the extreme difficulty of installing and maintaining fencing over two wetland areas (Wetlands 3 and 4), SWAs 6 and 7 do include additional acreage of one Residential parcel and one Commercial parcel in Segment 1, which encompasses an additional 3.6 ha (8.88 acres).

Seven sitewide alternatives were developed and evaluated. Disposal options are specifically coupled with sitewide alternatives. Each alternative is evaluated in detail in the following sections. To avoid the potential for redundancy in the detailed analysis discussion, a reference to previous alternative discussions is included when appropriate.

5.3.1 Description and Summary of Evaluation of Sitewide Alternative 1 (SWA 1)

Description

SWA 1, the No Action alternative, is considered in accordance with NEPA and CERCLA and provides a baseline for comparison with other alternatives. Table 5.2 reflects the areal extent of contamination within each RU. As presented, the information reflects relatively small percentages of contamination per RU. The numbers also indicate that if the No Action alternative were implemented, $<3\%$ of the EFPC OU would be affected by mercury contamination above remediation goal options.

This alternative would not provide for further remedial action at the EFPC OU. Although warning signs and fences are currently in place in some areas of the site, these controls would not be maintained. Environmental monitoring of groundwater, surface water, sediment, soil, and ambient air would be conducted periodically for all RUs except the Agricultural RU and the SLB. Biological monitoring of terrestrial and aquatic biota also would be conducted. In addition, because the contamination would remain in place, a statutory review would be required each 5 years after the initiation of this action.

Summary of Evaluation

SWA 1 would not protect human health and the environment in the long term because no action would be taken to reduce the potentially unacceptable hazard to human and ecological receptors from existing contaminants in the environment. Projected risks from chemical exposure to children and adults in the community would continue to exceed (HI > 1) the EPA target for noncancer effects. There would be no construction and transportation risks for SWA 1 because no action would be taken. Monitoring and maintenance activities would require a project health and safety plan to be developed for all future site activities; the plan would provide for mitigative measures to protect worker health and safety and ensure that the EPA target would not be exceeded for workers. Existing risks for ecological receptors (i.e., body burden and community impacts) would not change from baseline conditions. Floodplains and wetlands would continue to be affected if no action were taken. The total 30-year cost of this alternative would be $12.0 million in 1993 dollars (with no escalation or discount). This total includes costs for environmental monitoring and subsequent 5-year reviews.

5.3.1.1 Overall protection of human health and the environment

This alternative would not protect human health and the environment because no action would be taken to reduce the potentially unacceptable hazard to human or ecological receptors from existing contaminants in the environment. The RI report indicates that existing human health and environmental risks of exposure to contamination would not change from the preremedial (baseline) conditions at EFPC (DOE 1994a). Consequently, SWA 1 does not satisfy CERCLA's first threshold criterion.

Baseline human health risks from exposure to soil, through direct contact (dermal exposure) and incidental or inadvertent ingestion, exceeded (HI > 1) EPA targets for noncancer effects. The principal human health COC is mercury. Cancer target risks established by EPA were not exceeded for the soil exposure pathway.

Currently, there is ongoing endangerment to ecological resources, particularly aquatic organisms in the upper part of the creek, from exposure to contaminants in environmental and biological media. For aquatic biota, primary exposure routes are direct exposure to surface water and sediment; for terrestrial biota, the primary exposure route is soil. Indirect exposures of aquatic and terrestrial communities through the food web are also important. The primary COC for ecological receptors is mercury.

Continued exposures of aquatic biota and terrestrial arthropods and their habitats to contaminants would result in continued elevated body burdens of contaminants in these biota, along with impacts to biological community structure and taxa diversity. Risks to their predators

would also be expected. Ecological risks from continued exposure, as characterized in the ecological risk assessment (DOE 1994a), do not indicate a need for immediate mitigative action. As explained in Appendix G, balancing remediation risks with long-term risks to ecological receptors suggests that remediation to provide long-term protection of their receptors would be justified in habitats that would recover quickly (< 1 to 5 years). However, for receptors living in bottomland hardwood forest or wooded wetland habitats, which would require up to 50 years to recover from excavation, for example, the increased long-term protection afforded by remediation would not balance the short-term and mid-term impacts to those habitats and their inhabitants unless contaminant levels are acutely toxic.

5.3.1.2 Compliance with ARARs

Because no remedial action would be taken, action- and location-specific ARARs are not invoked. Currently, there are no chemical-specific ARARs for soil. Surface runoff from contaminated soil could be in conflict with the policy of the TDEC Water Quality Control Act, which requires abatement of existing pollution and reclamation of polluted waters [TCA 69-3-102(b)]. Also, because surface runoff contaminates the creek, the No Action alternative would not comply with federal regulations requiring protection of this resource. ARARs for the EFPC OU are presented in Appendix C. Table C-3 summarizes ARARs and TBC guidance for the No Action alternative.

5.3.1.3 Long-term effectiveness and permanence

This section evaluates the human health effects and long-term effectiveness of SWA 1. This evaluation considers two criteria: (1) residual risk and (2) protectiveness over time.

The No Action alternative includes no provisions for protection of human health or the environment; therefore, current and potential future risks would remain. The human health risk associated with this alternative would result from residual contamination at the site. Section 3.1 designated only the soil pathway as appropriate for determining the need for site remediation. The baseline soil exposure risks, those attributed to ingestion and dermal contact, are thus used to evaluate long-term effectiveness under the No Action alternative. Long-term baseline soil risks exceed EPA targets for noncancer effects (HI > 1); however, cancer risks are not associated with exposure to mercury in soil.

The No Action alternative would include no controls for exposure to contaminants and no measures for long-term management of the contaminants, the contaminated areas, or the risks from the contaminants. SWA 1 would include periodic monitoring of the environment for contaminated areas and a 5-year review of site conditions and risks from the contaminants to human health and the environment for all RUs. Workers would be protected through the use of mitigative measures, engineering controls, and a project health and safety plan, when collecting environmental samples and performing routine maintenance.

Irreversible and Irretrievable Commitment of Resources

As defined, SWA 1 calls for unrestricted land use at the site; however, in practice, this alternative would restrict use of the contaminated land in the long term.

5.3.1.4 Reduction of toxicity, mobility, or volume through treatment

Reduction of toxicity, mobility, or volume through treatment would not be applicable to SWA 1 because this alternative would not involve treatment.

5.3.1.5 Short-term effectiveness and environmental impacts

This section evaluates the short-term effectiveness of taking no remedial action at EFPC. The FS must consider the following two elements related to short-term human health risk for each alternative: (1) protection of the community during remedial actions and (2) protection of workers during remedial actions (EPA 1988a). Additional information concerning methodology and risk calculations is presented in Appendix F.

Community Protection

Chemical Exposure Risks. Under the No Action alternative, no short-term chemical exposure risks to members of the community would be induced because no remedial actions would be taken.

Physical Hazards. No remedial activities are evaluated under this alternative. Therefore, construction and transportation risks to the community are not considered under the No Action alternative.

Remediation Worker Protection

Chemical Exposure Risks. No remedial activities, except environmental monitoring, would be associated with the No Action alternative; thus, there would be minimal risk to workers. Under SWA 1, workers would be present at the RUs during monitoring and maintenance activities to collect environmental samples. A project health and safety plan would be developed for site activities. Under such a plan, the required mitigative measures necessary to protect worker health and safety would be addressed to ensure worker exposures do not exceed acceptable levels. Annual monitoring would be conducted, and maintenance would be minimal. Risks to these workers would be much lower than those of the open land-use scenarios considered in the RI report, which were below (HI < 1) EPA human health risk targets.

Physical Hazards. Under the No Action alternative, there would be no worker risks to consider for construction or transportation activities, and minimal worker risk for monitoring and maintenance activities.

Environmental Impacts—Soil and Floodplain

Soil. Contaminated floodplain soil would not be remediated under the No Action alternative. Redistribution of contaminated soil would be expected in the future. Contaminated soil could erode the floodplain during storm events and be transported to other parts of the floodplain. In addition, contaminated soil could erode from the stream bank and be carried as suspended load during flood events and deposited on floodplain soil as floodwaters recede. In this way, contaminants could become more broadly distributed in the floodplain. However, instream

contaminated sediments were reported to contain <100 mg/kg of mercury (DOE 1994a) and, thus, represent a minor threat of contributing to additional soil contamination.

Contaminants in surface water could contaminate floodplain soil; however, evidence presented in the RI report (DOE 1994a) indicates that contaminant concentrations, generally, are low in surface water (e.g., mostly <0.2 μg/L total mercury). Contaminants detected in surface water are primarily associated with particulates and are not dissolved in the water.

Floodplain. Under the No Action alternative, contaminated soil, sediment, and surface water would continue to be deposited in the floodplain during and after storm events. Modeling contaminated soil transported within EFPC during 1- and 5-year storm events indicates that resulting mercury concentrations in floodplain soil following deposition downstream would be <60 ppm. Thus, the No Action alternative would not cause additional contamination of concern above baseline conditions in floodplain soil (SAIC 1994). The basic functions of floodwater retention and flood protection would not change if no new construction took place in the floodplain.

Environmental Impacts—Water Quality

Surface Water. Under the No Action alternative, surface water quality in EFPC would be expected to remain within the range of conditions observed in recent years. Mercury is highly persistent in soil and sediment; therefore, the contaminated soil and sediment would remain sources of contamination for surface water by erosion and resuspension for as long as the contaminants persist.

Currently, discharge from the Y-12 Plant is monitored daily at the outfall of Lake Reality (Station 17). The average mercury concentration in EFPC at Station 17 in 1991 and 1992 was 1.4 μg/L; for the first 6 months of 1993, the average mercury concentration was 0.9 μg/L (Kornegay 1992, Vol. 2; Bunting 1994). This concentration exceeds the TDEC guideline for recreational use (0.15 μg/L), the Criterion Continuous Concentration (0.012 μg/L) (Rule 1200-4-3-.03 of Tennessee's Water Quality Standards), and federal ambient water quality criteria for protection of freshwater organisms (also 0.012 μg/L). Average uranium and radium concentrations were 31 μg/L and 110 pCi/L, respectively.

A proposed change in processing water at the Y-12 Plant would almost double the base flow at Station 17 by adding water pumped from the Clinch River. The increased flow would be expected to reduce the average contaminant concentrations to half of their current values, unless this change affects biological processes in Lake Reality that influence the form and quantity of mercury in the outfall from Lake Reality. Even at half the concentrations measured in 1993, mercury would still exceed TDEC guidelines.

Surface water quality in EFPC changes with distance downstream from the Y-12 Plant. Contaminant concentrations are generally higher near the Y-12 Plant and decrease in the downstream direction. A mercury concentration of 0.72 μg/L was detected at a station just downstream of Lake Reality during the RI sampling. Total mercury concentrations sampled in October 1991 were 0.54 μg/L at Station 1 (closest to the Y-12 Plant), 0.43 μg/L at Station 2, and 0.32 μg/L at Station 3.

As flow increases during storm events, contaminant concentrations increase as the result of erosion, runoff, and resuspension of sediments. During two storms sampled as part of the EFPC RI, the total mercury concentration was 10.5 μg/L at one station and 5.4 μg/L at another station at the peak flow (175 cfs) of the second storm sampled. Mercury was below the detection limit in all filtered samples, confirming that mercury was particle-bound.

The effects of the No Action alternative on surface water depend more on physical distance downstream from the Y-12 Plant and climatic conditions than on which land-use RU is under consideration. The baseline risk assessment conducted as part of the EFPC RI found no unacceptable risks to human health associated with contact with EFPC water under the assumed exposure scenarios for any land use. The primary effects expected are ecological impacts on aquatic biota closest to the Y-12 Plant and potentially episodic impacts to biota during storm events.

Groundwater. The results of the RI indicate that groundwater is not a medium of concern. Although total concentrations exceeding Safe Drinking Water Act levels were found in groundwater for several contaminants (beryllium, copper, lead, manganese, mercury, nickel, radium, and vanadium), only manganese—which is a common element in local groundwater—was present in dissolved concentrations (filtered) exceeding the Safe Drinking Water Act levels. The results suggest that the particle-reactive contaminants are attached to fine-grained particles in the total sample and are not necessarily mobile in groundwater. Geochemical modeling, described in the RI, supported the contention that mercury concentrations measured in groundwater samples are related to particulate-bound mercury and would tend to precipitate from the groundwater.

The baseline risk assessment results from the RI indicate that levels of mercury, manganese, and arsenic in unfiltered groundwater exceed EPA targets. A comparative risk assessment conducted using filtered groundwater samples resulted in lower risk for mercury, but manganese and arsenic exceeded the EPA target range. Ingestion of groundwater is considered to be an incomplete pathway because no one is currently using groundwater in the vicinity of EFPC because the residents have access to a municipal water supply. Therefore, groundwater is not a substantial risk and is not considered a medium of concern for remediation. If groundwater should become a drinking water source in the future, additional evaluation would be required.

The No Action alternative would not affect the quality of groundwater. Groundwater quality, in terms of contaminant concentrations, is controlled by the chemical equilibria associated with metal sorption/desorption on particles or the solubility of distinct mineralogical phases. Since the bulk of the COPCs in the floodplain were deposited years ago, the groundwater has most likely reached equilibrium, or some degree of steady-state, with respect to the contaminants.

Environmental Impacts—Air Quality

Contaminant migration by means of the air pathway should not significantly affect receptors if the site is undisturbed. With regard to gaseous contaminants, a recent study (ORNL 1992b) quantified ambient concentrations of vapor-phase mercury at several floodplain locations on EFPC that are known to have high soil concentrations of mercury. The study showed no significant ambient concentrations of mercury above background levels at these sites. Emissions from volatile-organic-compound and semivolatile-organic-compound contamination should not be a concern because of the low levels of these contaminants in the floodplain.

Airborne migration of contaminants to the off-site environment should not be a concern if the site remains undisturbed. The vast majority of the study site is vegetated and topographically stable, which inhibits windborne particulate entrainment. The low level of contamination found during soil sampling of particulate and/or particulate-bound contaminants (e.g., uranium, PCBs, metals, PAHs) should not contribute significantly to the air pathway.

Environmental Impacts—Land Use

The No Action alternative would have varying degrees of impacts on land use for the RUs along EFPC. The degree of impact would largely depend on the location and contaminant concentrations on specific properties. Most contaminants are located within the 100-year floodplain. The floodway zoning ordinance for the City of Oak Ridge applies to portions of properties that are in the floodplain; the regulations require buildings to be elevated above the 100-year flood level. Any future improvements to properties in the floodplain would be required to meet the zoning regulations.

Based on current trends in land use, land use for the properties along EFPC that are already developed probably would not change under the No Action alternative. Two public housing areas, a large complex of apartments, a condominium complex, two apartment complexes, the large-lot subdivision Wiltshire Estates, and the residential development known as the Grand Cove Lane area are in close proximity to the creek. A public school, Robertsville Junior High, also borders EFPC. Residential areas near EFPC are not currently experiencing high vacancy rates.

Recreational areas, such as the Sportsmen's Association firing range, the two city ball fields, and the country club golf course, are not expected to be affected by the No Action alternative.

Land-use change for commercial RU parcels, most of which are located along South Illinois Avenue and its intersection with Oak Ridge Turnpike, is also unlikely. Businesses that serve children, such as child care centers and private schools, are typically more sensitive to the contamination issue than other businesses. Site-specific sampling or surveillance was performed for four properties that serve children: Nana's Kiddie Corner, La Petite Academy, Montessori School, and property recently purchased by Girls, Inc. Results indicate little or no contamination on these properties. The Girls, Inc. property, which has been converted to a softball field, is located adjacent to EFPC. To date, the knowledge of contamination has not discouraged the purchase or development of the property.

Since the preliminary findings of the RI were released, three commercial projects have been developed in close proximity to EFPC, despite the knowledge of the contamination. Each development required backfill to elevate the building out of the 100-year floodplain. Two of the developments were in an existing commercial area, and the third, a quick oil change business, was constructed near a contaminated area known as the Bruner site. Adjacent portions of the property where the oil change business is located have been offered for lease. Commercial establishments typically have less concern over contamination than potential residential users because customers temporarily use the business, and interaction with the contaminated media is minimal.

Future land uses would be determined by several factors: zoning regulations for particular zoning districts, the location of the property, and the willingness of the property owner to develop

or sell the land. Developers and potential property buyers may be discouraged from developing vacant parcels in the floodplain, particularly around areas that contain higher levels of contaminants. Some of the larger vacant parcels are in a prime location along Oak Ridge Turnpike. Property owners may be discouraged by a perceived lack of tenants or buyers or by financial institutions that are reluctant to provide financing for developments in areas that have potential liability issues associated with them. Thus some land uses, especially residential uses, may not occur in the floodplain under the No Action alternative.

Environmental Impacts—Ecological Resources

Ecological resources consist of aquatic and terrestrial plants and animals and their habitats, wetlands, and threatened and endangered species. Impacts to aquatic and terrestrial biota from implementing SWA 1 are discussed in relation to the appropriate pathways.

Table 5.3 identifies 18 major pathways that reflect the potential impacts of contaminated sediment on biota. Each major pathway is comprised of a primary source, a direct pathway, and a primary receptor. The primary receptor can become a source to a secondary receptor by means of exposure through the ingestion or body contact pathway (including gill exposure pathway). The secondary receptor could then become a source to a tertiary receptor by means of exposure through the ingestion pathway.

Aquatic Biota. Major observations from the baseline risk assessment field sampling and historical studies indicate that the body burdens of several COPCs in the aquatic indicator organisms [central stonerollers (*Campostoma anomalum*), redbreast sunfish (*Lepomis auritus*), crayfish (*Astacidae*), and benthic macroinvertebrates], as well as several measures of community structure (fish and benthic macroinvertebrate species richness and diversity and percentage of fish species classified as tolerants) showed the greatest impacts closest to the Y-12 Plant, then decreased downstream in EFPC (DOE 1994a). In addition, COPC body burdens and community impacts in biota from all sites in EFPC usually were greater than equivalent impacts at a reference site.

Under SWA 1, all of these effects would be expected to continue, due mainly to the continual release of water-borne contaminants from the Y-12 Plant and, to a lesser extent, from exposure of aquatic biota to contaminated sediment, inputs of contaminated floodplain soil, and surface water runoff. For the Surface Water/Sediments RU, only 7 of the 18 major pathways for potential impacts from sediments were identified in which aquatic organisms were the primary or secondary receptor (see Table 5.3). The pathways include direct contact, ingestion, and leaching. These pathways would continue to exist under the No Action alternative. The pathways and the significance of the effects to receptors are discussed below.

Body contact with contaminated sediment (including suspended sediment) would continue for primary-receptor aquatic biota. Potential impacts would be greatest for sediment-dwelling organisms (most benthic macroinvertebrates and many amphibians) and certain bottom-feeding fish species because of their contact with the sediments. Bottom-feeding fish species that have been captured in EFPC include the stoneroller, which was also an indicator species for the ecological risk assessment (DOE 1994a), banded sculpin (*Cottus carolinae*), golden redhorse (*Moxostoma erythrurum*), northern hogsucker (*Hypentelium nigricans*), and yellow bullhead (*Ameiurus natalis*). Impacts to these species could include potential toxic sublethal effects and

bioaccumulation of contaminants. The significance of these impacts is that (1) bioaccumulation of certain contaminants in these biota could result in continued risk to predators that feed on them and (2) potential toxic impacts could limit taxa richness and diversity and maintain communities dominated by taxa tolerant of degraded conditions.

Body contact with potentially contaminated surface water (secondary source) resulting from partitioning of contaminants between sediment and surface water would continue for secondary-receptor aquatic biota. This pathway is not expected to be of major importance because most COPCs present in EFPC have low aqueous solubilities and/or high binding affinities to soil or organic matter. However, water-borne contaminant concentrations from the continual release from the Y-12 Plant would probably exceed the concentrations that occur from leaching of contaminants from the sediment into the surface water.

Ingestion of contaminated surface water (secondary source) would continue for secondary-receptor biota. However, this pathway is probably not significant for the same reasons discussed in the preceding paragraph.

Ingestion of contaminated sediment would continue for primary receptors. However, because contaminants that are bound to sediments are usually less bioavailable than contaminants incorporated into biota, these pathways are not expected to be of major importance.

Ingestion of contaminated aquatic biota (primary receptor) would continue for secondary-receptor aquatic organisms. The greatest potential impacts would probably occur to predatory fish and stonerollers in the water column and to predatory benthic macroinvertebrates in the sediments because they consume biota that could have elevated contaminant body burden concentrations from bioconcentration processes. The significance of these impacts is that the elevated body burdens of contaminants could continue to pose risk to piscivorous (fish-eating) predators. If contaminant source releases from the Y-12 Plant are controlled (which would require actions outside the boundaries and scope of this FS report), contaminant body burdens in aquatic biota in EFPC are expected to decrease.

The No Action alternative would result in no additional impacts to aquatic habitat because there would be no sediment excavation.

For the remaining RUs, there is only one major pathway (Soil-4) for soil impacts to aquatic biota (see Table 5.4) in which soil is deposited into the stream to become sediment. Under SWA 1, soil inputs into EFPC by means of stream bank erosion and tributary inputs would continue. Once the soil was deposited in the stream to become sediment, it could move through the same pathways described above for the Surface Water/Sediments RU.

Terrestrial Biota. Under SWA 1, terrestrial organisms would continue to be exposed to contaminants in EFPC (sediment and soil). The elevated contaminant body burdens of earthworms, small mammals, and insectivorous birds (e.g., wrens) would continue to place these populations and populations of predators of these organisms at risk of adverse effects. The abundance of insects with terrestrial juveniles at sites close to the Y-12 Plant would continue to be suppressed relative to downstream sites. The potential consequences of these changes in abundance of insects or elevated body burdens in prey organisms (earthworms, small mammals, and birds) on other ecosystem components (e.g., vegetation, predators) are numerous, subtle, and

without additional data can only be qualitatively assessed. The pathways by which contaminants in the EFPC soil and sediment are bioaccumulated in terrestrial biota, as well as the nature and significance of those exposures, are discussed below.

Terrestrial animals feeding in the creek would continue to be exposed to contaminants in EFPC sediment. The dominant mode of exposure to sediment contaminants for terrestrial predators is consumption of aquatic or terrestrial organisms that are themselves contaminated (Table 5.3). The significant pathways of exposure to contaminants in sediment for aquatic biota are discussed in the previous section. The trophic pathways from sediment to resident and migrant terrestrial predators that prey frequently upon aquatic biota (e.g., mink and several types of birds, including raptors and great blue herons) are numerous and represent the most significant exposure pathway for those predators.

Exposure to contaminants by ingestion of surface water contaminated by Y-12 Plant discharges and by resuspension of contaminated sediment is probably of secondary importance to terrestrial animals. Direct contact and ingestion of EFPC sediment is not a significant source of adverse effects.

Terrestrial organisms are potentially exposed directly and indirectly to contaminants in soil in the EFPC RUs by way of the pathways shown in Table 5.4. Terrestrial plants may directly uptake contaminants mobilized from soil in the root zone or receive particulate deposits on aboveground plant stems and leaves. Terrestrial animals may be exposed directly as a result of dermal contact with and ingestion of soil or by inhalation of soil or volatilized contaminants aboveground or in soil-air spaces. They may also be exposed indirectly by ingestion of contaminated animals or plants. The significance of these potential pathways and their consequences are discussed below for each RU.

Terrestrial organisms are also potentially exposed to the direct and indirect negative effects of contaminants on the abundance of terrestrial insects. Decreases in the abundances of the 10 most abundant families in the dominant orders of insects with terrestrial juveniles (Coleoptera, Homoptera, and Lepidoptera) at the upstream locations nearest the Y-12 Plant can be expected to have a negative impact on other organisms. Predators that feed predominately on EFPC floodplain insects during one or more periods of their life will experience changes in the availability or quality of their diets.

A large area of the EFPC floodplain is comprised of the Commercial/DOE and Other RUs, most of which are presently undeveloped bottomland hardwood forest. In such areas in the upstream segments nearest the Y-12 Plant, the No Action alternative would result in continued exposure of terrestrial animals to concentrations of contaminants sufficient to produce elevated body burdens in earthworms and their predators and reduced abundance of certain insects. These exposures will continue through all existing pathways. The evidence reported in the ecological risk assessment suggests that the dominant pathways of exposure to those terrestrial organisms showing elevated body burdens of EFPC contaminants are direct contact with and ingestion of soil (for earthworms and insects) and ingestion of contaminated biota (for mice, shrews, and wrens). Tissue samples were not collected for terrestrial predators, but it is likely that these predators would continue to be exposed to contaminants through ingestion of prey with elevated body burdens. The significance of these exposures for terrestrial predators is reflected in the ratio of average body burdens of mercury in prey organisms to the criterion for protection of terrestrial

predators (0.05 mg/kg). The risk quotients for a terrestrial predator consuming earthworms, insects, mice, shrews, and wrens at all EFPC sample sites range from 2 for insects to 664 for earthworms (RI report, Table 6.77, DOE 1994a).

Other exposure pathways from soil to terrestrial biota most likely do not individually present significant additional risk of adverse effects. The combined risk of these pathways could, however, be a significant fraction of the total risk. By itself, ingestion of water on the EFPC floodplain is probably a minor pathway of exposure for terrestrial animals. Terrestrial insects showing reduced abundance in the upstream segments of EFPC could also be exposed by ingestion of contaminated plant products or contaminated particles deposited on plant surfaces, but neither pathway is likely to be significant by itself. Evidence suggests that plants (e.g., browse, garden vegetables, and herbaceous vegetation) do not take up significant amounts of mercury from soil (Van Winkle et al. 1984; Gist 1987; DOE 1994b). Compared to undeveloped areas, exposures to contaminants in developed areas are probably not significant because populations of terrestrial organisms do not reside or forage to a significant degree in these areas.

Under the No Action alternative, contaminants in residential soil would continue to make relatively minor contributions to contaminant body burdens in terrestrial animals (e.g., earthworms and their predators) because fewer organisms would be residing and foraging in these areas. The contribution of this soil to contaminant-induced reductions in insect abundance is also likely to remain insignificant. Thus, there is little reason to expect soil contaminants at the Residential RU parcels to contribute significantly to the overall risk of adverse ecological effects to terrestrial biota. Organisms frequenting these developed areas (e.g., starlings) are most likely foraging over a wide area of similar habitat that is not contaminated. Without additional evidence indicating that urbanized species preferentially forage or reside at contaminated sites, it is reasonable to conclude that their expected exposure to contaminants is insignificant.

In summary, the No Action alternative would result in no additional impacts to aquatic or terrestrial ecological resources beyond those described in Sect. 2.5.2 of this document because no remedial actions would be implemented. This alternative would therefore result in the continued exposure of: (1) aquatic biota via direct contact and ingestion of EFPC surface water and sediment, (2) aquatic predators preying on other contaminated aquatic organisms or terrestrial insects, (3) terrestrial animals dwelling in or consuming contaminated soil, and (4) terrestrial predators preying on contaminated aquatic or terrestrial animals in the EFPC floodplain. The continued exposures of aquatic and terrestrial biota and their habitats to contaminants would result in continued elevated body burdens of contaminants in these biota and risks to their predators, along with impacts to community structure and taxa diversity.

Wetlands. Wetlands in contaminated areas of the floodplain would not be remediated under the No Action alternative. Wetlands in the EFPC floodplain have formed in low-lying areas of the floodplain subject to deposition and thus continue to receive additional contaminants during flood events. Under SWA 1, contaminated soil in wetlands would remain a potential source of contamination to soil, sediment, surface water, plants, animals, and humans.

Surface water could also act as an additional source of contamination to wetlands. However, evidence presented in the RI indicates that contaminant concentrations are low in instream sediments and very low in surface water. Contaminants detected in these media are associated with particulates and are not dissolved in the water.

Wetlands in Commercial/DOE, Other, and Residential RUs would remain contaminated and would continue to be a source of contamination. The consequences of wetland contamination are that each wetland could act as a sink and a source of contamination to soil, sediment, surface water, and groundwater as contaminants in floodplain soil and stream bed sediment erode and material is transported downstream. Relatively clean wetlands could be contaminated through the suspension, transport, and deposition of contaminated soil and sediment. Contaminated soil and sediment could be the source for contaminants that are exported during floods. In this way, contaminated soil and sediment in wetlands could adversely affect habitat quality and serve as a potential source for exposure to ecological receptors in aquatic, riparian, terrestrial, and wetland ecosystems in and adjacent to the floodplain. So far, no evidence exists that contaminants in soil, sediment, and surface water are mobile or soluble enough to affect groundwater quality.

Threatened and Endangered Species. Surveys for the occurrence of threatened and endangered species within the EFPC floodplain were conducted in the field after consultation with TDEC and FWS. An overview of known and potential threatened and endangered species was obtained from Resource Management Plans for the ORR and from TDEC and FWS. Based on this knowledge, field surveys were conducted in habitats most likely to support the identified species. Field surveys were performed by a qualified botanist during the appropriate seasons. Qualified ornithologists conducted field surveys but were limited to the fall season by scheduling constraints. Nationally recognized chiropteran experts performed a field survey in the late spring according to sampling protocols outlined by the FWS Indiana bat/gray bat recovery teams.

Fish species were surveyed during the fish sampling effort and during BMAP sampling. The only protected species known to occur in EFPC and its floodplain is the Tennessee dace (formerly included in *P. oreas*), a small fish listed as in need of management in Tennessee (Tennessee Wildlife Resources Proclamation 86-29, 1991). The species is present in five tributaries to EFPC (between the mouth of Mill Branch and Poplar Creek) and has been collected in EFPC downstream from Mill Branch (Ryon 1993). The Tennessee dace breeds and lives primarily in the headwaters of the tributaries rather than in EFPC; however, EFPC may serve as a dispersal pathway for the species. The primary threat to the species is considered to be siltation of streams. The upper reaches of the clear, small tributaries in which it is found are critical habitat for the species. Because of the species' preference for headwaters, exposure to EFPC contaminants is not likely.

Environmental Impacts—Archaeological, Cultural, and Historical Resources

Six historic sites and two prehistoric sites were identified in the floodplain and associated terraces. Four of the historic sites are located on the DOE ORR, two historic sites are on the Sportsmen's Association property, and the prehistoric sites are located on the East Fork Horse Farm and at the Y-12 Plant. The reconnaissance stated that two of the historic sites are eligible for inclusion in the National Register of Historical Places. The No Action alternative would not negatively affect archaeological, cultural, or historical resources that were identified in the COE reconnaissance of the stream. This alternative would leave the sites in place and allow future studies to be conducted along the stream.

Environmental Impacts—Socioeconomic and Institutional Issues

The following section describes potential impacts of the No Action alternative on the institutional setting, public services and facilities, and economic and demographic resources. To the extent possible, the discussion is based on RUs. Please refer to Sect. 2.1.7.1 for a complete description of the existing institutional environment, methods used for analysis, and a listing of identified stakeholder groups.

Institutional Considerations. The No Action alternative would have a net adverse impact on the community and institutional environment. Some stakeholder groups would be unaffected, but some stakeholder groups would experience adverse impacts under the No Action alternative.

The perception that a contaminated creek runs through the community would not change under SWA 1 and may be viewed as a hindrance to local leaders' ability to present Oak Ridge favorably to prospective home buyers. Based on the judgment of industrial recruitment leaders, the continued presence of contamination may also influence decisions of some industries and businesses to locate in the area. A No Action decision could thus hinder generation of new business activity.

Although some development did occur in the floodplain after the contamination was identified, commercial property developers would continue to be hindered in developing their properties, potentially depressing the economic value that would otherwise accrue and continuing the inconvenience that this has caused. Some developers could resort to legal action against DOE. Some property owners have expressed the opinion that DOE should pay them the equivalent of rent in exchange for tying up their property rights and reimburse them for expenses such as survey fees incurred because of the issue.

The City of Oak Ridge would be adversely affected by the No Action alternative. The City would remain indefinitely in a situation that was described by one official as a "liability vise" in granting building and subdivision permits—on the one hand being potentially liable for granting permits under conditions that may affect health or property values and, on the other, being potentially liable for depriving owners of potential real estate value.

The community of Oak Ridge as a whole, as well as city government, would be adversely affected by the No Action alternative. For example, issues of liability for current and potential title holders of properties along the creek could inhibit competition among developers, resulting in reduced availability of moderately priced housing to prospective home buyers in Oak Ridge. These issues would continue to affect market pressure to proceed with normal development.

Based on interviews with residents and comments offered in public forums, a proportion of resident/owners along EFPC would be amenable to selection of the No Action alternative. Such residents are those who consider themselves permanent residents, do not view the contamination as hazardous, and have no near-term interest in selling or developing their property. A No Action decision would remove the contamination as an issue affecting these residents and would generate no disruption or disturbance on their properties. However, liability issues could be expected to surface in the future with real estate transactions involving these properties.

Institutional arrangements and mechanisms to support the needs of stakeholders adversely affected by the No Action alternative are inadequate under present circumstances. DOE actions or commitments regarding property issues have been postponed until after the Record of Decision. New institutional mechanisms to address stakeholder needs could not be maintained with a No Action decision. Under such circumstances, stakeholders could consider legal action to address or mitigate impacts.

A No Action decision would not remove the contamination as an issue in people's minds, and it would continue to affect public and private economic decisions in the community. Although a number of residents do not consider the contamination to be a problem from the standpoint of health, uncertainty and apprehension about long-term potential health effects and children's safety expressed by a few residents could be expected to continue. Because the No Action alternative would not protect human health and the environment, it would not address issues expressed by organized citizen and environmental groups in the area.

Public Services and Facilities. The No Action alternative would not affect public utilities and solid waste disposal because no demand would be placed on these, and there would be no earth-moving activities.

The No Action alternative would affect facilities that serve special populations. Those facilities where some contamination has been identified could experience impacts on their operations, activities, and planning because of concerns about liability. For example, the YWCA board of directors would be hindered from taking action on developing the 0.6 ha (2 acres) that abut EFPC, if the status quo is maintained. Interim measures being taken to reduce exposure would not be reliable over the long term.

No short-term impacts on nearby public facilities would occur because no excavation or transportation activities would be involved. Impacts on emergency response services would be expected to be minimal because no disturbance of contamination, transportation, or construction activities would occur.

Economic and Demographic Resources. Employment resource impacts are estimated using the Regional Input-Output Multiplier System (RIMS II) for Anderson and Roane counties developed by the U.S. Bureau of Economic Analysis. Employment estimates form the basis for the calculation of associated changes in the number of households and population. For a description of this modeling framework, see Appendix E.

It is assumed that there would be ~1.0 annual full-time equivalent (FTE) position for the EFPC OU for each year of routine monitoring, even if no specific action were taken to remediate the properties. It is assumed that this standard monitoring activity would take place in years 1 to 4, 6 to 9, 11 to 14, 16 to 19, 21 to 24, and 26 to 29. Two survey teams would conduct semiannual sampling; one would focus on human health risk investigations, and the other would examine ecological risks. A low level of surveillance and maintenance activities would be continued. It is estimated that labor costs for these activities would be ~$40,000 per year. Laboratory analysis, which is also assumed to be conducted semiannually, is estimated to be $260,000. No capital expenditures are estimated for this alternative. Using RIMS II, it is estimated that this activity would generate 0.3 additional annual FTE position in the region, for a total employment effect of 1.3 FTEs.

The assumption that people would move into the area to fill the jobs created by the alternative provides an upper-bound estimate of the impacts on housing and employment. Under this assumption, the number of new households is estimated to be 1 and the total population increase is estimated to be 3. These values are so small relative to the total size of the region that there should be no adverse impact on the economic and demographic conditions in Anderson and Roane counties.

More extensive monitoring would take place every 5 years. During these years, direct employment would be increased to 2.7 FTEs. Using RIMS II, the associated secondary employment is 0.7 FTEs, for a total employment effect of 3.3 people. The estimated number of new households associated with this growth is 2, and the estimated population increase is 5. These values are so small relative to the size of the region that there should be no adverse impact on the economic and demographic conditions in Anderson and Roane counties.

Local Transportation Impacts. Under SWA 1, traffic levels and patterns in the area of EFPC would not change from present conditions as described in Sect. 2.1. Thus, no impacts on local transportation would occur.

Noise Impacts. Under SWA 1, ambient noise levels would not change from existing conditions as described in Sect. 2.1. Thus, no noise impacts would occur.

Environmental Impacts—Unavoidable Adverse Impacts

Under this alternative, the HI for soil exposures to members of the community would continue to exceed the EPA target for noncancer effects (HI > 1). Contaminated soil left in place under the No Action alternative would continue to be a source of contaminant migration. Surface water quality would be affected primarily by the contaminant load in water discharged from the Y-12 Plant. This continued source of contamination would also be expected to continue to negatively impact aquatic resources within EFPC. Human health and the environment would continue to be at risk from contaminant exposure. The degree of risk would vary among RUs. Adverse impacts resulting from this alternative would be considered long-term.

Contaminated soil allowed to remain on Commercial/DOE RU properties could represent a future risk to the environment and, to a lesser extent, human health. Contaminated soil on commercial properties outside the floodway is often covered by concrete, asphalt, or buildings, whereas human access is controlled on DOE properties. Surface water could receive contaminants from any exposed soil during periods of runoff.

Contaminated soil left on Other RU properties would represent a continued risk to human health and the environment. Exposure pathways to these receptors, resulting from the specific land uses and activities on these properties, would determine the degree of risk. Surface water could receive contaminants from this source during periods of runoff. Terrestrial biota would continue to receive direct and indirect exposure to contaminants.

Contaminated soil on Residential RU properties could represent a future risk to human health. Surface water could receive contaminants from this soil during periods of runoff. Direct and indirect exposure of terrestrial biota to contaminants would continue, although risk to this receptor from this source would be minor.

Contaminated sediment within the stream would remain and continue to be a source of contamination. However, contaminant concentrations in stream sediment are low compared to concentrations found in floodplain soil and would be considered a minor source of exposure to humans. Receptors of contaminants from this source would include floodplain soil, relatively clean stream sediment, surface water (when sediment is disturbed or banks slough), humans, and ecological resources. Ecological resources at greatest risk from contaminant exposure are those that live in direct contact with the sediments, such as most benthic macroinvertebrates, many other invertebrates, and bottom-feeding fish species. Secondarily, both aquatic and terrestrial predators of these biota could continue to be exposed to bioaccumulated contaminants.

Environmental Impacts—Short-Term Uses and Long-Term Productivity

Properties would experience varying degrees of impacts under the No Action alternative, based primarily on the current and future land use. Existing businesses, residences, developed public areas, and agricultural lands would continue to function with minimal to no impacts as a result of the No Action alternative. Existing uses that involve children, including residential areas, public and private schools, day care centers, and play areas, would have minor impacts such as limited potential interaction with the stream. Vacancy rates in residential areas would not be expected to increase as a result of awareness of the contamination.

Properties with the potential for development or redevelopment would experience impacts both in the short and long term due to the contamination. Potential developers could encounter difficulties with development projects because of the issues of liability, public concern, and financial backing. Potential residential developments would be expected to experience the greatest impact because of the potential for children to interact with the stream. Potential commercial developments would be expected to experience minimal impacts because there is little potential for interaction with the stream. Three commercial projects have been developed near the stream since the beginning of the EFPC RI.

Because development could be hindered under the No Action alternative, various ecological systems would not be disturbed. The land would continue to be used by wildlife. The impacts to development are primarily negative, while the impacts to ecological systems are positive because of habitat preservation.

5.3.1.6 Implementability

SWA 1 is considered to be implementable. If future monitoring indicates that additional action is necessary, the evaluation of remedial alternatives may need to be conducted again. This alternative would not impede implementation of other remedial activities in the future.

Under the No Action alternative, current environmental monitoring operations would continue. Long-term access to monitoring locations on Residential, Commercial, and Other RU properties could be refused by landowners. There would be no restrictions preventing landowners from constructing structures on private property that could eliminate or affect access to sampling locations.

5.3.1.7 Cost

Under the No Action alternative, there are no capital costs for site improvement activities. The present environmental monitoring program would continue at an annual operation and maintenance cost of $300,000. This is based on a semiannual sampling plan with estimated laboratory cost of $200,000 per year, labor cost of $56,000 per year, material cost of $4000 per year, and a surveillance and maintenance cost of $40,000 per year. A change in the frequency of the sampling from semiannually to quarterly would more than double the cost; a change to annual sampling would almost cut the cost in half. Five-year reviews would occur at an estimated annual cost of $500,000. The estimated 30-year total for this alternative is $12.0 million. The methodology and basis for the +50%, -30% cost estimate is presented in Appendix D.

5.3.2 Description and Summary of Evaluation of Sitewide Alternative 2 (SWA 2)

Description

SWA 2 involves the removal of soil contaminated with >180 ppm of mercury on the Residential RU [~25,100 m^3 (32,800 yd^3)] and disposal at the modified Landfill VII (described in Sect. 5.2.6.1). For the Commercial/DOE and Other RUs, containment and institutional actions would be implemented; a 45-cm (18-in.) soil cover would be installed where soil contamination is >200 ppm. The total surface area to be contained is 0.05 ha (0.12 acre) for Commercial property; 1.64 ha (4.05 acres) for Other RU property; and 0.81 ha (2.02 acres) for DOE property. Interim institutional actions (e.g., sign postings, environmental monitoring, and 5-year reviews) would be implemented for the Surface Water/Sediments RU. These interim institutional actions for surface water and sediments will not be evaluated in this FS. General action descriptions are provided in Sect. 5.2.

Summary of Evaluation

SWA 2 would comply with ARARs and would provide for the protection of human health and the environment in the long term by either covering or removing contaminated soil. Projected health risks of chemical exposure to children and adults in the community from dust generated during soil handling under SWA 2 are below (HI < 1) the EPA target for noncancer health effects. Remediation activities would cause noncancer risks to workers in excess (HI > 1) of EPA targets if no mitigation were used; however, if mitigative measures (such as personal protective equipment) were used, the EPA target would not be exceeded. Physical hazards for SWA 2 include construction and transportation risks for workers, and only transportation risks for the community since they would be excluded from the remediation area. Risks to the community are projected to result in 0.2 injury and 0.01 fatality; transportation risks to workers are calculated to cause 0.007 worker injury and 0.004 worker fatality. In addition, construction risks to workers are estimated at 8.4 injuries and 0.06 fatality. Thus, the total risks for SWA 2 would be expected to result in ~9 injuries and 0.07 fatality. For ecological receptors, the most significant impact would be the permanent habitat conversion of 2.50 ha (6.19 acres) resulting from containment. A total of 4.85 ha (11.97 acres) would be excavated. In addition, 1367 m (1495 yd) of riparian zones would be permanently altered as a result of bank stabilization actions. Short-term impacts would include direct mortality of vegetation, soil-dwelling organisms, and

some small mammals in the remediation area. A total of 0.90 ha (2.25 acres) of wetlands would be adversely affected by remedial actions. The total cost of this alternative would be $48 million.

5.3.2.1 Overall protection of human health and the environment

This alternative would protect human health and the environment in the long term. In the short term, risks to workers, the public, and ecological receptors would increase during implementation of remedial actions. Because of the quantity of contaminated material being processed (excavated and transported), risk to workers and the public would increase during implementation. Short-term health risks to unprotected workers from chemical exposure would exceed EPA targets for noncancer health effects for all RUs (HI > 1). A project health and safety plan would address mitigative measures to reduce risk to workers to below EPA target levels. Chemical exposure risks to the community would be negligible for the Commercial/DOE and Other RUs because soil disturbance would be limited. Community risks from excavation on the Residential RU would be greater than for Commercial/DOE and Other RUs but would not exceed EPA's target for noncancer health effects (HI > 1). Standard construction practices to reduce dust, such as covering trucks and wetting soil as needed, would reduce exposures and thereby reduce risk. Nonoccupational transportation risks are calculated to result in 0.2 injury and 0.01 fatality, based on ~8200 truckloads required to transport the volume of material needed to implement SWA 2. Occupational construction risks associated with SWA 2 are projected to cause 8.4 worker injuries and < 1 (0.06) worker fatality. Occupational transportation risks are projected to result in 0.007 injury and 0.004 fatality. (See Sect. 5.3.2.5, Physical Hazards, and Appendix F for a discussion of how these risks are calculated.)

For ecological receptors, the most significant impact from containment would be the permanent loss of woodland habitat. In addition, riparian zones would be permanently altered in the containment areas as a result of permanent bank stabilization actions. Containment actions in the floodplain would permanently alter those areas and could result in a change in floodwater flow patterns and extent. Both direct and indirect impacts to wetlands would result from this alternative; one wetland [0.36 ha (0.89 acre)] would be lost during excavation, and five others would be affected by excavation or filling during containment [0.54 ha (1.36 acres)].

Excavation and disposal of contaminated soil in the Residential RU would provide long-term protectiveness for the public and ecological receptors and would eliminate unacceptable risk for that RU. For the Commercial/DOE and Other RUs, protectiveness would depend on institutional actions (e.g., land-use restrictions and maintaining integrity of soil cover). If institutional actions were maintained, this alternative would be protective for the Commercial/DOE and Other RUs. Potential impacts resulting from loss of institutional controls are discussed in Sect. 5.6. Installation and maintenance of the cover would be expected to eliminate unacceptable risk to ecological receptors from mercury; however, emplacement of the cover would result in changes in wildlife community composition on the areas remediated because of their conversion to a grass habitat.

Disposal of contaminated material from the Residential RU in an approved on-site Y-12 Plant disposal facility would comply with EPA and TDEC regulations, and DOE policies and procedures and would be effective in the long term.

5.3.2.2 Compliance with ARARs

SWA 2 would comply with ARARs by controlling exposures through containment and institutional actions for Commercial/DOE and Other RUs, and by excavation and disposal of Residential RU soil.

CERCLA on-site remedial response actions must comply only with the substantive requirements of a regulation and not the administrative requirements to obtain federal, state, or local permits [CERCLA §121(e) and FFA §XXII]. However, containment and institutional actions and excavation and disposal actions would invoke the appropriate action-specific ARARs. These include standards of performance or specific environmental levels for contaminants discharged to surface water bodies and emission of airborne pollutants. Consultation with TDEC would be required for compliance with the substantive requirements of the NPDES permitting process, because in the absence of engineering controls, contaminated runoff could reach the creek during storm events.

On-site excavation and construction activities, which include development of additional roads for vehicular traffic, removal of vegetation and soil, loading into trucks, grading of excavated areas, surface runoff controls would comply with ARARs, which require Best Management Practices (BMPs) for these construction activities. These ARARs include: TDEC, Division of Air Pollution Control regulations governing fugitive dust emissions (Rules of the TDEC, Chapter 1200-3-8-.01), CWA § 404, 33 CFR 323, CWA § 404, and 33 CFR 323.4, which specify that BMPs be applied during construction to minimize vegetative disturbances and discharges of dredged or fill material. This alternative would comply with the requirements found in Executive Order 11990 Article 7(c), 40 CFR 6.302(b), 40 CFR 6 (Appendix A), 40 CFR 230.3(t), 33 CFR 328.3(b), and 10 CFR 1022, which require that an action avoid or minimize adverse impacts on wetlands and act to preserve and enhance their natural and beneficial values and incorporate wetland protection considerations into planning, regulating, and decision-making processes.

SWA 2 would comply with regulations which require that any contaminated soil, or other waste materials generated during remedial activities that are tested and do not contain low-level waste, but fail the TCLP, be managed as hazardous waste and disposed of at a RCRA Subtitle C permitted facility. The DOT Regulations for Hazardous Materials list general requirements for shipping and packaging at 49 CFR 172 and 173 and for carriage by public highway at 49 CFR 177. A hazardous material includes any RCRA-listed or RCRA-characteristic waste, or any CERCLA substance which is in a quantity, in one package, equal to or exceeding the reportable quantity, as listed in the Appendix to 49 CFR 172.101 (49 CFR 171.8). Also, DOE has implemented a "no-rad-added" policy (i.e., the moratorium on low-level waste shipments), which states that no media containing RCRA hazardous waste or TSCA-regulated waste and added radioactivity may be shipped from a DOE facility to an off-site disposal facility without undergoing a thorough review process for proper analysis, recording, and manifesting of waste shipments.

A summary of ARARs pertaining to SWA 2 is provided in Appendix C, Table C.8.

5.3.2.3 Long-term effectiveness and permanence

The evaluation of long-term effectiveness and permanence is accomplished by considering two criteria: (1) the magnitude of residual risk and (2) the adequacy and reliability of controls, or protectiveness over time. As explained in Sect. 5.1, long-term risk to ecological receptors is discussed in Sect. 5.3.2.5, thus this section will address residual risk and reliability of controls only in relation to human health. Analysis of residual risk for SWA 2 indicates that no unacceptable level of risk would remain for floodplain soil. Risk would be below EPA targets because the contaminated soil would be either excavated and placed in a disposal cell designed to be protective for the life of the contaminants or contained in place to eliminate pathways for unacceptable exposure.

Commercial/DOE and Other RUs. Soil within these RUs in all EFPC segments would be covered by a layer [45 cm (18 in.)] of topsoil and borrow soil, which would effectively eliminate the exposure pathways of soil ingestion and dermal contact to humans and would provide an acceptable depth of soil cover to reduce the potential exposure of animals. Elimination of these exposure pathways relies heavily on the effectiveness of soil cover maintenance. Erosional damage of the soil cover proposed for Commercial/DOE and Other RUs would be repaired, and continued maintenance of the vegetation over the soil cover would be required. For example, no trees would be allowed to grow above sapling size because the integrity of the cover could not be maintained with trees present; a dense vegetative cover would be difficult to maintain under tree canopy, and intrusions and exposures to contaminated soil could occur. Institutional actions other than maintenance of the cover (e.g., use restrictions such as prohibition of gardening) would be effective to the extent that the responsible agency was able to enforce them. The appropriate realty interests would be acquired to effect use restrictions. Because this action would leave contaminants on site, periodic monitoring and 5-year reviews would be conducted to assess the continued effectiveness of these management practices for protection of human health and the environment. Workers engaged in periodic environmental monitoring would do so under an approved health and safety plan designed to protect the workers from contact with contaminated materials.

Residential RU. The action proposed for the Residential RU would be effective in the long term because contaminated soil above the 180-ppm human health remediation goal option for mercury would be excavated. Residual concentrations of mercury would, therefore, be below the respective remediation goal option, which would result in residual risks that are within EPA targets. A 5-year review would not be required because contamination above the action level would be excavated.

Disposal of contaminated material from the Residential RU in the Y-12 Plant disposal facility would comply with DOE policies and procedures and be permitted by TDEC; therefore, the disposal facility is considered to be effective in the long term. The responsibility of long-term management, monitoring, and operation and maintenance would be placed with the receiving facility, which is assumed to have adequate and reliable controls.

Irreversible and Irretrievable Commitment of Resources

The implementation of SWA 2 would involve either an excavation and disposal action or containment and institutional actions within a given RU. Some aspects of each action would require the irreversible and/or irretrievable commitment of specific resources.

Excavation of contaminated soil in the Residential RU would involve 4.85 ha (11.97 acres). Containment actions within the Commercial/DOE and Other RUs would involve 0.86 ha (2.14 acres) and 1.64 ha (4.05 acres), respectively (see Table 4.2). These actions would require the use of an estimated total of 45,000 m^3 (58,800 yd^3) of ex situ borrow soil for backfill of excavated areas and for construction of the cover. This soil would be committed to this use and would be lost to the area from which it was excavated. On-site borrow areas for soil are readily available within the West End Borrow Area on the ORR. About 25,000 m^2 (30,000 yd^2) of a permeable high-density polyethylene netting would be used beneath the soil cover. Implementation of containment actions within these RUs would commit the contained areas to long-term restricted use, thereby limiting future land use.

Disposal of contaminated soil at the Y-12 Plant disposal facility would result in the permanent loss of some woodlot and old field habitat, which would be replaced with maintained cover following closure of the disposal facility. Irreversible commitment of land for the disposal facility would permanently limit future land use for ~4 ha (11 acres).

The use of heavy equipment (dump trucks, bulldozers, front-end loaders) for containment cover construction and soil excavation, disposal, and replacement would involve the irreversible use of fossil fuels. The consumption of an estimated 169,000 L (44,700 gal) of diesel fuel would be required for implementation of this alternative. Additional petroleum products would be used in the form of gasoline, lubricating oils, and greases.

5.3.2.4 Reduction of toxicity, mobility, or volume through treatment

Reduction of mobility, toxicity, or volume through treatment is not applicable to SWA 2 because this alternative does not involve treatment.

5.3.2.5 Short-term effectiveness and environmental impacts

This section evaluates the short-term effectiveness of SWA 2 by considering protection of the community and of workers during remedial actions at EFPC (refer to Appendix F for methodology and calculations for human health risks); residual risk to human receptors at the site is discussed in Sect. 5.3.2.3, Long-term effectiveness and permanence. Short-term and long-term environmental impacts are also discussed in this section. Because the actions to be taken differ for the various RUs, impacts within the RUs are identified. A summary of the impacts across all RUs is provided at the end of each subsection.

Community Protection

Chemical Exposures. Under SWA 2, contaminated soil within the Commercial/DOE and Other RUs would be covered with clean topsoil and borrow soil; therefore, exposures would be limited to workers within an RU (members of the community would not be allowed inside the

RUs during remediation). Migration of the contaminants into the community outside these RUs would be minimal because the contaminated soil would be only superficially disturbed. For this reason, community exposures related to remedial activities in these land-use areas are not considered further.

Excavation is planned for the Residential RU under SWA 2. Due to the potential for migration of contaminated soil outside the RUs (via dust), effects to the community must be considered. Chemical exposures to the community would result from inhalation of contaminants in dust transported downwind to existing nearby residences. Tables 5.5 through 5.7 summarize the short-term risk estimates associated with containment and institutional actions at EFPC, soil excavation, and placement (disposal) at the Y-12 Plant disposal facility. Risks to children and adults in the community from dust generated during soil handling under SWA 2 are below ($HI < 1$) the EPA target for noncancer effects. Mercury has not been shown to exhibit carcinogenic effects and has no cancer slope factor. Therefore, cancer risks from exposure to mercury have not been evaluated.

A temporary increase in internal combustion engine emissions would result from equipment operation during the remedial action (a more detailed evaluation of air quality impacts is presented later in this section). Dust control measures (e.g., wetting agents and foams) would limit the release of particulate matter during excavation, transport, and application of the borrow soil. These measures would mitigate potential increased risk to the community resulting from uncontrolled fugitive dust. Additionally, continuous environmental monitoring of the ambient air for mercury vapors would be conducted during the remedial activities.

The transport of contaminated materials to the Y-12 Plant disposal facility would comply strictly with applicable state and federal regulations. As required, predesignated routes would be traveled, and an emergency response program would be developed to respond to any accidents. Chemical risks for the community from contaminated soil spilled during a hypothetical transportation accident, described in detail in Appendix F, would all be below ($HI < 1$) the EPA target. These projected risks are shown in Table 5-8 and would be similar for any sitewide alternative in which contaminated soil is transported by truck.

Physical Hazards. No contaminated soil excavation or transport is planned for Commercial/DOE and Other RUs under SWA 2. Borrow soil would be required to cover areas contaminated above the 200-ppm mercury remediation goal option. Physical hazards to the community for actions in the Residential RU would be limited to transportation risk outside the RUs because the community would be excluded from the RUs.

Soil handling and heavy equipment use would occur during excavation of the Residential RU soil and during the placement of soil as a cover for all remaining RUs. However, since members of the community would be excluded from the RUs, construction risks related to the community are not evaluated.

The total projected transportation risk (see Appendix F) to implement SWA 2 is calculated to be 0.2 injury while carrying contaminated and borrow soil. The related projection of transportation fatalities is 0.01 fatality for all soil transported. These transportation projections are for nonoccupational (community) injuries and fatalities.

Summary. Projected risks of chemical exposure to children and adults in the community from dust generated during soil handling under SWA 2 are below (HI < 1) the EPA target for noncancer effects. Physical hazards for SWA 2 would be limited to transportation risk outside the RUs since the community would be excluded from the remediation area. The total projected transportation risk to implement SWA 2 is calculated to be 0.2 injury. The related projection of transportation fatalities is 0.01 fatality for soil transported. These transportation projections are for nonoccupational (community) injuries and fatalities.

Remediation Worker Protection

Chemical Exposures. There are no soil removal or excavation activities within the Commercial/DOE and Other RUs under this alternative. Risks from exposure to contaminants are nonetheless likely for workers, who would be in close proximity to contaminated surface soil when preparing the site for the cover material (e.g., cutting down and chipping trees and placing the intrusion barrier). These activities would not be likely, however, to cause contamination to migrate outside the RU because soil dust generation would be limited to a more localized area than is the case for soil removal.

Table 5.5 shows risks for workers conducting containment activities in the Commercial/DOE and Other RUs. These RUs exist in five of the nine segments. The soil ingestion risks are for unprotected workers (no personal protective equipment or precautions taken to minimize soil ingestion). These risks exceed EPA targets for noncancer effects in all five of the segments. Dermal contact and soil dust inhalation risks are below EPA targets. A project health and safety plan would be developed for site activities, and the required mitigative measures would be addressed to ensure worker exposures do not exceed acceptable EPA target levels. Cancer risks are not associated with exposures to mercury.

Exposure to contaminants in the Residential RU is likely for workers involved in the excavation and disposal activities. Risk estimates for unprotected workers involved in excavation and disposal activities are shown in Tables 5.6 and 5.7, respectively. Soil ingestion risks to workers under SWA 2 exceed the EPA target for noncancer effects. Inhalation and dermal contact risks are below the EPA target for all cases under SWA 2. For workers involved in cleaning up an accidental spill of contaminated soil that results from a hypothetical transportation accident (described in Appendix F), only the ingestion risks are above (HI > 1) the EPA target. Risks for unprotected workers are shown in Table 5.8 and would be similar for any sitewide alternative in which contaminated soil is transported by truck. Risks to workers would be reduced to within EPA target levels through the proper use of safety protocols, construction practices for dust suppression, personal protective clothing and equipment, environmental monitoring, and restrictions on access to contaminated areas. Precautionary measures would be implemented to minimize the potential for soil ingestion. In addition, all machinery and equipment would be inspected after use, surveyed for contamination, and decontaminated if necessary.

Physical Hazards. As explained in detail in Appendix F, risks for two categories—injuries and fatalities associated with construction activities—were estimated for SWA 2 by multiplying the total estimated labor (in man-hours) by a unit construction risk (per man-hour). These risk factors are general construction incidence rates published by the U.S. Department of Labor in

the Survey of Occupational Injuries and Illnesses for the years 1990 and 1991 (USDL 1992). The risk factors for construction risks are as follows:

- 6.7×10^{-5} injuries per man-hour (or 6.7 injuries per 100,000 man-hours)
- 5.0×10^{-7} fatalities per man-hour (or 5.0 deaths per 10,000,000 man-hours)

Risks associated with construction activities under SWA 2 are based on a labor estimate of 126,000 man-hours. Under these assumptions, 8.4 worker injuries and <1 (0.06) fatality are expected over the 1.7-year remedial action duration. This corresponds to a projected annual incidence of 4.7 worker injuries and <1 (0.03) worker fatality.

The total projected occupational (truck driver) transportation risks (see Appendix F) to implement SWA 2 are calculated to be 0.007 injury while carrying contaminated and borrow soil over the 1.7-year duration. The related projection of occupational transportation fatalities is 0.004 fatality for all soil transported.

Summary. Projected risks of chemical exposure to workers under SWA 2 would exceed EPA targets for noncancer effects. Use of personal protective equipment (e.g., respirators) or dust control actions would be expected to reduce risk tenfold; thus, risk to workers would be within EPA target levels. The total projected occupational (truck driver) transportation risks (see Appendix F) to implement SWA 2 are calculated to be 0.007 injury. The related projection of occupational transportation fatalities is 0.004 fatality for all soil transported. Construction risks for workers are calculated to be 8.4 injuries and 0.06 fatality.

Time Until Action is Completed

Estimated time to complete this action is 1.7 years. Short-term remedial response objectives would be achieved upon completion of actions. After receiving approval from the regulatory agencies, the actual time to complete this alternative would include $\sim$12 to 18 months for remedial design and the associated approval of the remedial action work plan prior to commencing the remedial action. Therefore, after final regulatory approval of the Record of Decision, it would take $\sim$3 to 5 years to complete the action, not including long-term environmental monitoring.

Environmental Impacts—Soil and Floodplain

Soil. Both excavation and containment actions would cause short- and long-term impacts to soil. Excavation and backfilling would result in long-term limitations on soil productivity by altering the biological, chemical, and physical properties of floodplain soil. Natural soil profiles would be lost, but most soil properties would be expected to recover over time. Containment actions would also alter soil profiles and soil properties. The surface areas of impact and the volumes of soil to be excavated for SWA 2 are given in Table 5.9. Volumes of borrow soil required to backfill excavated areas in the Residential RU in the floodplain would be similar to those listed for excavation. Borrow soil for covering contaminated soil in the Commercial/DOE and Other RUs is calculated by multiplying the surface area of contamination by a 45-cm- (18-in.-) deep soil cover; the totals are presented in Table 5.10. The assumption used to calculate the area of disturbance at the borrow location is that soil would be excavated to a depth of 5.5 m (18 ft).

In summary, the biological, chemical, and physical properties of 7.35 ha (18.16 acres) of the floodplain surface would be affected. The volume of in situ soil excavated in the floodplain would be 25,100 m^3 (32,800 yd^3); the volume of ex situ borrow soil to backfill excavated areas and cover contaminated soil left in the floodplain would be 45,000 m^3 (58,800 yd^3). Approximately 0.81 ha (2.0 acres) surface area would be disturbed at the borrow location; this would result in permanent alteration of soil profiles and topography in that area.

The adverse impacts to soil productivity caused by replacing floodplain soil with subsurface soil from a borrow location would be reduced over time as soil properties began to recover in response to physical and biological factors, such as addition of organic matter through root system penetration and establishment of soil microorganisms. A reclamation program designed to add nutrients and colonizing microorganisms to soil and the revegetation of disturbed areas would hasten this process. Containment would require permanent restrictions on land use that would limit the productivity of floodplain soil.

Floodplain. Actions taken under this alternative would result in placement of an additional volume of soil in the EFPC floodplain. A total of 14,800 m^3 (19,400 yd^3) of ex situ soil would be placed in the Commercial/DOE and Other RUs in the EFPC floodplain. Because remediation would be conducted in sequence, there would be no significant alteration of floodwater holding capacity during implementation of SWA 2. The amount of fill for containment would not be expected to adversely affect stream flow during floods or to affect other features of the floodplain. A general analysis conducted indicates that the flood levels would be increased by a few inches. A site-specific flood assessment would be conducted during the remedial design.

Excavation and disposal of contaminated soil in the Residential RU would have no effect on floodwater holding capacity of the EFPC floodplain. After contaminated soil was excavated from the Residential RU, clean soil would be used to backfill excavated areas, and each site would be restored by grading the land surface to its original contour, stabilizing the site to prevent erosion, and revegetating the site for long-term stability of the soil surface. This action would not interfere with the normal functions of the floodplain.

Summary. Remedial actions taken for SWA 2 would have no adverse short- or long-term effects on the floodplain resources of EFPC.

Environmental Impacts—Water Quality

Surface Water. The primary potential short-term impact of SWA 2 on surface water quality would be increased mercury and total suspended solids concentrations during storms as a result of soil erosion during excavation and backfilling (for the Residential RU) or disturbance related to site preparation and containment before vegetation stabilized the containment layer (for the Commercial/DOE and Other RUs). Use of Best Management Practices, including appropriate engineering controls, silt control, and reestablishment of vegetative cover, would prevent or minimize these short-term effects.

Based on results from the GLEAMS model (Sect. 2), the disturbance of soil during remediation could add between 0.08 μg/L mercury for remediation of Segment 2 to 1.73 μg/L for remediation of Segment 4 during a 5-year, 24-h storm event (Table 5.11). The GLEAMS model used the conditions at EFPCM 3.3 (the former USGS gauging station at location LB) as

a reference point for comparing scenarios. The modeled concentration of mercury is below the 2.4 μg/L maximum exposure level adopted by the State of Tennessee for the protection of fish and aquatic life. Mercury from sources other than soil erosion, such as creek bank scouring and input from Lake Reality, are more likely to affect surface water during storm events.

Over the long term, the contaminant concentrations in the instream sediment would be expected to decline as contaminated soil was removed or covered. This should cause the contaminant concentrations during storm events in the creek water to decrease below the levels currently observed. The GLEAMS model predicts a 30% reduction in the concentration of mercury during a 5-year event, from 0.44 to 0.30 μg/L. During base flow conditions, surface water quality would continue to depend on releases from the Y-12 Plant and the quality of the water received from tributaries and the sewage treatment plant.

The modeled potential increase in total suspended sediment in the creek generated by storm runoff during remediation activities ranged from 1.2 to 5.7 mg/L (Table 5.11). These concentrations are negligible when added to the sediment load from the rest of the watershed. Sediment concentrations of 800 mg/L were measured at EFPCM 3.3 during a storm with a 250-cfs flow (TVA 1985).

In the long term, a 10% increase in the contribution of total suspended sediment from the floodplain could be expected because of the change of vegetative cover from woods to grass in some of the remediated areas (Table 5.11). This increase would have a negligible effect on water quality.

Because the contaminants are mostly particle-bound, remediation is not predicted to cause transport of contaminants to the surface water through the groundwater. During soil removal and replacement, generated airborne dust may be deposited directly into the creek. The small surface area of the stream relative to the watershed makes direct contribution from the air small relative to potential input from surface runoff.

Impacts to surface water from development and use of the Y-12 Plant disposal facility would be limited to some modification of flow characteristics of surface drainage (i.e., the intermittent wet-weather stream arising in the vicinity of the disposal site).

Groundwater. The baseline risk assessment results from the RI indicate that certain contaminants exceed EPA's HI target of 1.0. However, the ingestion of groundwater is an incomplete pathway because no one is currently using groundwater in the vicinity of EFPC. If groundwater should become a drinking water source in the future, additional evaluation would be required.

Under SWA 2, groundwater quality in and near the EFPC floodplain would depend on the contribution of contaminants from sites of remedial activities. The conceptual model for the groundwater system, outlined in the RI, suggested that the likely COCs in the floodplain soil and sediments were particle-reactive metals (e.g., mercury, cadmium), which are present in relatively insoluble forms (e.g., mercury sulfide minerals) under ambient environmental conditions. The main concern is that disturbance of contaminated soil by remediation activities could result in changes in the ambient soil environment conditions and cause increased leaching of metals to groundwater.

The concentration of contaminants in groundwater is controlled by chemical equilibria associated with metal sorption/desorption on particles or the solubility of distinct mineral phases. Changes in the chemistry of groundwater or the chemistry of water recharging through soil to groundwater could release contaminants to groundwater. Hydrochemical changes of this nature are not likely to happen in undisturbed soil adjacent to soil that is being excavated. Excavation, removal, and backfilling would introduce no chemicals to soil that could cause hydrochemical changes. Excavated soil would be managed as waste material and therefore would not release metals to groundwater. Backfill material would be similar in chemistry (except for contaminants) to present soil; therefore, the chemistry of recharge to groundwater through backfill material would not change significantly. For these reasons, leaching of metals from soil to groundwater during soil replacement is not a pathway of concern.

Containment of soil in the EFPC floodplain with a soil cover similar in characteristics to existing soil would have a negligible impact on the hydrology of shallow groundwater. In the conceptual model for groundwater described in the RI, recharge for groundwater comes from upland slopes at the margins of the floodplain. Flow of shallow groundwater has two components, toward EFPC and along the valley strike towards Poplar Creek. Section 2.6.4 includes additional details on groundwater. A soil cover would not alter vertical groundwater flow rates and would have no effect on lateral flow of shallow groundwater below the capped soil. Therefore, a soil cover would cause little, if any, change in hydrology of the shallow groundwater in the vicinity of the cover. The chemistry of water that is recharged through the soil cover would be similar to that of water recharged at present; therefore, there would be no appreciable change in the concentration of metals in soil leachate. For these reasons, leaching of metals from covered soil to groundwater is not a pathway of concern.

Recharge of contaminated surface water that collects in excavations during the remedial operation is a possible pathway. However, contaminants are particle reactive, so the water is unlikely to become contaminated, and surface water recharge would not be an important contaminant pathway. Groundwater that collects during the excavations, drains from the excavated soil, or otherwise contacts contaminated soil, would be collected, analyzed, and disposed of according to ARARs. The pathway from surface water to groundwater outside these areas of excavation is insignificant.

Provided that adequate surface water controls are implemented during construction activities, the hydrochemical environment of the floodplain soil and the groundwater should not change under SWA 2 in a manner that would cause contaminant concentrations in groundwater to increase and pose a threat.

Environmental Impacts—Air Quality

Air quality impacts from construction of the containment cover would result from soil disturbances such as haul road traffic, loading, grading, and dumping and from associated internal combustion engine emissions from heavy equipment operation. Impacts from these activities would involve short-term exposure to airborne contaminants during the removal of vegetation, grading, and any other surface preparations for cover construction. Controlled emissions from grading activities are estimated at 0.007 kg/h (see Appendix F) and would not be a significant health risk to workers or the community if dust suppression control measures were taken.

Emissions from heavy equipment operation (i.e., fuel combustion) would be negligible and would not significantly affect local or regional air quality.

Excavation and handling of untreated soil would be a significant air pathway to potential receptors. Excavation operations such as loading, dumping, grading, excavating, and haul road traffic would cause excessive concentrations of contaminated dust, if not properly controlled. Storage piles of untreated soil and large areas of bare soil could also serve as significant sources of fugitive dust emissions. Control methods, such as wetting of haul roads, haul road speed limits, and limiting the number of exposed storage piles, would significantly lower emissions from these activities. Human health risk studies have shown that off-site risk from controlled fugitive dust emissions from excavation and soil-handling activities would be within acceptable limits. Worker health risk on site would be limited to inhalation and ingestion of airborne contaminants. Implementation of a project health and safety plan that addresses mitigative measures (i.e., engineering controls and personal protective equipment) would maintain health risks to on-site workers at acceptable levels.

Air quality impacts from activities at the Y-12 Plant disposal facility would be similar to those associated with excavation. Control measures for lowering fugitive dust emissions and limiting worker exposures would be similar to those used during excavation and handling of untreated soil.

Environmental Impacts—Land Use

The impacts at each RU would vary in degree according to the actions planned for the RU and the accessibility of contaminated areas on the properties within the RU. Impacts are primarily related to short-term remedial efforts, long-term maintenance of soil cover, and hindrances in future developments as a result of the remedial actions taken. Impacts will be described for each RU, and property-specific issues will be highlighted if necessary.

Commercial/DOE RU. The Commercial/DOE RU consists primarily of existing commercial parcels, small vacant parcels in commercial areas, and DOE-owned land. Under this alternative, only two commercial properties would undergo containment: a corner portion of an auto dealer on South Illinois Avenue and an area behind a tavern/auto repair building on Jefferson Avenue. Both of these areas are easily accessible and may not require new construction access roads. Short-term impacts would include clearing the areas for the soil cover, removing vegetation that could act as a visual buffer, noise from construction activities, and inconveniences to business operations resulting from truck traffic and construction activities. These impacts would be temporary and would not affect the existing land use.

Both areas of contamination are on the back vacant portions of the properties that would not be likely to contain buildings since they are located in the floodway zoning district, which places restrictions on building structures. These areas could be used for parking lots in the future. The containment would not severely restrict current operations or future redevelopment. Restrictions on future land use to protect the cover and minimize developments that could breach the cover would be necessary. A long-term effect is that a federal entity would be required to maintain the vegetation on the cover to prevent the growth of deep-rooted trees.

The lands in the DOE RU are located at the Y-12 Plant near the DOE boundary, at the NOAA site leased from DOE, and on the ORR on the west end of town near privately owned property. It is unlikely that DOE would release these areas, so future development could be limited. A future land-use limitation could be necessary for the NOAA site because residual contamination would remain, and it is located among private property, some of which could be developed for residences.

Other RU. The Other RU includes three properties that will be affected by this alternative: a small segment along Oak Ridge Turnpike behind a motel on South Illinois Avenue and two vacant lots adjacent to each other. Short-term impacts to these Other RU properties would include building an access road to the contaminated areas, clearing sites for staging areas, eliminating vegetation for the soil cover, and removing vegetation that could act as a visual and sound buffer. For the area behind the motel, additional short-term impacts would include noise from construction activities and inconveniences to business operations from truck traffic and construction activities. These impacts would be temporary and would not affect the surrounding land use.

Long-term impacts would include the need to maintain access roads to the covered areas, the requirement of a federal entity to maintain the cover so that deep-rooted vegetation would not occur, and limitations to future development on and near the covered areas. Most of the covered areas are in the floodway zoning district, which restricts the building of structures. These areas could be used for parking lots in the future. Since these areas are currently undeveloped, future land-use restrictions would be necessary to prevent a breach of the cover. Use restrictions and knowledge of the covered contaminated areas could deter future developers, but this is unlikely since an action would have been taken to eliminate perceived risks of adverse effects on human health.

Residential RU. The Residential RU contains the highest volume of soil to be removed. There are two variations of land uses associated with the Residential RU: (1) existing residential areas and (2) vacant land predicted to become residential in the future. Short-term impacts to both types of property could result from building access roads to the contaminated areas, clearing sites for staging areas, removing vegetation that could act as a visual and sound buffer, and temporarily removing fences. After remediation was completed, actions would include removing roads, replanting vegetation, and replacing fences and other amenities that were disturbed.

Additional short-term impacts to existing residential areas would include noise from remedial actions, truck and construction traffic through yards, and dust potentially coating buildings and other amenities. Additional short-term impacts to vacant parcels include the inconveniences or hindrances to developing the property before and during the remedial activities and noise disturbances to surrounding areas.

Removing potential adverse health impacts to residents and incidental users and removing hindrances to developing and redeveloping properties are long-term benefits to the Residential RU. Property owners would be relieved of perceived constraints that presently exist as a result of mercury contamination.

Environmental Impacts—Ecological Resources

This section includes the evaluation of impacts to aquatic resources, terrestrial resources, wetlands, and threatened and endangered species.

Aquatic Resources. In the evaluation of the No Action alternative (Sect. 5.3.1.5) and in the ecological risk assessment (Sect. 2.5.2), surface water and sediment were identified as the primary sources of contaminant exposure that resulted in the major risk to aquatic biota in EFPC. Contaminant discharges from the Y-12 Plant are assumed to continue, and final remediation alternatives for sediment are being deferred until the contaminant discharges from the Y-12 Plant are controlled. Thus, for SWAs 2 through 6, it is reasonable to assume that long-term impacts (impacts that occur after completion of all remedial activities) to the aquatic habitats and biota in EFPC from the remedial actions at each of the RUs would continue at least at the level described for the No Action alternative (Sect. 5.3.1.5). For example, body burdens of several COPCs in aquatic indicator organisms, as well as several measures of community structure (fish and benthic macroinvertebrate taxonomic richness and diversity and the percentage of fish species classified as tolerant of degraded water quality conditions) would be expected to show the greatest impacts closest to the Y-12 Plant, then decrease downstream. The COPC body burdens and community impacts in biota from all sites in EFPC would probably continue to exceed the impacts observed at an uncontaminated reference site at Hinds Creek.

Short-term effects from the specific remedial actions (containment or excavation and backfilling) at each RU could also occur. Short-term effects are the impacts that occur during implementation of the remedial activities, which are estimated to take 2 to 4 months per stream segment. The cause-effect relationships that comprise these short-term effects are discussed in the following paragraphs. A semiquantitative evaluation of the short-term effects is then discussed separately for each RU.

Containment, excavation, and backfilling activities would result in changes to existing riparian habitats. The type of riparian vegetation has indirect effects on the instream habitat features and biota, especially fish, as previously discussed in Sect. 2. For example, stream banks consisting primarily of shrub vegetation typically have a greater standing crop of fish than similar-sized streams with tree- or grass-dominated stream banks (Platts 1974). Shrubs and trees provide a source of coarse particulate organic matter derived from outside the stream (allochthonous) which is an important nutrient source for the stream, especially in the upper headwater areas (Ohio EPA 1988b). Removal of shrubby riparian vegetation during the remedial activities could result in increased mortality of fish. Removal of trees would increase the amount of incoming sunlight to the stream, which could result in increased production of nuisance algal blooms, which in turn could affect nutrient cycling and instream habitat alteration (Ohio EPA 1988a). Conversion of riparian bottomland hardwoods, old fields, or right-of-way habitats (each of which contains trees and shrubs) into grassy cover would have short-term as well as long-term impacts that would extend indefinitely because the grassy cover would have to be maintained.

Bank stabilization would reduce stream bank undercutting, which minimizes the potential for bank sloughing and erosion. However, stream bank undercuts provide excellent refuge habitat for many fish species (Platts et al. 1983). Refuge habitats are important hiding areas for many

fish species, and provide an escape from predators. Thus, bank stabilization would result in loss of valuable refuge habitat for fish.

Increased siltation could occur during the containment, excavation, and backfilling activities primarily because of accidental/incidental introduction of the stream bank or floodplain soil into the stream, or secondarily because of resuspension of instream sediments. Siltation can have five general deleterious impacts to aquatic biota. First, if the introduced soil is contaminated, an increase in contaminant exposures could occur. Once in the stream, the contaminated soil would become part of the sediment load, thereby becoming available for exposure to aquatic biota through the seven major pathways described for the No Action alternative. Second, increased suspended sediment could harm fish and benthic macroinvertebrates by interfering with their normal respiration. Suspended sediment concentrations of 1200 to 35,000 mg/L can cause fish mortality due to gill abrasion (Noggle 1978). Third, reproductive success of lithophilic fish (species that require clean gravel substrate for spawning) could be negatively affected if increased siltation occurred during the incubation period of the eggs. The incubation period occurs from the time of spawning until emergence of the fry from the gravel, which is typically late winter to early spring for most species in EFPC. Accumulation of fine sediment in the gravel used by lithophilic fish could result in decreased survival of ova (Olsson and Persson 1988), presumably because of the reduced capacity to transfer oxygen to the ova through the interstitial water in the gravel. Fourth, as sediment accumulates in the interstitial spaces in the gravel, the surviving fry (newly hatched fish) could be unable to emerge from the gravel (Phillips et al. 1975) or could emerge prematurely and be more susceptible to predation (Olsson and Persson 1988). Fifth, increased siltation could reduce the number of spawning sites for lithophilic fish. Eleven species of fish that have lithophilic spawning life histories have been captured at various locations in EFPC (Table 5.12).

The potential loss of riparian vegetation, degree of bank stabilization, and increased siltation are primarily a function of the length of stream bank that is subject to remedial activities in each RU within each of the nine segments in the stream. Table 5.13 summarizes the types and current lengths of the riparian habitats that are subject to remediation within each stream segment for each of the RUs.

Commercial/DOE RU

Implementing SWA 2 for the Commercial/DOE RU would result in the conversion of ~632 of 17,897 m (691 of 19,572 yd) (3%) of riparian bottomland hardwood into grassy cover. Grassy cover is ecologically less desirable than shrubby or tree-lined riparian habitat for reasons previously described in the introductory paragraphs of the Aquatic Resources portion of this section. Because the grassy cover would need to be maintained, the impacts would continue indefinitely as long as the cover remained in place. Short-term impacts to aquatic plants and animals could result from the conversion of riparian habitats, stream bank stabilization, and increased siltation. The general impacts from these three disturbances were also discussed in the introductory paragraphs of the Aquatic Resources portion in this section.

Moderate potential short-term impacts and long-term impacts could occur to aquatic biota in Segment 1 of this RU because 429 of 1219 m (469 of 1333 yd) of riparian bottomland hardwood would be permanently converted to grassy cover due to remediation. Short-term impacts would also be expected to be greatest during the months of March through May because

this is the period of maximum fish spawning activities for the species in EFPC. Four lithophilic spawning fish species [blacknose dace (*Rhinichthys atratulus*), striped shiner (*Luxilus chrysocephalus*), spotted sucker (*Minytrema melanops*), and white sucker (*Catostomus commersoni*)] were identified in Segment 1. Impacts to aquatic biota would be minor in Segments 3 and 9 because of the smaller lengths of riparian bottomland hardwoods that would be converted [62 and 141 m (68 and 154 yd), respectively]. Erosion prevention measures such as installation of coffer barriers during the surface preparation and cover application activities are expected to minimize the likelihood of significant impacts from increased siltation. There are no riparian habitats requiring remediation in Segments 2, 4, 5, 6, 7, or 8.

Other RU

Implementing SWA 2 for the Other RU would result in long-term impacts to aquatic biota and habitats due to the conversion of ~735 of 7828 m (804 of 8561 yd) (9%) of riparian bottomland hardwood and old field habitats into grassy cover. Riparian bottomland hardwoods comprise 7603 m (8315 yd) in this RU; 648 m (709 yd) (8%) would be permanently converted to grassy cover. Of the riparian old field habitat, 87 of the 225 m (95 of 246 yd) (39%) would be converted.

The most significant potential short-term and long-term impacts to aquatic biota in the Other RU would probably occur in Segments 4 and 5 and would potentially be most deleterious to fish communities if the impacts occurred during the spawning season in the late winter and early spring. In Segment 4, 509 of 1060 m (556 of 1159 yd) of riparian bottomland hardwoods and old fields would be converted to grassy cover, whereas 219 of 700 m (240 of 765 yd) of riparian bottomland hardwoods would be converted in Segment 5 (Table 5.13). Four lithophilic spawning fish species (blacknose dace, striped shiners, spotted suckers, and white suckers) were identified in Segments 4 and 5 (Table 5.12). Short-term impacts to aquatic biota would be negligible in Segment 1 because of the short length of riparian bottomland hardwoods that would be remediated [7 m (8 yd) of 674 m (737 yd)]. Erosion prevention measures, such as installation of coffer barriers during the surface preparation and cover application activities, should minimize the likelihood of significant impacts from increased erosion. There are no stream banks requiring remediation in Segments 2, 3, 6, 7, 8, or 9.

Residential RU

Implementing SWA 2 for the Residential RU would result in long-term impacts to aquatic biota and habitats in EFPC because the excavation and backfilling activities would result in the excavation of two riparian habitat types: bottomland hardwoods and old fields. Long-term impacts would be expected to continue until shrubby riparian vegetation had reestablished along the previously excavated stream banks. Shrubby riparian vegetation would eventually recolonize the stream banks through natural succession over several years. Potential short-term effects, similar to those described above for the Commercial/DOE RU under this sitewide alternative, could also occur and would be expected to be most deleterious during the months of March through May because this is the period of maximum fish spawning activities for the species in EFPC.

In this RU, riparian bottomland hardwoods comprise 14,285 m (15,622 yd); 1761 m (1927 yd) (12%) would be converted. Of the riparian old fields, 159 m (174 yd) of the 227 m (248 yd) (70%) would be converted.

The most significant potential short-term and long-term impacts to aquatic biota in the Residential RU would probably occur in Segments 1, 3, and 4 because of the long lengths of riparian habitats that would be excavated from each of these segments. The lengths of riparian bottomland hardwoods or riparian bottomland hardwoods and old field habitats that would be excavated in these three segments range from 254 m (278 yd) in Segment 3 to 706 m (772 yd) in Segment 4. The four lithophilic spawning fish species identified in the Commercial/DOE RU have also been identified in Segments 1, 3, 4, and 5 within the Residential RU. Three additional species are present in Segment 8 [emerald shiner (*Notropis atherinoides*), golden redhorse (*Moxostoma erythrurum*), and northern hogsucker (*Hypentelium nigricans*)]. Of the 11 lithophilic spawning fish species observed in EFPC, only the rosefin shiner was not present in Segment 9 (Table 5.12). Impacts to aquatic biota should be minor to moderate in Segments 5 and 8 because the lengths of remediated riparian habitats are 153 and 189 m (167 and 207 yd), respectively. Impacts should be minor in Segment 9 due to the short length of remediated stream bank [91 m (100 yd)]. There are no Residential RUs requiring remediation in Segments 2, 6 or 7.

Summary. Implementing SWA 2 would result in the continuation of impacts to the aquatic biota and habitats in EFPC similar to those described for the No Action alternative (Sect. 5.3.1.5) for all RUs because of the continued release of contaminants from the Y-12 Plant and deferred remediation of the surface water and sediments in EFPC. Additional long-term impacts would be expected as a result of the remedial actions. For example, containment in the Commercial/DOE and Other RUs would result in the conversion of ~1387 of 26,887 m (1495 of 29,404 yd) (5%) of riparian bottomland hardwood and old field habitats into grassy cover. As noted in the above sections, riparian grassy cover is less desirable than shrubby or tree-lined stream banks for reasons described in the introductory paragraphs of this section. Because the grassy cover would need to be maintained, the impacts would continue indefinitely as long as the cover remained in place. Long-term effects in the Residential RU would continue until shrubby riparian vegetation had reestablished along the previously excavated stream banks.

Potential short-term impacts (through implementation of the remedial activities) could also occur from the conversion of riparian habitats, plus stream bank stabilization and increased siltation due to surface preparation and cover application actions at the Commercial/DOE and Other RUs, and excavation at the Residential RU. The magnitude of potential short-term impacts is primarily a function of the length of stream bank that is subject to remedial actions within each segment and RU and the time of year that the remedial actions are performed. Since most fish species in EFPC spawn in the late winter and early spring, short-term impacts from increased siltation would be most deleterious during this period. Riparian bottomland hardwood in the Residential RU would be subjected to the most conversion [nearly 1761 of 14,285 m (1927 of 15,622 yd) (12%) (Table 5.13)]. Thus, potential short-term impacts to aquatic biota would be greatest in the Residential RU. Erosion prevention measures during the surface preparation, cover application, and excavation and backfilling activities are expected to minimize the likelihood of significant impacts from increased siltation.

Terrestrial Resources. Terrestrial habitats within the EFPC floodplain, described in Sect. 2.1.5.2, are predominantly bottomland hardwood forest, old field, and pasture. Remedial

actions for SWA 2 (i.e., containment and excavation) would produce significant short-term impacts during implementation and would result in some intermediate and long-term impacts through habitat conversion.

Short-term impacts include direct mortality of vegetation, soil-dwelling organisms, and some small mammals during the construction of access roads and surface preparation of the site (removal of all vegetation and rough grading). Terrestrial biota would be displaced or disrupted until the remedial action was completed. Also, terrestrial fauna (e.g., skunks) that feed on soil organisms potentially could be exposed to uncovered contaminated soil until the soil cover was completed or clean borrow soil was backfilled into excavated areas. This would primarily occur during periods of human inactivity (i.e., nights or weekends).

Impacts to habitat of intermediate duration would occur where a disturbed or destroyed habitat was allowed to reestablish after the removal of contaminated soil. Reestablishment could require 2 to 50 years, depending on the habitat type. Forested habitat would take longer (~50 years) to reestablish than would a field habitat (~2 to 5 years).

Containment actions (i.e., conversion of existing habitat and continual maintenance of a limited vegetative cover) would result in long-term impacts and changes to the plant and wildlife communities and populations in affected areas. Additionally, remedial actions for this alternative would not prevent terrestrial resources from continued exposure to contamination through contact with and/or ingestion of EFPC surface water, sediments, and aquatic biota.

Habitat disturbances, such as the clearing of a forested area, result in changes in the number and kinds of species that use a habitat. For many wildlife species, habitat diversity (the number of different habitat types in a given area) is beneficial. Habitat diversity makes it easier for an animal to find what it needs for a specific activity (e.g., feeding or resting). In areas of low habitat diversity (a low number of different habitats), the creation of new habitat types within the area can benefit wildlife. In areas of high diversity, additional diversity can have neutral effects, or possibly even negative impacts if the habitat pattern becomes too fragmented. The value of unique habitat, such as floodplain forests, may outweigh any benefit from an increase in diversity. Appendix G describes a method for comparing the relative values of different areas of habitat.

Regrowth of plant communities within a disturbed area occurs in a natural ecological succession. In the eastern United States, 40 to 60 years of natural succession in a disturbed area would result in the reestablishment of a forest. The succession of habitats would be from grasses (youngest) to old field, shrubs, saplings, and intermediate forest (oldest). Wildlife inhabiting these different stages would change as the succession of habitats progressed. The time necessary for succession to a forest habitat could be shortened by mitigation. Mitigation of this type would consist of planting appropriate tree and shrub seedlings, which would reduce the time necessary for them to reseed and establish naturally.

The general population trends and number of bird species observed following the clearing of forested areas exhibit an initial decline in overall numbers. Within a year of the disturbance, former numbers are usually regained but with a different species composition (Hagar 1960). Hooper (1967) reported similar trends during the early years of regrowth following clearing, with an increase in both species and numbers of breeding birds after 6 years of regrowth. Small

clearings [0.4 to 0.7 ha (0.9 to 1.7 acres)] showed no significant effects on the densities of birds. The population densities of breeding birds in a newly cleared area in East Tennessee were determined to be 4.08 pairs/ha (1.65 pairs/acre) and 3.78 pairs/ha (1.53 pairs/acre) in 1972 and 1973, respectively (Ambrose 1975). Densities in an adjacent forested area during the same years were 1.36 pairs/ha (0.55 pairs/acre) and 1.06 pairs/ha (0.43 pairs/acre). During both years, 30 species total were recorded: 9 species were found in both areas, 11 species were found only in the cleared area, and 10 species were found only in the forest.

Based on the above and similar studies, bird populations within the EFPC floodplain could be expected to increase in areas of removal following remediation. This increase would be accompanied by a loss of forest-dwelling species. Populations and species would change over time as the areas grew back into bottomland hardwood forests. In the areas remediated by containment, bird populations would be artificially maintained at levels and with species similar to those found during the early years of regrowth in the areas of removal. Forest-dwelling species would be effectively excluded as long as the containment covers were maintained.

Populations and species diversity of small mammals (e.g., white-footed mice, chipmunks, woodland voles) show responses to habitat disturbance similar to those of bird populations. Gashwiler (1970) reported increases in both small mammal populations and the number of species present after forest clearing. This study also showed a loss of some forest-dwelling species from the cleared area. The elevated populations showed a decline after 6 years of vegetation regrowth. Live-trap censusing of small mammals in a newly cleared area in East Tennessee yielded population densities of 8.5 individuals/ha (3.4 individuals/acre) and 7.1 individuals/ha (2.9 individuals/acre) for white-footed mice during two consecutive years (Ambrose 1975). Densities of 3.5 individuals/ha (1.4 individuals/acre) and 2.9 individuals/ha (1.17 individuals/acre) resulted from censusing in an adjacent forested area. Increases in population numbers were also observed for the Eastern chipmunk and the short-tailed shrew.

The population trends for small mammals within disturbed areas of the EFPC floodplain would be expected to be similar to those in the studies discussed above. Habitat conversion in areas of containment would likely result in an increase in small mammal population levels and in the number of species present.

The time of year when remedial activities would take place would also affect the degree of negative impacts to wildlife. Habitat destruction or disturbance during the reproductive season (spring and early summer for most wildlife species, especially birds) would be much more detrimental to population levels than if activities were carried out during the fall or winter. Wildlife populations generally reach a maximum during late summer, as many species (e.g., most song birds) often have more than one brood or litter. Late summer and early fall are times when many species are preparing physiologically for winter, whether they migrate or winter locally. This time factor would be common to all habitat types.

In assessing impacts to terrestrial resources, certain assumptions are made concerning long-term impacts to terrestrial habitats from excavation and containment activities. "Lawn," "grass," and "right-of-way" habitat units would not be converted by remediation because these areas would be expected to return to their present habitat type. However, these habitats would receive short-term impacts. Habitat defined as "commercial" is assumed to provide no significant habitat value. Habitat conversions of <0.04 ha (0.1 acre) are not included in these analyses. No

remediation would take place in the Surface Water/Sediments RU, although habitat conversion, especially of the stream bank, would be likely to result from the remediation of soil adjacent to the stream (see Aquatic Resources in this section). Terrestrial habitat conversions are summarized in Table 5.14.

The development of a dedicated disposal cell at the Y-12 Plant would require ~4 ha (11 acres). About 90% of the proposed area is old field habitat; the remainder is a hardwood woodlot and a young pine plantation. Disposal cell development would destroy these habitats, and closure would convert the area to a permanently maintained grassland. Wildlife use of the area after closure would be expected to be similar to that prior to disposal cell development, but with a notable loss of breeding birds suited to old field habitat.

Commercial/DOE RU

Terrestrial habitats within the Commercial/DOE RU consist of ~41.7 ha (103.1 acres) of bottomland hardwood forest, 1.3 ha (3.3 acres) of grass, 3.2 ha (8.0 acres) of hardwood plantation, 5.3 ha (13.1 acres) of old field, 6.4 ha (15.8 acres) of pine plantation, 22.3 ha (55.1 acres) of upland forest. This is a total of 71.7 ha (198.4 acres).

Containment actions would affect 0.85 ha (2.1 acres) of bottomland hardwood forest habitat within this RU. The impacts would occur in Segments 1, 3, and 9. Construction of access roads and staging areas would result in the additional loss of an estimated 0.020 ha (0.05 acre) of habitats within this RU.

Other RU

Terrestrial habitats within the 43.0-ha (106.3-acres) Other RU are dominated by bottomland hardwood forest [23.2 ha (57.3 acres)]. Old field is the next largest habitat component [8.4 ha (20.8 acres)]. The remainder of this RU is comprised of grass, upland forest, commercial, and fill.

Containment actions in this RU would affect a total of 1.6 ha (4.0 acres) of habitat. The impacts would occur in Segments 4 and 5 and would include 0.9 ha (2.3 acres) of bottomland hardwood forest and 0.7 ha (1.7 acres) of old field. Construction of access roads and staging areas would result in the additional loss of an estimated 0.2 ha (0.5 acre) of habitats within this RU.

Residential RU

Terrestrial habitats within the 78.2-ha (193.1-acres) Residential RU consist of ~47.2 ha (116.6 acres) of bottomland hardwood forest, 7.7 ha (18.9 acres) of old field, 9.4 ha (23.2 acres) of pasture, and 8.7 ha (21.6 acres) of grass. The remainder of this RU is comprised of commercial, fill, lawn, pine plantation, right-of-way, and upland forest.

Removal actions would affect a total of 4.8 ha (12.0 acres) of habitat in this RU. The impacts would occur in Segments 1, 3, 4, 5, 8, and 9 and would include 3.8 ha (9.4 acres) of bottomland hardwood forest and 1.0 ha (2.5 acres) of old field. Construction of access roads and staging areas would affect an additional 0.7 ha (1.8 acres) of habitats within this RU. However,

restoration of the affected areas would occur after the contaminated soil was removed. This would include backfilling, grading to original contour, sowing grass, and replanting shrubs and trees as needed. Over time, the habitat that was present prior to remediation would reestablish itself through natural succession. The time period would be ~2 to 5 years for reestablishment of old field and pasture habitat and ~50 years for bottomland hardwood forest habitat.

Wetlands. Table 5.15 provides a summary of the affected wetlands, the area to be excavated, and the area to be contained for each RU under SWA 2. Maps provided in Sect. 4 depict the wetland locations within each segment. Four wetlands in the Residential RU, one wetland in the Commercial/DOE RU, and one wetland in the Other RU would be affected. A total of 0.90 ha (2.25 acres) of wetlands would be directly disturbed by excavation or containment actions. Other indirect impacts to wetlands could be expected to occur because of work adjacent to wetlands.

Containment within wetlands would alter hydrological conditions and would cause a permanent disruption of wetland functions and values. Because containment would permanently change topography, it would not be possible to restore the loss of those functions at that wetland in the future. Wetland 1 on DOE property in Segment 1 and Wetland 7 in the Other RU in Segment 4 would be affected by containment. About 0.46 ha (1.14 acres) of disturbance in two wetlands would result from containment actions in the Commercial/DOE and Other RUs.

Adverse effects at excavated sites would not necessarily be permanent or irreversible. Wetland functions could be restored at excavated wetlands through implementation of a comprehensive mitigation and restoration program intended to restore original functions and value of each disturbed wetland. Wetlands affected by excavation would be Wetlands 3, 4, and 5 in the Residential RU in Segment 1 and Wetland 8 in the Residential RU in Segment 4. A total of ~0.44 ha (1.11 acres) of wetlands would be excavated in the Residential RU. Only one wetland (Wetland 8, the Residential RU in Segment 4) would be completely destroyed (98%) by remediation.

Any remediation of contaminated soil in wetlands would have significant short-term and long-term adverse effects to wetland functions. Short-term effects could last as long as a decade; long-term effects would affect wetland functions for several decades. Wetland functions identified thus far include floodwater attenuation, contaminant/silt retention, and wildlife habitat. The degree to which remediation affects a wetland depends largely on the remediation method selected, the size of the wetland, the portion of the wetland disturbed by remediation, and the original functions of the wetland prior to remediation. Any disturbance, whether temporary or permanent, would have to be mitigated through a comprehensive restoration or creation program. Options for wetlands mitigation are discussed in greater detail in Sect. 5.4, Monitoring and Mitigative Measures.

Threatened and Endangered Species. No impact to protected species would be expected under SWA 2. Excavation and containment along the EFPC floodplain is not expected to have a significant impact on the Tennessee dace because its critical habitat in the headwater regions of tributaries would not be affected.

It is not known at present whether protected species are present in the borrow soil or haul road area. The proposed areas would be surveyed for the presence of protected species prior to

selection as a borrow soil site. No impact to protected species would be expected in connection with development and use of the Y-12 Plant disposal facility.

Environmental Impacts—Archaeological, Cultural, and Historical Resources

The eight sites identified in the archaeological reconnaissance of EFPC (DuVall 1993) are in three different RUs. Five of the sites are located on DOE property and in the Commercial/DOE RU, two sites are on the Sportsman Association property in the Other RU, and one site is located on the East Fork Horse Farm, which is included in the Agricultural RU. None of these sites is in the areas to be remediated.

Environmental Impacts—Socioeconomic and Institutional Issues

The following section describes potential impacts on the institutional setting, public services and facilities, and economic and demographic resources. See Sect. 2.1.7.1. for a background review. To the extent possible, the discussion is based on RUs.

As described in Sect. 2.1.7.1, the institutional environment includes government entities, interest groups, organizations, and individuals who could be affected by or who have a stake in the outcome. The institutional analysis is not intended to yield frequencies or statistically representative results. Its purpose is to present prevalent issues and viewpoints among stakeholders and to describe, as completely as possible, the human context within which actions on EFPC would occur. Please refer to Sect. 2.1.7.1 for a full description of methods and a listing of identified stakeholder groups.

Institutional Considerations. The interim actions proposed for the Surface Water/Sediments RU under SWA 2 would not be likely to address community concerns. During interviews and public meetings, various individuals expressed concerns that remedial alternatives could not adequately address potential recontamination of remediated floodplain soil due to continuing releases from the Y-12 Plant. Commercial developers, City representatives, and representatives of citizen/environmental groups have raised questions about assignment of responsibility for any future remediation necessitated by releases from the Y-12 Plant.

Because interim actions proposed for the Surface Water/Sediments RU would not eliminate the uptake of mercury in fish, and increased consumption of fish could result in adverse impacts to human health, signs restricting fishing would be posted. Almost one-third of the Oak Ridge representatives interviewed mentioned the stigmatizing effects of EFPC on the image of Oak Ridge as a major past and current impact on the community. Stakeholder groups particularly affected by the perceived stigma include the City of Oak Ridge, developers who own property in the floodplain, persons involved in residential and commercial recruitment, and the community at large. Most of the individuals who mentioned stigma attributed a major source of impact to the public restriction signs currently posted at several highly visible points along the creek. Stigmatizing effects could be lessened somewhat if the signs were changed to restrict fishing only rather than the current restrictions on fishing and body contact.

With regard to the Commercial/DOE and Other RUs, City representatives, property developers, real estate interests, and residents generally appear to prefer whatever action would give the community "a clean bill of health" and remove the contamination as an issue in people's

minds, including the negative perceptions attached to it. Although a few individuals expressed doubt that capping would be sufficient to remove the negative image apparently held by outsiders, most community members consider containment to be sufficiently protective of human health. Some participants of the Citizens' Working Group have expressed skepticism concerning the long-term ability to maintain the integrity of institutional actions over time. The permanent elimination of mature trees and vegetation over expanses of the floodplain visible from city streets would be viewed as detrimental to the community's attractiveness, based on interviews with City representatives and residents who say they value the creek as an important aesthetic resource in the community.

With containment and institutional actions on Commercial/DOE and Other RUs, the liability issue would be likely to continue to affect the buying and selling of property. Impacts could be encountered over the long term when owners of these properties attempt to sell their properties. As explained in Sect. 2.1.7.1, many real estate agencies adhere to standard practice in conformance with the Code of Ethical Conduct of the National Association of Realtors to disclose to prospective buyers any known contamination remaining from past uses. Further, future lenders could take a hands-off stance toward those properties where contamination remains. Environmental sampling initiated by a lender in the future could include core samples that reveal the presence of contaminants, substantially hindering a buyer's ability to obtain real estate financing. To mitigate this impact, institutional mechanisms releasing future title holders from liability would be necessary. Some property owners have expressed the opinion that DOE should pay them the equivalent of rent in exchange for what they view as tying up their property rights and reimburse them for out-of-pocket expenses (e.g., survey fees) they have incurred because of the issue.

In the Commercial/DOE RU, there is no indication that any specific businesses would be adversely affected in the short term by containment and institutional actions, aside from unavoidable annoyances and inconveniences that could be expected with site preparation and construction of access roads. Long-term impacts would depend on the reliability of long-term monitoring, maintenance, and control.

Because DOE is expected to maintain ownership and control of DOE-owned property over the foreseeable future, no impacts to the institutional environment would be likely to result from implementing institutional actions on the ORR, assuming institutional actions are effective over the long term.

Excavation and disposal of contaminated floodplain soil in the Residential RU would affect different groups of residents differently. This alternative would have the potential to lessen liability concerns of owners and prospective buyers of property in the Residential RU. Property in this RU, such as the land adjacent to the country club and golf course, could be developed as prescribed by normal market pressures. The City would be able to proceed with issuance of subdivision permits to allow housing development. In contrast to containment actions, this alternative would remove contamination above action levels of 180 ppm within this RU and thus would be more likely than containment to relieve potential title holders of liability concerns and make financing available for the purchase of property. Institutional mechanisms to provide freedom from future liability could still be requested. In the interim, impacts to development plans would continue prior to completion of the remediation. To mitigate these impacts, institutional arrangements would be needed to provide interim development guidelines or

accommodations to the City and property developers to encourage some development projects to proceed.

Based on public comments and interviews, most owner/residents do not consider the contamination to be a problem from the standpoint of health and could consider excavation and disposal for the Residential RU to be an overly protective measure in the absence of clearcut threats. Several residents who were interviewed value the creek and the trees in the floodplain as an asset to their property and would be opposed to the removal of vegetation and disturbance of lawns and landscaping, even though restoration would occur over time. Though residents would not be relocated, considerable inconvenience and annoyance during excavation, grading for access roads, and transportation activities could be expected. Approximately six pieces of heavy equipment and approximately three trucks could be present at any one time within the area being remediated. To mitigate impacts, DOE staff would need close consultation and coordination with individual affected residents to accommodate their particular needs and schedules. Some residents whose houses are located very near the area to be excavated could request temporary relocation to avoid any impacts from noise and dust.

Public Services. Approximately 3800 L/d (1000 gal/d) of decontamination water would be tanked from Oak Ridge under this alternative. Decontamination water would be treated/filtered and recycled. Decontamination water for the transport trucks would be treated at each individual removal site by modular treatment units. Approximately 3040 L/d (800 gal/d) of decontamination water would be sampled and tested [760 L/d (200 gal/d) lost to evaporation]. The remaining water would be containerized and disposed of properly. This amount of water would represent an insignificant impact on the City of Oak Ridge public water supply.

Disposal of waste soil and debris generated during excavation and during tree clearing would be managed on the ORR. Therefore, no impact on local or regional solid waste disposal would occur.

Some public facilities would experience short-term impacts during remedial activities under this alternative. For example, Robertsville Junior High School and the public housing apartments on the opposite side of the creek would likely experience some disturbance of activities and annoyance due to noise and dust. DOE would coordinate with school and Oak Ridge Housing Authority personnel to minimize disruptions to educational and recreational activities to the extent possible. Because parents and students have expressed minimal concern about the contamination's health effects, this alternative is not likely to appreciably change behavior and/or attitudes regarding effects on school activities (Smallridge 1993; Hayes 1993). Close coordination and consultation with school authorities and the Oak Ridge Housing Authority would be required to mitigate impacts.

Excavation required in the floodplain adjacent to Hopkins-Strang Ball Park would not be expected to significantly affect recreational activities because the play areas are well away from the creek. However, coordination with the City Recreation Department would be advised to avoid truck traffic while children could be present.

Impacts on emergency response services would be expected to be minimal because potential accidents or incidents are fully within existing local capabilities.

Because the portion of the SLB from Illinois Avenue to the Oak Ridge Sewage Treatment Plant is within the EFPC floodplain, precautions would be necessary to avoid damaging the utility line during excavation activities required in the Residential RU. Standard practice would require coordination with the City of Oak Ridge Public Works department to be sure that care is exercised in operating heavy equipment near the utility line.

Institutional impacts under SWA 2 would include potential continuation of perceived stigmatizing effects on community image because of the need for signs restricting fishing in the creek; long-term devaluation of aesthetic quality along the creek where containment is required within the Commercial/DOE and Other RUs; continued liability issues for property owners and potential title holders in the Commercial/DOE and Other RUs in the absence of institutional mechanisms to reduce their potential liability; resistance by residents who prefer minimal disturbance to their properties; short-term annoyance and inconvenience to residents and schools affected by excavation and transportation activities; and net beneficial effects on public services.

Economic and Demographic Resources. Employment resource impacts are estimated using RIMS II for Anderson and Roane counties developed by the Bureau of Economic Analysis. Employment estimates form the basis for the calculation of associated changes in the number of households and population. For a description of this modeling framework, see Appendix E.

Remediation activities are assumed to take place in the first 2 years. In each of those years, it is estimated that the remediation would require 34.0 FTEs for construction activities, 34.0 for administrative support, and a crew of five for continuous sampling and monitoring activities. Annual average wages and salaries plus other household income from land purchases and relocation costs are estimated to be $2.9 million, with expenditures for equipment and materials at $6.1 million per year and associated expenditures for other business services at $12.7 million per year. The direct spending associated with the project going to local businesses and households is estimated to result in indirect employment of an additional 49.5 FTEs, for a total employment increase of 122.5 in each of the 2 years. This represents almost 0.2% of the 63,317 people employed in Anderson and Roane counties in 1990 (see Table 2.14). The upper bound on the number of households created by this increase in employment is 91, or ~0.2% of the 49,657 housing units in the two counties in 1990 (see Table 2.12). The associated population estimated consistent with the employment and housing impacts is 230, or nearly 0.2% of the 115,477 people living in Anderson and Roane counties in 1990 (see Table 2.11). These changes are so small relative to the totals for the region of influence that this alternative should not result in adverse impacts to the economic and demographic conditions in Anderson and Roane counties.

Routine monitoring activities are assumed to take place during years 3 to 6, 8 to 11, 13 to 16, 18 to 21, 23 to 26, and 28 to 30. It is estimated that direct wages and salaries for the 0.3 FTEs required for sampling and reporting would be $10,500 per year; other expenses are estimated to be $89,500. No capital expenditures are estimated during these years. Using RIMS II, it is estimated that this activity would generate 0.1 additional FTEs, for a total employment effect of 0.4. This employment effect is so small that there are no associated changes calculated for the number of households or population.

More extensive monitoring and sampling are assumed to be conducted at 5-year intervals, in years 7, 12, 17, 22, and 27. During these years, direct employment is to be increased to 0.8 FTEs. Using RIMS II, the associated secondary employment is 0.2 FTEs, for a total

employment increase of one person. The number of new households associated with this growth is estimated to be one, and the population increase is estimated to be three. These values are so small relative to the size of the region that there should be no adverse impact on the economic and demographic conditions in Anderson and Roane counties.

Transportation Impacts. General actions regarding transportation are presented in Sect. 5.2. For this alternative, the main transportation impacts would be an increase in average daily traffic volumes and potential road deterioration and damage. Impacts would occur along designated routes in each EFPC RU and along routes to the borrow site and disposal facility (see Table 2.18). The level of significance depends primarily on site-specific characteristics such as the volume of material to be transported, where the most activity would take place, existing level of service, and the time period in which the impacts would occur.

Site preparation activities (i.e., vegetation removal and construction of access roads and staging/decontamination areas) would require the transport of an estimated 700 m^3 (900 yd^3) of woody debris to a construction landfill and an estimated 3900 m^3 (5100 yd^3 or ~420 loads) of gravel from a commercial vendor. The remedial actions under this alternative (i.e., containment and excavation), would require the transport of large volumes of borrow soil and contaminated soil. Borrow soil would be transported from the borrow site on the ORR to each remedial unit in the EFPC floodplain. Contaminated soil would be transported from the floodplain to a disposal facility located at the Y-12 Plant. Approximately 8200 truckloads would be required to transport contaminated and borrow soil. Approximately the same volume of ex situ borrow soil [~45,000 m^3 (58,800 yd^3)] would be transported from the borrow site back to the EFPC floodplain for use as backfill in remediated areas and as soil cover. Transportation impacts would occur in each segment and RU in the EFPC floodplain, with the majority of the impacts occurring in the vicinity of Segments 1 and 4 in the Residential RU.

The increase in average daily traffic volumes could be a temporary inconvenience (~6 h/d, 5 d/week, over a 2- to 3-year period) for other vehicles (personal and commercial) on the affected routes and on connecting roads. Commercial operations could suffer temporarily reduced business while customers avoid affected areas because of traffic delays. Significant impacts are not expected because the remedial actions would be staged, temporary, and spread out over time.

A level-of-service analysis is available only for the intersection of Oak Ridge Turnpike at South Illinois Avenue (Sullivan 1993). Because this intersection is already operating at near capacity and the level of service is expected to decline to "F" in the near future, any remedial action truck traffic using this intersection would contribute to an increase in delay. Level of service is rated on a scale of A to F, with F being unacceptable.

Increased truck traffic on designated routes could result in increased pavement deterioration and damage. This would increase costs associated with maintaining or resurfacing these routes. Other potential impacts related to transportation include increased noise and air quality impacts. These impacts are discussed in separate sections.

Transportation impacts would be minimized by cooperation with local and state authorities to determine the most appropriate haul routes and trip times to reduce traffic congestion, accident potential, and road deterioration. Since the location of the borrow site(s) and disposal facility would be on the ORR, transportation impacts could possibly be minimized by using roads that

are normally restricted from public access (i.e., Bear Creek Road). Scheduling of vehicle movements during off-peak traffic hours and provision of turning lanes and other safety measures would also reduce impacts. Local, state, and federal ordinances regarding weight and speed limits would be obeyed, or appropriate waivers or temporary permits acquired.

Noise Impacts. Use of construction equipment at each of the remedial units and movement of trucks along transportation routes would result in the generation of noise. Typical sound levels generated by the types of equipment that could be used for the remedial activities are presented in Table 5.16. In general, the sound from the actions would be intermittent rather than constant. Receptor populations include wildlife, as well as humans, in the vicinity of the remedial actions.

Based on studies conducted for similar remedial actions, representative activities associated with the remedial actions along the EFPC floodplain could result in equivalent sound emissions of 85 to 88 dB for a receptor 15.2 m (50 ft) from the site of operations (ANL 1982). Using estimated background levels of 35 to 55 dB, 24-h equivalent sound levels at 16 m (50 ft) (adjusted for the action) can be estimated as ranging from 80 to 83 dB. These levels are above the day-night levels listed in Sect. 2.1.7.5 as being requisite for protection of public health and safety from interference with normal activities in residential, hospital, and educational areas. Sound levels could be above annoyance thresholds for up to a kilometer or more from the site. Thus, there will likely be some disruption of surrounding activities for the duration of any remedial action operations near residential areas and in the vicinity of Robertsville Jr. High School.

Equivalent sound-pressure levels for remedial activities in each RU are not expected to exceed the OSHA standard for an 8-h workday average of 90 dB, nor would anticipated noise levels from individual pieces of equipment (Table 5.16) exceed the OSHA standards for short-term exposure.

Summary. Noise levels associated with this alternative could result in short-term and minor annoyances to the public but are not expected to affect hearing or pose any occupational health hazards. Noise levels associated with this alternative would occur only during normal working hours and would be temporary. Noise impacts would be reduced, when feasible, by the following measures:

- replacing noisy operations with less noisy ones,
- selecting the quietest among alternative equipment pieces,
- proper maintenance and operation of equipment,
- scheduling noisiest operations at times when ambient levels are highest,
- maximizing the distance between the noise source and receptor, and
- providing enclosures or other barriers.

Environmental Impacts—Unavoidable Adverse Impacts

Contaminant concentrations in stream sediment are low compared to concentrations found in floodplain soil and would be considered a minor source of exposure to human health and terrestrial ecosystems. Receptors of contaminants from this source would include floodplain soil, relatively clean stream sediment, surface water (when sediment is disturbed), and human and ecological resources. Ecological resources at greatest risk from contaminant exposure are aquatic

organisms, especially those that live in direct contact with the sediment, such as most benthic macroinvertebrates, many other invertebrates, and bottom-feeding fish species. Secondarily, both aquatic and terrestrial predators of these biota could continue to be exposed to bioaccumulated contaminants.

The primary impact of SWA 2 on surface water quality would be short-term increases in mercury concentrations and total suspended solids during storms from erosion of contaminated soil during excavation or grading activities. Based on results from the GLEAMS model (Sect. 2), the disturbance of soil during remediation could contribute 2.5 μg/L of total mercury to the concentration in EFPC.

Certain remedial activities (e.g., excavation and containment cover construction) would produce significant short-term impacts during implementation and result in some long-term impacts on terrestrial habitat through habitat conversion. Some impacts would last an intermediate time period (e.g., if a disturbed habitat were allowed to reestablish after completion of remedial activities). This intermediate period would be in the range of 2 to 50 years, depending on the existing habitat. Short-term impacts include those such as direct mortality of individual organisms. Habitat conversion would occur in areas of containment, where existing habitats would be converted permanently to early-stage old field. Under this alternative, ~1.8 ha (4.4 acres) of bottomland hardwood forest habitat would be converted. Excavation of contaminated soil would result in the excavation of 4.85 ha (12.0 acres) of habitat. Remedial activities would also result in the permanent loss of 1367 m (1495 yd) (5% of the total) of tree- and shrub-lined riparian habitat along the stream. In addition, 1920 m (2101 yd) of riparian habitat would temporarily be lost as a result of excavation until the pre-existing habitat was reestablished through ecological succession.

Although residents would not be relocated during remedial activities, considerable inconvenience and annoyance during excavation, grading for access roads, and transportation activities could be expected. Local transportation impacts would be an increase in average daily traffic volumes and road deterioration along designated routes in each RU along EFPC.

A total of 0.90 ha (2.25 acres) of wetlands would be directly disturbed by excavation or containment actions.

Environmental Impacts—Short-Term Uses and Long-Term Productivity

Under SWA 2, properties would experience short-term inconveniences during the remedial action but would be free of most constraints in the long term. Short-term impacts for all involved properties include building access roads to the contaminated areas, clearing sites for staging areas, removing vegetation at the contaminated area that could act as a visual and noise buffer, and removing fences temporarily. After the remediation had been completed, actions would be taken to remove roads, replant vegetation, and replace fences and other amenities that were disturbed. Additional short-term impacts to properties with existing uses include noise annoyance from truck traffic, dust potentially covering buildings, and inconveniences from truck and construction traffic through residential yards and business properties. These short-term impacts would not necessarily alter short-term uses.

Because the contaminated soil would be removed from the Residential RU, property owners would be able to use their properties any way they preferred. The contaminated areas on the Commercial/DOE and Other RUs would be contained, and restrictions on future land use would be necessary to ensure that the containment would not be breached. Therefore, limitations on future use (nonresidential and nonagricultural) could affect long-term productivity of those properties.

5.3.2.6 Implementability

SWA 2 is implementable. Excavation of contaminated soil using standard construction power equipment is a technology that is readily available but requires trained personnel to perform. Trees and other vegetation would have to be removed in the area of excavation. Over-excavation could occur accidentally due to the shallow contamination and inherent inaccuracy of standard excavation equipment. Once the area was backfilled, it would be difficult to gain access to remaining contaminated soil separately from the clean backfill; this would only be an issue if action levels change in the future. Specialists with experience in excavation of contaminated soil and employees trained to perform remedial work are readily available. Equipment used would be standard excavation equipment and would be readily available on a lease or purchase basis.

Soil cover is a readily available technology that has been implemented many times on the ORR, most notably in the Closure and Post-Closure Activities (CAPCA) projects. Tree and shrub removal would be required for installation of the cover. Perpetual care would be required to maintain the cover. If specifications are followed, soil covers are considered reliable under ordinary circumstances. The proposed polyethylene net/liner would prevent animal intrusion into the contaminated soil. Floods could affect the integrity of the cover; inspection and repair, if necessary, would be required after such events. Containment could make future remedial actions such as soil removal more difficult because the cover would have to be removed to gain access to the contaminated material. Additionally, the soil cover could become contaminated or be difficult to differentiate from the contaminated material, effectively increasing the contaminated material volume. Containment is not proposed in this alternative for Residential RU soil. Containment in additional commercial areas of the floodplain would be readily implementable.

Fencing, berms, and posted signs are standard methods of institutional control that can be implemented by many contractors. Special equipment and qualifications (e.g., 40-h OSHA training) could be required if the fences, berms, or signs are to be installed in contaminated or otherwise hazardous areas. Fences would require periodic maintenance, and signs would require periodic replacement due to vandalism, theft, or natural wear. These measures would not prohibit further remedial action, should it become necessary. Construction permits and design approvals would be necessary for fencing installation. Some DOE properties currently use fencing and guards to limit access. Signs do not present implementability problems for Commercial, DOE, or Other properties.

Environmental monitoring of the EFPC OU or subsets of the site is easily performed. The site has been monitored in the past and would not be a problem to effectively monitor if an appropriate sampling plan were implemented and funding provided.

Property restrictions are not proposed under this alternative for the Residential RU because material considered harmful to human health and the environment would be excavated. DOE

properties would present no implementation concerns for restrictions on future use. These restrictions would limit proposed future development of the DOE-owned property.

Staged construction or temporary entrances could be required during construction to continue access to properties that front the Residential RU. It could be necessary to limit work hours for residential soil to avoid disturbing homeowners with construction noise. Access roads would be necessary to reach DOE and Other RU soil in areas that are removed from existing roads.

Transportation of soil during excavation, backfill, and containment would be performed by dump trucks. Excavated material would be moved from the excavation area to one of the staging areas located centrally at each of the major excavation areas. Haul roads within the site would be constructed in an area with no contamination or an area from which contaminated material was removed prior to installation of the haul road. Haul roads and trucks/equipment would be sampled and monitored for contamination to prevent contamination of clean areas along the haul roads or at the staging area. Hauling hours could be limited in residential areas to avoid traffic congestion in peak hours and noise disturbing to residents.

On-site borrow areas for topsoil are readily available within the West End Borrow Area at the Y-12 Plant. Little of the ORR has been contaminated by ongoing activities; however, borrow soil from the ORR would be sampled so that new contamination would not be introduced through backfill material. An on-site borrow area for the ORR would not require specific permitting but would have to comply with State of Tennessee construction standards for erosion control.

Transportation using dump trucks or larger over-the-road tandem dump trucks is an accepted transportation mode for short or long distances. Trucks capable of hauling the material from the EFPC remediation areas are readily available from commercial transporters. Because of the large volume of material to be moved, reconstruction of road damage could be required in some areas. Transportation permits would be required at state and local levels. Technology such as disposable truck liners and covered trucks are available to virtually eliminate the risk of releases of the material during transportation. Trucks could be sampled and monitored for cleanliness and decontaminated if necessary. The number of trucks operating could be adjusted for efficient and timely delivery of material to the disposal site.

Disposal at the Y-12 Plant disposal facility has been chosen as a representative technology for disposal of untreated soil from the EFPC remediation. Technology, experience, and modeling capabilities are available to establish that a landfill is capable of isolating the waste soil in accordance with state and federal regulations. The Y-12 Plant site has sufficient acreage available for the landfill for the volume of material generated by the EFPC remediation, ~4 ha (11 acres). Contractors capable of designing and constructing a landfill to accept the waste are readily available in the Oak Ridge area. Should the landfill fail to provide containment, further remedial actions could be easily implemented within the ORR due to the centralization of the contaminated material. Disposal facilities could be monitored for releases to the environment using widely accepted monitoring technologies.

5.3.2.7 Cost

Total capital cost for the site under this alternative is ~$39 million. Operation and maintenance costs are estimated to be:

Years	Cost (× $1000)
1 to 2	2318
3 to 30	150
5-year periodic	150

The total cost to complete this action in 1993 dollars is ~$48 million with no escalation or discount. Appendix D presents the assumptions and calculations used to calculate the cost estimate for SWA 2.

5.3.2.8 State acceptance

To be provided after receipt of comments.

5.3.2.9 Community acceptance

To be provided after receipt of comments.

5.3.3 Description and Summary of Evaluation of Sitewide Alternative 3 (SWA 3)

Description

SWA 3 involves the excavation of soil contaminated with > 180 ppm of mercury on the Residential RU [~25,100 m^3 (32,800 yd^3)]; the excavation of soil contaminated with > 200 ppm of mercury on the Commercial [400 m^3 (500 yd^3)], DOE [~6500 m^3 (8500 yd^3)], and Other RUs [~9400 m^3 (12,200 yd^3)]; and disposal at the modified Landfill VII. Institutional actions would be implemented for the Surface Water/Sediments RU. General action descriptions are provided in Sect. 5.2.

Summary of Evaluation

SWA 3 would protect human health and the environment in the long term by removing all contaminated soil above the human health and ecological remediation goal options. SWA 3 complies with ARARs, as described under SWA 2. Projected risks of chemical exposure to children and adults in the community from dust generated during soil handling under SWA 3 are below the EPA target for noncancer effects (HI < 1). Physical hazards would include construction and transportation risks for workers and only transportation risks for the community since the community would be excluded from the remediation area. Risks to the community are projected to result in 0.3 injury and 0.02 fatality; transportation risks to workers are calculated to cause 0.010 worker injury and 0.005 worker fatality. In addition, construction risks to workers are estimated at 10.3 injuries and 0.08 fatality. Thus, the total risks for SWA 3 would be expected to cause ~11 injuries and 0.1 fatality. Remediation activities would cause noncancer risks to

workers that exceed EPA targets (HI > 1) if no mitigative measures were used. However, if mitigative measures (e.g., personal protective equipment, dust suppression techniques) were used, the EPA target would not be exceeded. For ecological receptors, the most significant short-term impact from soil removal would be direct mortality of individual ecological receptors, temporary but total habitat loss in the areas [7.35 ha (18.16 acres)] of remediation, and indirect impacts such as disturbance of wildlife from noise and human activity. A total of 0.90 ha (2.25 acres) of wetlands would be adversely affected by the soil removal actions. Total cost to complete this alternative would be $52 million in 1993 dollars (with no escalation or discount).

Impacts resulting from the implementation of the soil removal under SWA 3 would be similar to those described under SWA 2 for soil removal in the Residential RU. To avoid redundancy, the discussion of impacts that are the same as those under SWA 2 are not repeated here; only the additions and deviations are discussed.

5.3.3.1 Overall protection of human health and the environment

This alternative would protect human health and the environment in the long term. However, in the short term, risks to workers, the public, and ecological receptors would increase during implementation because of the quantity of material being processed (excavated, transported, and disposed). Chemical exposure risks to the community from inhalation of contaminants in dust during excavation would not exceed (HI < 1) EPA's target for noncancer effects. Short-term risks to unprotected workers from chemical exposure would exceed (HI > 1) EPA targets for noncancer effects for all RUs if no mitigative measures were used. A project health and safety plan would address mitigative measures, such as engineering controls and use of personal protective equipment, and standard engineering practices to reduce dust, such as covering trucks and wetting soil, as needed, to reduce exposures and thereby reduce risk to target levels. Transportation and construction accidents are projected to result in < 1 (0.1) total fatality for SWA 3.

For ecological receptors, there would be significant short-term effects: direct mortality of individual organisms, temporary but total habitat loss in all remediated areas, and indirect impacts such as disturbance of wildlife from noise and human activity. Impacts would be particularly significant if remediation occurred during the most active reproductive season (e.g., March through May for spawning fish, February through June for nesting birds, etc.). Short-term impacts for aquatic resources would result from siltation and conversion of riparian habitats. Both direct and indirect impacts to wetlands would occur under this alternative; one wetland would be destroyed by excavation, and five others would be affected. A total of 0.90 ha (2.25 acres) would be directly affected.

Excavation of soil contaminated in excess of remedial goal options in each of the RUs would reduce residual human health risks to levels below EPA targets. Disposal of contaminated soil in the Y-12 Plant disposal facility would comply with relevant DOE and state requirements for protectiveness in the long term. Excavation and disposal of contaminated soil would also be expected to eliminate unacceptable risk to ecological receptors from the COC. However, it would take several years to reestablish terrestrial habitat disturbed during remediation, although planting appropriate plant species could speed the process somewhat. Recovery of bottomland hardwood forests would take nearly 50 years. Until shrubby riparian vegetation was reestablished along the excavated stream bank ecotones, impacts to aquatic resources could include decreased

fish abundance and increased algal blooms, which could negatively affect nutrient cycling. Valuable refuge habitat for fish (e.g., natural undercuts in the bank) would be lost as a result of bank stabilization following excavation.

5.3.3.2 Compliance with ARARs

See Sect. 5.3.2.2 for a discussion of compliance with ARARs.

5.3.3.3 Long-term effectiveness and permanence

The proposed removal of contaminated soil would reduce residual risks below the EPA target level (HI < 1). Five-year reviews would not be required because all contamination above the action level would be removed.

Long-term engineering controls would not be required to provide continued protection of human health as long as the land use did not change for the Commercial/DOE and Other RUs. Continued protection of human health over time would require that the land use remain nonresidential and nonagricultural because these areas could contain postremedial concentrations of mercury in excess of 180 mg/kg.

Disposal of contaminated material from the Commercial/DOE, Other, and Residential RUs at the Y-12 Plant disposal facility would comply with DOE policies and procedures and would be effective in the long term. The responsibility for long-term management, monitoring, and operation and maintenance would be placed with the receiving facility, which is expected to have adequate and reliable controls.

Irreversible and Irretrievable Commitment of Resources

The implementation of SWA 3 would involve excavation and disposal actions within all RUs designated for active remediation. Several aspects of the excavation and disposal action would involve the irreversible and/or irretrievable commitment of specific resources. Most materials used for revegetation of the excavated areas (sod, grass seed, natural-fiber stabilization netting, and woody plant materials) would be considered renewable.

Soil excavation proposed for the Commercial/DOE, Other, and Residential RUs would allow them to be released for unrestricted use. Implementation of SWA 3 would result in the excavation and disposal of contaminated soil from 0.86 ha (2.14 acres) for the Commercial/DOE RUs; from 1.64 ha (4.05 acres) for the Other RU; and from 4.85 ha (11.97 acres) for the Residential RU (see Table 4.2). Ex situ borrow soil of a similar amount [~49,500 m^3 (64,800 yd^3)] would be required to return the areas to their original grades and contours. The excavated soil would be disposed of and lost to any other future use, and the borrow soil would be lost to the area from which it was excavated. On-site borrow areas for topsoil are readily available within the West End Borrow Area on the ORR. Fuel use for excavation is expected to be 310,800 L (82,300 gal) of diesel fuel.

Disposal of contaminated soil at the Y-12 Plant disposal facility would result in the permanent loss of some woodlot and old field habitat, which would be replaced with maintained

cover following closure of the disposal facility. Irreversible commitment of land for the disposal facility would permanently limit future land use for ~6 ha (15 acres).

5.3.3.4 Reduction of toxicity, mobility, or volume through treatment

No treatment is involved in this sitewide alternative.

5.3.3.5 Short-term effectiveness and environmental impacts

This section evaluates the short-term effectiveness of SWA 3 by considering protection of the community and protection of workers during remedial actions at EFPC. Additional information concerning methodology for the human health evaluation and risk calculations is presented in Appendix F.

Community Protection

Chemical Exposure Risks. The excavation that is planned represents significant disturbance of contaminated soil and creates the potential for transport of dust outside the areas of remediation; therefore, effects to the community are evaluated. As explained in Appendix F, exposures to the community would result from inhalation of contaminants in dust transported downwind to existing nearby residences. Potential exposures by means of soil ingestion and dermal contact are considered to be minimal and are not considered further.

Tables 5.17 and 5.18 show short-term inhalation risks associated with soil excavation and disposal activities. Risks to the community exposed to dust would not exceed the EPA target for noncancer effects at any of the EFPC segments. Since there is no cancer slope factor for mercury (class D substance), cancer risks are not associated with exposure to mercury.

Physical Hazards. Because members of the community would not have access to the areas being remediated, construction risks related to the community are not evaluated. SWA 3 includes transport of contaminated soil from the RUs and transport of borrow soil for backfill to the RUs. Because this represents a considerable amount of travel, the potential for transportation accidents involving injuries and/or fatalities exists. Because the trucks would be covered before transport, exposures to hazardous materials during their transport are considered unlikely.

Under SWA 3, ~348,000 km (217,500 miles) would be traveled by trucks carrying both contaminated and clean borrow soil. The total (contaminated and borrow soil) projected transportation risks to the community would be 0.3 injury and 0.02 fatality. In other words, for the duration of the project (estimated as 1.6 years), it is unlikely that any injuries would occur and highly unlikely that any fatalities would occur.

Remediation Worker Protection

Chemical Exposures. Because excavation and disposal activities would be planned for the RUs under this alternative, risks from exposure to contaminants would be likely for workers. Risks related to remedial activities for unprotected workers (e.g., no personal protective equipment or other precautions taken) shown in Tables 5.17 and 5.18 indicate that for excavation and disposal activities the noncancer risks would exceed the EPA noncancer target due to soil

ingestion. The inhalation and dermal contact risks would be below the EPA noncancer target. A project health and safety plan would be developed for site activities and the required mitigative measures to protect worker health and safety would be addressed to ensure worker exposures do not exceed acceptable EPA target levels.

Physical Hazards. Risks associated with construction activities under SWA 3 are based on a labor estimate of 154,000 man-hours. Under these assumptions, 10.3 worker injuries and <1 (0.08) fatality are expected over the 1.6-year duration of the remedial action. This corresponds to a projected annual incidence rate of 6.4 worker injuries and <1 (0.04) worker fatality. Occupational (truck driver) transportation risks would result in 0.010 worker injury and <1 (0.005) worker fatality. This indicates that both injuries and fatalities are unlikely.

Time Until Action is Completed

Estimated time to complete this action is 1.6 years. Short-term remedial response objectives would be achieved upon completion of actions. After approval by the regulatory agencies, the actual time to complete this alternative would include ~12 to 18 months for remedial design and the associated approval of the remedial action work plan prior to commencing the remedial action. Therefore, after final regulatory approval of the Record of Decision, it would take ~3 to 5 years total to complete the action, not including long-term environmental monitoring.

Environmental Impacts—Soil and Floodplain

Soil. Under SWA 3, excavation would cause severe short- and long-term impacts to soil. These effects could be mitigated in part by implementing a comprehensive reclamation and revegetation program, but excavation and backfilling would adversely alter the biological, chemical, and physical properties of the soil. The alteration of these soil properties would affect the long-term productivity and future use of excavated areas.

A total in situ volume of 41,400 m^3 (54,000 yd^3) of contaminated soil would be excavated from the Commercial/DOE, Other, and Residential RUs, affecting an area of ~7.35 ha (18.16 acres) in the EFPC floodplain. A similar volume of ex situ borrow soil [~49,500 m^3 (64,800 yd^3)] would be required for backfilling excavated areas. Mitigative measures (discussed under SWA 2) would hasten the recovery of areas disturbed during remediation.

Floodplain. Excavation and disposal of contaminated soil would have no long-term adverse effects on the EFPC floodplain. Short-term effects would be mitigated by replacing contaminated soil with borrow soil in excavated areas and restoring each site by grading the land surface to its original contour, stabilizing the site to prevent erosion, and revegetating the site to ensure long-term stability of the soil surface. This action should not interfere with the normal functions of the floodplain.

Environmental Impacts—Ecological Resources

Aquatic Resources. Short-term effects from the excavation and backfilling remedial actions at each RU would most likely result from two major disturbances: temporary conversion of riparian habitat types and increased siltation. The general impacts for these activities are discussed in Sect. 5.3.2.5 for SWA 2. Table 5.13 presents the length of stream bank that is

subject to remediation, as well as the percentage of riparian habitat type that would be remediated. Riparian bottomland hardwoods in the Residential RU would be subjected to the most excavation [nearly 1761 m (1927 yd) out of 14,285 m (15,622 yd) (Table 5.13)]. Thus, potential short-term impacts to aquatic biota would be greatest in the Residential RU. Using Best Management Practices, including appropriate engineering controls, during the remedial activities should minimize the likelihood of significant impacts from increased siltation. Mitigative measures such as planting shrubs streamside after backfilling would hasten recovery of stream bank vegetation. Short-term impacts would also be expected to be greatest during the months of March through May because this is the period of maximum fish spawning activities for the species in EFPC.

The proposed soil removal action would be expected to create additional long-term impacts. For example, in the Commercial/DOE and Other RUs, excavation would result in the temporary conversion of 1367 m (1495 yd) (5%) of the 26,887 m (29,404 yd) of riparian bottomland hardwood and old field habitats. Until reestablishment of shrubby riparian vegetation occurs along the excavated stream bank, fish abundance could be affected. Shrubby riparian vegetation would eventually recolonize the stream banks through natural succession over several years. In the Residential RU, 1920 m (2100 yds) of bottomland hardwood and old field riparian habitat would be temporarily converted.

Commercial/DOE RU

Implementing SWA 3 for the Commercial/DOE RU would result in the excavation of ~632 m (691 yd) of 19,059 m (20,843 yd) (3%) of riparian bottomland hardwood habitat. Long-term impacts to aquatic biota would be expected to continue until shrubby riparian vegetation had reestablished along the previously excavated stream banks. Temporary conversion of riparian habitat type, stream bank stabilization, and increased siltation (as discussed in the introductory paragraphs of the Aquatic Resources subsection for SWA 2) could also create short-term impacts to aquatic biota.

Aquatic biota in Segment 1 in this RU could experience moderate potential short-term and long-term impacts because ~429 of 1219 m (469 of 1333 yd) of riparian bottomland hardwood habitat would be excavated. Short-term impacts would also be expected to be greater during the months of March through May because this is the period of maximum fish spawning activities in EFPC. Four lithophilic spawning fish species have been identified in Segment 1 (blacknose dace, striped shiner, spotted sucker, and white sucker). Impacts to aquatic biota should be negligible in Segments 3 and 9 because of the short lengths of riparian bottomland hardwoods that would be excavated [62 and 141 m (68 and 154 yd), respectively]. Erosion prevention measures are expected to minimize the likelihood of significant impacts from increased siltation. There are no riparian habitats requiring remediation in Segments 2, 4, 5, 6, 7, or 8.

Other RU

Implementing SWA 3 for the Other RU would result in the excavation of ~735 of 7828 m (804 of 8561 yd) (9%) of riparian bottomland hardwood and old field habitats. Riparian bottomland hardwoods comprise 7603 m (8315 yd) in this RU; 648 m (709 yd) (8%) would be excavated. Of the riparian old field habitat, 87 of the 225 m (95 of 246 yd) (39%) would be converted. As described above for the Commercial/DOE RU, long-term impacts to aquatic biota

would be expected to continue until shrubby riparian vegetation had reestablished along the previously excavated stream banks.

The most significant potential short-term and long-term impacts to aquatic biota in the Other RU would be expected to occur in Segments 4 and 5 and would potentially be most deleterious to fish communities if the impacts occurred during the spawning season in the late winter and early spring. In Segment 4, 509 of 1060 m (556 of 1159 yd) of riparian bottomland hardwoods and old fields would be excavated, whereas 219 of 700 m (240 of 765 yd) of riparian bottomland hardwoods would be excavated in Segment 5 (Table 5.13). Four lithophilic spawning fish species (blacknose dace, striped shiners, spotted suckers, and white suckers) were identified in Segments 4 and 5 (Table 5.12). Short-term impacts to aquatic biota would be minor in Segment 1 because of the short length of riparian bottomland hardwoods that would be remediated [7 m (8 yd) of 674 m (737 yd)]. Erosion prevention measures are expected to minimize the likelihood of significant impacts from increased erosion. There are no stream banks requiring remediation in Segments 2, 3, 6, 7, 8, or 9.

Residential RU

Long- and short-term impacts to aquatic biota would be similar to those described for SWA 2 because the excavation remedial actions are identical for both sitewide alternatives.

Terrestrial Resources. SWA 3 proposes only excavation and disposal for all RUs except Surface Water/Sediment. The excavation of contaminated soil would produce significant short-term impacts during implementation. Short-term impacts would include effects such as direct mortality of individual organisms and temporary but total loss of habitat, as well as indirect impacts such as wildlife disturbance from noise and human activity. Some impacts would also be intermediate in nature; habitat destruction would eventually recover within 2 to 50 years, depending on the type of habitat destroyed.

Habitat defined as "commercial" is assumed to provide no significant habitat value.

Commercial/DOE RU

Removal actions in the Commercial/DOE RU would affect 0.85 ha (2.1 acres) of bottomland hardwood forest habitat in Segments 1, 3, and 9. Construction of access roads and staging areas would result in the additional loss of an estimated 0.02 ha (0.05 acre) of habitat within this RU. Excavation would produce significant short-term effects during implementation because all vegetation would be removed from the areas to be remediated. However, the affected areas would be restored after the contaminated soil was removed and clean backfill soil was placed. Restoration would include grading to original contour, sowing grass, and replanting shrubs and trees as needed. Within ~50 years, the bottomland hardwood forest habitat that was present prior to remediation would reestablish itself through natural ecological succession.

Other RU

Removal actions would be implemented in Segments 4 and 5, which would affect a total of 1.6 ha (4.0 acres) of habitat within this RU. This would include 0.9 ha (2.3 acres) of bottomland hardwood habitat and 0.7 ha (1.7 acres) of old field habitat. Minor percentages of all other

habitats present would be disturbed by removal actions; of the 3.7 ha (9.1 acres) of upland forest habitat present, only 0.04 ha (0.01 acre) is estimated to be affected. Construction of access roads and staging areas would result in the additional loss of ~0.3 ha (0.8 acre) of habitat in this RU. Reestablishment of pasture and old field habitats would require less time than the reestablishment of bottomland hardwood forests. Pasture habitat could be restored in 2 or 3 years, and old field habitat could recover in 2 to 5 years, depending on the species present before remediation.

Residential RU

Removal actions would disturb 3.8 ha (9.4 acres) of bottomland hardwood habitat within this RU. Impacts would occur within Segments 1, 3, 4, 5, 8, and 9, with the majority occurring in Segments 1 and 4. Construction of access roads and staging areas would result in the additional temporary loss of ~0.06 ha (0.14 acre) of habitat in this RU.

Wetlands. A total of 0.90 ha (2.25 acres) in six wetlands would be directly disturbed by remediation under SWA 3. Excavation would affect Wetland 1 in the Commercial/DOE RU, Wetlands 3, 4, 5, and 8 in the Residential RU, and Wetland 7 in the Other RU. Other indirect impacts to wetlands would be expected to occur due to the amount of work adjacent to the wetlands.

Adverse effects at excavated sites would not necessarily be permanent or irreversible. Wetland functions could be successfully restored at excavated wetlands through implementation of a careful mitigation and restoration program based on the original functions and value of each disturbed wetland. Table 5.19 summarizes the wetlands affected by excavation under SWA 3.

Remediation of contaminated soil in wetlands would cause severe short-term and long-term adverse effects to wetland functions, which include floodwater attenuation, contaminant/silt retention, and wildlife habitat. Short-term effects could last as long as a decade; long-term effects would affect wetland functions for decades. The degree to which remediation affects a wetland depends largely on the remediation method selected, the size of the wetland, the portion of the wetland disturbed by remediation, and the original functions of the wetland prior to remediation. Disturbance, whether temporary or permanent, would be mitigated through a comprehensive restoration or creation program. Options for wetlands mitigation are discussed in greater detail in Sect. 5.4, Monitoring and Mitigative Measures.

Threatened and Endangered Species. No impact to protected species would be expected under SWA 3. Excavation along the EFPC floodplain is not expected to have a significant impact on the Tennessee dace because its critical habitat in the headwater regions of tributaries would not be affected. Impacts in the borrow soil or haul road areas would be similar to those described for SWA 2.

Environmental Impacts—Archaeological, Cultural, and Historical Resources

As described in SWA 2, there would be no impact to archaeological, cultural, and historical resources.

Environmental Impacts—Socioeconomic and Institutional Issues

Institutional Considerations. Institutional impacts related to the Commercial/DOE RU would be similar to those described for SWA 2, except that SWA 3 would eliminate all contamination above action levels. Institutional impacts on DOE-owned property would not be substantially different from those described for SWA 2. Only two commercial areas have been identified as having contamination above action levels. This alternative would allow the unrestricted selling, buying, and development of properties on the Commercial/DOE and Other RUs. Institutional mechanisms to release future title holders from liability probably would not be deemed necessary by property owners.

The excavation and disposal actions that would be performed on the Residential RU for SWA 3 are the same as those for SWA 2. Section 5.3.2.5 describes potential impacts for excavation and disposal of Residential soil and recommended mitigative measures.

Public Services and Facilities. Approximately 3800 L/d (1000 gal/d) of decontamination water would be tanked from the City of Oak Ridge under this alternative. Decontamination water would be treated/filtered and recycled for additional use. Decontamination water would be treated at each individual removal site by modular treatment units. Approximately 3040 L/d (800 gal/d) of decontamination water would be sampled and tested [760 L/d (200 gal/d) lost to evaporation]. The remaining water would be containerized and disposed of properly. The amount of public water used would represent an insignificant impact on the City of Oak Ridge water supply. Following testing, if remaining decontamination water was not contaminated, it would be discharged back into EFPC or, potentially, through the Oak Ridge Sewage Treatment Plant.

Disposal of waste soil and debris generated during excavation and vegetation removal would be managed on the ORR. Therefore, local or regional solid waste disposal would not be affected.

Some public facilities would experience short-term impacts during remedial activities under this sitewide alternative. For example, Robertsville Junior High School and the public housing apartments on the opposite side of the creek would probably experience some disturbance of activities and annoyance due to noise. DOE would coordinate with school and Oak Ridge Housing Authority personnel to minimize disruptions to educational and recreational activities, to the extent possible. Because parents and students have expressed minimal concern about the health effects of the contamination, this alternative probably would not appreciably change behavior or attitudes regarding effects on school activities. Close coordination and consultation with school authorities and the Oak Ridge Housing Authority would be required to mitigate impacts.

Excavation and disposal would enable the YWCA to proceed with development of the 0.8 ha (2 acres) abutting EFPC (which are contaminated above action levels) with reduced impacts on future liability. Thus, the public services provided to the community by the YWCA would be expanded.

Impacts on emergency response services would be expected to be minimal because potential accidents or incidents are fully within existing local capabilities.

Economic and Demographic Resources. Employment resource impacts are estimated using RIMS II for Anderson and Roane counties developed by the Bureau of Economic Analysis. Employment estimates form the basis for the calculation of associated changes in the number of households and population. For a description of this modeling framework, see Appendix E.

Remediation activities are assumed to take place in the first 2 years. In each of those years, it is estimated that the remediation would require 35.2 FTEs for construction activities, 35.2 for administrative support, and a crew of five for continuous sampling and monitoring activities. Average annual wages and salaries plus other income to households for land and relocation costs are estimated to be $3.0 million per year, with expenditures for equipment and materials at $7.0 million per year and associated expenditures for other business services at $14.5 million per year. The direct spending associated with the project that would go to local businesses and households is estimated to result in indirect employment of an additional 55.0 FTEs, for a total employment increase of 130.4 in each of the 2 years. This represents 0.2% of the 63,317 people employed in Anderson and Roane counties in 1990 (see Table 2.14). The upper bound on the number of households created by this increase in employment is 97, or nearly 0.2% of the 49,657 housing units in the two counties in 1990 (see Table 2.12). The associated population estimated consistent with the employment and housing impacts is 245 or 0.2% of the 115,477 people living in Anderson and Roane counties in 1990 (see Table 2.11). These changes are so small relative to the totals for the region of influence that this alternative should not result in adverse impacts to the economic and demographic conditions in Anderson and Roane counties.

Routine monitoring activities are assumed to take place during years 3 to 6, 8 to 11, 13 to 16, 18 to 21, 23 to 26, and 28 to 30. It is estimated that direct wages and salaries for the 0.2 FTEs required for sampling and reporting would be $7000 per year; other expenses are estimated to be $43,000. No capital expenditures are estimated during these years. Using RIMS II, it is estimated that this activity would generate 0.1 additional FTEs, for a total employment effect of 0.3. This employment effect is so small that there are no associated changes calculated for the number or households or population.

More extensive monitoring and sampling are assumed to be conducted at 5-year intervals, in years 8, 13, 18, 23, and 28. During these years, direct employment would be increased to 0.5 FTEs. Using RIMS II, the associated secondary employment is 0.1 FTEs, for a total employment increase of 0.6 FTEs. As reported during the routine monitoring years for this alternative, no associated changes are calculated for the number of households or population.

Transportation Impacts. Impacts would occur along designated routes in each EFPC RU and along routes to the borrow site(s) and disposal facility (see Table 2.18).

Site preparation activities (i.e., vegetation removal and construction of access roads and staging/decontamination areas) would require the transport of an estimated 600 m^3 (800 yd^3) of woody debris to a construction landfill located on the ORR and an estimated 4100 m^3 (5400 yd^3) (~450 loads) of gravel from a commercial vendor. Removal actions under this alternative would

require the transport of large volumes of contaminated soil from the EFPC floodplain to a disposal facility located at the Y-12 Plant. Approximately the same ex situ volume of borrow soil [~49,500 m^3 (64,800 yd^3)] would be transported from the borrow site(s) back to the EFPC floodplain for use as backfill in the remediated areas. Because on-site borrow areas of soil are available within the West End Borrow Area on the ORR, transportation impacts could be minimized by using roads that are normally restricted to the public. Approximately 10,800 truckloads would be required. Transportation would be affected in each segment and RU in the EFPC floodplain, with the majority of the impacts occurring in the vicinity of Segments 1 and 4 in the Residential RU.

Environmental Impacts—Unavoidable Adverse Impacts

A total in situ volume of 41,400 m^3 (54,000 yd^3) of contaminated soil would be excavated; a similar volume of clean borrow soil would be required for backfill. Aquatic resources would be affected by the temporary conversion of riparian habitat types. Riparian bottomland hardwood would be subjected to the most disturbance with a loss of nearly 3041 m (3227 yd) out of 40,947 m (44,780 yd), which would be about 7% of the total of this habitat type. The most significant disturbance of terrestrial habitats would be to bottomland hardwoods, with an affected area of 5.6 ha (13.8 acres), representing a 5% loss of this habitat type. A total of 0.90 ha (2.25 acres) in six wetlands would be directly disturbed by remediation. Transportation risks to the community would result in 0.4 accidental injury and 0.02 fatality.

Environmental Impacts—Short-Term Uses and Long-Term Productivity

Because the contaminated soil would be removed from all RUs, property owners would be able to use their property any way they prefer. Long-term productivity would not be affected for future uses.

5.3.3.6 Implementability

SWA 3 is considered an implementable alternative. The total in situ volume of contaminated soil to be removed and disposed would be ~41,400 m^3 (54,000 yd^3). The amount of borrow backfill material would be comparable to the amount of material excavated. Excavation could disrupt business at some commercial locations. Excavation of contaminated soil on DOE properties would not present specific implementability problems.

The modification of the Landfill VII disposal facility would be necessary to meet regulatory requirements to dispose of this type of waste. Delays in obtaining approvals to site and construct the new disposal facility could affect the implementation of this alternative.

No further remedial actions would be required under SWA 3. At the completion of remediation, the floodplain soil would not be considered a risk to human health or the environment.

5.3.3.7 Cost

Total capital cost for the site under this alternative is $42 million. Operation and maintenance costs are estimated to be:

Years	Cost (× $1000)
1 to 2	3346
3 to 30	100
5-year periodic	100

The total cost to complete this action would be ~$52 million in 1993 dollars with no escalation or discount. Appendix D provides the methodology and basis for the +50%, -30% cost estimate.

5.3.3.8 State acceptance

To be provided after receipt of comments.

5.3.3.9 Community acceptance

To be provided after receipt of comments.

5.3.4 Description and Summary of Evaluation of Sitewide Alternative 4 (SWA 4)

Description

SWA 4 would involve the excavation and treatment of soil contaminated with >180 ppm of mercury on the Residential RU [~25,100 m^3 (32,800 yd^3)] and placement of the treated soil in the excavated areas of the floodplain. Low-temperature thermal desorption would be used to treat the soil. Containment and institutional actions would include a soil cover where soil contamination was >200 ppm of mercury on the Commercial/DOE and Other RUs. Total surface area contained would be 0.05 ha (0.12 acre) for Commercial property, 0.81 ha (2.02 acres) for DOE property, and 1.64 ha (4.05 acres) for Other property. Institutional actions would be implemented for the Surface Water/Sediment RU. General action descriptions are provided in Sect. 5.2.

Summary of Evaluation

SWA 4 would protect human health and the environment in the long term by either covering or excavating and treating contaminated soil. Projected risks of chemical exposure to children and adults in the community from contaminated dust and mercury vapors generated during soil handling and treatment under SWA 4 would be below (HI < 1) the EPA target for noncancer effects. Physical hazards for the community would be limited to transportation risk outside the RUs since the community would be excluded from the remediation area. Risks to the community are projected to result in 0.2 injury and 0.01 fatality. A health and safety plan would address mitigative measures (e.g., engineering controls, personal protective equipment) to ensure that the

EPA target would not be exceeded. Transportation risks to workers are calculated to cause 0.007 worker injury and 0.004 worker fatality. In addition, construction risks to workers are estimated at 5.8 injuries and 0.04 fatality. Thus, the total risks for SWA 4 would be expected to cause ~6 injuries and <0.1 fatality. For ecological receptors, the most significant impact (from containment) would be the permanent conversion of 1.8 ha (4.4 acres) of bottomland hardwood habitat and the permanent alteration of 1367 m (1495 yd) of riparian zones as a result of bank stabilization actions. Short-term impacts would include direct mortality of individual ecological receptors in the remediation area. A total of 0.90 ha (2.25 acres) of wetlands would be adversely affected by remedial actions. The estimated total cost of implementing this alternative would be $59 million.

Impacts resulting from the implementation of SWA 4 would be similar to those discussed under SWA 2. However, different or additional impacts could result from the use of the low-temperature thermal desorption and beneficial reuse of the treated soil. To avoid redundancy, discussion of impacts that are the same as those under SWA 2 are not repeated here. Only those impacts that are different from or additional to SWA 2 are discussed below under the appropriate criteria.

5.3.4.1 Overall protection of human health and the environment

This alternative would protect human health and the environment in the long term. In the short term, risks to workers, the public, and ecological receptors would increase during implementation at the Residential RU because of the quantity of contaminated material being processed (excavated, transported, and treated). Potential long-term impacts could occur to aquatic habitats and organisms due to leaching of soil amendments from the treated soil. Short-term risks to unprotected workers from chemical exposure would exceed (HI > 1) EPA targets for noncancer effects. Community risks from excavation on the Residential RU would be below the EPA target for noncancer effects. A health and safety plan would address mitigative measures, which could include engineering controls to reduce dust (e.g., covering trucks and wetting soil as needed) and worker use of personal protective equipment to reduce exposures and thereby reduce risk to below target levels. Transportation and construction accidents for the worker are projected to result in <1 (0.1) total worker fatality for this alternative. Community transportation accidents are projected to cause <1 (0.01) fatality. To protect workers and the community from chemical risks during operation of the low-temperature thermal desorption, it is possible to design the low-temperature thermal desorption unit so that stack emissions cause exposure risks below (HI < 1) the EPA target (see Appendix F and Air Quality under Sect. 5.3.4.5).

5.3.4.2 Compliance with ARARs

There is no indication of RCRA-listed or -characteristic waste, so none of the RCRA regulations governing treatment are applicable to the waste from EFPC. However, since the intent of CERCLA is to protect human health and the environment, portions of the RCRA treatment standards [TDEC 1200-1-11-.06(19)(b)] that specify design and operating requirements for hazardous waste treatment units could be relevant and appropriate. SWA 4 would be designed to comply with these regulations. Soil containing mercury at levels exceeding the remediation goal options would be transported to the K-25 Site and treated by low-temperature thermal desorption. Off-gas and other residual waste streams from the treatment process that

contain concentrated mercury would be collected and managed as required based on an analysis of the waste.

The TDEC Division of Air Pollution Control requires construction and operating permits for new air contaminant sources (TDEC Rules, Chapter 1200-3-9-.01 and 1200-3-9-.02, respectively). According to TDEC Rules 1200-3-9-.04 (4), "no facility processing materials containing lead, beryllium, asbestos, mercury or any other pollutants named in rule 1200-3-11 shall be exempt" from permitting requirements. Although permits are not required for CERCLA response actions, the substantive requirements of the Division of Air Pollution Control regulations would be applicable for potential releases of hazardous pollutants (mercury) from the low-temperature thermal desorption process. Potential emissions rates should be estimated and the appropriate permit applications should be submitted for Division of Air Pollution Control approval. SWA 4 would comply with these regulations.

In addition, compliance with the NESHAPs rule that limits emissions of radionuclides to the ambient air from DOE facilities to amounts that would not cause any member of the public to receive an effective dose equivalent of 10 mrem/year (40 CFR 61.92) is applicable for emissions from the low-temperature thermal desorption unit and would be complied with.

Treatment residuals would be analyzed to determine whether they are RCRA hazardous waste, low-level waste, or a mixed waste. Based on the results of this analysis, the residuals would be disposed of according to standard DOE waste management policies and procedures. If the residual materials from treatment fail the TCLP test, compliance with the RCRA land disposal restrictions would be required. Disposal at a RCRA Subtitle C permitted facility would occur, if required.

Provided the treated soil does not contain contaminants above health-based levels, it would be transported by truck from the treatment unit to the EFPC floodplain for beneficial reuse as backfill in excavated areas. ARARs cited for general response activities would apply to this action (i.e., control of fugitive dust emissions, waste pile storage requirements, etc.) and are listed in Table C.4. There would be no further ARARs for the beneficial reuse scenario.

5.3.4.3 Long-term effectiveness and permanence

The excavation and treatment of contaminated soil and beneficial reuse of treated soil from the Residential RU would be effective in the long-term because no contamination above the 180-ppm human health remediation goal option would remain. Containment and institutional actions proposed for the Commercial/DOE and the Other RUs would be effective in reducing the risk of exposure to the contaminants by eliminating inhalation, ingestion, and dermal exposure pathways and should remain effective as long as the covers are properly maintained. Because this action would leave contaminants on site, environmental monitoring and 5-year reviews would be conducted to assess whether the remedy continued to provide adequate protection of human health and the environment. Workers engaged in periodic monitoring would be assumed to do so under an approved health and safety plan designed to protect workers from contact with contaminated materials.

Irreversible and Irretrievable Commitment of Resources

The low-temperature thermal desorption treatment process would require the use of natural gas as a heat source. Other ancillary materials for low-temperature thermal desorption operation (water, filters, nitrogen gas) would also be required. Some of these materials (e.g., filters) would become contaminated with use and would require disposal. Removed contaminants and any residual soil would also require disposal. The beneficial reuse of treated soil to backfill the floodplain excavations would eliminate the need for borrow soil for this remedial action, with the exception of ~1500 m^3 (2000 yd^3) of borrow soil that would need to be added to the treated soil to restore the anticipated losses from the treatment process. Containment actions would require the use of 14,800 m^3 (19,400 yd^3) of ex situ borrow soil for cover construction.

An estimated total of 169,000 L (44,700 gal) of diesel fuel would be consumed by trucks and heavy equipment in the performance of these remedial actions. Additional petroleum products would be consumed in the form of gasoline, lubricating oils, and greases.

5.3.4.4 Reduction of toxicity, mobility, or volume through treatment

The SWA 4 treatment option, low-temperature thermal desorption, would reduce the concentration of mercury in treated soil to below action levels. Pilot-scale testing was performed to identify performance standards and achievable levels of mercury removal and to define the constituents and characteristics of the waste stream(s) that would be generated. Concentrations of organics would also be reduced, but no reductions in the concentrations of PCBs, other heavy metals, or radionuclides would be expected. The volume of soil after treatment would be an estimated 28,500 m^3 (37,400 yd^3). The mercury that was removed during treatment would be collected in the air pollution control equipment and recycled or disposed of as necessary. The soil currently is below RCRA TCLP limits.

5.3.4.5 Short-term effectiveness and environmental impacts

This section evaluates the short-term effectiveness of SWA 4 by considering protection of the community and workers during remedial actions at EFPC; residual risks to human receptors at the site are discussed under Sect. 5.3.4.3, Long-term effectiveness and permanence. Short-term and long-term environmental impacts are also addressed in this section. Impacts within the RUs vary and, therefore, are presented by RU. A summary of the impacts for SWA 4 is provided at the end of each subsection. Additional information concerning the methodology used in the human health risk evaluation is presented in Appendix F.

Community Protection

Chemical Exposures. SWA 4 considers containment and institutional actions in the Commercial/DOE and Other RUs. The soil within the RUs would be covered with clean borrow soil, and exposures related to containment would be limited to those occurring within an RU. Because this sitewide alternative does not include excavation, soil migration exposures to the community outside the RUs is considered unlikely. In addition, because members of the community would not be allowed within the RUs during remediation, no community exposures related to remedial activities are expected for Commercial/DOE and Other RUs.

SWA 4 includes the excavation, treatment, and beneficial reuse of soil exceeding remediation goal options for the Residential RU. Projected exposures to the community result from inhalation of mercury vapor (emitted from the low-temperature thermal desorption unit) and contaminants in respirable airborne dust transported downwind to existing nearby residences. Chemical hazards would not be associated with treated soil, so risks to the community from exposure to treated soil are not evaluated.

Tables 5.20 and 5.22 present short-term risks to the community (adults and children) associated with soil removal and treatment activities. All risks to the community at EFPC under SWA 4 are below the EPA target for noncancer effects in humans.

Physical Hazards. The total projected transportation risks to implement SWA 4 are calculated to be 0.2 injury and 0.01 fatality (see Appendix F). These transportation risk estimates are for nonoccupational (community) injuries and fatalities. Under SWA 4, ~264,000 km (165,000 miles) would be traveled by trucks carrying both contaminated and clean borrow soil.

Remediation Worker Protection

Chemical Exposures. Risks of exposure to contaminants would be likely for workers in close proximity with surficial soil when preparing the site for containment for the Commercial/DOE and Other RUs. These activities, however, would not distu underlying soil and thus would not be likely to generate dust and cause migration of cor nants outside the RU. Table 5.21 shows risks for workers conducting containment vities in the Commercial/DOE and Other RUs. These RUs exist in five EFPC segments (Segments 1, 3, 4, 5, and 9). Noncancer risks for unprotected workers (no personal protective equipment or health and safety precautions) would exceed the EPA target for noncancer effects only for the soil ingestion pathway. The dermal and inhalation risks all would be below the EPA target for human health effects. Cancer risks from exposure to mercury are not estimated because mercury is not considered to be a human carcinogen.

Evaluation of the excavation activities planned for the Residential RU under this alternative includes potential exposure to contaminants in soil for workers by means of ingestion, dermal contact, dust inhalation, and exposure to mercury vapors in air emitted from the low-temperature thermal desorption unit. As shown in Table 5.20, risks related to excavation activities for unprotected workers (no personal protective equipment or other health and safety precautions) under SWA 4 would exceed (HI >1) the EPA target for noncancer effects, but only for worker soil ingestion. Dermal contact and inhalation noncancer risks would be below (HI <1) the EPA target.

Risks to unprotected workers associated with soil treatment at the K-25 Site (Table 5.22) also would exceed the EPA noncancer target for soil ingestion. The risks for the worker dermal exposure route and inhalation would be below the EPA target.

A project health and safety plan would be developed for site activities and the required mitigative measures to protect worker health and safety would be addressed to ensure worker exposures do not exceed acceptable EPA target levels.

Physical Hazards. Risks associated with construction activities (see Appendix F) are based on a labor estimate of 87,000 man-hours. Under these assumptions, 5.8 worker injuries and <1 (0.04) fatality are expected over the 1.7-year duration of the remedial activities. This corresponds to a projected annual incidence rate of 3.2 worker injuries and <1 (0.02) worker fatality. Occupational (truck driver) transportation risks were calculated to be 0.007 injury and 0.004 fatality (see Appendix F).

Time Until Action is Completed

Estimated time to complete this action is 1.7 years, the short-term remedial action objectives would be achieved upon completion of actions. After approval by the regulatory agencies, the actual time to complete this alternative would include ~12 to 18 months for remedial design and the associated approval of the remedial action work plan prior to commencing the remedial action. Therefore, after final regulatory approval of the Record of Decision, it would take ~3 to 5 years to complete the action, not including long-term environmental monitoring.

Environmental Impacts—Soil and Floodplain

Soil. A total of ~25,100 m^3 (32,800 yd^3) of contaminated in situ soil would be excavated, treated, and returned to the Residential RU. Treated soil would receive additions of agricultural lime, fertilizers, organic materials, and other soil amendments, as needed, before being used as backfill. These areas would then be regraded and revegetated. Approximately 1500 m^3 (2000 yd^3) of ex situ borrow soil would also be added to treated soil to restore anticipated losses from the treatment process. The use of treated EFPC floodplain soil in SWA 4 likely would be less disruptive to the soil regime than if borrow soil were to be used for backfill. Excavation would cause severe short-term impacts (<10 years), but these effects could be mitigated by implementation of a comprehensive reclamation and revegetation program. Approximately 14,800 m^3 (19,400 yd^3) of ex situ borrow soil would be needed to contain contaminated areas in the Commercial/DOE and Other RUs. Impacts from excavation, containment, and mitigative measures are discussed under SWA 2.

Floodplain. The impacts to the floodplain would be the same as those discussed for SWA 2.

Environmental Impacts—Water Quality

Surface Water. The treatment and beneficial reuse of excavated soil could affect surface water, depending on the design of the low-temperature thermal desorption facility and application methods for beneficial reuse. Best Management Practices including proper engineering controls would minimize the potential for contaminant releases from the low-temperature thermal desorption unit and its support facilities. Soil amendments (e.g., fertilizers) could be released to surface water from treated soil, depending on the properties of the treated soil and application methods. Again, proper use of soil amendments and engineering controls would minimize the potential for releases that could degrade water quality. Additionally, any potential impacts to surface water that could have resulted from the development of a borrow area would be eliminated by the beneficial reuse of treated soil.

Environmental Impacts—Air Quality

Air quality impacts from construction of the containment cover would result from soil disturbances such as haul road traffic, loading, grading, and dumping and from associated internal combustion engine emissions from heavy equipment operation. Impacts from these activities would involve short-term exposure to airborne contaminants during the removal of vegetation, grading, and any other surface preparations for cover construction. Controlled emissions from grading activities are estimated at 0.007 kg/h and would not be a significant health risk to workers or the community if dust suppression control measures were taken. Emissions from heavy equipment operation (i.e., fuel combustion) would be negligible and would not significantly impact local or regional air quality.

Excavation and handling of untreated soil would be a significant air pathway to potential receptors. Excavation operations such as loading, dumping, grading, excavating, and haul road traffic would cause excessive concentrations of contaminated dust if not properly controlled. Storage piles of untreated soil and large areas of bare soil could also serve as significant sources of fugitive dust emissions. Control methods, such as wetting haul roads, haul road speed limits, and limiting the number of exposed storage piles, would significantly lower emissions from these activities. Human health risk studies have shown that off-site risk from controlled fugitive dust emissions from excavation and soil handling activities and from mercury vapor emissions from the low-temperature thermal desorption unit would be within acceptable limits. Worker health risk on site would result from inhalation of fugitive dust emissions from excavation and soil handling activities, inhalation of mercury vapor emissions from the low-temperature thermal desorption unit, and from ingestion of and dermal contact with soil. Mitigative measures would be taken to maintain acceptable health risk levels to on-site workers.

An analysis was conducted to determine whether operation of the proposed low-temperature thermal desorption unit would pose risks to workers and/or the community in excess of the EPA target (HI of 1.0 for noncarcinogens). The low-temperature thermal desorption unit is not a currently existing structure. Therefore, risks projected in this analysis are hypothetical and are dependent on the assumptions used in the evaluation (see Appendix F).

As mentioned above, emissions of mercury vapor from the low-temperature thermal desorption unit are directly related to a number of assumptions regarding operation of the system. The key variables in this analysis include:

- the concentration of mercury in the soil,
- the soil feed rate to the low-temperature thermal desorption unit,
- the efficiency of the low-temperature thermal desorption unit in volatilizing mercury from the soil,
- the efficiency of the air pollution control system for the low-temperature thermal desorption unit,

- the dimensions of the stack (i.e., the height and diameter), and

- the distance from the stack to the receptor.

Initially, results of bench-scale tests and professional judgment were used to delineate operating characteristics and engineering design specifications needed to model emission rates and dispersion. This analysis was conducted for each segment using the 95% UCL concentration for mercury in soil. For the stack dimensions, a sensitivity analysis was conducted using varying combinations of stack heights and diameters and calculating corresponding HIs. In addition, distance to the receptor was set at the point at which the concentration of mercury vapor would be the greatest. Appendix F discusses the results of the sensitivity analysis. With the anticipated levels of contamination, an optimal permutation from the sensitivity analysis suggested that a stack height of 10.7 m (35.1 ft) or higher and an inside diameter of 0.2 m (0.66 ft) would minimize risks from mercury exposure. Many other permutations are possible. Soil with higher levels of contamination could require pretreatment (e.g., soil dilution with less or uncontaminated soil). It is therefore possible to design the low-temperature thermal desorption unit in such a way that worker exposures to the stack emissions would fall below (HI < 1) the EPA target.

Environmental Impacts—Ecological Resources

Aquatic Resources. The types and magnitudes of long- and short-term impacts to aquatic biota and habitats in the Commercial/DOE and Other RUs in EFPC from implementing SWA 4 should be similar to those described in SWA 2 (Sect. 5.3.2.5) because the remedial actions are identical for both sitewide alternatives. Long- and short-term impacts to aquatic biota and habitats in the Residential RU are expected to be at least comparable to those described for SWA 2 (Sect. 5.3.2.5), with potential additional long-term impacts that could occur from use of the treated and amended soil for soil restoration after treatment. Depending on the types and amounts of amendments necessary for soil restoration after treatment, nutrients or other additives could enter the stream by means of surface runoff. These mobilized soil amendments could ultimately result in high biological oxygen demand, short-term toxic water conditions, or other imbalances within the chemical and/or biological components of the stream. The proper use of soil amendments and engineering controls would minimize the potential for releases that could degrade water quality and affect aquatic resources. Additionally, potential impacts to the aquatic resources of EFPC or another stream that could have resulted from the development of a borrow area would be eliminated by the beneficial reuse of treated soil.

Terrestrial Resources. Impacts to terrestrial resources from implementing SWA 4 should be similar to those described in SWA 2 (Sect. 5.3.2.5). Significant potential negative impacts would result from the low-temperature thermal desorption treatment of soil. These impacts would include the loss of all soil fauna (micro- and macro-) as well as the loss of some soil nutrients and organic matter. However, certain practices would be used to mitigate these losses. Before the treated soil was replaced in the floodplain excavations, it would be amended for nutrient content. Additives would be based on soil analysis both before and after treatment. Once in place, organic material (probably in the form of wood chips) would be mechanically incorporated into the soil. A native topsoil used as final cover would provide a source of microscopic and larger soil fauna, enhancing the reestablishment of vegetation on these sites.

Wetlands. Under SWA 4, 0.90 ha (2.25 acres) in Wetlands 1, 3, 4, 5, 7, and 8 would be directly disturbed by excavation and containment. Approximately 0.44 ha (1.11 acres) would be directly disturbed by excavation in the Residential RU. Other indirect impacts to wetlands (e.g., changes in some surface water flow because of access road construction) could occur from remedial activities adjacent to wetlands.

Containment within wetlands would alter hydrological conditions and would cause a permanent disruption of wetland functions and values. Because containment would permanently change topography, it would not be possible to restore the loss of those functions at that wetland in the future. Wetland 1 on DOE property in Segment 1 and Wetland 7 in the Other RU in Segment 4 would be affected by containment. About 0.46 ha (1.14 acres) of disturbance in two wetlands would result from containment actions in the Commercial/DOE and Other RUs.

Threatened and Endangered Species. No impact to protected species would be expected under SWA 4. Excavation and containment along the EFPC floodplain is not expected to have a significant impact on the Tennessee dace because its critical habitat in the headwater regions of tributaries would not be affected. Impacts in the borrow soil or haul road areas would be similar to those described for SWA 2.

Environmental Impacts—Archaeological, Cultural, and Historical Resources

As described in SWA 2, there would be no impact to archaeological, cultural, and historical resources.

Environmental Impacts—Socioeconomic and Institutional Issues

The following sections describe potential impacts of SWA 4 on the institutional environment and on public services and facilities. Section 2.1.7.1 describes the existing institutional environment, methods used for analysis, and a listing of identified stakeholder groups.

Institutional Considerations. SWA 4 would result in net adverse impacts to the institutional environment. The actions to be performed for EFPC Commercial/DOE and Other RUs are similar to those for SWA 2. Section 5.3.2.5 describes institutional impacts related to these RUs.

Excavation, treatment, and beneficial reuse actions would be performed on the Residential RU under SWA 4. As described in Sect. 5.3.2.5 with regard to excavation and disposal of contaminated floodplain soil on the Residential RU, excavation activities would result in short-term impacts on residents in the form of disturbances and disruptions to their property, loss of valued vegetation, and inconveniences and annoyance. A significant number of residents may consider excavation to be an overly costly measure in the absence of clearcut threats to health and safety. For these residents, short-term impacts in the form of inconvenience and annoyance due to traffic, noise, and dust would be intensified. The relatively high cost of SWA 4 reduces the likelihood that the community would prefer this option.

Unlike excavation and disposal activities, treated soil rather than clean borrow soil would be used to fill excavated areas. Some potential problems must be considered with regard to beneficial reuse of soil on the Residential RU. First, questions may linger concerning any residual mercury in the soil and remaining levels of contaminants other than mercury that may

not have been destroyed in the treatment process. Impacts on the institutional environment could result from actual or perceived health risks associated with the treated soil used on residential and/or agricultural properties, particularly if standards for acceptable levels of these contaminants should become more conservative in the future. The soil would not be in situations that could be readily monitored, controlled and, if necessary, retrieved. Second, liability issues related to buying, selling, and financing property could resurface. A third potential impact could result from the treated soil itself, depending on the effectiveness of biological enhancement. The soil could be perceived as undesirable for use in lawns, landscaping, and agricultural areas.

The treatment process itself could contribute to institutional impacts and impacts on the quality of life of residents located near the treatment facility. As described in Sect. 2.1.7.1, the City of Oak Ridge and residents of Roane County have expressed concern regarding multiple thermal sources of air emissions from waste processing in and near the Oak Ridge area. Potential impacts on both Oak Ridge and Roane County residents include cumulative stigmatizing effects on community identity. Roane County residents, particularly those living near the Gallaher Road area, could be expected to experience heightened awareness and concern about the possible health effects of combined emissions, the equity of the distribution of waste processing facilities, and the long-term outlook for industrial development in that area of Roane County. Stakeholder groups from either Oak Ridge or Roane County could be expected to increase pressure on institutional leaders to monitor emissions and to avoid further development of thermal source facilities.

Public Services and Facilities. Approximately 3800 L/d (1000 gal/d) of decontamination water would be tanked from Oak Ridge under this alternative. Decontamination water would be treated/filtered and recycled. Decontamination water for the transport trucks would be treated at each individual removal site by modular treatment units. Approximately 3040 L/d (800 gal/d) of decontamination water would be sampled and tested [760 L/d (200 gal/d) lost to evaporation]. The remaining water would be containerized and disposed of properly. The daily water supply for the low-temperature thermal desorption unit is assumed to be ~1900 L/d (500 gal/d). It is assumed that the condensed process water would not contain radionuclides and could be recycled after treatment to re-wet the soil for easier handling. The amount of public water used would represent an insignificant impact on the City of Oak Ridge water supply. Following testing, if the remaining decontamination water were not contaminated, it would be discharged back into EFPC or, potentially, through the Oak Ridge Sewage Treatment Plant.

Noncontaminated soil and debris generated during excavation and vegetation removal would be disposed of on the ORR or returned to the floodplain. Excess vegetative cover could be disposed of at an approved construction landfill. Therefore, a slight impact on local or regional solid waste disposal would occur.

Some public facilities would experience short-term impacts during remedial activities under this alternative. For example, Robertsville Junior High School and the public housing apartments on the opposite side of the creek would likely experience some disturbance of activities and annoyance due to noise and traffic. DOE would coordinate with school and Oak Ridge Housing Authority personnel to minimize disruptions to educational and recreational activities to the extent possible. Because parents and students have expressed minimal concern about the health effects of the contamination, this alternative probably would not appreciably change behavior and/or attitudes regarding effects on school activities.

Excavation required in the floodplain adjacent to Hopkins-Strang Ball Park would not be expected to significantly affect recreational activities at those sites because the play areas are well away from the creek. However, coordination with the City Recreation Department would be advised to avoid truck traffic in the area while children could be present.

Impacts on emergency response services would be expected to be minimal because potential accidents or incidents are fully within existing local capabilities.

The portion of the SLB from Illinois Avenue to the Oak Ridge Sewage Treatment Plant is within the EFPC floodplain. Precautions would be necessary to avoid damaging the utility line during excavation activities. Standard practices would require coordination with the City of Oak Ridge Public Works department to ensure that care was exercised in operating heaving equipment near the utility.

The low-temperature thermal desorption would be supplied by natural gas and is assumed to burn 304 L (10.7 ft^3) of natural gas per hour.

Economic and Demographic Resources. Employment resource impacts are estimated using RIMS II for Anderson and Roane counties developed by the Bureau of Economic Analysis. Employment estimates form the basis for the calculation of associated changes in the number of households and population. For a description of this modeling framework, see Appendix E.

Remediation activities are assumed to take place in the first 2 years. In those years, it is estimated that the remediation would require 24.2 FTEs for construction activities, 12 people in a treatment crew, 24.2 for administrative support, and a crew of five for continuous sampling and monitoring activities. Average annual wages and salaries plus land and relocation costs are estimated to be $2.6 million, with expenditures for equipment and materials at $4.2 million and associated expenditures for other business services at $21.0 million. The direct spending associated with the project that would go to local businesses and households is estimated to result in indirect employment of an additional 40.0 FTEs, for a total employment increase of 105.4. This represents 0.2% of the 63,317 people employed in Anderson and Roane counties in 1990 (see Table 2.14). The upper bound on the number of households created by this increase in employment is 79 or 0.2% of the 49,657 housing units in the two counties in 1990 (see Table 2.12). The associated population estimated consistent with the employment and housing impacts is 200, or 0.2% of the 15,477 people living in Anderson and Roane counties in 1990 (see Table 2.11). These changes are so small relative to the totals for the region of influence that this alternative should not result in adverse impacts to the economic and demographic conditions in Anderson and Roane counties.

Routine monitoring activities are assumed to take place during years 3 to 6, 8 to 11, 13 to 16, 18 to 21, 23 to 26, and 28 to 30. It is estimated that direct wages and salaries for the 0.3 FTEs required for sampling and reporting would be $10,500 per year; other expenses are estimated to be $89,500. No capital expenditures are estimated during these years. Using RIMS II, it is estimated that this activity would generate 0.1 additional FTEs, for a total employment effect of 0.4. This employment effect is so small that there are no associated changes calculated for the number or households or population.

More extensive monitoring and sampling are assumed to be conducted at 5-year intervals, in years 7, 12, 17, 22, and 27. During these years, direct employment is to be increased to 0.8 FTEs. Using RIMS II, the associated secondary employment is 0.2 FTEs, for a total employment increase of one person. The number of new households associated with this growth is estimated to be one, and the population increase is estimated to be three. These values are so small relative to the size of the region that there should be no adverse impact on the economic and demographic conditions in Anderson and Roane counties.

Transportation Impacts. Remedial actions under this alternative would require the transport of large volumes of contaminated soil to the low-temperature thermal desorption treatment facility located at the K-25 Site. Approximately the same volume of treated soil would be transported from K-25 Site back to the EFPC floodplain for use as backfill in the remediated areas. Approximately 8200 truckloads would be required to transport contaminated and borrow soil. Transportation impacts would occur in each segment and RU of the EFPC floodplain, with the majority of the impacts occurring in the vicinity of Segments 1 and 4 in the Residential RU.

Transportation impacts would be minimized by cooperation with local and state authorities to determine the most appropriate haul routes and trip times to reduce traffic congestion, accident potential, and road deterioration. Since the location of the low-temperature thermal desorption treatment facility would be on the K-25 Site, and the location of the borrow site would be on the ORR, transportation impacts possibly could be minimized by using roads that are normally restricted to public access.

Noise Impacts. Sound levels that would be generated during the operation of the low-temperature thermal desorption treatment facility would not be expected to exceed the OSHA standard for an 8-h workday average of 90 dB, nor would anticipated noise levels from individual pieces of equipment exceed OSHA standards for short-term exposure.

Environmental Impacts—Unavoidable Adverse Impacts

The only additional unavoidable adverse impacts from SWA 4 compared with SWA 2 would result from the low-temperature thermal desorption treatment of contaminated soil. These impacts would involve the loss of all soil fauna as well as the loss of some soil nutrients and organic matter. However, certain practices such as the addition of nutrients and organic matter would be used to mitigate these losses before the treated soil was used for backfill material.

Environmental Impacts—Short-Term Uses and Long-Term Productivity

Short-term uses of Commercial/DOE, Other, and Residential properties would be affected by SWA 4, but the Residential RU would be free of most constraints in the long term. Short-term impacts for excavation and transportation of the soil are discussed in Sect. 5.3.3.5 for SWA 3. Short-term impacts from implementing treatment operations and returning the treated soil to the floodplain would increase the amount of short-term disturbances to local roadways.

The long-term use of the Commercial/DOE and Other property would be affected because the contamination would remain in place and therefore would limit the future use of these properties to nonresidential and nonagricultural uses.

5.3.4.6 Implementability

SWA 4 is considered to be implementable. Implementability concerns for SWA 4 would be the same as those discussed in Sect. 5.3.2.6 for excavation and containment. However, treated soil would be used in a beneficial manner (returned to the floodplain for backfill) and would not require disposal. Other implementability concerns discussed in SWA 2 are applicable to SWA 4.

Treatment of contaminated EFPC soil by low-temperature thermal desorption is considered to be an implementable treatment technology. Bench- and pilot-scale tests have successfully reduced mercury concentrations in EFPC soil by >99.5% by weight (Radian 1993b). With regular maintenance the unit should be able to operate on a 24-h schedule for the length of the remedial action. Thermal desorption would not prevent further remedial actions from being implemented. Posttreatment sampling would determine the effectiveness of the desorption unit at removing the contaminant from the soil. Use of wet scrubbers in the low-temperature thermal desorption treatment process has been shown to produce waste streams potentially equivalent in quantity to the amount of soil treated (IT 1994). These waste streams would require dewatering, solidification, and disposal according to ARARs.

Under a CERCLA action, the thermal desorption unit would not require an air permit (IT 1994). However, operation of the low-temperature thermal desorption unit would be required to meet the substantive requirements of TDEC Office of Air Pollution Control Rules. Pilot-plant testing determined that the air pollution control system is capable of removal efficiencies approaching 99.99% (IT 1994). Material and technology are available to construct additional units if required to treat the soil at the needed rate.

Beneficial reuse of the treated soil would be implementable but would require evaluation and approval by TDEC. Enhancement of the treated soil to an acceptable mixture for vegetative growth would be implementable based on testing of the soil after treatment. Fertilizers would be added to the soil as needed.

5.3.4.7 Cost

Total capital cost for the site under this alternative is $35 million. Operation and maintenance costs, including the treatment costs, are estimated to be:

Years	Cost (× $1000)
1-2	10,184
3 to 30	100
5-year periodic	150

The total cost to complete this action in 1993 dollars is ~$59 million with no escalation or discount. Appendix D provides the cost basis and methodology used to calculate the +50%, -30% cost estimate.

5.3.4.8 State acceptance

To be provided after receipt of comments.

5.3.4.9 Community acceptance

To be provided after receipt of comments.

5.3.5 Description and Summary of Evaluation of Sitewide Alternative 5 (SWA 5)

Description

SWA 5 involves the excavation and treatment of soil contaminated with >180 ppm of mercury on the Residential RU [~25,100 m^3 (32,800 yd^3)] and >200 ppm of mercury on the Commercial [~400 m^3 (500 yd^3)], DOE [~6500 m^3 (8500 yd^3)], and Other [~9400 m^3 (12,200 yd^3)] RUs and the beneficial reuse of the treated soil as backfill material for the areas of excavation within the floodplain. The low-temperature thermal desorption process would be used to treat the soil. Institutional actions would be implemented for the Surface Water/Sediments RU.

Summary of Evaluation

SWA 5 would protect human health and the environment in the long term by excavating and treating contaminated soil. SWA 5 would also comply with ARARs, as described under SWA 4. Projected risks of chemical exposure to children and adults in the community from contaminated dust and mercury vapors generated during soil handling and treatment under SWA 5 would be below (HI < 1) the EPA target for noncancer effects. Physical hazards for the community would be limited to transportation risk outside the RUs since the community would be excluded from the remediation area. Risks to the community are projected to result in 0.3 injury and 0.02 fatality. A project health and safety plan would address mitigative measures (e.g., engineering practices and personal protective equipment) to ensure that the EPA target would not be exceeded. Transportation risks to workers are calculated to cause 0.01 worker injury and 0.005 worker fatality. In addition, construction risks to workers are estimated at 7.6 injuries and 0.06 fatality. Thus, the total risks for SWA 5 would be expected to cause ~8 injuries and <0.1 fatality. For ecological receptors, the most significant impact would be disruption of 7.35 ha (18.16 acres) of terrestrial habitat and 3287 m (3596 yd) of riparian zones that would be temporarily altered as a result of the remedial actions until ecological succession resulted in the reestablishment of the pre-excavation habitat. Short-term impacts would include direct mortality of individual ecological receptors in the remediation area. A total of 0.90 ha (2.25 acres) of wetlands would be adversely affected by remedial actions. Total cost of this alternative would be ~$70 million in 1993 dollars.

Impacts within the Residential RU resulting from the implementation of SWA 5 would be identical to those discussed under SWA 4. While the impacts within the Commercial/DOE and Other RUs under SWA 5 would be similar to those discussed under SWA 3, different or additional impacts could result from the use of the low-temperature thermal desorption and beneficial reuse of the treated soil. To avoid redundancy, discussion of impacts that are the same as those under SWAs 3 and 4 are not repeated here; alternative-specific differences, such as

transportation risks, are given. Only different or additional impacts within the Commercial/DOE and Other RUs are discussed below under the appropriate criteria.

5.3.5.1 Overall protection of human health and the environment

SWA 5 would protect human health and the environment. In the short term, risks to workers, the public, and ecological receptors would increase during implementation because of the quantity of material being processed (excavated, transported, treated, and returned). Short-term risks to unprotected workers from chemical exposure would exceed (HI > 1) EPA targets for noncancer effects for all RUs if no mitigative measures were used. Chemical exposure risks from inhalation of contaminants in dust would not exceed the EPA target for noncancer health effects to the community. A project health and safety plan would address mitigative measures, which could include standard engineering practices to reduce dust (e.g., covering trucks and wetting soil as needed), and use of personal protective equipment to reduce exposures and thereby reduce risk to below EPA target levels. Risk to the community from soil roasting using low-temperature thermal desorption also would not exceed EPA targets. Transportation and construction accidents are projected to result in < 1 (0.1) fatality for this alternative.

Excavation and treatment of soil contaminated in excess of remediation goal options in each of the RUs, and backfilling with treated soil in excavated areas would result in residual human health risks below EPA targets, eliminating unacceptable risk. Removal, treatment, and replacement of contaminated soil with treated soil would also be expected to eliminate unacceptable risk to ecological receptors from mercury. However, it would take several years to reestablish terrestrial habitat disturbed during remediation, although planting appropriate plant species could speed the process somewhat. Recovery of bottomland hardwood forests would take nearly 50 years.

5.3.5.2 Compliance with ARARs

See Sect. 5.3.2.2 for a discussion of compliance with ARARs.

5.3.5.3 Long-term effectiveness and permanence

The excavation, treatment, and beneficial reuse actions proposed would be effective in the long term because contamination > 180 ppm of mercury for the Residential RU and > 200 ppm of mercury for the Commercial/DOE and Other RUs would be removed, significantly reducing residual risks.

Irreversible and Irretrievable Commitment of Resources

The low-temperature thermal desorption treatment process would require the use of natural gas as a heat source. Other ancillary materials for low-temperature thermal desorption operation (water, filters, nitrogen gas) would also be required. The beneficial reuse of treated soil to backfill the floodplain excavations would eliminate the need for ex situ borrow soil for this remedial action, with the exception of ~ 2400 m^3 (3200 yd^3) of borrow soil to restore the anticipated losses from the treatment process.

An estimated total of 310,800 L (82,300 gal) of diesel fuel would be consumed by trucks and heavy equipment in the performance of these remedial actions. Additional petroleum products would be consumed in the form of gasoline, lubricating oils, and greases.

5.3.5.4 Reduction of toxicity, mobility, or volume through treatment

The SWA 5 treatment option, low-temperature thermal desorption, would reduce the concentration of mercury in treated soil to acceptable levels. Although treatment removes mercury from the soil, the pilot studies show that it does not significantly reduce levels of the PCBs, heavy metals, and radionuclides present (IT 1994). However, other than mercury, only cadmium and arsenic were identified as COCs within the RI. Health risk assessment indicated that neither cadmium nor arsenic were of concern (Sect. 3.3.1.1). In addition, current soil levels of all of these contaminants are below RCRA TCLP concentrations for classification as hazardous waste. Evaluation and approval by TDEC of acceptable contaminant levels in treated soil would be required prior to beneficial reuse of the soil. The volume of soil after treatment would be an estimated 47,000 m^3 (61,600 yd^3).

5.3.5.5 Short-term effectiveness and environmental impacts

Community Protection

Chemical Exposures. Under SWA 5, excavation, treatment, and beneficial reuse of soil is planned for Commercial/DOE, Other, and Residential RUs. The excavated area would be backfilled with treated soil, and exposures during excavation activities would be possible outside of the RU. Transport of contaminants outside the RU would be by means of fugitive dust, which could be inhaled by members of the community. Table 5.23 shows short-term inhalation risks associated with soil excavation activities. Risks to the community exposed to dust for SWA 5 would not exceed EPA targets for noncancer human health effects.

In addition, members of the community living near the low-temperature thermal desorption unit could be exposed to mercury vapor emissions from the unit and to contaminated fugitive dust particulates generated during the pretreatment soil handling activities. Table 5.24 shows the risks associated with soil treatment. Risks to the community living near the low-temperature thermal desorption unit would not exceed (HI < 1) EPA targets for noncancer human health effects.

Physical Hazards. SWA 5 involves the transportation of contaminated soil to the low-temperature thermal desorption unit and the return of treated soil to the floodplain. Because of the time and distance traveled, the potential exists for transportation accidents involving injuries and/or fatalities. Because the trucks would be covered immediately and decontaminated before leaving EFPC, exposures to hazardous materials would not be expected to occur during their transport.

Under SWA 5, ~348,000 km (217,500 miles) would be traveled by trucks carrying both contaminated and clean borrow soil. The total projected nonoccupational (community) transportation risks from the implementation of SWA 5 are calculated to be 0.3 injury and 0.02 fatality (see Appendix F).

Remediation Worker Protection

Chemical Exposures. Soil excavation, treatment, and beneficial reuse are considered in the Commercial/DOE, Other, and Residential RUs under SWA 5. Risks from exposure to contaminants would be likely for workers in close proximity to soil. Table 5.23 shows risks for workers conducting soil excavation. For unprotected workers (no personal protective equipment or other health and safety precautions), only soil ingestion risks would exceed (HI > 1) the EPA target for noncancer effects. Dermal contact and inhalation noncancer risks would be below the EPA target. Risks to workers involved in soil treatment at the low-temperature thermal desorption unit would exceed the EPA noncancer risk target (see Table 5.24). The exceedances would be only for soil ingestion. A health and safety plan for the project would be developed to ensure that worker risks do not exceed EPA target levels. A health and safety plan for the project would be developed for site activities, and the required mitigative measures to protect worker health and safety would be addressed to ensure worker exposures do not exceed acceptable EPA target levels.

Physical Hazards. Risks associated with construction activities are based on a labor estimate of 113,000 man-hours. Under these assumptions, 7.6 worker injuries and < 1 (0.06) fatality are expected over the 1.6-year remedial duration. This corresponds to a projected annual incidence rate of 4.8 worker injuries and < 1 (0.04) worker fatality.

Occupational (truck driver) transportation risks were calculated to be 0.01 injury and 0.005 fatality (see Appendix F).

Time Until Action is Completed

Estimated time to complete this action is 1.6 years. The short-term remedial action objectives would be achieved upon completion of actions. The actual time to complete this alternative, after approval by the regulatory agencies, would include ~12 to 18 months for remedial design and the associated approval of the remedial action work plan prior to commencing the remedial action. Therefore, after final regulatory approval of the Record of Decision, it would take ~4 to 5 years to complete the action, not including long-term environmental monitoring.

Environmental Impacts—Soil and Floodplain

Soil. A total in situ volume of 41,400 m^3 (54,000 yd^3) of soil would be excavated and treated from the Commercial/DOE, Other, and Residential RUs. Additional small amounts of borrow soil [~2500 m^3 (3200 yd^3)] would also be added to treated soil to restore anticipated losses from the treatment process.

Floodplain. The impacts to the floodplain would be the same as those discussed for SWA 3.

Environmental Impacts—Water Quality

Surface Water. The potential short-term impacts of SWA 5 on surface water of EFPC are the same as those for SWA 4 because the same surface area of soil would be disturbed during remediation. Potential increases in concentrations of mercury and total suspended solids are

expected to be minimal and within regulatory guidelines (see Table 5.11). A larger volume of soil would be treated under SWA 5 than under SWA 4. The treatment and beneficial reuse of excavated soil could affect surface water, depending on the design of the treatment facility and application methods for beneficial reuse. Contaminants could be released to surface water from treated soil depending on the properties of the treated soil and application methods. Best Management Practices and appropriate engineering controls would be used to prevent adverse impacts to water quality.

Environmental Impacts—Air Quality

Excavation and handling of untreated soil would be a significant air pathway to potential receptors. Excavation operations such as loading, dumping, grading, excavating, and haul road traffic would cause excessive concentrations of contaminated dust, if not properly controlled. Storage piles of untreated soil and large areas of bare soil could also serve as significant sources of fugitive dust emissions. Control methods, such as wetting haul roads, haul road speed limits, and limiting the number of exposed storage piles, would significantly lower emissions from these activities. Human health risk studies have shown that off-site risk from controlled fugitive dust emissions from excavation and soil handling activities and from mercury vapor emissions from the low-temperature thermal desorption unit would be within acceptable limits. Worker health risk on site would result from inhalation of fugitive dust emissions from excavation and soil handling activities, inhalation of mercury vapor emissions from the low-temperature thermal desorption unit, and from ingestion of and dermal contact with soil. Mitigative measures would be taken to provide acceptable health risk levels to on-site workers. Controlled emissions from grading activities are estimated at 0.007 kg/h and would not be a significant health risk to workers or the community if dust suppression control measures were taken. Emissions from heavy equipment operation (i.e., fuel combustion) would be negligible and would not significantly affect local or regional air quality.

Environmental Impacts—Ecological Resources

Aquatic Resources. Implementing SWA 5 would result in short- and long-term impacts in the Commercial/DOE and Other RUs that are similar to the impacts described in SWA 3. Additional long-term impacts from the use of treated and amended soil for soil restoration (as described in this comparable section of SWA 4) could occur. Short- and long-term impacts to aquatic biota and habitats in the Residential RU would be similar to those described for SWA 4.

Terrestrial Resources. Excavation in the Commercial/DOE RU would affect 0.85 ha (2.1 acres) of bottomland hardwood forest habitat. Construction of access roads and staging areas would result in the additional loss of an estimated 0.02 ha (0.05 acre) of various habitats within this RU.

A total of 1.6 ha (4.0 acres) of habitat within the Other RU would be affected. This would include 0.9 ha (2.3 acres) of bottomland hardwood habitat and 0.7 ha (1.7 acres) of old field habitat. Minor percentages of all other habitats present would be disturbed by removal actions. Construction of access roads and staging areas would result in the additional loss of an estimated 0.3 ha (0.8 acre) of various habitats within this RU.

Excavation actions would disturb 3.8 ha (9.4 acres) of bottomland hardwood habitat within the Residential RU. Impacts would occur within Segments 1, 3, 4, 5, 8, and 9 with the majority in Segments 1 and 4. Construction of access roads would result in the additional temporary loss of ~0.06 ha (0.14 acre) of various habitats in this RU. Impacts would be the same as those described for SWA 3.

Wetlands. Under SWA 5, 0.90 ha (2.25 acres) of wetlands would be directly disturbed by remediation (see Table 5.19). Other indirect impacts to wetlands could be expected because of the amount of work that would occur adjacent to the wetlands. Wetlands affected by excavation would be Wetland 1 on DOE property; Wetlands 3, 4, 5, and 8 in the Residential RU; and Wetland 7 in the Other RU. Only one wetland (Wetland 8 in the Residential RU in Segment 4) would be completely destroyed by remediation.

Threatened and Endangered Species. No impact to protected species would be expected under SWA 5. Excavation along the EFPC floodplain is not expected to have a significant impact on the Tennessee dace because its critical habitat in the headwater regions of tributaries would not be affected. Impacts in the borrow soil or haul road areas would be similar to those described for SWA 2.

Environmental Impacts—Archaeological, Cultural, and Historical Resources

There would be no impact to archaeological, cultural, and historical resources as described in SWA 2.

Environmental Impacts—Socioeconomic and Institutional Issues

The following section describes potential impacts of SWA 5 on the institutional setting and on public services and facilities. To the extent possible, the discussion is based on RUs. Section 2.1.7.1 describes the existing institutional environment, methods used for analysis, and a listing of identified stakeholder groups.

Institutional Considerations. The interim action proposed for the Surface Water/Sediments RU under SWA 5 would not be likely to address community concerns. The institutional impacts would be similar to those described in Sect. 5.3.2.5 for the Surface Water/Sediments RU.

Removal of excavated soil contaminated above action levels on Commercial/DOE and Other RUs would rid those areas of contamination. As described for SWA 3, this alternative would allow the unrestricted selling, buying, and development of these properties in accordance with normal market pressures. Institutional mechanisms to release future title holders from liability probably would not be deemed necessary by property owners.

In the Commercial/DOE RU, there is no indication that any specific businesses would be adversely affected in the short-term by excavation activities, aside from unavoidable annoyances and inconveniences that may be expected with these activities. DOE would coordinate with property owners in Commercial and Other RUs to minimize short-term disturbances due to excavation.

Because DOE is expected to maintain ownership and control of DOE-owned property for the foreseeable future, no impacts to the institutional environment would be likely to result from this alternative on the ORR. Short-term impacts on aesthetic quality could be expected as a result of removing vegetation on portions of DOE property visible from Oak Ridge Turnpike, although replanting and eventual natural restoration would occur..

Excavation, treatment, and beneficial reuse of floodplain soil in the Residential RU would result in institutional impacts similar to those described in Sect. 5.3.4.5. These include short-term impacts on residents, uncertainty regarding residual contaminants remaining in soil returned to the floodplain, potential for future actions if environmental standards become more stringent, potential liability issues, and uncertainty about the desirability of treated soil in lawns and gardens. The treatment process itself could contribute to institutional impacts in Roane County and Oak Ridge and impacts on the quality of life of nearby residents, similar to those described in Sect. 5.3.4.5.

Public Services and Facilities. The anticipated impacts on public services and facilities under SWA 5 would be the same as those described for SWA 4 in Sect. 5.3.4.5.

Economic and Demographic Resources. Employment resource impacts are estimated using RIMS II for Anderson and Roane counties developed by the Bureau of Economic Analysis. Employment estimates form the basis for the calculation of associated changes in the number of households and population. For a description of this modeling framework, see Appendix E.

Remediation activities are assumed to take place in the first 2 years. In those years, it is estimated that the remediation would require 34.4 FTEs for construction activities, 12 people in a treatment crew, 34.4 for administrative support, and a crew of five for continuous sampling and monitoring activities. Average annual wages and salaries plus other income to households for land and relocation costs are estimated to be $3.4 million, with expenditures for equipment and materials at $3.8 million per year and associated expenditures for other business services at $26.9 million. The direct spending associated with the project that would go to local businesses and households is estimated to result in indirect employment of an additional 44.4 FTEs, for a total employment increase of 130.2. This represents 0.2% of the 63,317 people employed in Anderson and Roane counties in 1990 (see Table 2.14). The upper bound on the number of households created by this increase in employment is 97 or 0.2% of the 49,657 housing units in the two counties in 1990 (see Table 2.12). The associated estimated population consistent with the employment and housing impacts is 245, or 0.2% of the 115,477 people living in Anderson and Roane counties in 1990 (see Table 2.11). These changes are so small relative to the totals for the region of influence that this alternative should not result in adverse impacts to the economic and demographic conditions in Anderson and Roane counties.

Routine monitoring activities are assumed to take place during years 3 to 6, 8 to 11, 13 to 16, 18 to 21, 23 to 26, and 28 to 30. It is estimated that direct wages and salaries for the 0.2 FTEs required for sampling and reporting would be $7000 per year; other expenses are estimated to be $43,000. No capital expenditures are estimated during these years. Using RIMS II, it is estimated that this activity would generate 0.1 additional FTEs, for a total employment effect of 0.3. This employment effect is so small that there are no associated changes calculated for the number or households or population.

More extensive monitoring and sampling are assumed to be conducted at 5-year intervals, in years 7, 12, 17, 22, and 27. During these years, direct employment would increase to 0.5 FTEs. Using RIMS II, the associated secondary employment is 0.1 FTEs, for a total employment increase of 0.6 FTEs. As reported during the routine monitoring years for this alternative, there are no associated changes calculated for the number of households or population.

Transportation Impacts. Remedial actions under this alternative would require the transportation of large volumes of contaminated soil to the low-temperature thermal desorption treatment facility located at the K-25 Site. Approximately the same volume of treated soil would be transported back to the EFPC floodplain for use as backfill in the remediated areas. Approximately 10,800 truckloads would be required to transport contaminated and borrow soil. Transportation impacts would occur in each segment and RU of the EFPC floodplain, with the majority of the impacts occurring in the vicinity of Segments 1 and 4 in the Residential RU.

Transportation impacts would be minimized by cooperation with local and state authorities to determine the most appropriate haul routes and trip times to reduce traffic congestion, accident potential, and road deterioration. Because the low-temperature thermal desorption treatment facility would be located on the K-25 Site and the borrow site would be located on the ORR, transportation impacts possibly could be minimized by using roads that are normally restricted to public access.

Noise Impacts. Sound levels that would be generated during the operation of the low-temperature thermal desorption treatment facility would not be expected to exceed the OSHA standard for an 8-h workday average of 90 dB nor would anticipated noise levels from individual pieces of equipment exceed OSHA standards for short-term exposure.

Environmental Impacts—Unavoidable Adverse Impacts

Under SWA 5, a total of 0.90 ha (2.25 acres) of wetlands would be directly disturbed by excavation. Other unavoidable adverse impacts are the same as those described under SWA 3 and those associated with the low-temperature thermal desorption unit that are discussed under SWA 4.

Environmental Impacts—Short-Term Uses and Long-Term Productivity

Short-term uses of Commercial/DOE, Other, and Residential properties would be affected by SWA 5 but would be free of most constraints in the long term. Short-term impacts for excavation and transportation of the soil are discussed in Sect. 5.3.3.5 for SWA 3; impacts from treatment operations are discussed in Sect. 5.3.4.5 for SWA 4.

5.3.5.6 Implementability

SWA 5 is considered to be implementable. Implementability concerns for SWA 5 are the same as those discussed for SWA 3 in Sect. 5.3.3.6, with the exception of treatment of the soil using a thermal desorption unit. Disposal alternatives for treated soil would be different from those for untreated soil because the mercury contamination would be removed. All other implementability concerns discussed for SWA 3 are applicable to SWA 5. Implementability

concerns for treatment of contaminated soil, reuse of treated soil, and disposal of residuals are the same as those discussed for SWA 4 in Sect. 5.3.4.6.

In summary, SWA 5 is considered to be implementable. Vendors are available to provide low-temperature thermal desorption units. Additional remedial actions would be possible, if required. The effectiveness of the low-temperature thermal desorption process could be monitored easily by proven techniques. Treatability bench- and pilot-scale testing indicates that the technology is feasible for removing mercury from EFPC contaminated soil. Placement of the treated soil in the excavated areas of the floodplain would require coordination with other agencies.

5.3.5.7 Cost

Total capital cost for the site under SWA 5 would be $35 million. Operation and maintenance costs, including the treatment costs, are estimated to be:

Years	Cost (× $1000)
1-2	16,302
3 to 30	50
5-year periodic	100

The total cost to complete this action in 1993 dollars is ~$70 million with no escalation or discount. Appendix D provides the cost basis and methodology used to calculate the +50%, -30% cost estimate.

5.3.5.8 State acceptance

To be provided after receipt of comments.

5.3.5.9 Community acceptance

To be provided after receipt of comments.

5.3.6 Description and Summary of Evaluation of Sitewide Alternative 6 (SWA 6)

Description

SWA 6 involves containment and institutional actions where soil contamination is >200 ppm of mercury on the Commercial/DOE and Other RUs. Total surface area to be contained is ~0.05 ha (0.12 acre) for Commercial RU property, ~0.81 ha (2.02 acres) for DOE-owned property, and ~1.64 ha (4.05 acres) for Other RU property (see Table 4.2). SWA 6 also involves acquisition of real estate interests in Residential RU properties with soil contamination >180 ppm of mercury and containment and institutional actions on the acquired portion(s) with soil contamination >200 ppm of mercury. To provide protectiveness for containment and institutional actions on Residential RU properties, DOE would acquire the real estate interest for areas necessary to implement the remedial action (i.e., areas containing mercury concentrations

> 180 ppm, areas for access roads, etc.), and access controls (i.e., fence) would be installed around the acquired areas. In the Residential RU, ~4.85 ha (11.97 acres) of soil with mercury concentrations > 180 ppm would be acquired and contained with a soil cover. SWA 6 includes the fencing of additional acreage for one Residential parcel and a portion of one Commercial parcel in Segment 1, which encompasses an additional 3.6 ha (8.88 acres). The additional acreage is being acquired and fenced because of the extreme difficulty of installing and maintaining fencing over the two wetland areas (Wetland 3 and 4). Figure 4.2 presents the areas involved in containment and institutional actions.

Interim institutional actions would be implemented for the Surface Water/Sediments RU. Section 5.2 describes general remedial actions.

Summary of Evaluation

SWA 6 would comply with ARARs and would protect human health and the environment in the long term by covering contaminated soil and maintaining institutional actions. With the implementation of SWA 6, potentially the most significant impact would be the aspect of acquiring and fencing portions of residential property and ensuring the long-term effectiveness of institutional actions. Potential physical hazards to the community would be limited to transportation hazards outside of the RU areas because access to the remediation areas would be controlled and the community would not be allowed to enter. In the absence of any mitigative measures, SWA 6 remediation activities would cause noncancer risks to workers which exceed (HI > 1) the EPA target value. A project health and safety plan would address mitigative measures (i.e., engineering practices and personal protective equipment) to ensure that noncancer risks to workers would be below (HI < 1) the EPA target value. Transportation risks to the community are projected to result in 0.1 injury and 0.01 fatality. Transportation risks to workers are calculated to cause 0.004 worker injury and 0.002 worker fatality. In addition, construction risks to workers are estimated at 4.8 injuries and 0.04 fatality. Thus, the total risk for SWA 6 would be expected to cause 5 injuries and < 0.1 fatality. The most significant impact on ecological receptors from containment and institutional actions would be permanent conversion of 7.35 ha (18.16 acres) of habitat, and 3287 m (3596 yd) of riparian zones would be permanently altered as a result of bank stabilization actions. Short-term impacts would include direct mortality of individual ecological receptors in the areas of remediation. A total of 0.90 ha (2.25 acres) of wetlands would be adversely affected by implementation of SWA 6. Total cost of this alternative would be $41 million.

5.3.6.1 Overall protection of human health and the environment

This alternative would protect human health and the environment in the long term. In the short term, risks to workers and ecological receptors would increase during implementation of remedial actions. Because of the quantity of cover material being transported, risk to workers would increase during implementation. Short-term risks to unprotected workers from chemical exposure by soil ingestion would exceed the EPA target for noncancer effects for all RUs. A project health and safety plan would address mitigative measures, which could include engineering controls to reduce dust (e.g., covering trucks and wetting soil, as needed) and worker use of personal protective equipment to reduce exposure, and thereby reduce risk to below the EPA target value. Chemical exposure risks to the community would be minimal because contaminated soil disturbance would be limited. Transportation accident risks for workers and

the public are calculated to result in a total of 0.1 injury and 0.01 fatality, based on ~4700 truckloads required to transport the volume of material needed to implement SWA 6. Occupational construction accidents associated with SWA 6 are projected to cause 4.8 worker injuries and <1 (0.04) worker fatality.

For ecological receptors, the most significant impact from containment would be the permanent loss of 7.35 ha (18.16 acres) of habitat. In addition, 3287 m (3596 yd) of riparian zones would be permanently altered in the containment areas as a result of bank stabilization actions. Containment actions in the floodplain would permanently alter those areas and could result in a change in floodwater flow patterns and extent. There would be both direct and indirect impacts to wetlands under this alternative; six wetlands would be affected as a result of fill/cover material added for the containment action [0.90 ha (2.25 acres)].

For the public, protectiveness would depend on institutional actions (e.g., land-use restrictions and maintaining integrity of soil cover). If institutional actions were maintained, this alternative would be protective. Potential impacts resulting from loss of institutional actions are discussed in Sect. 5.6. Installation and maintenance of the cover is expected to eliminate unacceptable risk to ecological receptors from mercury. However, emplacement of the cover would result in lost habitat for most existing species on the areas to be remediated because no woody vegetation would be allowed to grow on the contained areas.

5.3.6.2 Compliance with ARARs

SWA 6 would comply with ARARs. Containment and institutional actions would comply with ARARs as discussed in Sect. 5.3.2.2 for containment and institutional actions.

5.3.6.3 Long-term effectiveness and permanence

Analysis of residual risk for mercury under SWA 6 indicates that risk levels would be below EPA human health targets. This sitewide alternative provides for DOE to gain control of the portions of the Residential RU exceeding 180 ppm of mercury in the soil. This would change the land use, precluding unrestricted residential and agricultural land uses. Under the change in land use to DOE-controlled, the effective remediation goal option in soil would become 200 ppm. DOE control would also effectively preclude food-chain exposures because land uses supporting vegetable, beef, or dairy production would not be allowed. Within the Residential RU, soil >180 ppm of mercury would be acquired and covered by a 45-cm (18-in.) layer of borrow soil, eliminating exposure to contaminants at portions of the RU >200 ppm. Signs, fences, and other institutional controls would maintain DOE control of the RUs. Maintenance of the soil cover would be required at these RUs to provide continued protection of human health. As with any institutional actions, these measures would be effective only to the extent that the responsible agency was able to enforce them. Workers engaged in periodic monitoring in these RUs would be required to use mitigative measures to protect themselves from contact with contaminated materials.

Irreversible and Irretrievable Commitment of Resources

The implementation of SWA 6 would involve containment and institutional actions within each RU. Some aspects of this action would require the irreversible and/or irretrievable

commitment of specific resources, the most significant being the use of 43,600 m^3 (57,000 yd^3) of ex situ soil as cover material (see Table 5.24). The soil would be lost to the area from which it was excavated. On-site borrow areas for topsoil are readily available within the West End Borrow Area on the ORR.

The use of heavy equipment (e.g., dump trucks, bulldozers, front-end loaders) for cover construction would consume petroleum-based fuels and products. The consumption of an estimated 45,000 L (11,900 gal) of diesel fuel would be required for the implementation of this alternative. Additional petroleum products would be used in the form of gasoline and various lubricating oils and greases.

The containment action proposed would commit all of the RUs to long-term restricted use. Contaminated areas proposed to undergo containment would be excluded from some future land uses. Containment actions would convert an estimated 7.35 ha (18.16 acres) of habitat to maintained open areas within the Commercial/DOE, Other, and DOE-Acquired (formerly Residential RU) property. This habitat conversion would result in changes in the wildlife species and populations that are currently supported by this mostly wooded habitat.

Decontamination of equipment and vehicles during site preparation and cover construction could require the use of up to an estimated 3800 L/d (1000 gal/d) of water to be tanked from Oak Ridge. Reduction techniques, such as filtering and reuse, would be used to minimize the volume of waste water. An estimated 760 L/d (200 gal/d) could be lost to evaporation. However, as water became too contaminated for use or a high concentration of dissolved solids impaired filter effectiveness, proper treatment or disposal would be required.

5.3.6.4 Reduction of toxicity, mobility, or volume through treatment

Reduction of toxicity, mobility, or volume through treatment is not applicable to SWA 6 because this alternative does not involve treatment.

5.3.6.5 Short-term effectiveness and environmental impacts

This section evaluates the short-term effectiveness of SWA 6 by considering protection of the community and of workers during remedial actions at EFPC; residual risk to human receptors at the site is discussed under Sect. 5.3.6.3, Long-term effectiveness and permanence. Short-term environmental impacts are also discussed in this section. A summary of the impacts across all RUs is provided at the end of each subsection.

Community Protection

Chemical Exposures. SWA 6 involves containment of contaminated soil. Chemical exposures under this sitewide alternative (i.e., through fugitive dust, etc.) would likely be nominal and limited to the remediation area, from which the community would be excluded. Migration by other means would be minimal because the contaminated soil would be only superficially disturbed. Therefore, community chemical exposure scenarios were not considered.

Physical Hazards. The potential physical hazard to the community stemming from implementation of SWA 6 would be limited to transportation risks from transporting clean soil

as cover material from the borrow site to the remediation areas within the RUs. The total projected transportation risks (see Appendix F) to the community under SWA 6 are <1 (0.1) injury and <1 (0.01) fatality. Therefore, injuries or fatalities to the community related to transportation would be unlikely.

Remediation Worker Protection

Chemical Exposures. The risks of chemical exposure would be for on-site workers in close proximity to the surface soils during site preparation of the remedial area (i.e., during grading, etc.). These activities would not be likely to cause migration of contamination outside the RU, and soil dust generation would be limited to a more localized area (the immediate area of remediation) within the RU.

Table 5.26 shows risks for workers conducting containment activities in the various RUs. Soil ingestion risks for unprotected workers (no personal protective equipment or other health and safety precautions) with no mitigative measures would exceed the EPA target of 1.0 for human noncancer health effects. However, a project health and safety plan would be developed for site activities, which would include mitigative measures to ensure the risk to workers would not exceed the EPA target level. Soil dermal contact and soil dust inhalation risks to workers would be below the EPA target level for noncancer chemical exposure risks.

Physical Hazards. Risks (both injury and fatality) associated with remediation activities under SWA 6 are based on a labor estimate of 72,000 man-hours. The cumulative (remediation activities over the 2.3-year duration for remedial action) worker injury risks for transportation are projected to be 0.004 injury, and worker fatality risks are projected to be <1 (0.002) fatality. Worker construction risks are projected to be 4.8 injuries and 0.04 fatality over the 2.3-year duration.

Summary. Under SWA 6, the total projected risks associated with transportation (i.e., hauling borrow soil from the borrow area to the area of remediation) for workers would be 1 to 2 orders of magnitude lower than the transportation risks to the community. As stated for Community Protection above, projected transportation risks were so low that transportation related injuries or fatalities would be only remotely possible.

Time Until Action is Completed

The estimated time frame for completion of remedial actions under SWA 6 is 2.3 years. Short-term remedial response objectives would be achieved upon completion of implementation of this alternative. The actual time to complete this alternative after approval by the regulatory agencies would include ~12 to 18 months for remedial design and the associated approval of the remedial action work plan prior to commencing the remedial action. Therefore, after final regulatory approval of the Record of Decision, it would take ~4 to 5 years to complete the action, not including long-term environmental monitoring.

Environmental Impacts—Soil and Floodplain

Soil. Containment actions would cause both short- and long-term impacts to soil. The volumes of soil cover that would be needed for SWA 6 are identified in Table 5.25.

The biological, chemical, and physical properties of 7.35 ha (18.16 acres) of the floodplain surface soil would be affected. Containment would result in permanent limitations on the future use of soil in contaminated areas. The volume of ex situ borrow soil required as cover would be 43,600 m^3 (57,000 yd^3), which would result in permanent alteration of soil profiles and topography in borrow areas.

Floodplain. Actions taken under this alternative would result in the placement of an additional volume of soil in the EFPC floodplain. An additional volume of ~300 m^3 (400 yd^3) of soil would be placed in the floodplain in the Commercial RU, and 4800 m^3 (6300 yd^3) of soil would be placed in the DOE RU. In the Other RU, 9700 m^3 (12,700 yd^3) of soil would be placed in the floodplain. Approximately 28,800 m^3 (37,600 yd^3) of soil would be placed in the floodplain in the DOE-Acquired (previously Residential) RU.

Actions taken under this alternative should have no adverse effects on the floodplain resources of EFPC.

Environmental Impacts—Water Quality

Surface Water. The primary short-term impact of SWA 6 on surface water quality would be the potential for increased concentrations of mercury and total suspended solids during storms as the result of erosion of contaminated soil during removal of vegetation before containment. Best Management Practices and appropriate engineering control measures would be implemented as discussed for SWA 2 in Sect. 5.3.2.5 for Surface Water. Covering contaminated soil would eliminate the potential for increase in contaminants in EFPC from storm runoff. Reestablishing vegetative cover would reduce the amount of soil eroded into the creek.

Over the long term, the contaminant concentrations in the instream sediment should decline as contaminated soil is removed or covered. This should cause the contaminant concentrations in the creek water during storm events to decrease below levels currently observed. During base flow conditions, the concentration of mercury would continue to depend on releases from the Y-12 Plant.

Environmental Impacts—Air Quality

Air quality impacts from construction of the containment cover would result from soil disturbances such as haul road traffic, loading, grading, and dumping and from associated internal combustion engine emissions from heavy equipment operation. Impacts from these activities would involve short-term exposure to airborne contaminants during the removal of vegetation, grading, and any other surface preparations for cover construction. Controlled emissions from grading activities are estimated at 0.007 kg/h and would not be a significant health risk to workers or the community if dust suppression control measures were taken. Emissions from heavy equipment operation (i.e., fuel combustion) would be negligible and would not significantly impact local or regional air quality.

Environmental Impacts—Land Use

DOE-Acquired (previously Residential) RU. The largest volume of soil to be contained would be in the residential areas. Two variations of land uses would be associated with the

residential areas: (1) existing residential areas and (2) vacant land predicted to become residential in the future. Short-term impacts to both of these types of residential areas include building an access road to the contaminated areas, clearing sites for staging areas, removing vegetation that could act as a visual and sound buffer, and removing fences temporarily. After the remediation was completed, actions would be taken to replant vegetation and to replace fences and other amenities that were disturbed. However, it could be necessary to leave access roads in place to maintain the cover and institutional actions.

Additional short-term impacts to existing residential areas include noise annoyance from remedial actions, truck and construction traffic through yards, and dust potentially coating buildings and other amenities. Additional short-term impacts to vacant parcels include noise disturbances to surrounding land uses. In addition, long roads could be necessary to provide access to contaminated areas in the future.

Long-term impacts to the existing Residential RU include acquiring portions of properties that the owner was allowed to use in the past, placing fences that restrict use of a former portion of the property, the potential reduction in property value due to the knowledge that contamination exists, and the continual maintenance of the containment and institutional actions by a federal entity. In addition, the majority of the real estate interests would be acquired for four properties with homes in the Greenview residential area in west Oak Ridge. The entire parcel would potentially have to be acquired for the aforementioned parcels.

Long-term impacts to vacant parcels predicted to turn residential could result from restrictions on future use caused by the acquisition of real estate interests for portions of the properties and the knowledge that contamination exists. These long-term impacts could include potential reduction in property values and inconveniences to development due to the placement of fences and the continual maintenance by a federal entity associated with the fencing and containment.

The environmental impacts on land use for the Commercial/DOE and Other RUs are similar to those in SWA 2, Sect. 5.3.2.5.

Environmental Impacts—Ecological Resources

Aquatic Resources. As indicated for SWA 2 (Sect. 5.3.2.5, Aquatic Resources), long-term impacts to the aquatic habitats and biota in Lower EFPC from the remedial actions at each of the RUs are expected to continue at least at the level described for SWA 1, the No Action alternative (Sect. 5.3.1.5), because of the continued release of contaminants from the Y-12 Plant and deferred remediation of the surface water and sediment in Lower EFPC until those releases are controlled. Additional long-term effects could occur from the remedial activities involving containment. Short-term effects (effects that occur up through implementation of the remedial activities) from the specific remedial actions at each RU could also occur. The short-term impacts would most likely result from three major disturbances, including conversion of riparian habitats, permanent stream bank stabilization, and increased siltation. The general nature of the short-term effects (i.e., the cause-effect relationships that comprise these effects) was discussed in the introductory paragraphs of the Aquatic Resources section for SWA 2 (Sect. 5.3.2.5).

The potential loss of riparian vegetation and the degree of permanent bank stabilization and increased siltation would primarily be a function of the length of stream bank that was subject to remedial activities in each RU within each of the nine ecological risk stream segments in Lower EFPC. A semiquantitative estimate of the short-term impacts associated with the remedial activities for each RU is discussed under each RU evaluation.

Commercial/DOE RU

Implementing SWA 6 would result in the same short-term and long-term effects that were described for SWA 2 (Sect. 5.3.2.5, Aquatic Resources, Commercial/DOE RU) because the containment activities for both alternatives would result in the conversion of the same types and lengths of riparian habitats. Potential short-term effects that were described for SWA 2 (Sect. 5.3.2.5) could also occur for SWA 6 due to loss of riparian vegetation, bank stabilization, and increased siltation. The general impacts from these three disturbances were discussed in the introductory paragraphs of the Aquatic Resources subsection in Sect. 5.3.2.5.

Other RU

Implementing SWA 6 for the Other RU would result in the same short-term and long-term effects that were described for SWA 2 (Sect. 5.3.2.5, Aquatic Resources, Other RU) because the containment activities for both alternatives would result in the conversion of the same types and nearly equal lengths of riparian habitat (Table 5.13).

DOE-Acquired (Previously Residential) RU

Implementing SWA 6 would result in the conversion of 1920 m (2101 yd) of riparian bottomland hardwood and old field habitats in the DOE-Acquired (previously Residential) RU (Table 5.13). Riparian bottomland hardwoods comprise 1761 m (1927 yd) of the converted riparian habitat.

Potential short-term and long-term impacts to aquatic biota would probably be greatest in Segments 1, 3, and 4 because these segments have the longest lengths of remediated riparian habitat [254 to 706 m (278 to 772 yd)]. Four species of lithophilic spawning fish have been identified in Segments 1 and 4, whereas, two additional species have been identified in Segment 3 (Table 5.12). Impacts to aquatic biota in Segments 5, 8, and 9 should be minor because the lengths of remediated riparian habitats only range from 91 to 189 m (100 to 207 yd). No riparian habitats would be remediated in Segments 2, 6, or 7.

Terrestrial Resources. Impacts to terrestrial habitats and biota resulting from the implementation of SWA 6 would be similar to those discussed under SWA 2 (see Sect. 5.3.2.5). These impacts would include direct mortality of vegetation, soil-dwelling organisms, and some small mammals and displacement or disruption of certain biota (e.g., deer) until remedial actions were completed and vegetative cover was reestablished on the contained areas. Habitat conversion in areas to be contained would result in permanent changes in plant and wildlife communities and populations. In addition, terrestrial biota would continue to be exposed to contamination through contact with and/or ingestion of EFPC surface water, sediments, and aquatic biota.

The implementation of SWA 6 also would involve the extensive use of fencing to limit human access to contaminated soil. Fencing would enclose contaminated areas totaling 7.35 ha (18.16 acres) and additional acreage in Segment 1 totaling 3.6 ha (8.88 acres). The additional area in Segment 1 would be fenced to incorporate two wetlands (Wetlands 3 and 4). Narrow bands of vegetation would be eliminated during construction of the fence and periodically thereafter during fenceline maintenance. The type of fence proposed, intended to serve as a physical barrier to human entrance, could also limit the movement of the larger wildlife species (i.e., those larger than rabbits). These limitations of movement could produce negative impacts to some wildlife species by excluding them from certain areas of the floodplain. Mitigative measures (e.g., wildlife pass-throughs) could be incorporated into the fence design and construction (see Mitigative Measures in this section).

Commercial/DOE RU

Containment actions would affect 0.85 ha (2.1 acres) of bottomland hardwood forest habitat within this RU. The impacts would occur in Segments 1, 3, and 9. Construction of access roads and staging areas would result in the additional loss of an estimated 0.02 ha (0.05 acre) of habitats within this RU.

Other RU

Containment actions would affect a total of 1.6 ha (4.0 acres) of habitat in this RU. The impacts would occur in Segments 4 and 5 and would include 0.9 ha (2.3 acres) of bottomland hardwood forest and 0.7 ha (1.7 acres) of old field habitats. Construction of access roads and staging areas would result in the additional loss of an estimated 0.32 ha (0.8 acre) of habitats within this RU.

DOE-Acquired (Previously Residential) RU

SWA 6 proposes an approach that also would result in containment actions being performed within the DOE-Acquired (previously Residential) RU. This would result in the permanent conversion of an additional 4.9 ha (12.0 acres) of various habitat types within this RU. Bottomland hardwoods would comprise 3.8 ha (9.4 acres) of this area. The impacts would occur in Segments 1, 3, 4, 5, 8, and 9.

Summary. Implementing SWA 6 would result in the continuation of long-term impacts to the aquatic biota and habitats in EFPC similar to those described for SWA 1, the No Action alternative (Sect. 5.4.1.5), for all RUs. Additional minor long-term impacts would be expected for the Commercial/DOE, Other, and formerly Residential RUs because the containment activities would result in the conversion of 3287 of 41,399 m (3596 of 45,274 ft) (6%) of riparian bottomland hardwood and old field habitats into riparian grassy cover that would have to be maintained indefinitely. In addition, potential short-term impacts could result from loss of riparian vegetation, permanent bank stabilization, and increased siltation due to containment remedial actions at the Commercial/DOE, DOE-Acquired (formerly Residential), and Other RUs. Long-term and short-term impacts in the DOE-Acquired (formerly Residential) RU would be expected to be minor due to the short length of riparian bottomland hardwood habitat that would be converted to grassy cover. Bottomland hardwood habitat would be subjected to the most

conversion [5.6 ha (13.8 acres) total]. Erosion prevention measures during the remedial activities should minimize the likelihood of significant impacts from increased siltation.

Environmental Impacts—Wetlands

Under SWA 6, 0.90 ha (2.25 acres) of wetlands would be directly affected by remediation (see Table 5.27). SWA 6 would affect Wetlands 1, 3, 4, 5, 7, and 8. Wetland functions in contained wetlands could not be restored (i.e., alterations to wetlands would be permanent and unavoidable). Other indirect impacts to wetlands could be expected to occur because of the amount of work that would be performed adjacent to the wetlands.

Containment within wetlands would alter hydrological conditions and would cause permanent disruption of wetland functions and values. Because containment would permanently change topography, it would not be possible to restore the loss of those functions at that wetland in the future. Wetland functions identified thus far include floodwater attenuation, contaminant/silt retention, and wildlife habitat. Permanent disturbance would have to be mitigated through a comprehensive restoration or wetland creation program. Options for wetlands mitigation are discussed in greater detail in Sect. 5.4, Monitoring and Mitigative Measures.

Environmental Impacts—Threatened and Endangered Species

SWA 6 would not be expected to affect protected species. Remedial activities along the EFPC floodplain are not expected to have a significant impact on the Tennessee dace since its critical habitat in the headwater regions of tributaries would not be affected.

Environmental Impacts—Archaeological, Cultural, and Historical Resources

As described in SWA 2, there would be no impact to archaeological, cultural, and historical resources.

Environmental Impacts—Socioeconomic and Institutional Issues

Institutional Considerations. SWA 6 would result in generally adverse effects on the institutional environment. With the exception of DOE-Acquired property (previously Residential) under this alternative, the actions to be performed for the Commercial/DOE and Other RUs are similar to those for SWA 2 and SWA 4. Section 5.3.2.5 describes the institutional impacts related to these RUs. The following section describes potential impacts that would be expected from containment and institutional actions performed on properties that changed from residential to DOE-owned under this alternative.

Under SWA 6, DOE would acquire the real estate interests for areas in the Residential RU that would be necessary to implement remedial action. Access controls (fencing and warning signs) would be installed around the acquired areas, and those acquired areas with mercury concentrations >200 ppm would be covered with soil. Construction and maintenance of access roads would be necessary for installing and maintaining access controls. DOE would implement a long-term maintenance program for such institutional actions as mowing and upkeep of fencing and signs.

Based on interviews with ~60 representatives of stakeholder groups and comments made in public forums, most City representatives, property developers, and residents prefer whatever action would give the community a relatively "clean bill of health" and remove the contamination, and the negative perceptions attached to it, as an issue in people's minds. Some individuals expressed doubt that containment would be sufficient to remove the negative image apparently held by outsiders. Most community members consider containment to be sufficiently protective of human health, although some participants in the Citizens' Working Group meeting on June 30, 1993, expressed skepticism concerning the long-term reliability of institutional actions to maintain the integrity of the soil cover. Containment and institutional actions would not address concerns of environmental/citizen organizations, which would place priority on long-term protectiveness of human health and minimizing destruction of natural ecological habitats.

The requirement for extensive fencing and warning signs under SWA 6 could have a negative impact on property owners and on the community as a whole and could be expected to be strongly opposed by stakeholder groups. Approximately one-third of City representatives interviewed mentioned the perceived stigmatizing effects of EFPC on the image of Oak Ridge as a major past and current impact on the community. Stakeholder groups particularly affected by the stigma include the City of Oak Ridge, developers who own property in the floodplain, persons and the community at large. Most of the individuals who mentioned the perceived stigma attributed a major source of impact to the public restriction signs currently posted at several highly visible points along the creek. Several individuals noted that they are aware of reports that people are afraid to live in Oak Ridge. City representatives asserted that an effort is needed that publicizes Oak Ridge as a clean, attractive place to raise children. They agree that fences would not be an appropriate action anywhere along EFPC. Under SWA 6, 1.8-m (6-ft) chain link fences would be visible from Oak Ridge Turnpike and would be visible upon closer inspection by visitors. Virtually all resident/owners who were interviewed stated that fencing is not an acceptable option.

The fact that SWA 6 would require the permanent removal of trees and deep-rooted vegetation on contained areas intensifies the adverse impact that this alternative would have on the community. City representatives and several residents who were interviewed emphasized that the creek contributes aesthetic value to individual properties and to the community as a whole.

Containment and institutional actions to be implemented on all RUs (except for Surface Water/Sediments, the SLB, and Agricultural) would give property owners a relatively "clean bill of health" but would not remove the lender liability issues described in Sect. 2.1.7.1. Impacts from lender liability on buying and selling of properties could be expected over the long term. These impacts are described in more detail for SWA 2. Fencing required under this alternative also could have an additional adverse impact on the marketability of property. For example, planned residential development in Segments 8 and 9 on the land adjacent to the country club and golf course could be hindered if prospective buyers are deterred by visible indications of contamination.

Several specific property owners could potentially be affected by the acquisition of real estate interests that would be required to implement SWA 6. The appropriate acquisition of real estate interests would be determined on the basis of a Final Real Estate Planning Report, which would be prepared upon approval of the Record of Decision. The acquisition could include fee title, permanent or temporary easements, licenses, permits, or leases. The Final Real Estate Planning

Report would address the highest and best use of the land and its current monetary value and would determine the subsequent retention, use, or disposal of any land acquired. As authorized by P.L. 91-646 (Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970) as amended by P.L. 100-17, subject to rules and regulations in 49 CFR Part 24, the real estate acquisition process is subject to negotiation with the property owner.

Under this alternative, approximately ten households would require temporary relocation. These families would experience inconvenience, potentially extreme in some cases.

Any attempt to specify which property owners would experience negative or positive effects due to the acquisition process would be premature prior to the Final Real Estate Planning Report. Some affected property owners could benefit from DOE's acquisition of real estate interests, particularly if that acquisition releases the property owner from future liability. Others may believe that such acquisition limits their ability to use their property as they had planned. Still other property owners may place value on their property over and above its current monetary value, on which compensation would be based. Also, based on a question raised by a participant in the Citizens' Working Group meeting of June 30, 1993, some disagreement could be expected to arise concerning whether the current market price paid for real estate rights adequately takes into account the devaluation of property attributable to the EFPC contamination. Some residents have expressed resentment toward acquisition affecting only a part of their properties because that could reduce the value of the remaining property.

Public Services. Because no excavation would occur under SWA 6, decontamination water would not be needed. Thus, the City of Oak Ridge public water supply would not be affected.

Disposal of waste soil and debris generated during preparation of the area for containment would be managed on the ORR. Therefore, no impact on local or regional solid waste disposal would occur.

Some public facilities would experience adverse impacts under this alternative. The bridge that crosses EFPC between the Oak Ridge Housing Authority and Robertsville Junior High School is used extensively by children in the Housing Authority and the Garden Apartments and also provides access to and from the YWCA; Girls, Inc.; and the Montessori School. This bridge would be rendered useless by the fencing required on the north side of the creek. Therefore, SWA 6 would adversely affect public services in the community.

Fencing would be erected on floodplain area adjacent to Hopkins-Strang Ball Park (Segment 1). However, no recreational activity occurs in that area, and fencing is already in place between the playing fields and the creek. Therefore, no impacts would be expected on the recreational facilities.

Economic and Demographic Resources. Employment resource impacts are estimated using RIMS II for Anderson and Roane counties developed by the Bureau of Economic Analysis. Employment estimates form the basis for the calculation of associated changes in the number of households and population. For a description of this modeling framework, see Appendix E.

The first year of the action would involve property acquisition and remediation activities. It is estimated that the number of positions associated with remediation activities would be

9.7 FTEs for construction-related tasks, with 5.0 FTEs directly involved in property acquisition activities (including attorneys and real estate professionals), 14.7 FTEs in administrative activities, and 0.3 FTEs for sampling and monitoring. It is assumed that payments for property acquisition activities would take place in one period. Approximately $1.4 million is estimated to be spent on property acquisition; it is assumed that this expenditure would go to households. The direct spending associated with the project going to local businesses and households is estimated to result in indirect employment of an additional 18.5 FTEs, for a total employment increase of 48.2. This represents 0.1% of the 63,317 people employed in Anderson and Roane counties in 1990 (see Table 2.14). The upper bound on the number of households created by this increase in employment is 36, or 0.1% of the 49,657 housing units in the two counties in 1990 (see Table 2.12). The associated population estimated consistent with the employment and housing impacts is 91, or 0.1% of the 115,477 people living in Anderson and Roane counties in 1990 (see Table 2.11). These changes are so small relative to the totals for the region of influence that this alternative should not result in adverse impacts to the economic and demographic conditions in Anderson and Roane counties.

Remediation activities are assumed to take place in the second and third years. It is estimated that the remediation would require 14.7 FTEs annually for construction activities, 14.7 for administrative support, and a crew of five for continuous sampling and monitoring activities. Average annual wages and salaries are estimated to be $1.3 million, with expenditures for equipment and materials at $3.7 million, and associated expenditures for other business services at $7.9 million. The direct spending associated with the project going to local businesses and households is estimated to result in indirect employment of an additional 27.5 FTEs, for a total employment increase of 61.9. This represents 0.1% of the 63,317 people employed in Anderson and Roane counties in 1990 (see Table 2.14). The upper bound on the number of households created by this increase in employment is 46, or 0.1% of the 49,657 housing units in the two counties in 1990 (see Table 2.12). The associated population estimated consistent with the employment and housing impacts is 116, or 0.1% of the 115,477 people living in Anderson and Roane counties in 1990 (see Table 2.11). These changes are so small relative to the totals for the region of influence that this alternative should not result in adverse impacts to the economic and demographic conditions in Anderson and Roane counties.

Routine monitoring activities are assumed to take place during years 4 to 7, 9 to 12, 14 to 17, 19 to 22, 24 to 27, and 29 to 30. It is estimated that direct wages and salaries for the 0.8 FTEs required for sampling and reporting would be $28,000 per year; other expenses are estimated to be $212,000. No capital expenditures are estimated during these years. Using RIMS II, it is estimated that this activity would generate 0.2 additional FTEs, for a total employment effect of one. This employment effect is so small that there are no associated changes calculated for the number or households or population.

More extensive monitoring and sampling are assumed to be conducted at 5-year intervals, in years 8, 13, 18, 23, and 28. During these years, direct employment is to be increased to 2.1 FTEs. Using RIMS II, the associated secondary employment is 0.6 FTEs, for a total employment increase of 2.7 FTEs. The number of new households associated with this growth is estimated to be two, and the population increase is estimated to be five. These values are so small relative to the size of the region that there should be no adverse impact on the economic and demographic conditions in Anderson and Roane counties.

Transportation Impacts. General actions regarding transportation are presented in Sect. 5.2. For this alternative, impacts would be similar to those described for SWA 2 (i.e., an increase in average daily traffic volumes and potential road deterioration and damage). Impacts would occur along designated routes in each EFPC RU and along routes to the borrow site(s) and construction landfill (Table 2.18).

Site preparation activities (i.e., vegetation removal and construction of access roads and staging/decontamination areas) would require the transport of an estimated 500 m^3 (700 yd^3) of woody debris to a construction landfill located on the ORR and a estimated 800 m^3 (1000 yd^3) (~83 loads) of gravel from a commercial vendor. Borrow soil cover material would be transported from the borrow site(s) on the ORR to the areas to be contained in the EFPC floodplain. Approximately 4700 truckloads would be required. Transportation impacts would occur in Segments 1, 3, 4, 5, 8, and 9 in each RU undergoing remediation. The majority of the impacts would occur in the vicinity of Segments 1 and 4 in the Residential RU.

Transportation impacts would be minimized by cooperation with local and state authorities to determine the most appropriate haul routes and trip times to reduce traffic congestion, accident potential, and road deterioration. Since the location of the borrow site(s) and construction landfill would be on the ORR, transportation impacts could possibly be minimized by using roads that are normally restricted from public access. Scheduling of vehicle movements during off-peak traffic hours and provision of turning lanes and other safety measures would also reduce impacts. All local, state, and federal ordinances regarding weight and speed limits would be obeyed, or appropriate waivers or temporary permits would be acquired.

Noise Impacts. Impacts would be similar to those described for SWA 2 in Sect. 5.3.2.5.

Environmental Impacts—Unavoidable Adverse Impacts

Under SWA 6, 7.35 ha (18.16 acres) would be contained with a soil cover. Alterations to wetlands [0.90 ha (2.25 acres)] would be permanent and unavoidable. Containment cover construction would produce significant short-term impacts during implementation and result in long-term impacts on terrestrial habitat through conversion of 5.6 ha (13.8 acres) of bottomland hardwood forest. Also, 3287 m (3596 yd) of riparian bottomland hardwood and old field habitats would be converted to grassy cover. These impacts are similar to those described in Sect. 5.3.2.5.

Environmental Impacts—Short-Term Uses and Long-Term Productivity

Under SWA 6, all properties would experience short-term inconveniences, and long-term productivity would be hindered to certain degrees for the properties in the RUs. Short-term impacts to the involved properties would result from building an access road to the contaminated areas, clearing sites for staging areas, removing vegetation that could act as a visual and sound buffer, noise annoyances from remedial actions, truck and construction traffic through yards, and removing fences temporarily. After the remediation was completed, actions would be taken to replant vegetation and replace fences and other amenities that were disturbed. However, it could be necessary to leave some access roads in place to provide access to personnel who would maintain the fences around acquired properties and the cover of the remediated areas.

Long-term productivity would be hindered on properties in the previously Residential RU. Real estate interests would be acquired for those portions of properties that contain contamination. Fences would be placed around those areas of contamination, severely limiting future use. There is the potential for reduction in property values due to the knowledge that contamination exists. Any future development or redevelopment of those properties could be hindered due to stigma created by the fenced contaminated areas. In addition, four properties with homes in the Greenview residential area in west Oak Ridge would have the majority of the real estate interests acquired. These parcels may have to have the real estate interests acquired for the whole property.

The contaminated areas on the properties in the Commercial/DOE and Other RUs would be contained by a soil cover. Deed restrictions would be necessary to prohibit a future breach of the cover. Since the real estate interests would not be acquired and fences not constructed, future development would not be as hindered as in the previously Residential RU. However, the knowledge that contamination is still on those properties could potentially lower property values and deter future developers. It is doubtful that existing commercial establishments whose properties contain contamination would be negatively affected in the future, as long as those businesses continue.

5.3.6.6 Implementability

SWA 6 is considered an implementable alternative. Deed, land-use, and digging-permit restrictions historically have been used to limit future activities on properties. For the purpose of informing a potential property purchaser of the hazards of the property, restrictions would be considered reliable and effective. A property restriction would not preclude further remedial actions if deemed necessary. Because contaminated properties would be DOE-owned or acquired, there would be no implementation concerns for property restrictions. The actual acquisition of real estate interests could be a lengthy process. The acquisition could only occur after the Record of Decision has been issued and a Final Real Estate Plan has been approved. Several property owners may contest the acquisition, further delaying the action. Also, funding for such acquisition could take time to approve and implement. In addition, acquisition of real estate interests would limit proposed future development of the properties.

Fencing, berms, and signs are standard technologies that are readily available with many contractors available to install these institutional controls. Special equipment and qualifications may be required if the fences, berms, and signs are to be installed in contaminated or otherwise hazardous areas. Fences would require periodic maintenance and signs would require periodic replacement due to vandalism, theft, or natural wear. The maintenance program of the installed fence, including clearing debris accumulated due to flooding, would provide long-term protection. These measures would not limit further remedial action. Construction permits and design approvals would be obtained as necessary for fencing installation. Access to most DOE properties currently is limited by fencing and guards. Signs would not present implementability problems because properties would be owned by DOE.

Environmental monitoring of the EFPC OU or subsets of the site is easily performed. The site has been monitored in the past and would not be a problem to monitor effectively if an appropriate sampling plan were implemented. Continued monitoring would not preclude further remedial actions but would indicate the need for further actions.

Containment is a readily available technology that has been implemented many times on the ORR, most notably in the CAPCA projects. Tree and shrub removal would be required for installation of the cover, and perpetual care would be required thereafter to prevent penetration of the cover by tree or shrub roots. If specifications are followed, containment is considered reliable under ordinary circumstances. The proposed polyethylene netting would prevent animal intrusion into the covered soil, and add durability to a soil cover. Special conditions such as floods or droughts could affect the integrity of a soil cover. Containment may make further remedial actions more difficult because the cover would have to be removed to access the contaminated material to perform further actions. Additionally, the cap soil may become contaminated or be difficult to differentiate from the contaminated material, effectively increasing the contaminated material volume.

Cross-site transportation for containment would be performed by dump trucks. Cross-site transportation would involve moving the material from the borrow area to one of the containment areas. Haul roads for cross-site transportation would be constructed in an uncontaminated area or contaminated material would be removed from an area prior to installation of the haul road. Haul roads and trucks/equipment would be sampled and monitored for contamination to prevent contamination of clean areas along the haul roads or at the staging area. Cross-site transportation would involve the use of public roads, risking potential accidents and traffic congestion. Hauling hours could be limited in residential areas to avoid disturbing residents with the noise.

On-site borrow areas for both topsoil and common earth soil are readily available within the West End Borrow Area on the ORR. Little of the ORR has been contaminated by ongoing and past activities; however, borrow soil from the ORR would be sampled to confirm that new contamination would not be introduced through backfill material. An on-site borrow area for the ORR would not require specific permitting but would have to comply with State of Tennessee construction standards for erosion control.

5.3.6.7 Cost

Total capital cost for the site under SWA 6 would be $31 million. Operation and maintenance costs are estimated to be:

Years	Cost (× $1000)
1	75
2 to 3	724
4 to 30	240
5-year periodic	400

The total cost to complete this action would be ~$41 million in 1993 dollars with no escalation or discount. Appendix D presents the methodology and cost basis used in calculating the +50%, -30% cost estimate.

5.3.6.8 State acceptance

To be provided after receiving comments.

5.3.6.9 Community acceptance

To be provided after receiving comments.

5.3.7 Description and Summary of Evaluation of Sitewide Alternative 7 (SWA 7)

Description

SWA 7 involves the excavation of soil contaminated with > 180 ppm of mercury from the Residential RU and disposal at the modified Landfill VII. This alternative was developed using ecologically sensitive land-use assumptions with SWAs 1 through 6. Parcel 571, (undeveloped private property) currently not in residential or agricultural use, was considered in SWAs 1 through 6 to be in the Residential RU based on potential future land use. Realty interests would be acquired for part of Parcel 571, which is adjacent to DOE property, and for a small portion of a commercial parcel, Parcel 58 [0.01 ha (0.03 acre)], in Segment 1 and fenced along with the DOE parcel to prevent human access to the contaminated area. The remaining portion of Parcel 571, which is outside the area of contamination, would remain in the Residential RU. Figure 4.3 presents the areas of consideration in Segment 1 that would involve institutional actions (fencing, land-use restrictions, etc.). This change is based on restricting future land use to prevent residential development or agricultural use, thereby reducing the risk of exposure. SWA 7 includes the fencing of additional acreage for one Residential parcel and a portion of one Commercial parcel in Segment 1, which encompasses an additional 3.6 ha (8.88 acres). The additional acreage is being acquired and fenced because of the extreme difficulty of installing and maintaining fencing over the two wetland areas (Wetland 3 and 4).

Institutional actions, such as future use restrictions and digging permits, would be taken on the contaminated areas of Other and Commercial RU properties (> 200 ppm of mercury), which are relatively small in size [~ 1.64 ha (4.05 acres) and ~ 0.04 ha (0.09 acre), respectively]. Institutional actions would also be implemented on contaminated areas of DOE property in Segments 1 and 9 on the ORR. Exposure to residual contaminants on DOE property in Segment 1 [~ 0.53 ha (1.30 acres)] and a small portion within the Y-12 Plant boundary [~ 0.07 ha (0.19 acre)] would be prevented by fencing and future use restrictions.

Summary of Evaluation

SWA 7 would protect human health and the environment in the long term by removing ~ 18,700 m^3 (24,500 yd^3) of the contaminated soil and by establishing land-use limitations or restrictions on specific areas of EFPC to reduce the potential for human health exposure. Projected risks to children and adults in the community from dust generated during soil handling under SWA 7 are below (HI < 1) the EPA target level. Physical hazards for the community would be limited to transportation risk outside the RU because the community would be excluded from the area of remediation. Remediation activities would cause noncancer risk to unprotected workers in excess (HI > 1) of the EPA target levels. A project health and safety plan would address mitigative measures such as the use of personal protective equipment and dust suppression

techniques to confirm that the EPA target level would not be exceeded. Risks to the community are projected to result in 0.1 injury and 0.01 fatality. Transportation risks to workers are calculated to cause 0.004 worker injury and 0.002 worker fatality. In addition, construction risks for the worker are estimated at 4.3 injuries and 0.03 fatality. Thus, the total risks for SWA 7 would be expected to cause ~4 injuries and <0.1 fatality. The most significant impact on ecological receptors would be excavation of 2.5 ha (6.1 acres) of bottomland hardwood forest; 0.38 ha (0.94 acre) of wetlands; and 1424 m (1558 yd) of riparian habitat. The total cost of SWA 7 is estimated to be $31 million in 1993 dollars with no escalation.

5.3.7.1 Overall protection of human health and the environment

The protectiveness of SWA 7 for excavation and disposal actions (for the Residential RU) is the same as described for SWA 2. For the Commercial/DOE and Other RUs, SWA 7 is considered protective of human health and the environment, although the potential long-term exposure to ecological receptors from residual contaminants would exceed the level determined to be protective. The balancing of risks to ecological receptors from remediation (ecoremedial) and from remaining contamination (ecotoxicological) is explained in Appendix G. The risk to ecological receptors during implementation of excavation actions is considered to result in greater and more certain adverse effects than the potential long-term risk from residual contaminants. Loss of habitat during excavation would be expected to result in more direct and drastic impacts to biota and their habitats than continued exposure of the populations to soil contaminants. A total of 0.38 ha (0.94 acre) of wetland would be excavated under SWA 7.

5.3.7.2 Compliance with ARARs

SWA 7 would comply with ARARs. Section 5.3.2.2 discusses location-specific and action-specific ARARs for actions similar to those in SWA 7.

5.3.7.3 Long-term effectiveness and permanence

This section evaluates the effectiveness of SWA 7 in protecting human health in the long term. Long-term risk to ecological receptors is discussed in Sect. 5.3.7.5. The evaluation of this alternative considers two criteria: (1) residual risk and (2) protectiveness over time. Analysis of residual risk for SWA 7 indicates that no unacceptable risk to humans would remain. Actions for SWA 7 provide for the excavation of the contaminants, implementation of land use restrictions, or access limitations for certain areas to reduce the potential for human exposure. Excavated material would be disposed of in an approved landfill designed to be protective of human health and the environment.

Commercial/DOE RU. Under SWA 7, institutional actions would be applied to soil within the Commercial/DOE RU. Areas of these RUs containing >200 ppm mercury in soil would be subjected to land-use restrictions that would serve to minimize contact with this soil. Continued maintenance of the institutional actions is an important component of the long-term management proposed for SWA 7. This includes 5-year reviews of site conditions and assessment of the continued effectiveness of these institutional actions.

The fencing proposed for Segment 1 within the Commercial/DOE RU would be effective in minimizing exposure because it would restrict human access to these areas. Future land-use

limitations and acquisition of real estate interests would also be imposed to minimize contact by sensitive receptors by providing for land uses that would be other than residential or agricultural. Five-year reviews and assessments of site conditions would be required to confirm the continued effectiveness of these institutional actions. These institutional actions would be effective only to the extent that the responsible agency was able to enforce them. Enforcement is assumed to occur in this analysis by a federal agency.

Other RU. Under SWA 7, institutional actions would be applied to contaminated soil within the Other RU exceeding 200 ppm mercury. Residual concentrations of mercury at the exposure point (the surface) would be below the human health remediation goal option for mercury in these land-use areas, and postremedial soil risks would be below the EPA human health risk target. Continued maintenance would be part of the long-term management practices under the proposed institutional controls. SWA 7 would include periodic monitoring and 5-year reviews of site conditions to assess the continued effectiveness of these management practices.

Institutional actions (e.g., digging permits, land-use restrictions, and posting) would be effective to the extent that the responsible agency was able to enforce them. Because this action would leave contaminants on site, periodic monitoring, well survey, and 5-year reviews would be conducted to assess the continued effectiveness of these management practices to protect human health and the environment. Workers engaged in periodic monitoring and maintenance would be required to do so under an approved health and safety plan designed to protect them from contact with contaminated materials.

Residential RU. Under SWA 7, soil in the Residential RU exceeding 180 ppm mercury would be excavated and disposed. As a result, the residual risks at the RU would fall below the health risk target because the mercury-contaminated soil above the remediation goal option would be removed.

The excavation activities proposed for designated segments within the Residential RU would be effective in the long term because contaminated soil above the 180-ppm human health remediation goal option for mercury would be removed. Residual concentrations of mercury would, therefore, be below the remediation goal option, which would result in residual risks below the EPA health risk target. Five-year reviews would not be required for the soil excavation activities because contamination above the action level would be removed.

Disposal of contaminated material from these RUs at the Y-12 Plant disposal facility would comply with DOE policies and procedures and would be effective in the long term. The responsibility of long-term management, monitoring, and operation and maintenance would be placed with DOE, which is assumed to have adequate and reliable controls.

Under SWA 7, a portion of Parcel 571 (undeveloped property) falls under the Residential/Agricultural land-use category as the most sensitive potential future land use. This property has certain characteristics that warrant special consideration under SWA 7. Rather than undergo excavation and removal of soil containing >180 ppm of mercury, the property would be subject to land-use restrictions designed to preclude residential and/or agricultural land uses. In this way, the appropriate soil human health remediation goal option becomes 938 ppm of mercury. Since the remediation goal option is a risk-based goal, residual risks would be below

the EPA human health risk target, and no long-term management would be required to provide continued protection of human health.

Irreversible and Irretrievable Commitment of Resources

The implementation of SWA 7 would involve excavation, disposal, and institutional actions. Excavation actions would require the excavation of 18,700 m^3 (24,500 yd^3) of contaminated in situ soil. Excavation would disturb 2.5 ha (6.1 acres) of bottomland hardwood forest and 0.38 ha (0.94 acre) of wetlands. An estimated total of 22,400 m^3 (29,400 yd^3) of ex situ borrow soil would be needed for SWA 7. This soil would be committed to this use indefinitely. On-site borrow areas for topsoil are readily available within the West End Borrow Area on the ORR.

Institutional actions would require the rezoning of several land parcels. Long-term control measures also would be required (land-use restrictions and maintenance of solid cover and fencing).

Disposal of contaminated soil at the Y-12 Plant disposal facility would result in the permanent loss of some woodlot and old field habitat, which would be replaced with maintained cover following closure of the disposal facility. Irreversible commitment of land for the disposal facility would permanently limit future land use for ~4 ha (10 acres).

The use of heavy equipment for soil excavation, disposal, and replacement would involve the consumption of an estimated 126,200 L (33,400 gal) of diesel fuel. Additional petroleum products to be used include gasoline, lubricating oils, and greases.

5.3.7.4 Reduction of toxicity, mobility, or volume through treatment

SWA 7 does not include treatment; therefore, there is no reduction of toxicity, mobility, or volume due to treatment.

5.3.7.5 Short-term effectiveness and environmental impacts

Community Protection

Chemical Exposure. Under SWA 7, no excavation is planned for the Commercial/DOE RU soil. Therefore, no excavation exposures are considered. The contaminated soil exceeding 200 ppm mercury would not be disturbed in any way. For this reason, community exposures related to remedial activities would not occur as a result of remediation of the Commercial/ DOE RU.

Under SWA 7, no excavation is planned for the Other RU soil. The contaminated soil exceeding 200 ppm of mercury would not be disturbed in any way. Therefore, no excavation exposures are considered. For this reason, community exposures resulting from remediation of the Other RU have not been evaluated.

Excavation and removal of 18,700 m^3 (24,500 yd^3) of in situ soil containing > 180 ppm of mercury is planned for the Residential RU under SWA 7. Exposures are considered for the community via dust transported downwind outside the RUs and away from the disposal facility.

The soil ingestion and dermal contact exposure routes for the community outside the RUs are not considered because these exposure pathways are assumed to be minimal. As shown in Table 5.28, none of the community inhalation exposures to the dust would exceed the EPA noncancer risk target of 1.0.

Physical Hazards. The potential physical hazards to the community resulting from implementation of SWA 7 would be limited to transportation risks.

For the Residential RU, SWA 7 involves transport of contaminated soil from the RU and the return of clean borrow soil as backfill. No soil transport is planned for the Commercial/DOE and Other RUs under SWA 7. The time and distance traveled while hauling soil would be associated with the potential for transportation accidents involving injuries and/or fatalities. Since the trucks would either be covered and decontaminated before transport or filled with clean borrow soil, no significant exposures to hazardous materials are expected to occur during their transport.

The projected transportation risks to the community are 0.1 injury and 0.01 fatality. This indicates that transportation injuries would be unlikely, and transportation fatalities related to remediation under SWA 7 would be only a remote possibility.

Remediation Worker Protection

Chemical Exposures. Tables 5.31 and 5.32 show risks for workers remediating soil for SWA 7 during excavation and disposal actions, respectively. For unprotected workers (no personal protective equipment or other health and safety precautions), only soil ingestion risks would exceed (HI > 1) the EPA target for noncancer effects. Dermal contact and inhalation noncancer risks would be below (HI < 1) the EPA target in all cases. Cancer risks are not associated with exposures to mercury. A project health and safety plan would be developed for site activities, and the required mitigative measures to protect worker health and safety would be addressed to ensure worker exposure does not exceed acceptable EPA target levels.

Physical Hazards. Risks associated with construction activities for SWA 7 include 4.3 worker injuries and < 1 (0.03) fatality expected over the 1.8-year duration of the remedial activities. This corresponds to a projected annual incidence rate with construction activities for SWA 7 of 2.4 worker injuries and < 1 (0.02) worker fatality. Relocation of clean borrow soil for use as backfill to the remedial units would provide the potential for transportation accidents involving injuries and/or fatalities. Since the trucks would be filled with clean borrow soil, no exposures to hazardous materials are expected during their transport. The total transportation risks for workers are projected to result in 0.004 injury and 0.002 fatality. This indicates that for workers, both injuries and fatalities related to soil transport would be only a remote possibility.

Time Until Action is Completed

Estimated time to complete this action is 1.8 years. The short-term remedial response objectives would be achieved upon completion of actions. The actual time to complete this alternative, after approval by the regulatory agencies, would include ~12 to 18 months for remedial design and the associated approval of the remedial action work plan prior to

commencing the remedial action. Therefore, after final regulatory approval of the Record of Decision, it would take ~3 to 5 years to complete the action, not including long-term environmental monitoring.

Environmental Impacts—Soil and Floodplain

Soil. Remediation activities for soil under SWA 7 are described below.

Commercial/DOE RU

Under SWA 7, soil contaminated with >200 ppm mercury in a portion of the Commercial/DOE RU in Segment 1 would be fenced to limit human access, and some form of real estate interest would be acquired to restrict intrusive use of the property. Fencing would be placed around 5.53 ha (13.67 acres) of land encompassing 0.53 ha (1.30 acres) of DOE property and 0.01 ha (0.03 acre) of Commercial property in Segment 1. Other institutional actions would be used to limit exposure to contaminated soil on 0.04 ha (0.09 acre) of Commercial property in Segment 3, 0.07 ha (0.19 acre) of DOE property in Segment 1, and 0.21 ha (0.53 acre) of DOE property in Segment 9.

Other RU

In the Other RU, institutional actions including land-use restrictions would be applied to 1.64 ha (4.05 acres) of contaminated soil with >200 ppm mercury.

Residential RU

In the Residential RU, 18,700 m^3 (24,500 yd^3) of contaminated soil from six stream segments would be excavated and disposed. Access to an additional 1.94 ha (4.79 acres) would be restricted by fencing in Segment 1. Approximately 22,400 m^3 (29,400 yd^3) of ex situ borrow soil would be required for backfilling excavated areas.

Under SWA 7, Commercial/DOE and Residential RU soil in Segment 1 would be fenced. Sediment transport (HEC-6) and overland flow (GLEAMS) models were used to predict the downstream effect of the contaminated soil left in place. The mercury concentration in the depositional area resulting from sediment deposited during 1- and 5-year storm events downstream from the fenced area in Segment 1 was determined to be <60 ppm. Thus, the modeling evaluation indicated that it is not probable that contaminated soil from Segment 1 would recontaminate the downstream sections of the creek above levels of concern (SAIC 1994).

Floodplain. Remediation of the floodplain under SWA 7 is described below.

Commercial/DOE and Other RUs

Institutional actions would be applied to soil in the Commercial/DOE and Other RUs that are contaminated with 200 ppm mercury.

Residential RU

Excavation and disposal of contaminated soil in the Residential RU would not impede flood flow or adversely affect any other feature of the floodplain. Fencing placed in Segment 1 would be inspected after each high-water event and flood debris would be removed so that debris would not accumulate on fences and impede flood flow during future flood events.

Environmental Impacts—Water Quality

Surface Water. The primary short-term impact of SWA 7 on surface water quality would be the potential for changes in concentrations of mercury and total suspended solids during storms from erosion of soil during removal and backfilling (for the Residential RU). The effects would vary with position along the stream relative to the remediation activity rather than according to which RU was being remediated. Based on results from the GLEAMS model of a 5-year storm event (Sect. 2), the largest predicted total mercury concentration at the location LB reference point would be 2.00 μg/L during remediation of Creek Segment 4 (Table 5.11). Best Management Practices and appropriate engineering controls would be used to prevent adverse impacts during remedial activities. Reestablishing vegetative cover would reduce the amount of soil eroded into the creek.

Over the long term, the contaminant concentrations in the instream sediment are expected to decline as contaminated soil is removed. Based on the GLEAMS model, a 15% reduction in contribution of mercury from surface erosion during storms could be expected (Table 5.11). During base flow conditions, mercury concentrations would continue to depend on releases from the Y-12 Plant.

Environmental Impacts—Air Quality

The impacts to air quality that would result the implementation of SWA 7 would be expected to be similar to those described for SWA 2 in Sect. 5.3.2.5. Fewer segments along EFPC would be excavated and backfilled, so the actual impacts would be less.

Environmental Impacts—Land Use

Each RU would experience varying degrees of impacts, depending on the actions taken on each property within the RU and the accessibility to contaminated areas. Impacts would result from short-term remedial efforts and constraints to future developments as a result of the remedial efforts. Impacts would be similar to those described for the Residential and Other RUs for SWA 2.

Under SWA 7, the land-use designations of a portion of Parcel 571, identified in the Residential RU, would be altered to nonresidential use. This parcel (privately owned undeveloped land located in Segment 1) would be acquired by DOE, fenced, and future use would be restricted. This property is zoned to allow residential development. Future land-use limitations restricting residential development, such as a change in zoning, would be necessary for this parcel. The parcel could be rezoned for commercial, industrial, greenbelt, or other nonresidential uses. For the privately owned undeveloped property in Segment 1, the presence of nearby contamination and fencing could affect future development. Developers could be

deterred from pursuing certain developments due to the knowledge of the nearby contaminated area. If the property were developed for residential use, some prospective home buyers could be deterred from purchasing property near a fenced contaminated area. Lending institutions could be reluctant to lend money for residential developments near the contaminated area.

Commercial/DOE RU. The Commercial/DOE RUs consist of small sections of existing commercial parcels, small vacant parcels in commercial areas, and DOE-owned land. Only two commercial properties would require institutional actions: a corner portion of an auto dealership and an area behind an auto repair building. The small corner portion of the auto dealership would be acquired and would incur short-term impacts associated with the installation of a fence. Future land-use limitations would be necessary for these properties. The posting of the contaminated area could deter prospective buyers from purchasing the property. However, because the contaminated areas are relatively small and on the back portion of the properties, it is unlikely that land use on these properties would be affected.

The lands in the DOE RU are located near the Y-12 Plant at Pine Ridge gap, the NOAA property leased from DOE, and on the ORR on the west end of town. The areas near the Y-12 Plant and on the ORR have some institutional actions in place, such as fencing and posting. No impacts on land use are predicted for these areas. The NOAA site would incur short-term impacts associated with the installation of a fence. Land use for the NOAA property would be restricted to nonresidential and nonagricultural uses.

Environmental Impacts—Ecological Resources

Aquatic Resources. As indicated for SWA 2 (Sect. 5.3.2.5), long-term impacts to the aquatic habitats and biota in EFPC from the remedial actions at each of the RUs should continue at least at the level described for SWA 1, the No Action alternative (Sect. 5.3.1.5), because of the continued release of contaminants from the Y-12 Plant and deferred remediation of the surface water and sediments in EFPC until those releases are controlled. Any additional long-term and short-term impacts from the remedial activities are discussed below for each RU.

Commercial/DOE and Other RUs

Implementing SWA 7 for the Commercial/DOE and Other RUs would be expected to result in no additional impacts to aquatic biota and habitats because only institutional actions would be employed. No riparian habitats would require remediation in the three segments in this RU.

Residential RU

Implementing SWA 7 for the Residential RU would result in the excavation of 1424 m (1558 yd) of two riparian habitat types (bottomland hardwoods and old field). Riparian bottomland hardwoods comprise 1265 m (1384 yd) of the total excavated length of stream bank. The most significant potential short-term effects on aquatic biota in the Residential RU would occur in Segments 3 and 4 because of the greater lengths of excavated stream banks [254 and 706 m (278 and 772 yd), respectively] (Table 5.30). Short-term impacts would be expected to be greatest during the months of March through May because this is the period of maximum fish spawning for the species in EFPC. Four lithophilic spawning fish species have been identified in Segments 4, 5, and 6 (Table 5.12). Ten lithophilic species have been captured in Segment 9.

In Segments 1, 5, 8, and 9, short-term impacts to aquatic biota are expected to be negligible to minor because the lengths of excavated stream banks are fairly short [31 to 189 m (34 to 207 yd)]. Aquatic biota would be expected to experience minor long-term effects until shrubby riparian vegetation reestablished on the backfilled stream bank areas. No properties in Segments 2, 6, or 7 of the Residential RU have stream banks that require remediation.

Terrestrial Resources. Impacts to terrestrial habitats and biota resulting from the implementation of SWA 7 would be similar to those discussed under SWA 2. Construction of access roads and staging areas to implement remedial actions for this alternative would result in impacts to an estimated 0.04 ha (0.05 acre) of habitat.

Commercial/DOE RU

No excavation or containment actions are proposed for this RU. Institutional actions, including fencing in Segment 1, would not negatively affect terrestrial resources. Risk to ecological receptors would remain for the bottomland hardwood forest habitat in Segment 1. However, negative effects on terrestrial resources from excavation or containment would be significantly greater than the potential risk from contamination left in place. See Appendix G for an explanation of the balancing of ecoremedial and ecotoxicological effects.

Other RU

No excavation or containment actions are proposed for this RU.

Residential RU

Excavation actions in the Residential RU would destroy 2.4 ha (6.0 acres) of bottomland hardwood forest and 1.0 ha (2.5 acres) of old field habitat. Resident wildlife would also be destroyed or displaced. Disturbance would occur in Segments 1, 3, 4, 5, 8, and 9 of this RU. Habitats would begin reestablishing in these areas after completion of remedial activities (see Sect. 5.3.2.5, Terrestrial Resources).

Wetlands. Two wetlands would be affected by remediation in the Residential RU (Table 5.31). Wetland 5 in Segment 1 and Wetland 8 in Segment 4 [0.38 ha (0.94 acre)] would be excavated during remediation. Access to ~0.46 ha (1.13 acres) of Wetlands 3 and 4 would be restricted by fencing and other institutional actions, but these two wetlands would otherwise be unaffected by remediation.

Threatened and Endangered Species. No impacts to protected species would be expected under SWA 7. Excavation and any fencing along the EFPC floodplain is not expected to have a significant impact on the Tennessee dace since its critical habitat in the headwater regions of tributaries would not be affected.

It is not known at present whether protected species are present in the borrow soil or haul road areas. The proposed areas would be surveyed for the presence of protected species prior to selection.

Environmental Impacts—Archaeological, Cultural, and Historical Resources

There would be no impact to archaeological, cultural, and historical resources as described in SWA 2.

Environmental Impacts—Socioeconomic and Institutional Issues

The following sections describe potential impacts of SWA 7 on the institutional environment, public services and facilities, and economic and demographic resources. The discussion focuses on RUs to the extent practical. Section 2.1.7.1 describes the existing institutional environment, methods used for analysis, and a listing of identified stakeholder groups.

Institutional Considerations. SWA 7 would result in varied impacts on the institutional environment. The interim actions proposed for the Surface Water/Sediments RU would be similar to those for other alternatives. Section 5.3.2.5 describes the impacts on the institutional environment.

Institutional actions would be implemented on the Commercial/DOE RU. Only two commercial properties have been identified as having contamination >200 ppm. The effects on these properties would depend on the reliability and integrity of institutional actions over the long term and potential liability issues that could arise regarding transfer of the properties. The small corner portion of the auto dealership, Parcel 58, would be acquired by DOE. Because DOE is expected to maintain ownership and control of DOE-owned property over the foreseeable future, no impacts to the institutional environment would be likely to result from implementing institutional actions on the ORR.

City representatives, property developers, real estate interests, and residents generally appear to prefer whatever actions would give the community a relatively "clean bill of health" and remove the contamination, and the negative perceptions attached to it, as an issue in people's minds. With regard to the Other RU, particularly on those properties in Segments 4 and 5, institutional actions would give these properties a "clean bill of health." However, it would not completely remove the liability issue from future property transfers and financing. (Please refer to Sects. 2.1.7.1 and 5.3.2.5 for further detail.) To mitigate this impact, institutional mechanisms releasing future title holders from liability would be necessary.

Excavation and disposal of contaminated floodplain soil in the Residential RU would have similar effects as those described for SWA 2. Namely, these actions would have the potential to lessen liability concerns of current and future title holders and free lands for development. In the interim, effects on development could be expected to continue until completion of the remediation. To mitigate these impacts, institutional arrangements would be needed to provide interim development guidelines to the City and property developers.

As described in Sects. 2.1.7.1 and 5.3.2.5, a significant number of residents do not consider the contamination to be a problem from the standpoint of health and may consider excavation and disposal actions to be overly costly in the absence of clearcut threats. Short-term effects such as annoyance and inconvenience from traffic, noise, and dust would likely be intensified under these conditions. Residents whose properties would require excavation, approximately nine of whom live in the Grand Cove Lane area, would experience short-term (~2 years) disturbances to their

property and the temporary loss of trees and vegetation that contribute to aesthetic value. To mitigate impacts, DOE staff would consult and coordinate with individual affected residents to accommodate their particular needs and schedules to the extent possible.

Implementation of institutional actions and the exclusion of future residential uses would be unlikely to adversely affect current and future activities on the parcel in Segment 1 designated for future land-use limitations under SWA 7.

Public Services. SWA 7 would result in impacts on public services similar to those described for SWA 2 (Sect. 5.3.2.5). These would include short-term annoyance and inconvenience to schools systems and other facilities affected by excavation and transportation activities, and net beneficial effects on public services.

Economic and Demographic Resources. Employment resource impacts are estimated using RIMS II for Anderson and Roane counties developed by the Bureau of Economic Analysis. Employment estimates form the basis for the calculation of associated changes in the number of households and population. For a description of this modeling framework, see Appendix E.

Remediation activities are assumed to take place in the first 2 years of the action. In the first year, it is estimated that the remediation would require 11.5 FTEs annually for construction activities, 3.0 FTEs directly involved in acquiring real estate interests in selected properties, 14.5 for administrative support, and 0.3 FTEs for sampling and monitoring activities for a total of 29.3 FTEs. Wages and salaries in the first year are estimated to be $1.5 million, with expenditures for equipment and materials at $3.2 million, and associated expenditures for other business services at $5.3 million. Real estate transactions are estimated to require $0.4 million. The direct spending associated with the project that would go to local businesses and households is estimated to result in indirect employment of an additional 25.5 FTEs, for a total employment increase of 54.8. This represents 0.1% of the 63,317 people employed in Anderson and Roane counties in 1990 (see Table 2.14). The upper bound on the number of households created by this increase in employment is 41, or 0.1% of the 49,657 housing units in the two counties in 1990 (see Table 2.12). The associated population estimated consistent with the employment and housing impacts is 104, or 0.1% of the 115,477 people living in Anderson and Roane counties in 1990 (see Table 2.11). These changes are so small relative to the totals for the region of influence that this alternative should not result in adverse impacts to the economic and demographic conditions in Anderson and Roane counties.

In the second year, all activities associated with the acquisition of real estate interests would be completed. It is estimated that the project would require 14.5 FTEs for construction activities, 14.5 for administrative support, and a crew of five for sampling and monitoring activities. Wages and salaries are estimated to be $1.3 million, with expenditures for equipment and materials at $2.3 million, and associated expenditures for other business services at $6.3 million. The direct spending associated with the project that would go to local businesses and households is estimated to result in indirect employment of an additional 20.0 FTEs for a total employment increase of 54.0. This represents nearly 0.1% of the 63,317 people employed in Anderson and Roane counties in 1990 (see Table 2.14). The upper bound on the number of households created by this increase in employment is 40 or <0.1% of the 49,657 housing units in the two counties in 1990 (see Table 2.12). The associated population estimated consistent with the employment and housing impacts is 101 or nearly 0.1% of the 115,477 people living in Anderson and Roane

counties in 1990 (see Table 2.11). These changes are so small relative to the totals for the region of influence that this alternative should not result in adverse impacts to the economic and demographic conditions in Anderson and Roane counties.

Routine monitoring activities are assumed to take place during years 3 to 6, 8 to 11, 13 to 16, 18 to 21, 23 to 26, and 28 to 30. It is estimated that direct wages and salaries for the 0.3 FTEs required for sampling and reporting would be $10,500 per year; other expenses are estimated to be $89,500. No capital expenditures are estimated during these years. Using RIMS II, it is estimated that this activity would generate 0.1 additional FTEs, for a total employment effect of 0.4. This employment effect is so small, that there are no associated changes calculated for the number or households or population.

More extensive monitoring and sampling is assumed to be conducted at 5-year intervals, in years 7, 12, 17, 22, and 27. During these years, direct employment is to be increased to 0.8 FTEs. Using RIMS II, the associated secondary employment is 0.2 FTEs, for a total employment increase of one person. The number of new households associated with this growth is estimated to be one, and the population increase is estimated to be three. These values are so small relative to the size of the region that there should be no adverse impact on the economic and demographic conditions in Anderson and Roane counties.

Transportation Impacts. Remedial actions under this alternative would require the transport of large volumes of contaminated and borrow soil. Approximately 4900 truckloads would be required. Possible delays because of the increase in daily traffic would occur in each segment along the EFPC with the majority occurring in the vicinity of Segment 4.

Noise Impacts. Noise impacts from the remedial actions conducted for this alternative would be similar to those described for SWA 2. However, because the level of activity within the EFPC floodplain would be reduced and the time frame to complete the action would be shorter, the expected increase in noise level would not be significant.

Environmental Impacts—Unavoidable Adverse Impacts

SWA 7 would result in varied impacts on the institutional environment from the proposed institutional actions. The most significant of these would be land-use changes/restrictions. Unacceptable ecotoxicological risk to ecological receptors would remain in Segment 1 within the Commercial/DOE RU. However, the negative effects, or ecoremedial risk (see Appendix G for an explanation of the balancing method) on terrestrial resources resulting from remedial actions would be expected to be greater than the potential risk from residual contamination. Excavation actions within the Residential RU would destroy 2.4 ha (6.0 acres) of bottomland hardwood forest. Two wetlands within the Residential RU would be excavated. About 6% [0.02 ha (0.05 acre)] of Wetland 5 would be excavated, and 98% of Wetland 8 [0.36 ha (0.89 acre)] would be excavated.

Environmental Impacts—Short-Term Uses and Long-Term Productivity

Under SWA 7, short-term inconveniences would be expected during the remedial action, but the affected properties would be free of most constraints in the long term. Short-term impacts on all involved properties could result from building an access road to the contaminated areas,

clearing sites for staging areas, removing vegetation at the contaminated areas that could act as visual or sound buffers, and removing fences temporarily. After the remediation was completed, actions would be taken to remove roads, replant vegetation, and replace fences and other amenities that were disturbed. Additional short-term impacts to properties with existing uses could result from noise annoyance from truck traffic, dust potentially covering buildings, and inconveniences from truck traffic through residential yards and business properties. These short-term impacts would not necessarily alter short-term uses.

Residential RU. Because the contaminated soil would be excavated from the Residential RU, property owners would be able to use their properties any way they preferred. In this alternative, a portion of one property in the Residential RU would require future land-use limitations, such as a change to a different zoning district that would not allow residential developments. This property in Segment 1 is an undeveloped parcel zoned for residential use. Under this alternative, a portion of the property would be acquired by DOE and future land-use limitations would be implemented and the contaminated portion of the property would be fenced to prevent use of that portion of the property. If adjacent property were developed for residential use, some prospective home buyers could be deterred from purchasing property near a fenced contaminated area. Lending institutions could be hindered from lending money for developments because of the contaminated area.

Commercial/DOE RU. The contaminated areas on the Commercial/DOE RU would be left in place with institutional actions limiting disturbance of the areas. Signs would be posted to delineate the area. This action would not affect current commercial land uses but could be an impediment to selling the property in the future. The contaminated areas are near the stream and not directly involved in the functional portions of the properties. Two of the contaminated areas on DOE property are currently behind fences with posting. The other DOE property, currently leased to NOAA, along with a small corner portion of Commercial Parcel 58, would have the contaminated area fenced with signs.

Other RU. The contaminated areas in the Other RU would be left in place with institutional actions limiting disturbance of the areas. Therefore, minor constraints that limit future use would be placed on the long-term productivity of those properties. Future developers could be deterred from developing the property, but this would be unlikely since an action would have been taken to prevent adverse human health effects.

5.3.7.6 Implementability

Because SWA 7 involves limited excavation and containment, it is considered a particularly implementable alternative. Implementability concerns for SWA 7 (i.e., fencing and institutional actions) are similar to those discussed for SWA 2 (see Sect. 5.3.2.6) with the addition of future land-use restrictions for one parcel.

Parcel 571, owned by a private developer, is currently zoned for medium-density residential developments. A portion of the property in the floodplain is proposed to be acquired and fenced by DOE, thus changing the RU from Residential to Other. This action can only occur after the Record of Decision and a Final Real Estate Plan have been approved. The property owner may object to the acquisition, which would delay the implementation due to possible lengthy court

trials and negotiations. The owner has informally stated that he would like to use the property for commercial purposes, not residential.

A portion of Parcel 58, an auto dealership would be acquired and fenced. This action would also occur after the Record of Decision and a Final Real Estate Plan had been approved.

Implementability concerns for excavation, disposal, transportation, and borrow material for the Residential RU soil would be the same as discussed for SWA 2 (see Sect 5.3.2.6). Leaving Commercial/DOE and Other property soil in place would limit the total volume of waste to ~18,700 m^3 (24,500 yd^3). This decreased excavation would require less disposal volume.

5.3.7.7 Cost

Total capital cost for the site under this alternative would be $47 million. Operation and maintenance costs are estimated to be:

Years	Cost (× $1000)
1	75
2	3082
3 to 30	100
5-year periodic	150

The total cost to complete this action in 1993 dollars would be ~$31 million with no escalation or discount. Appendix D presents the methodology and cost basis used in calculating the +50%, -30% cost estimate.

5.3.7.8 State acceptance

To be provided after receipt of comments.

5.3.7.9 Community acceptance

To Be provided after receipt of comments.

5.4 MONITORING AND MITIGATIVE MEASURES

The primary monitoring and mitigative measures that would be used in implementing any of the final action alternatives at the EFPC OU are summarized in Table 5.32. These measures would provide a high degree of effectiveness in minimizing the potential for adverse effects associated with implementation of the alternatives. The DOE will prepare a mitigation action plan to track mitigation commitments made in the Record of Decision for this remedial action, in accordance with DOE procedures for implementing NEPA (10 CFR 1021). Similar measures would be implemented for activities related to disposal cell.

Mitigative measures for protecting air quality, such as surface wetting and use of covers or chemical dust suppressants, would be implemented to control fugitive dust during excavation, cover construction, surface grading, and other associated construction activities. Air quality would be monitored for all of the remedial action alternatives to assess protectiveness and to provide that applied control measures were adequate. Air quality would be monitored at the soil treatment facility (SWAs 4 and 5) to assess compliance with air quality standards and to provide that any additional controls could be applied in a timely manner.

Mitigative measures and good engineering practices would be used in excavation and construction areas to control surface water runoff and to minimize erosion and transport of sediment from exposed areas. These measures would include: construction of berms to direct the flow of surface water; construction of silt fences to minimize the amount of sediment leaving the area; covering of exposed surfaces with straw, mulch, riprap, or membranes; and using revegetation mats in those areas with high water velocity. Siltation ponds would be constructed where necessary to provide additional protection against any off-site transport of sediment or contaminated surface runoff. Runoff from contaminated areas would be contained within those areas in siltation ponds, sampled for contamination, and treated or filtered (if necessary) before release. The use of mitigative measures and good engineering practices near disturbed areas, in combination with the use of siltation ponds and the management of potentially contaminated runoff, would effectively limit the potential for off-site movement of contaminants in water or sediment.

Surface water is currently being monitored and would continue to be monitored during and after remedial action activities. If contaminant concentrations above background were detected during implementation, work would be stopped until the source was identified and controlled or appropriate contingency plans could be implemented.

Monitoring of terrestrial animals would be done yearly. Emphasis would be on total mercury and methyl mercury concentrations in whole-body (likely depurated) organisms. Aquatic organisms would be monitored regularly through the Biological Monitoring Abatement Program. See Appendix D for more assumptions on biological monitoring.

Good engineering practices would include taking necessary precautions to avoid damaging the buried utility line with heavy equipment during the remedial activities. DOE would coordinate with the City of Oak Ridge Public Works Department to ensure proper care is exercised and to avoid any conflicts in work schedules.

For disposal or treatment, waste would be transported in bulk by truck. Truck beds would be covered (and lined, if necessary). Contingency plans would be in place to address spills that might occur during any phase of off-site transport. Haul vehicles would be decontaminated and inspected before leaving any contaminated area. Potential impacts from accidental spills on site would be minimized by implementing appropriate operation procedures and contingency plans.

Following completion of construction and excavation activities, disturbed areas on site would be backfilled and revegetated, and disturbed areas outside the site boundaries (staging areas, access roads) would be restored to preremedial action conditions. Terrestrial and aquatic habitat restoration would be carried out in consultation with appropriate state and federal agencies.

Fences constructed to restrict access by humans and/or livestock can also create barriers to wildlife movement. Minimal disruption to wildlife populations along EFPC would be expected to result from the type of fence proposed. Impacts probably would be limited to animals larger than rabbits (e.g.,skunks, raccoons, foxes). Although deer could be hindered in their movements into and out of the fenced areas, the height of the proposed fence would not prevent movement of this species. Fence design and construction could incorporate features to allow easy ingress and egress for wildlife. The mesh size of the fence material could be specified large enough [10 to 12.7 cm (4 to 5 in.)] to allow passage of most species. A fence with a mesh of 10 cm (4 in.) would allow access to species as large as raccoons, while a 12.7-cm (5-in.) mesh would permit foxes to enter and leave a fenced area (Newby 1993). This feature could be used for the entire fence or only along specified sections. Another technique to allow wildlife access to fenced areas is raising the mesh no more than 12.7 cm (5 in.) off the ground. If greater security to human access is required, this would be performed by reinforcing the bottom of the mesh with a horizontal pipe along short sections [about 3 m (10 ft)] between fence posts. Incorporation of these or similar structural mitigative measures would minimize impacts to wildlife and could help reduce long-term maintenance costs by allowing access to animals that might otherwise burrow underneath the fence. Some burrowing is expected even with these measures in place (Newby 1993).

Wetlands Mitigation. Mitigation would be used to offset lost wetland resource values when impacts could not be avoided or further minimized. The objective of mitigation would be to compensate for environmental losses by providing substitute resources and would be based on the replacement of wetland functions and values. Ideally, compensation in kind and on site is preferred.

Mitigation of wetlands typically provides a minimum of one-for-one functional replacement (i.e., no net loss of values), with a margin of safety based on the anticipated success of the mitigation plan. However, the final mitigation ratio would depend on the quality of the wetland to be taken; the COE Regulatory Branch seldom sets mitigation ratios less than two-to-one (Hedrick 1993).

Restoration and creation of wetlands are the two methods used most often for mitigation. Restoration is usually considered preferable to creation because restoration of wetland functions to a former wetland or a degraded wetland has been demonstrated to be more successful than creating a wetland in a nonwetland environment (Hammer 1992). Wetland banking is a form of mitigation using restoration or creation in advance of the proposed action to establish mitigation credits that can be used to compensate for adverse impacts to wetlands. In the case of the EFPC remediation, DOE would devise a wetland mitigation plan (including replacement ratios) with the cooperation and assistance of TDEC, COE, and FWS.

5.5 POTENTIAL CUMULATIVE IMPACTS

Cumulative impacts are the effects on the environment that would result from the incremental impacts of the proposed action when added to other past, present, and reasonably foreseeable future actions. Cumulative impacts could result from individually minor but collectively significant actions taking place over a period of time (40 CFR 1508.7). Cumulative impacts could be short-term (during construction) or long-term and could include habitat loss, increases

in pollutant emissions or discharge rates, noise pollution, and alteration of hydrology or nutrient cycling in watersheds. The area of focus for consideration of cumulative impacts in this evaluation will be the City of Oak Ridge, including the ORR. The alternatives developed to remediate the site would result in activities and potential impacts within the corporate boundaries of Oak Ridge. The potential effects of the alternatives are considered in combination with currently planned future projects for the reservation, particularly in the EFPC and Bear Creek watersheds and in the vicinity of the low-temperature thermal desorption, and with past and present actions on the reservation. The identified future actions that could contribute to potential cumulative impacts are identified in Table 5.33.

The following analysis assumes the remedial actions are approved and are constructed within 5 years and that DOE continues to maintain operations on the ORR in the long term. Remedial actions in the EFPC floodplain are expected to begin in late summer 1996 and to be completed within 3 years.

5.5.1 Land Use, Archaeological/Cultural Resources

Approximately 2.5 ha (6.19 acres) that are currently in natural habitat would be converted to maintained grassy fields in the containment actions for SWAs 2 and 4, thus land use would change from natural area to waste containment. This conversion would be for the long term, since reversion to natural area would be prevented as part of the cap maintenance. Conversion to grassy cover, associated with actions proposed for the ORR in the next 5 years would result in additional land-use change on the ORR; the change would be from natural area to waste management or DOE programmatic use. Private land within the city is also expected to be converted from natural area to residential or commercial use.

5.5.2 Geology and Soils

No impacts to geology related to remedial action in EFPC floodplain are expected. Cumulative impacts to soil would result from the alteration of topography and soil profiles at borrow soil sites for the construction and/or restoration work planned for the ORR. Repair of the city-owned sewer line within the floodplain could result in residual contaminated soil in the contained areas being brought to the surface.

5.5.3 Water Quality

Adverse impacts to surface water quality are unavoidable during implementation of action alternatives, although stringent erosion controls are expected to minimize the impact. Projects scheduled for construction on the ORR during the same time period as remediation in the EFPC floodplain are shown in Table 5.33. These would not be expected to have a cumulative adverse impact on water quality in EFPC and Poplar Creek. The volume of flow in the Clinch River is of sufficient quantity that contribution of sediment during simultaneous construction of several projects is unlikely to have an adverse impact on its water quality. Ongoing releases from the Y-12 Plant and future releases related to decontamination and decommissioning at the Y-12 Plant could also contribute contaminants to EFPC. Increased discharge of process water into EFPC by the Y-12 Plant beginning in mid-1994 could have a beneficial effect on water quality by reducing the average contaminant concentrations to half of their current values.

Road construction and property development in the EFPC watershed could also result in increased sediment load in EFPC. A proposed new east-west transportation corridor in Oak Ridge could be built along Wiltshire Drive and Tuskeegee Drive; however, the location has not yet been determined. The Tennessee Department of Transportation has begun plans to develop and improve an east-west transportation route between I-40 and I-75. This project would involve widening Highway 95 west of Oak Ridge and Highway 62 between Oak Ridge and Clinton. Highway 62 between Oak Ridge and Clinton is currently being widened. Specific details of the route through Oak Ridge are not known at present. Road construction at the west end of Oak Ridge would be expected to have a potentially significant adverse impact to surface water quality if this activity were to be concurrent with remediation of EFPC.

Oak Ridge is planning to renovate its sewer system; the improvements would be expected to prevent stormwater overflow from the system and to improve water quality downstream from the outfall of the treatment facility.

5.5.4 Air Quality

Fugitive dust and equipment emissions would be minimized during excavation, handling, and transport of soil during remediation; however, some fugitive emissions are unavoidable. Other projects on the ORR would release both dust and combustion byproducts. The combustion byproducts from the remediation activities and other projects on the ORR would not be expected to have a cumulative adverse impact on workers and residents in the area.

Air dispersion modeling analysis for fugitive dust indicated that the 24-h average concentrations of inhalable dust would be 104 and 5 $\mu g/m^3$ at the downwind distance of 100 and 1500 m (109 and 1640 yd), respectively. According to data in the *Oak Ridge Environmental Report for 1991*, the maximum PM_{10} (particulate matter) ambient concentration near the K-25 Site is 21 $\mu g/m^3$. This background value represents all natural background and contributions from existing sources. Therefore, the cumulative PM_{10} concentration would be 125 and 26 $\mu g/m^3$ at 100 and 1500 m (109 and 1640 yd), respectively, from the site. These concentration values are lower than the primary and secondary standard of 150 $\mu g/m^3$ for PM_{10} for the state of Tennessee. Therefore, no cumulative impact would be expected.

According to Oak Ridge's EQAB, at least four commercial incinerator facilities are operating or planned: the DOE TSCA Incinerator at the K-25 Site, which burns ~3 million lb/year of both TSCA (PCBs) and RCRA hazardous waste contaminated with uranium; Scientific Ecology Group (SEG) waste incinerators, which burn ~7 million lb/year of low-level radioactive waste at its Bear Creek Road facility; another proposed incinerator at SEG's Bear Creek Road facility that will be capable of burning mixed waste (regulated as both RCRA and radiologic wastes); Diversified Scientific Service Incorporated's incinerator on Gallaher Road, which is permitted to burn up to 2 gal/h of mixed waste; and IT Corporation's proposed mobile RCRA incinerator. Based on the information currently available, EQAB does not believe there are significant cumulative impacts from operation of the commercial waste incinerators in or near Oak Ridge (Smith 1993). In fact, with respect to the cumulative impacts to the PM_{10} standard, the impacts of the existing sources (including existing incinerators and other sources) are reflected in the actual ambient monitoring data discussed above.

Since there is no national or state ambient standard for mercury, the cumulative impact regarding mercury would be on human health and is discussed in Sect. 5.5.6.

5.5.5 Ecological Resources

For SWAs 2 through 5, the loss of bottomland forest habitat and wetland habitat should be considered in the context of the status of these habitats on the ORR and within the city. Approximately 60% of the ORR is in natural area, at present ~8498 ha (21,000 acres); however, very little of this is comprised of bottomland hardwood or wetland. Areas of these habitats on the ORR have not been quantified but are considered limited but important ecological resources. The city has a system of greenbelts, which are mostly comprised of upland hardwood forest.

Riparian forested wetlands are present on headwater streams in many of the drainages on the ORR and in greenbelts within the city. If many riparian wetlands in a watershed were eliminated, it would be reasonable to expect an adverse cumulative loss of habitat for plants and animals requiring wetlands; reduction in ability to sustain aquatic life related to adverse effects on nutrient cycling and sediment loading; an increase in incident light and water temperature resulting from elimination of shading, which may change species composition and reduce tolerance to other environmental stressors (e.g., chlorine releases); and, an adverse impact on groundwater recharge to springs and seeps in the drainages of the watershed. SWAs 2 through 5 include permanent conversion of floodplain forest, including some jurisdictional wetlands, to grassy cover and artificially stabilized banks which would in effect channelize the stream.

5.5.6 Human Health and Safety

To evaluate the cumulative effects of mercury on human health and safety, three groups of contributors should be considered: mercury sources of this remediation project, all existing mercury sources, and future mercury sources. Their cumulative effects would be through the air pathway. According to the information available, no new sources would emit significant amounts of mercury into the atmosphere in the area during the EFPC remediation.

Contributions from existing sources (including natural background) are reflected in ambient mercury monitoring data. Ambient mercury concentrations are monitored around the Y-12 Plant. One station (Rain Gage No. 2) in the monitoring network was designed to obtain mercury background concentration. The highest concentration measured during a 2-year period (1988-89) was 0.016 $\mu g/m^3$, and the average was 0.006 $\mu g/m^3$. The worst-case contribution (0.016 $\mu g/m^3$) from all other sources combined is 2 orders of magnitude lower than either the contributions from the remediation activities at the EFPC OU or the contributions from the low-temperature thermal desorption and contaminated soil storage located at the K-25 Site. Therefore, with the consideration of the cumulative effects, the conclusions throughout Sect. 5.3 are the same.

In fact, calculations with the worst-case cumulative impacts show that the HIs in the human risk assessment for all alternatives would increase by <0.1, which does not change those HIs with values <1 to values >1.

5.6 IMPACTS OF POTENTIAL LOSS OF INSTITUTIONAL CONTROLS

DOE would maintain institutional controls at EFPC if SWAs 2, 4, 6, or 7 were selected. These controls would include signs limiting access, fences, land-use restrictions, digging permits, and soil cover of contaminated areas, which were described in Sect. 5.2.2. The site vicinity would continue to be monitored to detect changes in the containment system resulting from natural physical or biological forces such as erosion of the cover, damage to fences, or biotic intrusion by animal burrows or tree blowdowns. In the event of uncorrected cover failure, contaminants released to off-site areas by means of surface water transport could affect biota and habitats off site. If deterioration of the cover were detected, DOE would undertake repairs, replacement, or actions to maintain continued containment of contaminants and safety of the nearby environment. In the unlikely event that institutional controls were lost at some time in the future, deterioration of the containment system without corrective measures could result in the release of contaminants and possible future impacts on human health and the environment under any of the containment alternatives. The magnitude of the impacts that could occur in the future would depend on the extent of releases, on local land use at the time it occurred, and on the resulting exposure of human or ecological receptors to contaminants.

It is possible that humans could inadvertently intrude into the limited access area if institutional controls were lost at some time in the future. Such intrusion could result in temporary exposure to contaminants if containment were to fail at the same time as institutional controls. It is unlikely that protracted exposure would occur because the local community would be expected to retain awareness of the site. Fencing and signs restricting access would be in place. Regular monitoring would be expected to determine if these institutional controls were removed or damaged so that they could be repaired or replaced in a timely way.

SECTION 5

TABLES

This page intentionally left blank.

Table 5.1. Integration of NEPA values with CERCLA evaluation criteria

Overall Protection of Human Health and the Environment
Compliance with ARARs
Long-Term Effectiveness and Permanence
Irreversible and Irretrievable Commitment of Resources
Short-Term Effectiveness and Environmental Impacts
Direct and Indirect Environmental Impacts and Their Significance
Soils, and Floodplains
Water Quality/Resources
Air Quality
Ecological Resources
Aquatic Resources
Terrestrial Resources
Threatened and Endangered Species
Wetlands
Archaeological, Historical, and Cultural Resources
Land Use and Recreational/Aesthetic Resource Issues
Socioeconomic and Institutional Issues
Economic and Demographic Impacts
Institutional Environment
Ambient Noise Impacts
Transportation Impacts
Unavoidable Adverse Impacts
Short-term Uses and Long-term Productivity
Mitigative Measures[a]
Cumulative Impacts[a]
Reduction of Toxicity, Mobility, and Volume through Treatment
Implementability
Cost
State Acceptance
Community Acceptance

[a]To be discussed for all alternatives, after the detailed analysis and before the comparative analysis (Sects. 5.4 and 5.5).

Table 5.2. Contamination within each RU

RU	Total area[a]	Total area contaminated[a]	Total %[a]
Residential (>180 ppm)	78 ha (192 acres)	4.85 ha (11.97 acres)	6
Commercial (>200 ppm)	13 ha (33 acres)	0.05 ha (0.12 acre)	0.3
Other (>200 ppm)	43 ha (107 acres)	1.64 ha (4.05 acres)	1
DOE (>200 ppm)	90 ha (223 acres)	0.81 ha (2.02 acres)	0.9
Total[b]	224 ha (555 acres)	7.35 ha (18.16 acres)	3

[a] All numbers were approximated.

[b] This number represents the total area for all RUs within EFPC but does not include the total area for the entire EFPC site, which also includes additional area for roads and the creek.

Table 5.3. Primary, secondary, and tertiary sediment exposure pathways

ID	Primary source	Pathway	Primary receptor/ secondary source	Secondary pathway	Secondary receptor/ tertiary source	Tertiary pathway	Tertiary receptor
Sediment-1	Sediment	Body contact[a]	Aquatic biota	Ingestion	Aquatic biota	Ingestion	Terrestrial biota
Sediment-2	Sediment	Ingestion	Aquatic biota	Ingestion	Aquatic biota	Ingestion	Terrestrial biota
Sediment-3	Sediment	Ingestion	Aquatic biota	Ingestion	Terrestrial biota		
Sediment-4	Sediment	Dermal contact	Terrestrial biota				
Sediment-5	Sediment	Ingestion	Terrestrial biota				
Sediment-6	Sediment	Leaching	Surface water	Body contact	Aquatic biota	Ingestion	Terrestrial biota
Sediment-7	Sediment	Leaching	Surface water	Ingestion	Aquatic biota	Ingestion	Terrestrial biota
Sediment-8	Sediment	Leaching	Surface water	Dermal contact	Terrestrial biota		
Sediment-9	Sediment	Leaching	Surface water	Ingestion	Terrestrial biota		
Sediment-10	Sediment	Leaching	Groundwater	Ingestion	Terrestrial biota		
Sediment-11	Sediment[b]	Body contact[a]	Aquatic biota	Ingestion	Aquatic biota	Ingestion	Terrestrial biota
Sediment-12	Sediment[b]	Ingestion	Aquatic biota	Ingestion	Aquatic biota	Ingestion	Terrestrial biota
Sediment-13	Sediment[b]	Ingestion	Terrestrial biota				
Sediment-14	Sediment[b]	Deposition	Soil	Dermal contact	Terrestrial biota	Ingestion	Terrestrial biota
Sediment-15	Sediment[b]	Deposition	Soil	Ingestion	Terrestrial biota	Ingestion	Terrestrial biota
Sediment-16	Sediment[b]	Deposition	Plants	Ingestion	Terrestrial biota	Ingestion	Terrestrial biota
Sediment-17	Sediment[b]	Deposition	Wetlands				
Sediment-18	Sediment	Excavation	Aquatic habitat				

[a] Gill exposure pathway is the predominant component
[b] Suspended sediment

Table 5.4. Primary, secondary, and tertiary soil exposure pathways

ID	Primary source	Pathway	Primary receptor/ secondary source	Secondary pathway	Secondary receptor/ tertiary source	Tertiary pathway	Tertiary receptor
Soil-1	Soil	Dermal contact	Terrestrial biota	Ingestion	Terrestrial biota		
Soil-2	Soil	Ingestion	Terrestrial biota	Ingestion	Terrestrial biota		
Soil-3	Soil	Deposition	Plants	Ingestion	Terrestrial biota		
Soil-4	Soil	Deposition	Sediments	[a]	[a]	[a]	[a]
Soil-5	Soil	Inhalation	Terrestrial biota	Ingestion	Terrestrial biota		
Soil-6	Soil	Leaching	Groundwater	Ingestion	Terrestrial biota		
Soil-7	Soil	Deposition	Wetlands				

[a] See Sediment-1 through Sediment-17 in Table 5.3.

Table 5.5. Summary of short-term risks associated with containment activities at EFPC (SWA 2)

Segment	Receptor	Hazard index			
		Ingestion	Dermal contact	Inhalation	Total
1	Workers	1.13E + 01 *E*	2.71E - 01 B	1.06E - 02 B	1.16E + 01 *E*
2	Workers	NA	NA	NA	NA
3	Workers	5.03E + 00 *E*	1.20E - 01 B	4.73E - 03 B	5.15E + 00 *E*
4	Workers	6.87E + 00 *E*	1.65E - 01 B	6.46E - 03 B	7.04E + 00 *E*
5	Workers	5.51E + 00 *E*	1.32E - 01 B	5.18E - 03 B	5.65E + 00 *E*
6	Workers	NA	NA	NA	NA
7	Workers	NA	NA	NA	NA
8	Workers	NA	NA	NA	NA
9	Workers	7.79E + 00 *E*	1.87E - 01 B	7.33E - 03 B	7.99E + 00 *E*
1	Adults	NA	NA	NA	NA
2	Adults	NA	NA	NA	NA
3	Adults	NA	NA	NA	NA
4	Adults	NA	NA	NA	NA
5	Adults	NA	NA	NA	NA
6	Adults	NA	NA	NA	NA
7	Adults	NA	NA	NA	NA
8	Adults	NA	NA	NA	NA
9	Adults	NA	NA	NA	NA
1	Children	NA	NA	NA	NA
2	Children	NA	NA	NA	NA
3	Children	NA	NA	NA	NA
4	Children	NA	NA	NA	NA
5	Children	NA	NA	NA	NA
6	Children	NA	NA	NA	NA
7	Children	NA	NA	NA	NA
8	Children	NA	NA	NA	NA
9	Children	NA	NA	NA	NA

B — below or equal to EPA target for noncancer hazard index (HI ≤ 1)
E — exceeds EPA target for noncancer hazard index (HI > 1)
NA - pathway not evaluated

Table 5.6. Summary of short-term risks associated with excavation activities at EFPC (SWA 2)

Segment	Receptor	Hazard index			
		Ingestion	Dermal contact	Inhalation	Total
1	Workers	1.13E + 01 *E*	2.71E - 01 B	3.69E - 01 B	1.19E + 01 *E*
2	Workers	NA	NA	NA	NA
3	Workers	5.03E + 00 *E*	1.20E - 01 B	1.64E - 01 B	5.31E + 00 *E*
4	Workers	6.87E + 00 *E*	1.65E - 01 B	2.24E - 01 B	7.25E + 00 *E*
5	Workers	5.51E + 00 *E*	1.32E - 01 B	1.80E - 01 B	5.82E + 00 *E*
6	Workers	NA	NA	NA	NA
7	Workers	NA	NA	NA	NA
8	Workers	3.47E + 00 *E*	8.31E - 02 B	1.13E - 01 B	3.67E + 00 *E*
9	Workers	7.79E + 00 *E*	1.87E - 01 B	2.54E - 01 B	8.24E + 00 *E*
1	Adults	NA	NA	2.20E - 01 B	2.20E - 01 B
2	Adults	NA	NA	NA	NA
3	Adults	NA	NA	1.11E - 01 B	1.11E - 01 B
4	Adults	NA	NA	1.34E - 01 B	1.34E - 01 B
5	Adults	NA	NA	1.07E - 01 B	1.07E - 01 B
6	Adults	NA	NA	NA	NA
7	Adults	NA	NA	NA	NA
8	Adults	NA	NA	6.76E - 02 B	6.76E - 02 B
9	Adults	NA	NA	1.52E - 01 B	1.52E - 01 B
1	Children	NA	NA	5.03E - 01 B	5.03E - 01 B
2	Children	NA	NA	NA	NA
3	Children	NA	NA	2.54E - 01 B	2.54E - 01 B
4	Children	NA	NA	3.06E - 01 B	3.06E - 01 B
5	Children	NA	NA	2.45E - 01 B	2.45E - 01 B
6	Children	NA	NA	NA	NA
7	Children	NA	NA	NA	NA
8	Children	NA	NA	1.54E - 01 B	1.54E - 01 B
9	Children	NA	NA	3.47E - 01 B	3.47E - 01 B

B — below or equal to EPA target for noncancer hazard index (HI ≤ 1)
E — exceeds EPA target for noncancer hazard index (HI > 1)
NA - pathway not evaluated

Table 5.7. Summary of short-term risks associated with disposal activities at the Y-12 Plant disposal facility (SWA 2)

Segment	Receptor	Hazard index			
		Ingestion	Dermal contact	Inhalation	Total
1	Workers	1.13E + 01 *E*	2.71E - 01 **B**	7.44E - 01 **B**	1.23E + 01 *E*
2	Workers	NA	NA	NA	NA
3	Workers	5.03E + 00 *E*	1.20E - 01 **B**	3.31E - 01 **B**	5.48E + 00 *E*
4	Workers	6.87E + 00 *E*	1.65E - 01 **B**	4.52E - 01 **B**	7.48E + 00 *E*
5	Workers	5.51E + 00 *E*	1.32E - 01 **B**	3.63E - 01 **B**	6.01E + 00 *E*
6	Workers	NA	NA	NA	NA
7	Workers	NA	NA	NA	NA
8	Workers	3.47E + 00 *E*	8.31E - 02 **B**	2.28E - 01 **B**	3.78E + 00 *E*
9	Workers	7.79E + 00 *E*	1.87E - 01 **B**	5.13E - 01 **B**	8.49E + 00 *E*
1	Adults	NA	NA	3.42E - 02 **B**	3.42E - 02 **B**
2	Adults	NA	NA	NA	NA
3	Adults	NA	NA	1.52E - 02 **B**	1.52E - 02 **B**
4	Adults	NA	NA	2.07E - 02 **B**	2.07E - 02 **B**
5	Adults	NA	NA	1.67E - 02 **B**	1.67E - 02 **B**
6	Adults	NA	NA	NA	NA
7	Adults	NA	NA	NA	NA
8	Adults	NA	NA	1.05E - 02 **B**	1.05E - 02 **B**
9	Adults	NA	NA	2.36E - 02 **B**	2.36E - 02 **B**
1	Children	NA	NA	7.80E - 02 **B**	7.80E - 02 **B**
2	Children	NA	NA	NA	NA
3	Children	NA	NA	3.47E - 02 **B**	3.47E - 02 **B**
4	Children	NA	NA	4.74E - 02 **B**	4.74E - 02 **B**
5	Children	NA	NA	3.80E - 02 **B**	3.80E - 02 **B**
6	Children	NA	NA	NA	NA
7	Children	NA	NA	NA	NA
8	Children	NA	NA	2.39E - 02 **B**	2.39E - 02 **B**
9	Children	NA	NA	5.38E - 02 **B**	5.38 - 02 **B**

B — below or equal to EPA target for noncancer hazard index (HI ≤ 1)
E — exceeds EPA target for noncancer hazard index (HI > 1)
NA - pathway not evaluated

93-008P/080794

Table 5.8. Summary of short-term risks associated with cleanup from a hypothetical accident during off-site transport of contaminated soils from the EFPC floodplain

Segment	Receptor	Hazard index			
		Ingestion	Dermal contact	Inhalation	Total
1	Workers	5.50E + 00 *E*	1.32E - 01 B	2.45E - 01 B	5.88E + 00 *E*
2	Workers	NA	NA	NA	NA
3	Workers	2.45E + 00 *E*	5.86E - 02 B	1.09E - 01 B	2.61E + 00 *E*
4	Workers	3.34E + 00 *E*	8.01E - 02 B	1.49E - 01 B	3.57E + 00 *E*
5	Workers	2.68E + 00 *E*	6.43E - 02 B	1.20E - 01 B	2.87E + 00 *E*
6	Workers	NA	NA	NA	NA
7	Workers	NA	NA	NA	NA
8	Workers	1.69E + 00 *E*	4.04E - 02 B	7.52E - 02 B	1.80E + 00 *E*
9	Workers	3.79E + 00 *E*	9.09E - 02 B	1.69E - 01 B	4.05E + 00 *E*
1	Adults	NA	NA	1.62E - 01 B	1.62E - 01 B
2	Adults	NA	NA	NA	NA
3	Adults	NA	NA	7.19E - 02 B	7.19E - 02 B
4	Adults	NA	NA	9.83E - 02 B	9.83E - 02 B
5	Adults	NA	NA	7.89E - 02 B	7.89E - 02 B
6	Adults	NA	NA	NA	NA
7	Adults	NA	NA	NA	NA
8	Adults	NA	NA	4.96E - 02 B	4.96E - 02 B
9	Adults	NA	NA	1.12E - 01 B	1.12E - 01 B
1	Children	NA	NA	3.70E - 01 B	3.70E - 01 B
2	Children	NA	NA	NA	NA
3	Children	NA	NA	1.64E - 01 B	1.64E - 01 B
4	Children	NA	NA	2.25E - 01 B	2.25E - 01 B
5	Children	NA	NA	1.80E - 01 B	1.80E - 01 B
6	Children	NA	NA	NA	NA
7	Children	NA	NA	NA	NA
8	Children	NA	NA	1.13E - 01 B	1.13E - 01 B
9	Children	NA	NA	2.55E - 01 B	2.55E - 01 B

B — below or equal to EPA target for noncancer hazard index (HI ≤ 1)
E — exceeds EPA target for noncancer hazard index (HI > 1)
NA - pathway not evaluated
Note: The hypothetical accident does not take place within any of the segments. However, risks are calculated for Segments 1, 3, 4, 5, 8, and 9 because trucks will be carrying excavated soil from these segments.

Table 5.9. Estimated in situ volumes and surface areas of EFPC soils contaminated above the mercury remediation goal option[a]

		Excavation				Containment	
		Soil volume[b]		Affected area[c]		Affected area[c]	
	Sitewide alternative	yd^3	m^3	acres	ha	acres	ha
1	No action	0	0	0	0	0	0
2	Partial excavation, on-site disposal, soil cover	32,800	25,100	11.97	4.85	6.19	2.50
3	Complete excavation, on-site disposal	54,000	41,400	18.16	7.35	0	0
4	Partial excavation, treatment, disposal (beneficial reuse)	32,800	25,100	11.97	4.85	6.19	2.50
5	Complete excavation, treatment, disposal (beneficial reuse)	54,000	41,400	18.16	7.35	0	0
6	Containment	0	0	0	0	18.16[d]	7.35
7	Land use (rezoning), partial excavation, containment	24,500	18,700	8.70[e]	3.52	0	0

[a] Remediation goal option levels are 180 ppm mercury in soil in the Residential and Agricultural RUs and 200 ppm mercury in soil in the Commercial/DOE and Other RUs. For comparison of soil volumes excavated and surface area affected, by RU and segment, see Tables 4.2 and 4.3.

[b] All volume values rounded to the hundreds figure after conversion.

[c] All area values rounded to two decimal places after conversion.

[d] In SWA 6, an additional 3.6 ha (8.88 acres) would be acquired and fenced to encompass two wetland areas.

[e] In SWA 7, ~1.94 ha (4.79 acres) of contaminated soil >180 ppm mercury not affected inside a 5.53-ha (13.67-acre) fenced area encompassing two wetlands.

Table 5.10. Estimated ex situ volumes of soil covers for containment of mercury-contaminated soil in the EFPC floodplain for SWAs 2 and 4

	Commercial		Other		DOE		Total	
Segment	yd^3	m^3	yd^3	m^3	yd^3	m^3	yd^3	m^3
1	100	100	0	0	4,700	3,600	4,800	3,700
2	0	0	0	0	0	0	0	0
3	300	200	0	0	0	0	300	200
4	0	0	10,500	8,000	0	0	10,500	8,000
5	0	0	2,200	1,700	0	0	2,200	1,700
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
9	0	0	0	0	1,600	1,200	1,600	1,200
Total	400	300	12,700	9,700	6,300	4,800	19,400	14,800

Table 5.11. Contribution of soil erosion to sediment load and mercury concentration at Location LB (EFPCM 3.3) based on the GLEAMS model of a 5-year, 24-h storm event under various remedial alternatives

Remedial alternative	Contribution of creek segment to sediment load (mg/L)[a]									
	1	2	3	4	5	6	7	8	9	Total
1	0.7	1.0	0.8	0.5	0.2	0.6	2.8	0.5	3.7	10.8
During 2, 3, 4, 5	2.9	1.3	1.3	4.3	1.2	1.4	4.9	2.6	5.7	25.7
After 2, 4	0.9	1.0	0.8	0.8	0.3	0.6	2.9	0.7	3.9	11.9
After 3, 5	0.7	1.0	0.8	0.5	0.2	0.6	2.8	0.5	3.7	10.8
During 6	1.7	1.0	1.1	3.5	0.6	0.6	2.8	1.3	3.9	16.5
After 6	0.8	1.0	0.8	0.8	0.2	0.6	2.8	0.6	3.7	11.4
During 7	0.7	1.2	1.3	4.1	1.1	1.4	4.4	1.5	4.7	20.5
After 7	0.7	1.0	0.8	0.5	0.2	0.6	2.8	0.5	3.7	10.8

Remedial alternative	Contribution of creek segment to mercury concentration (μg/L)[a]									
	1	2	3	4	5	6	7	8	9	Total
1	0.13	0.03	0.05	0.09	0.01	0.02	0.04	0.02	0.04	0.44
During 2,3,4,5	1.42	0.08	0.17	1.73	0.21	0.16	0.31	0.32	0.29	4.69
After 2,3,4,5	0.07	0.03	0.04	0.06	0.01	0.01	0.03	0.01	0.04	0.30
During 6	0.69	0.03	0.10	1.40	0.09	0.02	0.04	0.14	0.07	2.59
After 6	0.11	0.03	0.05	0.06	0.01	0.02	0.04	0.02	0.04	0.39
During 7	0.13	0.06	0.16	1.65	0.20	0.16	0.26	0.16	0.17	2.95
After 7	0.13	0.03	0.04	0.06	0.01	0.01	0.03	0.02	0.04	0.37

[a] Contributions to the concentration at Location LB (former U.S.G.S. gauging station at EFPCM 3.3) were based on the results from the GLEAMS model reported in Sect. 2. Properties of the Hamblen soils were used for all creek segments. (Model results for the Hamblen and Newark soils were very similar). Model estimates surface soil erosion only, not bank scouring or sediment resuspension. No erosion controls are assumed in this model. Current vegetative cover were assumed for projections except where precluded by remedial action.

Table 5.12. List of lithophilic fish species captured at various locations in Lower EFPC

Species	Capture locations (EFK)[a]	Segment(s)[b]
Blacknose dace (*Rhinichthys atratulus*)	EFK 23.4 to EFK 6.3	All nine
Striped shiner (*Luxilus chrysocephalus*)	EFK 23.4 to EFK 2.3	All nine
Emerald shiner (*Notropis atherinoides*)	EFK 18.2, EFK 10.0 to EFK 6.3	Segments 3, 8, and 9
Rosefin shiner (*Notropis ardens*)	EFK 18.2 and EFK 13.2	Segments 3 & 7
Spotted sucker (*Minytrema melanops*)	EFK 23.4 to EFK 6.3	All nine
White sucker (*Catostomus commersoni*)	EFK 23.4 to EFK 6.3	All nine
Black redhorse (*Moxostoma duquesnei*)	EFK 6.3	Segment 9
Golden redhorse (*Moxostoma erythrurum*)	EFK 13.8 to EFK 6.3	Segments 7, 8, and 9
Northern hogsucker (*Hypentelium nigricans*)	EFK 10.0 to EFK 2.3	Segments 8 & 9
Logperch (*Percina caprodes*)	EFK 6.3 to EFK 2.3	Segment 9
Sauger (*Stizostedion canadense*)	EFK 6.3	Segment 9

[a] EFK is East Fork kilometer.
[b] Segment refers to the nine segments described in the ecological risk assessment.

Source: Hintzman 1992; DOE 1994a.

Table 5.13. Riparian habitat type, current lengths, remediated lengths, and percentage converted for SWAs 2 through 6, summarized by segment and RU

Segment	RU	Current length (m)	Current length (yd)	Remediated length (m)	Remediated length (yd)	Length remaining (m)	Length remaining (yd)	Percentage converted	Riparian type
Seg 1	Com/DOE	1,219	1,333	429	469	790	864	35.2	BOT
	Other	674	737	7	8	667	729	1.0	BOT
	Residential	1,766	1,931	527	576	1,239	1,355	29.8	BOT
	Total riparian[a]	963	1,053						
	Total in segment[b]	4,396	4,808					21.9	
Seg 3	Com/DOE	907	992	62	68	845	924	6.8	BOT
	Residential	1,122	1,227	254	278	868	949	22.6	BOT
	Total riparian[a]	316	346						
	Total in segment[b]	2,752	3,010					11.5	
Seg 4	Other	835	913	422	462	413	452	50.5	BOT
	Other	225	246	87	95	138	151	38.7	OF
	Residential	929	1,016	547	598	382	418	58.9	BOT
	Residential	159	174	159	174	0	0	100.0	OF
	Total riparian[a]	1,215	1,329					54.8	
	Total in segment[b]	2,217	2,425						
Seg 5	Other	700	766	219	240	481	526	31.3	BOT
	Residential	706	772	153	167	553	605	21.7	OF
	Total riparian[a]	372	407						
	Total in segment[b]	1,405	1,537					26.5	

Table 5.13 (continued)

Segment	RU	Current length (m)	Current length (yd)	Remediated length (m)	Remediated length (yd)	Length remaining (m)	Length remaining (yd)	Percentage converted	Riparian type
Seg 8	Residential	2,141	2,341	189	207	1,952	2,135	8.8	BOT
	Total riparian[a]	189	207						
	Total in segment[b]	2,205	2,411						
Seg 9	Com/DOE	16,694	18,257	141	154	16,553	18,103	0.8	BOT
	Residential	4,892	5,350	91	100	4,801	5,250	1.9	BOT
	Total riparian[a]	232	254						
	Total in segment[b]	23,581	25,788					1.0	

[a]Total length of riparian habitat subject to remediation, by segment.
[b]Total length segment.
BOT = Bottomland hardwood/stream
OF = Old field/stream
RU = Remedial unit

Table 5.14. Summary of bottomland hardwood forest habitat (acres) subject to conversion

Segment	RU							Total area converted[a]	Total area of habitat within segment	Percent of habitat loss[a]
	Residential			DOE	Commercial	Other				
	Area 1	Area 2	Area 3	Area 1	Area 1	Area 1	Area 2			
1	0.2	0.4	2.8[b]	1.5[b]				4.9	27.4	17.9%
3	0.6[c]				0.1[c]			0.7	9.8	7.1%
4	0.3	1.3	3.4			0.3	0.4	5.7	20.2	28.2%
5	0.5					0.3	0.2	1.0	9.2	10.9%
8	0.7							0.7	15.1	4.6%
9	0.3			0.5				0.8	176.8	0.5%
							Total	13.8	258.5[d]	

[a]Note: Converted areas apply to SWA 2-5. SWAs 6 and 7 convert less area.
[b]These areas comprise one contiguous area.
[c]These areas comprise one contiguous area.
[d]Total of Area of Bottomland Hardwood Forest within all segments is 340.3 acres.

Table 5.15. EFPC wetlands affected by excavation and containment actions (SWAs 2 and 4)

Remedial units	Affected wetlands	Area excavated		Area contained	
		(ha)	(acres)	(ha)	(acres)
Residential	3, 4, 5, 8	0.44	1.11		
Commercial/DOE	1			0.01	0.02
Other	7			0.45	1.12
Total		0.44	1.11	0.46	1.14

Table 5.16. Typical sound levels for equipment used during remedial activities[a]

Equipment	Maximum sound level at 16 m (50 ft)
Air compressor	81
Backhoe	85
Bulldozer	87
Chain saw	80
Compactor	87
Crane, mobile	83
Dump truck	86
Front-end loader	85
Generator	78
Water truck	89

[a] Kessler et al. 1978

Table 5.17. Summary of short-term risks associated with excavation activities at EFPC (SWA 3)

Segment	Receptor	Hazard index			
		Ingestion	Dermal contact	Inhalation	Total
1	Workers	1.13E + 01 *E*	2.71E - 01 B	3.69E - 01 B	1.19E + 01 *E*
2	Workers	NA	NA	NA	NA
3	Workers	5.03E + 00 *E*	1.20E - 01 B	1.64E - 01 B	5.31E + 00 *E*
4	Workers	6.87E + 00 *E*	1.65E - 01 B	2.24E - 01 B	7.25E + 00 *E*
5	Workers	5.51E + 00 *E*	1.32E - 01 B	1.80E - 01 B	5.82E + 00 *E*
6	Workers	NA	NA	NA	NA
7	Workers	NA	NA	NA	NA
8	Workers	3.47E + 00 *E*	8.31E - 02 B	1.13E - 01 B	3.67E + 00 *E*
9	Workers	7.79E + 00 *E*	1.87E - 01 B	2.54E - 01 B	8.24E + 00 *E*
1	Adults	NA	NA	2.20E - 01 B	2.20E - 01 B
2	Adults	NA	NA	NA	NA
3	Adults	NA	NA	1.11E - 01 B	1.11E - 01 B
4	Adults	NA	NA	1.34E - 01 B	1.34E - 01 B
5	Adults	NA	NA	1.07E - 01 B	1.07E - 01 B
6	Adults	NA	NA	NA	NA
7	Adults	NA	NA	NA	NA
8	Adults	NA	NA	6.76E - 02 B	6.76E - 02 B
9	Adults	NA	NA	1.52E - 01 B	1.52E - 01 B
1	Children	NA	NA	5.03E - 01 B	5.03E - 01 B
2	Children	NA	NA	NA	NA
3	Children	NA	NA	2.54E - 01 B	2.54E - 01 B
4	Children	NA	NA	3.06E - 01 B	3.06E - 01 B
5	Children	NA	NA	2.45E - 01 B	2.45E - 01 B
6	Children	NA	NA	NA	NA
7	Children	NA	NA	NA	NA
8	Children	NA	NA	1.54E - 01 B	1.54E - 01 B
9	Children	NA	NA	3.47E - 01 B	3.47E - 01 B

B — below or equal to EPA target for noncancer hazard index (HI ≤ 1)
E — exceeds EPA target for noncancer hazard index (HI > 1)
NA - pathway not evaluated

Table 5.18. Summary of short-term risks associated with disposal activities at the Y-12 Plant facility (SWA 3)

Segment	Receptor	Hazard index			
		Ingestion	Dermal contact	Inhalation	Total
1	Workers	1.13E + 01 *E*	2.71E - 01 **B**	7.44E - 01 **B**	1.23E + 01 *E*
2	Workers	NA	NA	NA	NA
3	Workers	5.03E + 00 *E*	1.20E - 01 **B**	3.31E - 01 **B**	5.48E + 00 *E*
4	Workers	6.87E + 00 *E*	1.65E - 01 **B**	4.52E - 01 **B**	7.48E + 00 *E*
5	Workers	5.51E + 00 *E*	1.32E - 01 **B**	3.63E - 01 **B**	6.01E + 00 *E*
6	Workers	NA	NA	NA	NA
7	Workers	NA	NA	NA	NA
8	Workers	3.47E + 00 *E*	8.31E - 02 **B**	2.28E - 01 **B**	3.78E + 00 *E*
9	Workers	7.79E + 00 *E*	1.87E - 01 **B**	5.13E - 01 **B**	8.49E + 00 *E*
1	Adults	NA	NA	3.42E - 02 **B**	3.42E - 02 **B**
2	Adults	NA	NA	NA	NA
3	Adults	NA	NA	1.52E - 02 **B**	1.52E - 02 **B**
4	Adults	NA	NA	2.07E - 02 **B**	2.07E - 02 **B**
5	Adults	NA	NA	1.67E - 02 **B**	1.67E - 02 **B**
6	Adults	NA	NA	NA	NA
7	Adults	NA	NA	NA	NA
8	Adults	NA	NA	1.05E - 02 **B**	1.05E - 02 **B**
9	Adults	NA	NA	2.36E - 02 **B**	2.36E - 02 **B**
1	Children	NA	NA	7.80E - 02 **B**	7.80E - 02 **B**
2	Children	NA	NA	NA	NA
3	Children	NA	NA	3.47E - 02 **B**	3.47E - 02 **B**
4	Children	NA	NA	4.74E - 02 **B**	4.74E - 02 **B**
5	Children	NA	NA	3.80E - 02 **B**	3.80E - 02 **B**
6	Children	NA	NA	NA	NA
7	Children	NA	NA	NA	NA
8	Children	NA	NA	2.39E - 02 **B**	2.39E - 02 **B**
9	Children	NA	NA	5.38E - 02 **B**	5.38E - 02 **B**

B — below or equal to EPA target for noncancer hazard index (HI ≤ 1)
E — exceeds EPA target for noncancer hazard index (HI > 1)
NA - pathway not evaluated

93-008P/080794

Table 5.19. EFPC wetlands affected by excavation actions (SWAs 3 and 5)

Remedial units	Affected wetlands	Area excavated	
		(ha)	(acres)
Residential	3, 4, 5, 8	0.44	1.11
Commercial/DOE	1	0.01	0.02
Other	7	0.45	1.12
Total		0.90	2.25

Table 5.20. Summary of short-term risks associated with excavation activities at EFPC (SWA 4)

Segment	Receptor	Hazard index			
		Ingestion	Dermal contact	Inhalation	Total
1	Workers	1.13E + 01 *E*	2.71E - 01 B	3.69E - 01 B	1.19E + 01 *E*
2	Workers	NA	NA	NA	NA
3	Workers	5.03E + 00 *E*	1.20E - 01 B	1.64E - 01 B	5.31E + 00 *E*
4	Workers	6.87E + 00 *E*	1.65E - 01 B	2.24E - 01 B	7.25E + 00 *E*
5	Workers	5.51E + 00 *E*	1.32E - 01 B	1.80E - 01 B	5.82E + 00 *E*
6	Workers	NA	NA	NA	NA
7	Workers	NA	NA	NA	NA
8	Workers	3.47E + 00 *E*	8.31E - 02 B	1.13E - 01 B	3.67E + 00 *E*
9	Workers	7.79E + 00 *E*	1.87E - 01 B	2.54E - 01 B	8.24E + 00 *E*
1	Adults	NA	NA	2.20E - 01 B	2.20E - 01 B
2	Adults	NA	NA	NA	NA
3	Adults	NA	NA	1.11E - 01 B	1.11E - 01 B
4	Adults	NA	NA	1.34E - 01 B	1.34E - 01 B
5	Adults	NA	NA	1.07E - 01 B	1.07E - 01 B
6	Adults	NA	NA	NA	NA
7	Adults	NA	NA	NA	NA
8	Adults	NA	NA	6.76E - 02 B	6.76E - 02 B
9	Adults	NA	NA	1.52E - 01 B	1.52E - 01 B
1	Children	NA	NA	5.03E - 01 B	5.03E - 01 B
2	Children	NA	NA	NA	NA
3	Children	NA	NA	2.54E - 01 B	2.54E - 01 B
4	Children	NA	NA	3.06E - 01 B	3.06E - 01 B
5	Children	NA	NA	2.45E - 01 B	2.45E - 01 B
6	Children	NA	NA	NA	NA
7	Children	NA	NA	NA	NA
8	Children	NA	NA	1.54E - 01 B	1.54E - 01 B
9	Children	NA	NA	3.47E - 01 B	3.47E - 01 B

B — below or equal to EPA target for noncancer hazard index (HI ≤ 1)
E — exceeds EPA target for noncancer hazard index (HI > 1)
NA - pathway not evaluated

Table 5.21. Summary of short-term risks associated with containment activities at EFPC (SWA 4)

Segment	Receptor	Hazard index			
		Ingestion	Dermal contact	Inhalation	Total
1	Workers	1.13E + 01 *E*	2.71E - 01 B	1.06E - 02 B	1.16E + 01 *E*
2	Workers	NA	NA	NA	NA
3	Workers	5.03E + 00 *E*	1.20E - 01 B	4.73E - 03 B	5.15E + 00 *E*
4	Workers	6.87E + 00 *E*	1.65E - 01 B	6.46E - 03 B	7.04E + 00 *E*
5	Workers	5.51E + 00 *E*	1.32E - 01 B	5.18E - 03 B	5.65E + 00 *E*
6	Workers	NA	NA	NA	NA
7	Workers	NA	NA	NA	NA
8	Workers	NA	NA	NA	NA
9	Workers	7.79E + 00 *E*	1.87E - 01 B	7.33E - 03 B	7.99E + 00 *E*
1	Adults	NA	NA	NA	NA
2	Adults	NA	NA	NA	NA
3	Adults	NA	NA	NA	NA
4	Adults	NA	NA	NA	NA
5	Adults	NA	NA	NA	NA
6	Adults	NA	NA	NA	NA
7	Adults	NA	NA	NA	NA
8	Adults	NA	NA	NA	NA
9	Adults	NA	NA	NA	NA
1	Children	NA	NA	NA	NA
2	Children	NA	NA	NA	NA
3	Children	NA	NA	NA	NA
4	Children	NA	NA	NA	NA
5	Children	NA	NA	NA	NA
6	Children	NA	NA	NA	NA
7	Children	NA	NA	NA	NA
8	Children	NA	NA	NA	NA
9	Children	NA	NA	NA	NA

B — below or equal to EPA target for noncancer hazard index (HI ≤ 1)
E — exceeds EPA target for noncancer hazard index (HI > 1)
NA - pathway not evaluated

Table 5.22. Summary of short-term risks associated with soil treatment at the K-25 Site (SWA 4)

Segment	Receptor	Hazard index			
		Ingestion	Dermal contact	Inhalation	Total
1	Workers	1.13E + 01 *E*	2.71E - 01 *B*	8.90E - 01 B	1.25E + 01 *E*
2	Workers	NA	NA	NA	NA
3	Workers	5.03E + 00 *E*	1.20E - 01 *B*	3.96E - 01 B	5.54E + 00 *E*
4	Workers	6.87E + 00 *E*	1.65E - 01 *B*	5.41E - 01 B	7.57E + 00 *E*
5	Workers	5.51E + 00 *E*	1.32E - 01 *B*	4.34E - 01 B	6.08E + 00 *E*
6	Workers	NA	NA	NA	NA
7	Workers	NA	NA	NA	NA
8	Workers	3.47E + 00 *E*	8.31E - 02 *B*	2.73E - 01 B	3.83E + 00 *E*
9	Workers	7.79E + 00 *E*	1.87E - 01 *B*	6.14E - 01 B	8.59E + 00 *E*
1	Adults	NA	NA	1.94E - 01 B	1.94E - 01 B
2	Adults	NA	NA	NA	NA
3	Adults	NA	NA	8.64E - 02 B	8.64E - 02 B
4	Adults	NA	NA	1.18E - 01 B	1.18E - 01 B
5	Adults	NA	NA	9.47E - 02 B	9.47E - 02 B
6	Adults	NA	NA	NA	NA
7	Adults	NA	NA	NA	NA
8	Adults	NA	NA	5.96E - 02 B	5.96E - 02 B
9	Adults	NA	NA	1.34E - 01 B	1.34E - 01 B
1	Children	NA	NA	4.44E - 01 B	4.44E - 01 B
2	Children	NA	NA	NA	NA
3	Children	NA	NA	1.97E - 01 B	1.97E - 01 B
4	Children	NA	NA	2.70E - 01 B	2.70E - 01 B
5	Children	NA	NA	2.16E - 01 B	2.16E - 01 B
6	Children	NA	NA	NA	NA
7	Children	NA	NA	NA	NA
8	Children	NA	NA	1.36E - 01 B	1.36E - 01 B
9	Children	NA	NA	3.06E - 01 B	3.06E - 01 B

B — below or equal to EPA target for noncancer hazard index (HI ≤ 1)
E — exceeds EPA target for noncancer hazard index (HI > 1)
NA — pathway not evaluated

93-008P/08794

Table 5.23. Summary of short-term risks associated with excavation activities at EFPC (SWA 5)

Segment	Receptor	Hazard index			
		Ingestion	Dermal contact	Inhalation	Total
1	Workers	1.13E + 01 *E*	2.71E - 01 **B**	3.69E - 01 **B**	1.19E + 01 *E*
2	Workers	NA	NA	NA	NA
3	Workers	5.03E + 00 *E*	1.20E - 01 **B**	1.64E - 01 **B**	5.31E + 00 *E*
4	Workers	6.87E + 00 *E*	1.65E - 01 **B**	2.24E - 01 **B**	7.25E + 00 *E*
5	Workers	5.51E + 00 *E*	1.32E - 01 **B**	1.80E - 01 **B**	5.82E + 00 *E*
6	Workers	NA	NA	NA	NA
7	Workers	NA	NA	NA	NA
8	Workers	3.47E + 00 *E*	8.31E - 02 **B**	1.13E - 01 **B**	3.67E + 00 *E*
9	Workers	7.79E + 00 *E*	1.87E - 01 **B**	2.54E - 01 **B**	8.24E + 00 *E*
1	Adults	NA	NA	2.20E - 01 **B**	2.20E - 01 **B**
2	Adults	NA	NA	NA	NA
3	Adults	NA	NA	1.11E - 01 **B**	1.11E - 01 **B**
4	Adults	NA	NA	1.34E - 01 **B**	1.34E - 01 **B**
5	Adults	NA	NA	1.07E - 01 **B**	1.07E - 01 **B**
6	Adults	NA	NA	NA	NA
7	Adults	NA	NA	NA	NA
8	Adults	NA	NA	6.76E - 02 **B**	6.76E - 02 **B**
9	Adults	NA	NA	1.52E - 01 **B**	1.52E - 01 **B**
1	Children	NA	NA	5.03E - 01 **B**	5.03E - 01 **B**
2	Children	NA	NA	NA	NA
3	Children	NA	NA	2.54E - 01 **B**	2.54E - 01 **B**
4	Children	NA	NA	3.06E - 01 **B**	3.06E - 01 **B**
5	Children	NA	NA	2.45E - 01 **B**	2.45E - 01 **B**
6	Children	NA	NA	NA	NA
7	Children	NA	NA	NA	NA
8	Children	NA	NA	1.54E - 01 **B**	1.54E - 01 **B**
9	Children	NA	NA	3.47E - 01 **B**	3.47E - 01 **B**

B — below or equal to EPA target for noncancer hazard index (HI ≤ 1)
E — exceeds EPA target for noncancer hazard index (HI > 1)
NA - pathway not evaluated

Table 5.24. Summary of short-term risks associated with soil treatment at the K-25 Site (SWA 5)

Segment	Receptor	Hazard index			
		Ingestion	Dermal contact	Inhalation	Total
1	Workers	1.13E + 01 *E*	2.71E - 01 B	8.90E - 01 B	1.25E + 01 *E*
2	Workers	NA	NA	NA	NA
3	Workers	5.03E + 00 *E*	1.20E - 01 B	3.96E - 01 B	5.54E + 00 *E*
4	Workers	6.87E + 00 *E*	1.65E - 01 B	5.41E - 01 B	7.57E + 00 *E*
5	Workers	5.51E + 00 *E*	1.32E - 01 B	4.34E - 01 B	6.08E + 00 *E*
6	Workers	NA	NA	NA	NA
7	Workers	NA	NA	NA	NA
8	Workers	3.47E + 00 *E*	8.31E - 02 B	2.73E - 01 B	3.83E + 00 *E*
9	Workers	7.79E + 00 *E*	1.87E - 01 B	6.14E - 01 B	8.59E + 00 *E*
1	Adults	NA	NA	1.94E - 01 B	1.94E - 01 B
2	Adults	NA	NA	NA	NA
3	Adults	NA	NA	8.64E - 02 B	8.64E - 02 B
4	Adults	NA	NA	1.18E - 01 B	1.18E - 01 B
5	Adults	NA	NA	9.47E - 02 B	9.47E - 02 B
6	Adults	NA	NA	NA	NA
7	Adults	NA	NA	NA	NA
8	Adults	NA	NA	5.96E - 02 B	5.96E - 02 B
9	Adults	NA	NA	1.34E - 01 B	1.34E - 01 B
1	Children	NA	NA	4.44E - 01 B	4.44E - 01 B
2	Children	NA	NA	NA	NA
3	Children	NA	NA	1.97E - 01 B	1.97E - 01 B
4	Children	NA	NA	2.70E - 01 B	2.70E - 01 B
5	Children	NA	NA	2.16E - 01 B	2.16E - 01 B
6	Children	NA	NA	NA	NA
7	Children	NA	NA	NA	NA
8	Children	NA	NA	1.36E - 01 B	1.36E - 01 B
9	Children	NA	NA	3.06E - 01 B	3.06E - 01 B

B — below or equal to EPA target for noncancer hazard index (HI ≤ 1)
E — exceeds EPA target for noncancer hazard index (HI > 1)
NA - pathway not evaluated

Table 5.25. Estimated ex situ volumes of soil covers for containment of mercury-contaminated soil in the EFPC floodplain for SWA 6

	Residential		Commercial		Other		DOE		Total	
Seg	yd^3	m^3	yd^3	m^3	yd^3	m^3	yd^3	m^3	yd^3	m^3
1	10,600	8,100	100	100	0	0	4,700	3,600	15,400	11,800
2	0	0	0	0	0	0	0	0	0	0
3	1,900	1,500	300	200	0	0	0	0	2,200	1,700
4	19,990	15,200	0	0	10,500	8,000	0	0	30,400	23,200
5	1,700	1,300	0	0	2,200	1,700	0	0	3,900	3,000
6	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0
8	2,600	2,000	0	0	0	0	0	0	2,600	2,000
9	900	700	0	0	0	0	1,600	1,200	2,500	1,900
Total	37,600	28,800	400	300	12,700	9,700	6,300	4,800	57,000	43,600

Table 5.26. Summary of short-term risks associated with containment activities at EFPC (SWA 6)

Segment	Receptor	Hazard index			
		Ingestion	Dermal contact	Inhalation	Total
1	Workers	1.13E + 01 *E*	2.71E - 01 **B**	1.06E - 02 **B**	1.16E + 01 *E*
2	Workers	NA	NA	NA	NA
3	Workers	5.03E + 00 *E*	1.20E - 01 **B**	4.73E - 03 **B**	5.15E + 00 *E*
4	Workers	6.87E + 00 *E*	1.65E - 01 **B**	6.46E - 03 **B**	7.04E + 00 *E*
5	Workers	5.51E + 00 *E*	1.32E - 01 **B**	5.18E - 03 **B**	5.65E + 00 *E*
6	Workers	NA	NA	NA	NA
7	Workers	NA	NA	NA	NA
8	Workers	3.47E + 00 *E*	8.31E - 02 **B**	3.26E - 03 **B**	3.56E + 00 *E*
9	Workers	7.79E + 00 *E*	1.87E - 01 **B**	7.33E - 03 **B**	7.99E + 00 *E*
1	Adults	NA	NA	NA	NA
2	Adults	NA	NA	NA	NA
3	Adults	NA	NA	NA	NA
4	Adults	NA	NA	NA	NA
5	Adults	NA	NA	NA	NA
6	Adults	NA	NA	NA	NA
7	Adults	NA	NA	NA	NA
8	Adults	NA	NA	NA	NA
9	Adults	NA	NA	NA	NA
1	Children	NA	NA	NA	NA
2	Children	NA	NA	NA	NA
3	Children	NA	NA	NA	NA
4	Children	NA	NA	NA	NA
5	Children	NA	NA	NA	NA
6	Children	NA	NA	NA	NA
7	Children	NA	NA	NA	NA
8	Children	NA	NA	NA	NA
9	Children	NA	NA	NA	NA

B — below or equal to EPA target for noncancer hazard index (HI ≤ 1)
E — exceeds EPA target for noncancer hazard index (HI > 1)
NA - pathway not evaluated

Table 5.27. EFPC wetlands affected by SWA 6

Remedial units	Affected wetlands	Area excavated	
		(ha)	(acres)
Residential	3, 4, 5, 8	0.44	1.11
Commercial/DOE	1	0.01	0.02
Other	7	0.45	1.12
Total		0.90	2.25

Table 5.28. Summary of short-term risks associated with excavation activities at EFPC (SWA 7)

Segment	Receptor	Hazard index			
		Ingestion	Dermal contact	Inhalation	Total
1	Workers	1.13E + 01 *E*	2.71E - 01 B	3.69E - 01 B	1.19E + 01 *E*
2	Workers	NA	NA	NA	NA
3	Workers	5.03E + 00 *E*	1.20E - 01 B	1.64E - 01 B	5.31E + 00 *E*
4	Workers	6.87E + 00 *E*	1.65E - 01 B	2.24E - 01 B	7.25E + 00 *E*
5	Workers	5.51E + 00 *E*	1.32E - 01 B	1.80E - 01 B	5.82E + 00 *E*
6	Workers	NA	NA	NA	NA
7	Workers	NA	NA	NA	NA
8	Workers	3.47E + 00 *E*	8.31E - 02 B	1.13E - 01 B	3.67E + 00 *E*
9	Workers	7.79E + 00 *E*	1.87E - 01 B	2.54E - 01 B	8.24E + 00 *E*
1	Adults	NA	NA	2.20E - 01 B	2.20E - 01 B
2	Adults	NA	NA	NA	NA
3	Adults	NA	NA	1.11E - 01 B	1.11E - 01 B
4	Adults	NA	NA	1.34E - 01 B	1.34E - 01 B
5	Adults	NA	NA	1.07E - 01 B	1.07E - 01 B
6	Adults	NA	NA	NA	NA
7	Adults	NA	NA	NA	NA
8	Adults	NA	NA	6.76E - 02 B	6.76E - 02 B
9	Adults	NA	NA	1.52E - 01 B	1.52E - 01 B
1	Children	NA	NA	5.03E - 01 B	5.03E - 01 B
2	Children	NA	NA	NA	NA
3	Children	NA	NA	2.54E - 01 B	2.54E - 01 B
4	Children	NA	NA	3.06E - 01 B	3.06E - 01 B
5	Children	NA	NA	2.45E - 01 B	2.45E - 01 B
6	Children	NA	NA	NA	NA
7	Children	NA	NA	NA	NA
8	Children	NA	NA	1.54E - 01 B	1.54E - 01 B
9	Children	NA	NA	3.47E - 01 B	3.47E - 01 B

B — below or equal to EPA target for noncancer hazard index (HI ≤ 1)
E — exceeds EPA target for noncancer hazard index (HI > 1)
NA - pathway not evaluated

Table 5.29. Summary of short-term risks associated with disposal activities at the Y-12 Plant disposal facility (SWA 7)

Segment	Receptor	Hazard index			
		Ingestion	Dermal contact	Inhalation	Total
1	Workers	1.13E + 01 *E*	2.71E - 01 B	7.44E - 01 B	1.23E + 01 *E*
2	Workers	NA	NA	NA	NA
3	Workers	5.03E + 00 *E*	1.20E - 01 B	3.31E - 01 B	5.48E + 00 *E*
4	Workers	6.87E + 00 *E*	1.65E - 01 B	4.52E - 01 B	7.48E + 00 *E*
5	Workers	5.51E + 00 *E*	1.32E - 01 B	3.63E - 01 B	6.01E + 00 *E*
6	Workers	NA	NA	NA	NA
7	Workers	NA	NA	NA	NA
8	Workers	3.47E + 00 *E*	8.31E - 02 B	2.28E - 01 B	3.78E + 00 *E*
9	Workers	7.79E + 00 *E*	1.87E - 01 B	5.13E - 01 B	8.49E + 00 *E*
1	Adults	NA	NA	3.42E - 02 B	3.42E - 02 B
2	Adults	NA	NA	NA	NA
3	Adults	NA	NA	1.52E - 02 B	1.52E - 02 B
4	Adults	NA	NA	2.07E - 02 B	2.07E - 02 B
5	Adults	NA	NA	1.67E - 02 B	1.67E - 02 B
6	Adults	NA	NA	NA	NA
7	Adults	NA	NA	NA	NA
8	Adults	NA	NA	1.05E - 02 B	1.05E - 02 B
9	Adults	NA	NA	2.36E - 02 B	2.36E - 02 B
1	Children	NA	NA	7.80E - 02 B	7.80E - 02 B
2	Children	NA	NA	NA	NA
3	Children	NA	NA	3.47E - 02 B	3.47E - 02 B
4	Children	NA	NA	4.74E - 02 B	4.74E - 02 B
5	Children	NA	NA	3.80E - 02 B	3.80E - 02 B
6	Children	NA	NA	NA	NA
7	Children	NA	NA	NA	NA
8	Children	NA	NA	2.39E - 02 B	2.39E - 02 B
9	Children	NA	NA	5.38E - 02 B	5.38E - 02 B

B — below or equal to EPA target for noncancer hazard index (HI ≤ 1)
E — exceeds EPA target for noncancer hazard index (HI > 1)
NA - pathway not evaluated

Table 5.30. Riparian habitat type, current lengths, remediated lengths, and percentage converted for SWA 7, summarized by segment and RU

Segment	RU	Current length (m)	Current length (yd)	Remediated length (m)	Remediated length (yd)	Length remaining (m)	Length remaining (yd)	Percentage converted	Riparian type
Seg 1	Residential	632	691	31	34	601	657	4.9	BOT
	Total riparian[a]	31	34						
	Total in segment[b]	4,428	4,843					0.7	
Seg 3	Residential	1,120	1,225	254	278	866	947	22.7	BOT
	Total riparian[a]	254	278						
	Total in segment[b]	2,753	3,011					9.2	
Seg 4	Residential	671	734	547	598	124	136	81.5	BOT
	Residential	159	174	159	174	0	0	100.0	OF
	Total riparian[a]	706	772					31.6	
	Total in segment[b]	2,231	2,440						
Seg 5	Residential	712	779	153	167	559	611	21.5	BOT
	Total riparian[a]	153	167						
	Total in segment[b]	1,417	1,550					13.3	
Seg 8	Residential	2,161	2,363	189	207	1,972	2,157	8.7	BOT
	Total riparian[a]	189	207						
	Total in segment[b]	2,225	2,433					8.5	
Seg 9	Residential	4,937	5,399	91	100	4,846	5,300	1.8	BOT
	Total riparian[a]	91	100						
	Total in segment[b]	23,755	25,979					0.4	

[a]Total length of riparian habitat subject to remediation, by segment.
[b]Total length segment.
BOT = Bottomland hardwood/stream; OF = Old field/stream; RU = Remedial unit.

Table 5.31. EFPC wetlands affected by excavation and containment actions (SWA 7)

Remedial unit	Creek segment	Affected wetlands	Affected area			
			Excavation		Containment	
			(ha)	(acres)	(ha)	(acres)
Residential	1,4	5, 8	0.38	0.94		
Other	1	3, 4			0.46	1.13
Total			0.38	0.94	0.46	1.13

Table 5.32. Major monitoring and mitigative measures for the action alternatives

Factor	Potential impact on area of concern	Mitigative measure
Construction activities (excavation and containment)	Transport of uncontaminated soil to surface water	Good construction practices would be implemented, including sediment barriers, dikes, siltation ponds, coffer dams, and drainage channels to direct silt runoff away from downstream or downgradient surface waters. Surface grading and revegetation would be performed upon completion of excavation.
	Transport of contaminated surface soil to surface water and wetlands, runoff of contaminated surface water, and possible transport to groundwater	Good construction practices would be implemented, as described above. In addition, surface water and sediment would be monitored for chemical contaminants so that potential transport of contaminated media could be detected and controlled through appropriate management.
	Loss of aquatic and terrestrial habitats	Habitats would be restored, as appropriate. The final form of mitigation would be determined in consultation with appropriate state and federal agencies.
	Disturbance of local biota, area residents, and recreational visitors by noise	Vehicle and equipment mufflers would be checked periodically and maintained in good condition.
	Disturbance of local biota, area residents and recreational visitors, and impacts to local air quality as a result of fugitive dust emissions	Dust would be controlled using wet methods and/or covers at remedial sites, along haul roads, storage and staging areas, and at any off-site areas. Chemical dust suppressants would be used if needed.
Transport of contaminated material from remedial sites to the treatment facility or the disposal facility	Accidental spill (release) of contaminated material as a result of equipment failure or vehicular accident	Waste would be transported in covered trucks traveling at low speeds. Contingency plans would be in place to address any spills that might occur during waste transport.
	Inadvertent transport of contaminated material on haul vehicle surfaces or tires when leaving controlled areas	Haul vehicles would be decontaminated and inspected before leaving the remedial sites.

Table 5.32 (continued)

Factor	Potential impact on area of concern	Mitigative measure
Excavation of off-site borrow material	Erosion of soil with transport to surface water	Good construction practices would be implemented, including sediment barriers and siltation ponds, as needed.
	Disturbance of area residents, local biota, and recreational visitors by noise	Vehicle and equipment mufflers would be checked periodically and maintained in good condition.
	Disturbance of area residents, local biota, and recreational visitors and impacts to local air quality as the result of fugitive dust emissions	Dust would be controlled using wet methods at the borrow area and along haul roads. Chemical dust suppressants would be used if needed.
Transport of borrow materials and supplies to remedial sites	Inadvertent transport of contaminated material from the site on the haul vehicle surfaces or tires	Trucks hauling borrow material would not enter contaminated areas.
All phases of active remedial activities	Protection of workers	All activities would be conducted in accordance with project health and safety plans and would include continuous monitoring of the work environment and the use of protective equipment, as needed.
	Protection of the general public	Air and water would be monitored at the remediation sites and appropriate responses would be implemented if measured contaminant levels increased significantly above background. Access to construction and excavation areas would be limited; public access would also be limited along some of the off-site haul roads. Engineering controls would be applied to minimize dust, noise, and erosion during remedial action activities. Decontamination methods would be employed to minimize vehicle tracking of contaminants to uncontaminated areas. All traffic associated with the remedial action would be coordinated to minimize impacts on nearby facilities.

Table 5.32 (continued)

Factor	Potential impact on area of concern	Mitigative measure
	Environmental monitoring	Air quality would be monitored for contaminated particulates. Surface water and groundwater downgradient of excavation and construction areas would be monitored for mercury. Biological monitoring will also be conducted on aquatic and terrestrial organisms. Appropriate responses would be implemented as indicated by monitoring results.
	Environmental restoration	Disturbed areas would be restored by regrading and revegetating with native and/or forage species.
	On-site disposal cell maintenance and cell integrity	An operations plan would be in place to ensure monitoring of long-term disposal cell integrity. This plan would include regular cell inspection and site vegetation control programs, and monitoring programs for groundwater, surface water, and air. Contingency plans would be developed to address any loss of disposal cell integrity and/or release of disposed materials.
Fencing	Restriction of wildlife movement and use of fenced habitat	Fence design and construction would incorporate features to allow easy ingress and egress for wildlife.
Wetlands	Loss of wetland functions	Wetland mitigation to be determined in consultation with TDEC, COE, and FWS.

Table 5.33. Actions on the ORR 1993-1998

Description	When	Where	Activities required/notes
Steam Plant Ash Disposal Facility, Line Item Facility	FY 94-98	Y-12 Plant	Earthmoving
Melton Valley liquid low-level waste - collection and transfer	FY 94-98	ORNL	Earthmoving; upgrade and replace existing tanks and pipelines
Chestnut Ridge			
OU 1 security pits	FY 93-98	Y-12 Plant	Field work, document generation (groundwater a concern)
OU 2 Filled Coal Ash Pond/McCoy Branch	FY 95-98		Earthmoving; construction for remedial action
OU 3 UNC disposal site	FY 93-98		Field work and document generation
OU 4 Roger's Quarry/McCoy Branch	FY 93-98		Field work and document generation
Bear Creek			
OU 1, OU 2, OU 3, OU 4	FY 92-98	Y-12 Plant	Field work and document generation
Upper East Fork Poplar Creek (above Lake Reality)			
OU 1	FY 93-98		Field work, document generation
OU 2 ANAP	FY 92-98		Field work, document generation
OU 3	FY 93-98		Field work, document generation
Closure activities and post-closure activities (11 units)	FY 93-95	Y-12 Plant	Earthmoving, borrow soil use, groundwater remediation and monitoring
ORNL Waste Area Grouping (WAG) 1 ER (main plant area)	FY 93-98	ORNL	Document generation; field work; begin remediation, monitoring, and borrow soil area construction and use
ORNL WAG 2 ER (White Oak Creek/White Oak Lake - drainage)	FY 93-98	ORNL	Document generation; field work; begin remediation, monitoring, and borrow soil area construction and use
ORNL WAG 3 ER (3 sites)	FY 93-98	ORNL	Document generation; field work; begin remediation, monitoring, and borrow soil area construction and use
ORNL WAG 4 ER (3 sites)	FY 93-98	ORNL	Document generation; field work; begin remediation, monitoring, and borrow soil area construction and use

Table 5.33 (continued)

Description	When	Where	Activities required/notes
ORNL WAG 5 ER (16 sites)	FY 93-98	ORNL	Document generation; field work; begin remediation, monitoring, and borrow soil area construction and use
ORNL WAG 6 ER (3 sites)	FY 93-98	ORNL	Document generation; field work; begin remediation, monitoring, and borrow soil area construction and use
ORNL WAG 7 ER (17 sites)	FY 95-98	ORNL	Document generation, field activities, ISV unit fabrication
ORNL WAG 8 ER (17 sites)	FY 95-98	ORNL	Document generation, field activities
ORNL WAG 9 ER (17 sites)	FY 96-98	ORNL	Document generation, field activities
ORNL WAG 10 ER (17 sites)	FY 90-98	ORNL	Document generation, field activities
ORNL WAG 11 ER (17 sites)	FY 90-98	ORNL	Document generation, field activities, final remediation preliminary planning action
ORNL WAG 13 ER (17 sites)	FY 90-98	ORNL	Document generation, field activities, final remediation preliminary planning action
ORNL inactive liquid low-level waste tank systems	FY 94-98	ORNL	Removal, treatment, and disposal of tank contents; construction of facilities
K-25 Site Process Plant area remediation action	FY 93-98	K-25 Site	Document generation, monitoring, field activities
K-25 Site External Plant area	FY 93-98	K-25 Site	Document generation, monitoring, field activities
Pond Waste Management Project	FY 93-98	K-25 Site	Construction of storage facilities, dewatering process
Groundwater Protection Program	FY 93-98	K-25 Site	Groundwater monitoring, report generation
Drain wastewater treatment upgrade	FY 93-97	Y-12 Plant	Reduce liquid discharge to EFPC, construction, drain rerouting
New Facilities			
ILF-V/CDL-VII, ILF-V, CDL-VII Phase II, PWTFII, MTF, OSTF, PCSF, sanitary sewer upgrades, SIWPF, TPF	FY 93-98	Y-12 Plant	Construction and design

6. COMPARATIVE ANALYSIS OF SITEWIDE ALTERNATIVES

The purpose of the comparative analysis is to identify the advantages and disadvantages of the sitewide alternatives when compared with each other, based on the results of the detailed analysis described in Sect. 5.3. It should be noted that aquatic effects related to mercury sources other than floodplain soil would continue under all alternatives because final remedial actions for surface water and sediment have been deferred. Thus effects related to these sources are not discussed in the comparative analysis. The comparative analysis allows the identification of key tradeoffs the decision maker must balance during the final selection of a preferred alternative. Three tables are provided to summarize and compare the alternatives: Table 6.1 compares the sitewide alternatives by seven CERCLA evaluation criteria; Table 6.2 quantifies impacts to habitats for each sitewide alternative; and Table 6.3 compares the success of each alternative in meeting the ecological measurement endpoints. The results of the comparative analysis are summarized in Table 6.4. Rankings assigned to the alternatives in Table 6.4 are relative to the other alternatives evaluated and are not a comparison with a standard. State and community acceptance will be addressed in the Record of Decision once formal comments on the Proposed Plan have been received.

6.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

All of the sitewide alternatives (excluding SWA 1, the No Action alternative) would protect human health and the environment, though habitat recovery would be slow or habitat loss permanent in some sections of the floodplain. All six action sitewide alternatives would involve some risk during transport of contaminated and borrow soil; however, transportation risks would be low for all sitewide alternatives (<1 injury or fatality projected). Risk related to construction accidents would range from ~4.3 injuries for SWA 7 to 10.3 injuries for SWA 3 (Appendix F). No fatalities would be expected during implementation of the sitewide alternatives. Worker exposure during treatment would be higher for SWAs 4 and 5, as a result of additional soil handling, than for alternatives without treatment (SWAs 2, 3, 6 and 7). Although treatment removes mercury from the soil, the pilot studies show that it does not significantly reduce levels of the PCBs, heavy metals, and radionuclides present. However, other than mercury, only cadmium and arsenic were identified as COCs within the RI. Health risk assessment indicated that neither cadmium nor arsenic were of concern (Sect. 3.3.1.1). In addition, based on TCLP analysis, current soil levels of all of these contaminants are below concentrations that would require classification as hazardous waste. Evaluation and approval by TDEC of acceptable contaminant levels in treated soil would be required prior to beneficial reuse of the soil. A health and safety plan would be developed for site activities and the required mitigative measures would be used for SWAs 2 through 7 to keep exposure as low as possible and within limits determined by EPA to be protective. Risks to the community from the low-temperature thermal desorption unit would be considered negligible (Sect. 5.3.4.5) because emissions would be captured by the off-gas collection and treatment system at an efficiency of 99.99% (IT 1994).

The greatest risk from implementing SWAs 2 through 7 would be to ecological receptors, and the alternatives vary in the degree of impacts. SWA 7 would result in fewer short-term adverse impacts to these receptors than SWAs 2 through 6. Residential soil >180 ppm of

mercury would be excavated under SWA 7; however, the amount of soil excavated would be less than the amount excavated under the other action alternatives, and no habitats would be permanently altered.

The recovery time required for areas disturbed during remediation would vary among the sitewide alternatives. Recovery to natural habitat in containment areas would not occur in SWAs 2, 4, and 6 because grass would be maintained in these areas, and an intrusion barrier to deter burrowing animals would prevent the deep rooting of trees. Stream banks would be stabilized with gabions, thus preventing recovery of the riparian zone. Areas excavated under SWAs 2 through 5 and 7 would recover from loss of vegetation; some properties would recover quickly (e.g., lawns or pasture) while others (e.g., mature bottomland hardwood) would regenerate to their preremedial action condition within ~50 years.

Considering both short- and long-term effects, SWA 7 is ranked high based on comparatively little disturbance and no permanent alteration of habitat. For SWA 7, residual risk from contaminants on small [< 1.5 ha (3.7 acres)], nonresidential areas would be present with potential pathways to ecological receptors; however the toxicological risk is not manifest and elimination of this risk would require destruction of the bottomland hardwood forest present in those areas. For a more detailed discussion of the balancing of toxicological risk versus habitat loss, see Appendix G. SWAs 3 and 5 are ranked medium-high because unacceptable residual risk would be eliminated in the floodplain, and although impacts during implementation would be high for ecological receptors and recovery slow in some areas, floodplain habitats would not be permanently altered. SWAs 2 and 4 are ranked medium because residual contaminants would remain and habitat and land use would be permanently altered. SWA 6 is ranked medium-low because containment and extensive fencing throughout the floodplain would result in permanent habitat alteration, and maintaining fencing and access controls is considered difficult over the long term. SWA 1 is ranked low to reflect the conclusion of the baseline risk assessment that unacceptable risk is present in the floodplain, and under this alternative, no action would be taken to reduce that risk.

6.2 COMPLIANCE WITH ARARS

Because no remedial action would be taken, action- and location-specific ARARs would not be invoked for SWA 1; however, the No Action alternative would not meet chemical-specific ARARs for surface water quality.

SWA 2 would comply with ARARs by controlling access to contaminated sediment and surface water and resulting exposures through institutional actions. Containment and institutional actions for Commercial/DOE and Other RU soil, and excavation and disposal of Residential RU soil would comply with ARARs.

SWA 3 would comply with ARARs by controlling access to contaminated sediment and surface water and resulting exposures through institutional actions. Excavation and disposal of Commercial/DOE, Other, and Residential soil would comply with ARARs.

SWA 4 would comply with ARARs by controlling access to contaminated sediment and surface water and resulting exposures through institutional actions. Containment and institutional actions for Commercial/DOE and Other soil and excavation, treatment, and beneficial reuse of Residential soil would comply with ARARs.

SWA 5 would comply with ARARs by controlling access to contaminated sediment and surface water and resulting exposures through institutional actions. Excavation, treatment, and beneficial reuse of Commercial/DOE, Other, and Residential soil would comply with ARARs.

SWA 6 would comply with ARARs by controlling access to contaminated sediment and surface water and resulting exposures through institutional actions. Acquisition of real estate interests for Residential soil (mercury concentrations >180 ppm), coupled with containment, fencing, and institutional actions for these areas would comply with ARARs. Also, containment of nonresidential soil with mercury concentrations >200 ppm would comply with ARARs.

SWA 7 would comply with ARARs by either excavating the contaminated soil or by establishing land-use limitations or access restrictions on some properties in the EFPC floodplain to reduce the potential for exposures. Actions to comply with ARARs would include (1) excavation of soil contaminated with >180 ppm of mercury from the Residential RU and disposal at an approved lined landfill with leachate collection at the Y-12 Plant, (2) institutional actions (future land-use limitations, construction-permit restrictions, sign postings) for soil >180 ppm of mercury in the Commercial/DOE and Other RUs, (3) fencing and institutional actions (future land-use limitations, construction-permit restrictions, sign postings) for soil >180 ppm of mercury in a 5.53-ha (13.67-acre) area in Segment 1 of the floodplain, and (4) institutional actions for sediment and surface water.

6.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

This criterion addresses long-term risk to human health; long-term risk to the environment is addressed under Sect. 6.4, Short-Term Effectiveness and Environmental Impacts. Risks to human health after completion of remedial action at a site and the reliability of controls indicate the long-term effectiveness of an alternative. SWAs 3 and 5 are ranked high because they would remove contaminated material from the site, thereby eliminating unacceptable residual risk, and because the contaminated material would be placed in a disposal facility at the Y-12 Plant that would be designed specifically to isolate waste from the environment and would be operated as a landfill. SWAs 2 and 4 are ranked medium-high because they would remove some of the contaminated material from the floodplain and would cover the remaining contaminated areas with a soil cover. The covered residual contaminated soil would require active controls (maintenance of the cover and land-use restrictions) to prevent unacceptable exposure. SWA 7 is ranked medium because maintenance of fencing in Segment 1 and land-use restrictions would be required for long-term effectiveness. SWA 6 would involve leaving all contaminated material in place, DOE acquisition of real estate interests, restricting access to acquired areas with fencing, and covering the most contaminated (>180 ppm mercury) areas. The active control measures, particularly the maintenance of fencing, over the entire site to provide long-term effectiveness result in the assignment of the rank of medium-low for SWA 6. SWA 1 is ranked low because no action would be taken to reduce the risk to humans over the long term.

6.4 SHORT-TERM EFFECTIVENESS AND ENVIRONMENTAL IMPACTS

This criterion addresses the risk to human health and the environment during implementation and the environmental impacts after implementation. All action alternatives would involve transportation and construction accident risks—4.3 (SWA 7) to 10.3 (SWA 3) injuries and no fatalities are expected during implementation. Risk to the community from exposure to contaminants would be within acceptable limits for all alternatives. Risk to workers would vary by alternative but would be within acceptable limits if mitigative measures (e.g., engineering controls or personal protective equipment) were used. SWAs 4 and 5 would be expected to result in net adverse impacts to the institutional environment because of expressed concerns regarding thermal sources of air emissions and potential actual or perceived risks from reuse of treated soil (described in Sect. 5.3.4.5). Impacts to ecological receptors and environmental media would be less for SWA 7 than for SWAs 2 through 6, because both excavation actions and containment would negatively impact biota and habitat to a greater degree in SWAs 2 through 6. For example, for SWA 7, the area of disturbance to wetlands and bottomland hardwoods, two habitat types that have relatively long recovery times, would be less than half that for the other action alternatives (Table 6.2). In addition, there would be no permanent alteration of habitat from implementation of SWA 7; stream banks would recover in the areas excavated and no permanent bank stabilization (gabions) would be emplaced. The natural dynamic character of the terrestrial and riparian habitats would be maintained. Appendix G provides a more detailed discussion of the balancing of implementation risk relative to long-term toxicological risk and habitat loss. SWA 7 is ranked high and SWAs 2 through 6 are ranked medium. SWA 1 would cause no impacts during implementation (periodic monitoring) but would have significant potential for negative impacts to the environment if no action were taken; thus, it is ranked low.

6.5 REDUCTION IN TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT

SWAs 4 and 5 would reduce the toxicity of mercury-contaminated soil through treatment and are ranked high. The other alternatives do not reduce toxicity, mobility, or volume through treatment and are ranked low.

6.6 IMPLEMENTABILITY

SWAs 2 through 7 are considered implementable; however, some may be more difficult to implement than others. Excavation and containment actions in SWAs 2 through 7 are well known and readily implemented. On-site disposal of soil at the Y-12 Plant would require a "special waste" approval from the TDEC. This is not anticipated to present significant impediments to implementing alternatives requiring disposal. The treatment technology proposed for SWAs 4 and 5 (i.e., low-temperature thermal desorption) has not been proven to be effective in removing mercury from EFPC soil on a full scale; however, treatability tests and pilot-scale testing indicate that the process would be effective and implementable. SWAs 4 and 5 (which include treatment) are ranked lower (medium) than SWAs 2 and 3 (which are ranked high) because of the uncertainty of the treatment technology. An additional factor that affects the implementation of SWAs 4 and 5 is that TDEC evaluation and approval would be required for treated soil before its beneficial reuse in the floodplain. Also, the use of wet scrubbers in the low-temperature thermal desorption treatment process has been shown to produce waste streams that are potentially

equivalent in quantity to the amount of soil treated. SWAs 2 and 4 would require DOE access to containment areas in the future to maintain the soil cover and repair any breaches in the gabions used to stabilize stream banks. This would require continuing access agreements with private landowners and expenditures for maintenance in the future. While such activities are not expected to be difficult, they would require continuing attention and expenditures by DOE. SWA 7 is considered comparable to SWAs 4 and 5, because although no unproven treatment technologies would be used, DOE would have to acquire a portion of one contaminated parcel of land adjoining DOE property in Segment 1 and restrict access by fencing. These activities also would not be expected to be difficult to implement but would require more separate actions than SWAs 2 and 3. Thus SWA 7 is ranked medium-high. SWA 6 would require acquisition of real estate interest by DOE along several portions of the creek length on many separate properties in residential tracts, restricting these properties to nonresidential and nonagricultural land use, and fencing the acquired areas; this could prove difficult if landowners were reluctant to negotiate agreements with DOE for contaminated portions of their property. In addition, long-term maintenance of the soil cover and fencing may be difficult. Therefore, SWA 6 is ranked medium.

6.7 COST

This section compares the estimated total cost in 1993 dollars for all sitewide alternatives; the cost estimates in the FS are expected to provide an accuracy of +50% to -30%. Details on the methods used and assumptions for estimating the costs for each sitewide alternative, including itemization of individual components and a sensitivity analysis are provided in Appendix D. Costs range from $12 million to $70 million. The sitewide alternatives in order of increasing cost by their respective total costs in 1993 dollars, without escalation or discount, are as follows:

Sitewide alternative	Cost in 1993 dollars (× $1,000,000)
1	12
7	31
6	41
2	48
3	52
4	59
5	70

6.8 CONCLUSION

The comparative analysis of sitewide alternatives provides the basis for the decision maker in selection of the preferred alternative. The preferred alternative, which will be described in the Proposed Plan, will be selected from among the sitewide alternatives evaluated in this document. The National Contingency Plan and statutory requirements will be encompassed in the selected preferred alternative.

This page intentionally left blank.

SECTION 6

TABLES

This page intentionally left blank.

Table 6.1. Comparison of sitewide alternatives by evaluation criteria

SWA 1 No action	SWA 2 Containment and institutional actions; excavation and disposal	SWA 3 Excavation and disposal	SWA 4 Containment and institutional actions; excavation, treatment, and beneficial reuse	SWA 5 Excavation, treatment, and beneficial reuse	SWA 6 Containment and institutional actions; acquisition, containment and institutional actions	SWA 7 Institutional actions; excavation and disposal
Overall protection of human health and the environment						
Not protective of human health or the environment because risks from exposure exists.	Protective. Contaminated soil either excavated and isolated in a disposal cell or covered, thus pathways of exposure at the site are eliminated. Long-term control measures required (land use restrictions and maintenance of soil cover). Transportation risk to public - 0.2 injury. Estimated construction injuries - 8.4. Excavation of 4.85 ha (11.97 acres); conversion of 2.50 ha (6.19 acres) by containment. Borrow soil required - 45,000 m^3 (58,800 yd^3).	Protective. Contaminated soil excavated and isolated in a disposal facility. Pathways of exposure at the site eliminated. No long-term control measures required at the site. Transportation risk to public - 0.3 injury. Estimated construction injuries - 10.3. Excavation of 7.35 ha (18.16 acres). Borrow soil required - 49,500 m^3 (64,800 yd^3).	Protective. Same as SWA 2 except: Transportation risk to public - 0.2 injury. Estimated construction injuries - 5.8. Worker exposure higher because of treatment process; risk to community from treatment facility negligible. Borrow soil required - 16,400 m^3 (21,400 yd^3).	Protective. Same as SWA 3 except: Transportation risk to public - 0.3 injury. Estimated construction injuries - 7.6. Worker exposure higher because of treatment process; risk to community from treatment facility negligible. Borrow soil required - 2,400 m^3 (3,200 yd^3).	Protective. Contaminated soil either isolated by fencing or fenced and covered, thus pathways to receptors are eliminated. Long-term control measures required (maintenance of extensive fencing and soil cover). Transportation risk to public - 0.1 injury. Estimated construction injuries - 4.8. Conversion of 7.35 ha (18.16 acres) by containment. Acquisition of 10.9 ha (27.04 acres). Borrow soil required - 43,600 m^3 (57,000 yd^3).	Protective. Most contaminated soil excavated and isolated in a disposal cell. One area to be acquired by DOE would be fenced but not contained; ecological receptors thus exposed to some residual toxicological risk but important habitat preserved. Long-term control measures required (land use restrictions and maintenance of fencing). Transportation risk to public - 0.1 injury. Estimated construction injuries - 4.3. Excavation of 3.52 ha (8.70 acres). Borrow soil required - 22,400 m^3 (29,400 yd^3).

Table 6.1 (continued)

SWA 1 No action	SWA 2 Containment and institutional actions; excavation and disposal	SWA 3 Excavation and disposal	SWA 4 Containment and institutional actions; excavation, treatment, and beneficial reuse	SWA 5 Excavation, treatment, and beneficial reuse	SWA 6 Containment and institutional actions; acquisition, containment and institutional actions	SWA 7 Institutional actions; excavation and disposal
			Compliance with ARARs			
Because no remedial action would be taken, action- and location-specific ARARs are not invoked. However, chemical-specific standards for surface water may be exceeded.	Would comply with ARARs through use of institutional actions, containment actions, and excavation and disposal actions.	Would comply with ARARs through use of institutional actions and excavation and disposal actions.	Would comply with ARARs through use of institutional actions, containment actions, and excavation and treatment actions.	Would comply with ARARs through use of institutional actions and excavation and treatment actions.	Would comply with ARARs through use of institutional actions and acquisition with institutional and containment actions.	Would comply with ARARs through use of institutional actions, acquisition, and excavation and disposal actions.
			Long-term effectiveness			
No action would be taken to reduce the risks to humans; current exposures and risks to human health would continue.	Excavation of some of the contaminated material from the floodplain and containment of the remainder would eliminate most of the pathways of residual risks to human health. The contained residual contaminated soils would require active controls to prevent unacceptable exposures.	Excavation of all contaminated material from the site would eliminate unacceptable residual risks to human health. Contaminated material would be isolated in a disposal facility. No long-term control measures required at the site.	Excavation of some of the contaminated material from the floodplain and containment of the remainder would eliminate most of the pathways of residual risks to human health. The contained residual contaminated soils would require active controls to prevent unacceptable exposures.	Excavation of all contaminated material from the site would eliminate unacceptable residual risk to human health.	All contaminated material would remain in place, with access restricted by fencing. The areas of highest contamination would be contained. The containment and access restriction would require active controls to prevent unacceptable exposures.	Contaminated materials would be excavated from some properties, and access restriction and institutional actions would be implemented on other properties. Long-term control measures would be required at the site.

Table 6.1 (continued)

SWA 1 No action	SWA 2 Containment and institutional actions; excavation and disposal	SWA 3 Excavation and disposal	SWA 4 Containment and institutional actions; excavation, treatment, and beneficial reuse	SWA 5 Excavation, treatment, and beneficial reuse	SWA 6 Containment and institutional actions; acquisition, containment and institutional actions	SWA 7 Institutional actions; excavation and disposal
Short-term effectiveness and environmental impacts						
No impacts would occur during implementation (periodic monitoring), but significant potential exists for negative impacts to the environment if no action were taken.	Implementation would involve transportation and construction accident risks. Containment and excavation would negatively affect biota and habitat. Excavation would disturb 3.8 ha (9.4 acres) of bottomland hardwood forest; containment would convert 1.8 ha (4.4 acres). Excavation would disturb 0.44 ha (1.11 acres) of wetlands; 0.46 ha (1.14 acres) would be contained. Excavated areas could recover to natural habitat; contained areas would be permanently maintained as grassland. Borrow soil required - 45,000 m^3 (58,800 yd^3) - could result in the disturbance of 0.81 ha (2.0 acres) at the borrow site.	Implementation would involve transportation and construction accident risks. Excavation would negatively affect biota and habitat. Excavation would disturb 5.6 ha (13.8 acres) of bottomland hardwood forest and 0.90 ha (2.25 acres) of wetlands. Borrow soil required - 49,500 m^3 (64,800 yd^3) - could result in disturbance of 0.90 ha (2.25 acres) at the borrow site.	Same as SWA 2, except the borrow soil required would be 16,400 m^3 (21,400 yd^3), and the area of potential disturbance at the borrow site would be 0.30 ha (0.74 acres). Perceived net adverse impacts to the institutional environment as a result of low-temperature thermal desorption unit and beneficial reuse of treated soils.	Same as SWA 3, except the borrow soil required would be 2,400 m^3 (3,200 yd^3), and the area of potential disturbance at the borrow site would be 0.04 ha (0.10 acres). Perceived net adverse impacts to the institutional environment as a result of low-temperature thermal desorption unit and beneficial reuse of treated soils.	Implementation would involve transportation and construction accident risks. Containment would negatively affect biota and habitat; 5.6 ha (13.8 acres) would be contained; 0.90 ha (2.25 acres) of wetlands would be converted. Borrow soil required - 43,600 m^3 (57,000 yd^3) - could result in disturbance of 0.81 ha (2.0 acres) at the borrow site.	Implementation would involve transportation and construction accident risks. Excavation would disturb 2.5 ha (6.1 acres) of bottomland hardwood forest and 0.38 ha (0.94 acres) of wetlands. Borrow soil required - 22,400 m^3 (29,400 yd^3).

Table 6.1 (continued)

SWA 1 No action	SWA 2 Containment and institutional actions; excavation and disposal	SWA 3 Excavation and disposal	SWA 4 Containment and institutional actions; excavation, treatment, and beneficial reuse	SWA 5 Excavation, treatment, and beneficial reuse	SWA 6 Containment and institutional actions; acquisition, containment and institutional actions	SWA 7 Institutional actions; excavation and disposal
Reduction in toxicity, mobility, or volume through treatment						
No action to reduce toxicity, mobility, or volume.	No reduction in toxicity, mobility, or volume would result from implementation of this alternative.	Same as SWA 2.	Low-temperature thermal desorption treatment would reduce the concentrations of mercury in treated soils to below action levels.	Same as SWA 4.	Same as SWA 2.	Same as SWA 2.
Implementability						
No implementation actions required.	Institutional actions could be readily implemented but likely would require continuous activity. Excavation and containment techniques are well known and could be readily implemented. On-site disposal at Y-12 requires a special waste approval from the TDEC.	Excavation techniques are well known and could be readily implemented. On-site disposal at Y-12 requires a special waste approval from the TDEC.	Institutional actions could be readily implemented but likely would require continuous activity. Containment and excavation techniques are well known and could be readily implemented. Pilot studies indicate that the low-temperature thermal desorption treatment technology would be effective and implementable but may involve large-volume waste streams. Requires TDEC approval for beneficial reuse.	Excavation techniques are well known and could be readily implemented. Treatment factors are same as SWA 4.	Extensive fencing and other institutional actions could be readily implemented but likely would require long-term controls and maintenance activity. Acquisition of real estate interest by DOE for the long term along much of the creek length could prove difficult.	Institutional actions, including some fencing, could be readily implemented but likely would require long-term controls and maintenance activity. Excavation could be readily implemented. Acquisition of adjoining DOE property in Segment 1 not considered difficult. On-site disposal at the Y-12 Plant requires a special waste approval from TDEC.
Cost (1993 dollars)						
$12,000,000	$48,000,000	$52,000,000	$59,000,000	$70,000,000	$41,000,000	$31,000,000

Table 6.2. Habitat impacts summary

Categories of impact	SWA 1	SWA 2	SWA 3	SWA 4	SWA 5	SWA 6	SWA 7
Residual contamination - surface soil above 180 ppm mercury	7.35 ha (18.16 acres)	0	0	0	0	0	1.89 ha (4.67 acres)
Riparian							
Length of stream bank and riparian habitat excavated (could regenerate)	0	1,921 m (2,101 yd)	3,288 m (3,596 yd)	1,921 m (2,101 yd)	3,288 m (3,596 yd)	0	1,424 m (1,557 yd)
Length of stream bank permanently stabilized and riparian habitat lost	0	1,367 m (1,495 yd)	0	1,367 m (1,495 yd)	0	3,288 m (3,596 yd)	0
Bottomland hardwood							
Area of bottomland hardwood excavated (could regenerate)	0	3.81 ha (9.4 acres)	5.59 ha (13.8 acres)	3.81 ha (9.4 acres)	5.59 ha (13.8 acres)	0	2.47 ha (6.1 acres)
Area of bottomland hardwood permanently converted to grassland	0	1.78 ha (4.4 acres)	0	1.78 ha (4.4 acres)	0	<5.59 ha (<13.8 acres)	0
Wetlands							
Wetlands area excavated (would be restored)	0	0.44 ha (1.11 acres)	0.90 ha (2.25 acres)	0.44 ha (1.11 acres)	0.90 ha (2.25 acres)	0	0.38 ha (0.94 acre)
Wetlands area contained (filled; permanently altered)	0	0.46 ha (1.14 acres)	0	0.46 ha (1.14 acres)	0	0.90 ha (2.25 acres)	0
Wetlands area with surface residual contamination above 180 ppm	0.90 ha (2.25 acres)	0	0	0	0	0	1.31 ha (0.52 acre)

Table 6.3. Comparative impacts of sitewide alternatives on ecological measurement endpoints

SWA 1	SWA 2	SWA 3	SWA 4	SWA 5	SWA 6	SWA 7
No action	Containment and institutional actions; excavation and disposal	Excavation and disposal	Containment and institutional actions; excavation, treatment, and beneficial reuse	Excavation, treatment, and beneficial reuse	Containment and institutional actions; acquisition, containment and institutional actions	Institutional actions excavation and disposal
No harm to T&E[a] species or to plant communities or other resources required for their support						
No impact (T&E species not found in EFPC floodplain)	No impact (T&E species not found in EFPC floodplain)	No impact (T&E species not found in EFPC floodplain)	No impact (T&E species not found in EFPC floodplain)	No impact (T&E species not found in EFPC floodplain)	No impact (T&E species not found in EFPC floodplain)	No impact (T&E species not found in EFPC floodplain)
No harm to migratory birds						
Exposure to contaminated soils and food would continue	**Short term:** Food sources reduced by excavation and containment in 7.35 ha (18.16 acres) **Long term:** Food sources would slowly recover in 4.85 ha (11.97 acres) but be reduced by containment of 2.5 ha (6.19 acres); exposures through food reduced	**Short term:** Food sources reduced by excavation of 7.35 ha (18.16 acres) **Long term:** Food sources would slowly recover by succession in excavated area; exposures through food reduced	**Short term:** Food sources reduced by excavation and containment in 7.35 ha (18.16 acres) **Long term:** Food sources would slowly recover in 4.85 ha (11.97 acres) but be reduced by containment of 2.5 ha (6.19 acres); exposures through food reduced	**Short term:** Food sources reduced by excavation of 7.35 ha (18.16 acres) **Long term:** Food sources would slowly recover by succession in excavated area; exposures through food reduced	**Short term:** Food sources reduced by containment in 7.35 ha (18.16 acres) **Long term:** Food sources would be reduced by containment of 7.35 ha (18.16 acres); exposures through food higher than in SWA 2 through SWA 5	**Short term:** Food sources reduced by excavation of 3.52 ha (8.7 acres) **Long term:** Exposure to contaminated soils and food would continue

Table 6.3 (continued)

SWA 1	SWA 2	SWA 3	SWA 4	SWA 5	SWA 6	SWA 7
No action	Containment and institutional actions; excavation and disposal	Excavation and disposal	Containment and institutional actions; excavation, treatment, and beneficial reuse	Excavation, treatment, and beneficial reuse	Containment and institutional actions; acquisition, containment and institutional actions	Institutional actions excavation and disposal
Maintenance of wetland functions						
No change in wetland functions	**Short term:** Excavation of 0.44 ha (1.11 acres) wetland **Long term:** Permanent loss of 0.46 ha (1.14 acres) wetland; function of excavated wetland may not be restored	**Short term:** Excavation of 0.9 ha (2.25 acres) wetland **Long term:** Function of all excavated wetland may not be restored	**Short term:** Excavation of 0.44 ha (1.11 acres) wetland **Long term:** Permanent loss of 0.46 ha (1.14 acres) wetland; function of excavated wetland may not be restored	**Short term:** Excavation of 0.9 ha (2.25 acres) wetland **Long term:** Function of excavated wetland may not be restored	**Short term:** Disruption of 0.9 ha (2.25 acres) wetland by containment **Long term:** Permanent loss of 0.9 ha (2.25 acres) wetland	**Short term:** Excavation of 0.38 ha (0.94 acres) wetland **Long term:** No permanent loss of wetlands
Fraction of fish species tolerant of degraded conditions not to exceed 30%						
Tolerant species would remain >30% at upstream sites	**Short term:** Loss of riparian edge might increase percentage of tolerant species **Long term:** Tolerant species would remain >30% at upstream sites	**Short term:** Loss of riparian edge might increase percentage of tolerant species **Long term:** Tolerant species would remain >30% at upstream sites	**Short term:** Loss of riparian edge might increase percentage of tolerant species **Long term:** Tolerant species would remain >30% at upstream sites	**Short term:** Loss of riparian edge might increase percentage of tolerant species **Long term:** Tolerant species would remain >30% at upstream sites	**Short term:** Loss of riparian edge might increase percentage of tolerant species **Long term:** Tolerant species would remain >30% at upstream sites	**Short term:** Tolerant species would remain >30% at upstream sites **Long term:** Tolerant species would remain >30% at upstream sites

Table 6.3 (continued)

SWA 1	SWA 2	SWA 3	SWA 4	SWA 5	SWA 6	SWA 7
No action	Containment and institutional actions; excavation and disposal	Excavation and disposal	Containment and institutional actions; excavation, treatment, and beneficial reuse	Excavation, treatment, and beneficial reuse	Containment and institutional actions; acquisition, containment and institutional actions	Institutional actions excavation and disposal
Surface water contaminants less than CCC[b]						
Mercury concentrations would remain above CCC at upstream sites	**Short term:** Mercury concentrations might increase by erosion and would remain above CCC at upstream sites **Long term:** Mercury concentrations would remain above CCC at upstream sites	**Short term:** Mercury concentrations might increase by erosion and would remain above CCC at upstream sites **Long term:** Mercury concentrations would remain above CCC at upstream sites	**Short term:** Mercury concentrations might increase by erosion and would remain above CCC at upstream sites **Long term:** Mercury concentrations would remain above CCC at upstream sites	**Short term:** Mercury concentrations might increase by erosion and would remain above CCC at upstream sites **Long term:** Mercury concentrations would remain above CCC at upstream sites	**Short term:** Mercury concentrations might increase by erosion and would remain above CCC at upstream sites **Long term:** Mercury concentrations would remain above CCC at upstream sites	**Short term:** Mercury concentrations might increase by erosion and would remain above CCC at upstream sites **Long term:** Mercury concentrations would remain above CCC at upstream sites
Aquatic body burdens less than levels toxic to receptors						
PCB body burdens would continue above levels potentially toxic to receptors	PCB body burdens would continue above levels potentially toxic to receptors	PCB body burdens would continue above levels potentially toxic to receptors	PCB body burdens would continue above levels potentially toxic to receptors	PCB body burdens would continue above levels potentially toxic to receptors	PCB body burdens would continue above levels potentially toxic to receptors	PCB body burdens would continue above levels potentially toxic to receptors
Aquatic body burdens less than levels toxic to predators						
Mercury and PCB body burdens would remain above levels potentially toxic to predators	Mercury and PCB body burdens would remain above levels potentially toxic to predators	Mercury and PCB body burdens would remain above levels potentially toxic to predators	Mercury and PCB body burdens would remain above levels potentially toxic to predators	Mercury and PCB body burdens would remain above levels potentially toxic to predators	Mercury and PCB body burdens would remain above levels potentially toxic to predators	Mercury and PCB body burdens would remain above levels potentially toxic to predators

Table 6.3 (continued)

SWA 1	SWA 2	SWA 3	SWA 4	SWA 5	SWA 6	SWA 7
No action	Containment and institutional actions; excavation and disposal	Excavation and disposal	Containment and institutional actions; excavation, treatment, and beneficial reuse	Excavation, treatment, and beneficial reuse	Containment and institutional actions; acquisition, containment and institutional actions	Institutional actions excavation and disposal
Terrestrial populations not reduced >20%						
No change in impact on terrestrial populations	**Short term:** Some terrestrial populations reduced by excavation and containment **Long term:** No permanent loss of >20% of any habitat type in any RU or segment	**Short term:** Some terrestrial populations reduced by excavation **Long term:** No permanent loss of >20% of any habitat type in any RU or segment	**Short term:** Some terrestrial populations reduced by excavation and containment **Long term:** No permanent loss of >20% of any habitat type in any RU or segment	**Short term:** Some terrestrial populations reduced by excavation **Long term:** No permanent loss of >20% of any habitat type in any RU or segment	**Short term:** Some terrestrial populations reduced by excavation and containment **Long term:** With mitigative measures, no permanent loss of >20% of any habitat type in any RU or segment; without mitigative measures, possible exclusion of some taxa from 7.35 ha (18.16 acres) habitat by fencing	**Short term:** Some terrestrial populations reduced by excavation **Long term:** With mitigative measures, no permanent loss of >20% of any habitat type in any RU or segment
Terrestrial body burdens less than levels toxic to receptors						
Mercury body burdens in terrestrial biota would remain above levels potentially toxic to receptors	Body burdens in terrestrial biota would be below levels potentially toxic to receptors	Body burdens in terrestrial biota would be below levels potentially toxic to receptors	Body burdens in terrestrial biota would be below levels potentially toxic to receptors	Body burdens in terrestrial biota would be below levels potentially toxic to receptors	Body burdens in terrestrial biota would be below levels potentially toxic to receptors	Body burdens in terrestrial biota could exceed levels potentially toxic to receptors, but in <20% of any habitat or segment

Table 6.3 (continued)

SWA 1	SWA 2	SWA 3	SWA 4	SWA 5	SWA 6	SWA 7
No action	Containment and institutional actions; excavation and disposal	Excavation and disposal	Containment and institutional actions; excavation, treatment, and beneficial reuse	Excavation, treatment, and beneficial reuse	Containment and institutional actions; acquisition, containment and institutional actions	Institutional actions excavation and disposal
Terrestrial body burdens less than levels toxic to predators						
Mercury body burdens in terrestrial biota would remain above levels potentially toxic to predators	Body burdens in terrestrial biota would be below levels potentially toxic to predators	Body burdens in terrestrial biota would be below levels potentially toxic to predators	Body burdens in terrestrial biota would be below levels potentially toxic to predators	Body burdens in terrestrial biota would be below levels potentially toxic to predators	Body burdens in terrestrial biota would be below levels potentially toxic to predators	Mercury body burdens in terrestrial biota could remain above levels potentially toxic to predators, but in <20% of any habitat or segment

Table 6.3 (continued)

SWA 1	SWA 2	SWA 3	SWA 4	SWA 5	SWA 6	SWA 7
No action	Containment and institutional actions; excavation and disposal	Excavation and disposal	Containment and institutional actions; excavation, treatment, and beneficial reuse	Excavation, treatment, and beneficial reuse	Containment and institutional actions; acquisition, containment and institutional actions	Institutional actions excavation and disposal
Overall impact to aquatic ecosystem						
Aquatic ecosystem would remain typical of degraded conditions	**Short term:** Increased degradation by erosion, siltation, and disturbance of 3,288 m (3,596 yd) of riparian edge; disturbance of >20% of edge in Segments 1,4, and 5 **Long term:** Increased degradation by loss of 1,367 m (1,495 yd) of riparian edge	**Short term:** Increased degradation by erosion, siltation, and disturbance of 3,288 m (3,596 yd) of riparian edge; disturbance of >20% of edge in Segments 1, 4, and 5 **Long term:** Return to baseline condition by recovery of disturbed riparian edge	**Short term:** Increased degradation by erosion, siltation, and disturbance of 3,288 m (3,596 yd) of riparian edge; disturbance of >20% of edge in Segments 1, 4, and 5 **Long term:** Increased degradation by loss of 1,367 m (1,495 yd) of riparian edge	**Short term:** Increased degradation by erosion, siltation, and disturbance of 3,288 m (3,596 yd) of riparian edge; disturbance of >20% of edge in Segments 1, 4, and 5 **Long term:** Return to baseline condition by recovery of disturbed riparian edge	**Short term:** Increased degradation by erosion, siltation, and disturbance of 3,288 m (3,596 yd) of riparian edge; disturbance of >20% of edge in Segments 1, 4, and 5 **Long term:** Increased degradation by loss of 3,288 m (3,596 yd) of riparian edge	**Short term:** Increased degradation by erosion, siltation, and disturbance of 1,424 m (1,558 yd) of riparian edge; disturbance of >20% of edge in Segment 4 **Long term:** none

Table 6.3 (continued)

SWA 1	SWA 2	SWA 3	SWA 4	SWA 5	SWA 6	SWA 7
No action	Containment and institutional actions; excavation and disposal	Excavation and disposal	Containment and institutional actions; excavation, treatment, and beneficial reuse	Excavation, treatment, and beneficial reuse	Containment and institutional actions; acquisition, containment and institutional actions	Institutional actions excavation and disposal
Overall impact to terrestrial ecosystem						
Exposures potentially toxic to receptors and predators would continue in ~7 ha (18 acres) of habitat	**Short term:** Disturbance and habitat destruction would decrease some populations in ~6.5 ha (16 acres) **Long term:** Permanent loss of ~2.5% of riparian edge; slow recovery of habitat in excavated areas would allow return of populations	**Short term:** Disturbance and habitat destruction would decrease some populations in ~6.5 ha (16 acres) **Long term:** No permanent loss of habitat; slow recovery of habitat in excavated areas would allow return of populations	**Short term:** Disturbance and habitat destruction would decrease some populations in ~6.5 ha (16 acres) **Long term:** Permanent loss of ~2.5% of riparian edge; slow recovery of habitat in excavated areas would allow return of populations	**Short term:** Disturbance and habitat destruction would decrease some populations in ~6.5 ha (16 acres) **Long term:** No permanent loss of habitat; slow recovery of habitat in excavated areas would allow return of populations	**Short term:** Disturbance and habitat destruction would decrease some populations in ~6.5 ha (16 acres) **Long term:** Permanent loss of ~2.5% riparian edge; slow recovery of habitat in contained areas would allow return of populations	**Short term:** Disturbance and habitat destruction would decrease some populations in ~2.8 ha (7 acres) **Long term:** No permanent loss of habitat; slow recovery of habitat in contained and fenced areas would allow return of populations; some taxa might be excluded by fencing

[a] Threatened and Endangered.
[b] Criterion Continuous Concentration.

Table 6.4. Comparative analysis summary and ranking of alternatives

Evaluation criteria	Sitewide alternatives						
	1	2	3	4	5	6	7
Overall protectiveness of human health and the environment	Low	Medium	Medium -high	Medium	Medium -high	Medium -low	High
Compliance with ARARs	NA	Comply	Comply	Comply	Comply	Comply	Comply
Long-term effectiveness	Low	Medium -high	High	Medium -high	High	Medium -low	Medium
Short-term effectiveness and environmental impacts	Low	Medium	Medium	Medium	Medium	Medium	High
Reduction in toxicity, mobility, or volume through treatment	Low	Low	Low	High	High	Low	Low
Implementability	NA	High	High	Medium	Medium	Medium	Medium -high
Cost (× $1,000,000)	12	48	52	59	70	41	31

NA = Not applicable

7. REFERENCES

Adriano, D.C., ed. 1992. *Biogeochemistry of Trace Metals (Advances in Trace Substances Research)*. Lewis Publishers Inc., Boca Raton, Florida.

Alsop, F.J. 1971. *A Checklist of Birds of Knox County, Tennessee*. Tennessee Ornithological Society.

Ambrose, R.E. 1975. "The Effect of Small-tract Clearcutting on Populations of Birds and Small Mammals." Doctoral Dissertation, University of Tennessee, Knoxville.

ANL (Argonne National Laboratory). 1982. *Methods for Assessing Environmental Impacts of a FUSRAP Property-Cleanup/Interim-Storage Remedial Action.* ANL/EIS-16. U.S. Department of Energy, Washington, D.C., December.

ATSDR (Agency for Toxic Substances and Disease Registry). 1991a. *Toxicological Profile for Arsenic*. U.S. Department of Health and Human Services.

ATSDR. 1991b. *Toxicological Profile for Cadmium*. U.S. Department of Health and Human Services.

ATSDR. 1991c. *Toxicological Profiles for Selected PCBs (Aroclor-1260, -1254, -1248, -1242, -1232, -1221, and -1026)*. U.S. Department of Health and Human Services.

ATSDR. 1992. *Toxicological Profile for Mercury*. U.S. Department of Health and Human Services.

Baes, C.F. III, R.D. Sharp, A.L. Sjoreen, and R.W. Shor. 1984. *A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture*. ORNL-5786. Oak Ridge National Laboratory, Oak Ridge, Tennessee, November.

Baker, J. 1993. Personal communication from J. Baker, Owner, Nana's Kiddie Kampus, Oak Ridge, Tennessee, to J.C. Morrissey, SAIC, March 8.

Barnthouse, L.W., G.W. Suter II, S.M. Bartell, J.J. Beauchamp, R.H. Gardner, E. Lindner, R.V. O'Neill, and A.E. Rosen. 1986. *User's Manual for Ecological Risk Assessment*. Publication No. 2679, ORNL-6251. Environmental Services Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Barry, J. 1993. "Fear, Anger in Pompton Lakes Neighborhood," *The Record,* May 6, p. 4.

Battelle (Battelle Pacific Northwest Laboratories). 1984. *Chemical Attenuation Rates, Coefficients, and Constants in Leachate Migration, Volume I: A Critical Review*. Prepared for Electric Power Research Institute. EPRI EA-3356.

Baudo, R., J. Giesy, and H. Muntau, ed. 1990. *Sediments: Chemistry and Toxicity of In-Place Pollutants*. Lewis Publishers, Inc., Boston.

Beyer, N., E. Conner, and S. Gerould. 1991. *Survey of Soil Ingestion by Wildlife*. Report on work funded by U.S. Environmental Protection Agency and supervised by Ruth Miller, OPPE.

Birge, W.J., J.A. Black, A.G. Westerman, and J.E. Hudson. 1979. "The Effect of Mercury on Reproduction of Fish and Amphibians," Pages 629-655, *The Biogeochemistry of Mercury in the Environment*, J.O. Nriagu (ed.). Eisevier/North-Holland Biomedical Press, New York.

Borror, D.J., and D.M. DeLong. 1964. *An Introduction to the Study of Insects* (revised ed.). Holt, Rinehart, and Winston, New York.

Burke, B.E., and R.M. Pfister. 1988. "The Removal of Cadmium from Lake Sediment Bacteria," in *Proceedings of the Annual Meeting of the American Society for Microbiology* Miami Beach, Florida, May 8-13, 1988, Vol. 88, p. 312.

Bunting, L. 1994. Personal communication from L. Bunting, TDEC Water Pollution Control, Nashville, Tennessee, to Tom Hanrahan, SAIC, July 11.

Campbell, P. 1993. Personal communication from P. Campbell, Director, YWCA, Oak Ridge, Tennessee, to J.C. Morrissey, SAIC, February 19.

Carle, F.L., and M.R. Strub. 1978. "A New Method for Estimating Population Size from Removal Data," *Biometrics* 34:621-630.

Carmichael, J.K. 1989. *An Investigation of Shallow Groundwater Quality Near East Fork Poplar Creek, Oak Ridge, Tennessee*. Water Resources Investigation Report 88-4219, U.S. Geological Survey.

Carson, J. 1993. Personal communication from J. Carson, Executive Director, Oak Ridge Housing Authority, Oak Ridge, Tennessee, to J.C. Morrissey, SAIC, May 11. MS/87-9304081/1650.

Caruthers, T. 1993. "DOE Finishes Protective Cap on Girls, Inc.'s Field," *The Oak Ridger*, Oak Ridge, Tennessee, May 17.

Cashwell, J.W., K.S. Neuhauser, P.C. Reardon, and G.W. McNair. 1986. *Transportation Impacts of the Commercial Radioactive Waste Management Program*. SAND85-2715.TTC-0633. Prepared by Sandia National Laboratories, Albuquerque, New Mexico, and Livermore, California, for U.S. Department of Energy, under Contract DE-AC04-76DP00789, April.

CDM (Camp, Dresser, & McKee, Inc.). 1993. *Risk Assessment: Almaden Quicksilver County Park*, Vol. I - Text. Prepared for Santa Clara County Parks and Recreation Department, Los Gatos, California, May 29 (revised September 2, 1993).

Chambles, A. 1993. Personal communication from A. Chambles, Member, Environmental Quality Advisory Board, Oak Ridge, Tennessee, to J.C. Morrissey, SAIC, May 17.

Chason, J. 1991. Personal communication to C. Wenzel, SAIC, Oak Ridge, Tennessee. SAIC Site Accession #1033.930317.002.

Cinder, G. 1993. Personal communication from G. Cinder, Director, Public Works, City of Oak Ridge, Oak Ridge, Tennessee, to J.C. Morrissey, SAIC, March 1.

COE (U.S. Army Corps of Engineers). 1977. *HEC-6: Scour and Deposition in Rivers and Reservoirs, Users Manual.* Computer Program 723-G2-L24740.

COE. 1988. *Floodway Determination Using Computer Program HEC-2.* Training Document No. 5. Hydrologic Engineering Center.

COE. 1991. *HEC-6 Scour and Deposition in Rivers and Reservoirs: Users Manual.* CPD-6. Hydrologic Engineering Center.

COE. 1992. *An Inventory of Wetlands in the East Fork Poplar Creek Floodplain in Anderson and Roane Counties, Tennessee.* Final Report to the U.S. Department of Energy, December. 21 pp. plus appendices.

COE. 1993. *Draft Analyses for Temporary Channel Diversions, East Fork Poplar Creek, Anderson and Roane Counties, Tennessee.* Prepared for Environmental Restoration Division, U.S. Department of Energy, Oak Ridge, Tennessee.

Collins, T. 1993. Personal communication from T. Collins, Clean Water Section, Martin Marietta Energy Systems, Oak Ridge, Tennessee, to T. Hanrahan, SAIC, May 13. 138C.930513.004.

Cook, R.B., S.M. Adams, J.J. Beauchamp, M.S. Bevelhimer, B.G. Blaylock, C.C. Brandt, C.J. Ford, M.L. Frank, M.J. Gentry, S.K. Holladay, L.A. Hook, D.A. Levine, R.C. Longman, C.W. McGinn, J.L. Skiles, G.W. Suter, and L.F. Williams. 1992. *Phase I Data Summary Report for the Clinch River Remedial Investigation: Health Risk and Ecological Risk Screening Assessment.* Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee. ORNL/ER-155.

Crockett, M.L. 1993. Personal communication from M.L. Crockett, Director, La Petite Academy, Oak Ridge, Tennessee, to J.C. Morrissey, SAIC, March 3.

Dawdy, D.R., and V.A. Vanoni. 1986. "Modeling Alluvial Channels," *Water Resources Research* 22(9):71S-81S.

D'itri, F.M. 1990. "The Biomethylation and Cycling of Selected Metals and Metalloids in Aquatic Sediments." In: *Sediments: Chemistry and Toxicity of In-place Pollutants.* (Eds.) R. Baudo, J.P. Giesy, H. Muntan. Lewis Publishers, Inc., Ann Arbor, Michigan. (pp. 163-214).

DOE (U.S. Department of Energy). 1991. *Tennessee Department of Energy Monitoring and Oversight Agreement - An Overview.* Fact Sheet OER-0022, Oak Ridge, Tenn.

DOE. 1994a. *East Fork Poplar Creek-Sewer Line Beltway Remedial Investigation Report.* DOE/OR/02-1119&D1. Prepared by Science Applications International Corporation, Oak Ridge, Tennessee; Submitted to U.S. Department of Energy under Contract No. DE-AC05-91OR21950;ESC, January.

DOE. 1994b. *Addendum to the East Fork Poplar Creek - Sewer Line Beltway Remedial Investigation Report.* DOE/OR/02-1119&D2/A1/R1, Prepared by Science Applications International Corporation, Oak Ridge, Tennessee; Submitted to U.S. Department of Energy under Contract DE-AC05-91OR21950;ESC, June.

Domm, T.C. 1993a. Personal communication from T.C. Domm, Chairman, Oak Ridge Planning Commission, Oak Ridge, Tennessee, to J.C. Morrissey and J. Rush, SAIC, May 10.

Domm, T.C. 1993b. Letter with attachment from T. C. Domm, Oak Ridge Regional Planning Commission, Oak Ridge, Tennessee, to D.G. Page, U.S. DOE, Oak Ridge, Tennessee.

DuVall, G.D. 1993. *An Archaeological Reconnaissance of a 14 Mile Section of the East Fork Poplar Creek for the Environmental Restoration Project, Anderson and Roane Counties, Tennessee.* Prepared for the U.S. Army Corps of Engineers, Nashville District, January.

Edwards, T. 1993. Personal communication from T. Edwards, Sheriff, Anderson County, Clinton, Tennessee, to M.R. Zanotti, SAIC, February 5.

Eisler, R. 1986. *Polychlorinated Biphenyl Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review.* Biological Report 85(1.7), U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Laurel, Maryland.

Eisler, R. 1987. *Mercury Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review.* Biological Report 85(1.10), U.S. Department of the Interior, Fish and Wildlife Service, Patuxent, Maryland.

Energy Systems (Martin Marietta Energy Systems, Inc.). 1992. *Environmental Assessment for the Steam Plant Ash Disposal Facility and Industrial Landfill at the Y-12 Plant, Anderson County, Tennessee.* DOE/EA-0564. Oak Ridge National Laboratory, Oak Ridge, Tennessee, April.

Energy Systems. 1994. *Lower East Fork Poplar Creek Floodplain Soil Roasting Information.* Y/EN-5234, Prepared by IT Corporation, Knoxville, Tennessee, for Martin Marietta Energy Systems, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, May 3.

Environmental Laboratory. 1987. *Corps of Engineers Wetlands Delineation Manual.* Technical Report Y-87-1. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi.

EPA (U.S. Environmental Protection Agency). 1974. *Information on Levels of Environmental Noise Requirements to Protect Public Health and Welfare with an Adequate Margin of Safety*. EPA 550/9-74/004. Washington, D.C.

EPA. 1976a. "Noise Emission Standards for Construction Equipment," 40 CFR Part 205.

EPA. 1976b. "Transportation Equipment Noise Emissions Control," 40 CFR Part 205.

EPA. 1976c. *Loading Functions for Assessment of Water Pollution from Nonpoint Sources*. EPA 600/2-76/151. Office of Air, Land, and Water Use, Washington, D.C.

EPA. 1979. *Water-related Fate of 129 Priority Pollutants*. EPA 440/4-79/029a. Office of Water Planning and Standards, Washington, D.C., December.

EPA. 1982. *An Exposure and Risk Assessment for Arsenic*. EPA 440/4-85/005. Office of Water Regulations and Standards, Washington, D.C.

EPA. 1983. *Treatability Manual, Vol. I. Treatability Data*. EPA 600/2-82/001a. Office of Research and Development, Office of Health and Environmental Assessment, Washington, D.C.

EPA. 1985a. *Drinking Water Criteria Document on Cadmium*. Office of Water Regulations and Standards, Washington, D.C.

EPA. 1985b. *Environmental Profiles and Hazard Indices for Constituents of Municipal Sludge: Cadmium*, Office of Water Regulations and Standards, U.S. EPA, Washington, D.C.

EPA. 1986. *Superfund Public Health Evaluation Manual*. EPA 540/1-86/060. Office of Emergency and Remedial Response, Washington, D.C., October.

EPA. 1987a. *MINTEQA1, An Equilibrium Metal Speciation Model: User's Manual*. EPA 600/3-87/012. October.

EPA. 1987b. *Processes, Coefficients, and Models for Simulating Toxic Organics and Heavy Metals in Surface Waters*. EPA 600/3-87/015.

EPA. 1987c. *Data Quality Objectives for Remedial Response Activities: Development Process*. EPA/540/G-87/003 (OSWER Directive 9355.0-7B). Office of Emergency and Remedial Response, Washington, D.C., March.

EPA. 1987d. *Remedial Action Costing Procedures Manual*. EPA/600/8-87/049. Prepared by JRB Associates for U.S. Environmental Protection Agency, Washington, D.C.

EPA. 1988a. *Superfund Exposure Assessment Manual*. EPA 540/1-88/001. Office of Remedial Response, Washington, D.C., April. OSWER Directive 9285.5-1.

EPA. 1988b. *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA*. Interim Final. EPA 540/G-89/004. Office of Emergency and Remedial Response, Washington, D.C., October. OSWER Directive 9335.3-01.

EPA. 1989a. *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A)*. Interim Final. EPA 540/1-89/002. Office of Emergency and Remedial Response, Washington, D.C., December. OSWER Directive 9285.701A.

EPA. 1989b. *Exposure Factors Handbook*. EPA 600/8-89/043. Exposure Assessment Group, Office of Health and Environmental Assessment, Washington, D.C., May.

EPA. 1989c. *Rapid Bioassessment Protocols for Use in Streams and Rivers. Benthic Macroinvertebrates and Fish*. EPA 440/4-89/001. Washington, D.C.

EPA. 1991a. *Risk Assessment Guidance for Superfund - Volume I: Human Health Evaluation Manual, Supplemental Guidance - Standard Default Exposure Factors*. Interim Final. Office of Emergency and Remedial Response, Toxics Integration Branch, Washington, D.C., March 25. OSWER Directive 9285.6-03.

EPA. 1991b. *Risk Assessment Guidance for Superfund: Volume I: Human Health Evaluation Manual (Part C, Risk Evaluation of Remedial Alternatives), Interim*. Office of Emergency and Remedial Response. U.S. Environmental Protection Agency. Washington, D.C., December.

EPA. 1991c. *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual (Part B), Development of Risk-Based Preliminary Remediation Goals*. EPA Office of Emergency and Remedial Response. OSWER Directive 9285.7-01B.

EPA. 1991d. *LEAD 0.60. A PC Software Application of the Uptake/Biokinetic Model*. Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, September.

EPA. 1992a. *Dermal Exposure Assessment: Principles and Applications*. EPA 600/8-91/001B. Office of Health and Environmental Assessment, Office of Research and Development, Washington, D.C., January.

EPA. 1992b. *Health Effects Assessment Summary Tables. Annual Update and Supplement Nos. 1 and 2*. OHEA ECAO-821. Office of Health and Environmental Assessment, Office of Research and Development, Washington, D.C., March.

EPA. 1992c. *Framework for Ecological Risk Assessment*. EPA 630/R-92/001. Risk Assessment Forum, Washington, D.C.

EPA. 1993a. *Integrated Risk Information System (IRIS). U.S. Environmental Protection Agency On-line Database of Toxicity Measures*. Office of Research and Development, Environmental Criteria And Assessment Office, Cincinnati, Ohio. Electronic Mail Account Information via TOXNET, National Library of Medicine, Bethesda, Maryland.

EPA. 1993b. *Wildlife Exposure Factors Handbook*, EPA/600/R-93/187A,B. U.S. Environmental Protection Agency, Office of Research and Development.

EPA. 1994a. *Baseline Public Health Evaluation, Sulphur Bank Mercury Mine Superfund Site, Clear Lake, California.* EPA Region IX, January 24.

EPA. 1994b. *Preliminary Draft, Human Health Risk Assessment/Remedial Investigation Report, Carson River Mercury Site, San Francisco, California.* EPA Region IX, April.

EPA, DOE, and TDEC. 1992. Federal Facilities Agreement under Section 120 of CERCLA and Sections 3008(h) and 6001 of RCRA. U.S. Environmental Protection Agency, U.S. Department of Energy, and Tennessee Department of Environment and Conservation, January 1.

Espenshade, E.B., ed. 1980. *Goode's World Atlas*. 15th edition. Rand McNally, Chicago.

Etnier, E.L., E.P. McDonald, and L.M. Haulberg. 1992. *Applicable or Relevant and Appropriate Requirements (ARARs) for Remedial Action at the Oak Ridge Reservation: A Compendium of Major Environmental Laws*. Environmental Restoration Program, Oak Ridge National Laboratory, Oak Ridge, Tennessee. ES/ER/TM-1/R1.

Fausch, K.D., J.R. Karr, and P.R. Yant. 1984. "Regional Application of an Index of Biotic Integrity Based on Stream Fish Communities," *Transactions of the American Fisheries Society 113*, 39-55.

Federal Highway Administration. 1976. "Procedures for Abatement of Highway Traffic Noise and Construction Noise," *Federal Register* 41, No. 80, April 23.

FICWD (Federal Interagency Committee for Wetland Delineation). 1989. *Federal Manual for Identifying and Delineating Jurisdictional Wetlands*. Cooperative Technical Publication, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and U.S. Department of Agriculture Soil Conservation Service, Washington, D.C. 76 pp. plus appendices.

Fitzgerald, W. 1993. "City Draws Up List of Key Creek Issues," *The Oak Ridger,* Oak Ridge, Tennessee, Wednesday, March 24.

Foster, G.R., and V.A. Ferreira. 1981. "Deposition in Uniform Grade Terraces," pp. 185-197 in *Proceedings of the American Society of Agricultural Engineers Conference on Crop Production with Conservation in the 80's*, American Society of Agricultural Engineers, St. Joseph, Michigan.

Fritts, K. 1993. Personal communication from K. Fritts, Director, Anderson County Emergency Management Agency, Clinton, Tennessee, to M.R. Zanotti, SAIC, February 5.

FWS (U.S. Fish and Wildlife Service). 1980. *Habitat Evaluation Procedures (HEP)*. ESM 102.

FWS. 1985. *Cadmium Hazards to Fish, Wildlife, and Invertebrates. A Synoptic Review.* Biological Report 85(1.2). U.S. Department of the Interior, Fish and Wildlife Service, Patuxent, Maryland.

FWS. 1991. Letter from R.T. Bay, Acting Field Supervisor, Fish and Wildlife Service, U.S. Department of the Interior, Cookeville, Tennessee, to M. Cunningham, SAIC (August 29). Subject: List of threatened and endangered species in Anderson and Roane Counties, Tennessee.

Gashwiler, J.S. 1970. "Plant and Mammal Changes on a Clearcut in West-central Oregon," *Ecology* 51:1018-1026.

Gawarecki, S. 1993. Personal communication from S. Gawarecki, Chair, Environmental Committee, League of Women Voters, Oak Ridge, Tennessee, to J.C. Morrissey, SAIC, May 20.

Gist, C.S. 1987. *Soil Contaminant Uptake by Plants in the Terrestrial Food Chain in the Floodplain of East Fork Poplar Creek.* Oak Ridge Associated Universities, Oak Ridge, Tennessee, April 28.

Golder Associates, Inc. 1989. *East Chestnut Ridge Site Hydrogeologic Characterization.* ORNL/Sub/30X-SA706C. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Hagar, D.C. 1960. "The Interrelationships of Logging, Birds, and Timber Regeneration in the Douglas Fir Region of Northwestern California," *Ecology* 41:116-125.

Hammer, Donald A. 1992. *Creating Freshwater Wetlands.* Lewis Publishers, Inc. 256 pp. plus appendices.

Harris, L.D., 1965. Geologic Map of the Tazewell Quadrangle, Claiborne County, Tennessee: U.S. Geological Survey Map, GQ-465, Scale 1/24,000.

Harris, L.D., and R.B. Mixon. 1970. Geologic Map of Howard Quarter Quadrangle, Northeastern Tennessee: U.S. Geological Survey Map GQ-842, Scale 1/24,000.

Harvey, M.J. 1992. *Survey for Endangered Indiana and Gray Bats Along East Fork Poplar Creek in the Vicinity of Oak Ridge, Tennessee.* Report submitted by M.J. Harvey, Chairman, Department of Biology, Tennessee Technological University, Cookeville, Tennessee, to SAIC, May.

Hayes, J. 1993. Personal communication from J. Hayes, Principal, Robertsville Junior High School, Oak Ridge, Tennessee, to J.C. Morrissey, SAIC, March 8.

Hedrick, R. 1993. Personal communication from R. Hedrick, COE Regulatory Branch, to J. Groton, SAIC, August 12.

Heit, M., and M. Fingerman. 1977. "The Influence of Size, Sex and Temperature on the Toxicity of Mercury to Two Species of Crayfishes," *Bull. Environ. Contam. Toxicol.*, 18:572-580.

Hinzman, R.L., ed. 1992. *Second Report on the Oak Ridge Y-12 Plant Biological Monitoring and Abatement Program for East Fork Poplar Creek.* Y/TS-888. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Hershfield, D.M. 1961. *Rainfall Frequency Atlas of the United States, for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years.* Prepared for Engineering Division, Soil Conservation Service, U.S. Department of Agriculture. Weather Bureau, U.S. Department of Commerce, Washington, D.C.

Hnilicka, P.A., and C.R. Wenzel. 1991. "Small Mammal Abundance in a Short-Rotation Plantation." Poster presentation at Environmental Sciences Division Annual Information Meeting, March 16, 1991, Oak Ridge National Laboratory, Oak Ridge, Tennessee. SAIC Memo 380.930318.003.

Hoffman, F.O., B.G. Blaylock, C.C. Travis, K.L. Daniels, E.L. Etnier, K.E. Cowser, and C.W. Weber. 1984. *Preliminary Screening of Contaminants in Sediments.* ORNL/TM-9370. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Hoffman, F.O., B.G. Blaylock, M.L. Frank, L.A. Hook, E.L. Etnier, and S.S. Talmage. 1991. *Preliminary Screening of Contaminants in the Off-site Surface Water Environment Downstream of the U.S. Department of Energy Oak Ridge Reservation.* Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee. ORNL/ER-9.

Hooper, R.G. 1967. "The Influence of Habitat Disturbances on Bird Populations." Master's Thesis. Virginia Polytechnic Institute, Blacksburg, Virginia.

Howard, P.H., ed. 1990. *Handbook of Environmental Fate and Exposure Data for Organic Chemicals: Volume II.* Lewis Publishers, Chelsea, Michigan.

Howard, P.H., ed. 1991. *Handbook of Environmental Fate and Exposure Data for Organic Chemicals: Volume III - Pesticides.* Lewis Publishers, Boca Raton, Florida.

Howard, P.H., R.S. Boethling, W.F. Jarvis, W.M. Meylan, and E.M. Michalenko. 1991. *Handbook of Environmental Degradation Rates.* Lewis Publishers, Chelsea, Michigan.

Howell, J.C., and M.B. Monroe. 1957. "The Birds of Knox County, Tennessee," *J. Tennessee Acad. Sci.* 32(4):247-322.

HSDB (Hazardous Substance Data Bank). 1992. The National Library of Medicine Toxicology Data Network (TOXNET), Bethesda, Maryland.

Hunt, R.L. 1975. "Use of Terrestrial Invertebrates as Food by Salmonids." In A.D. Hasler (ed.), *Coupling Land and Water Systems.* Springer-Verlag, New York, pp. 137-151.

Hutchison, R. 1993. Personal communication from R. Hutchison, Oak Ridge Environmental Peace Alliance, Knoxville, Tennessee, to J.C. Morrissey, SAIC, May 5.

Issell, B. 1993. Personal communication from B. Issell, Director, Oak Ridge Community Development, Oak Ridge, Tennessee, to J.C. Morrissey, SAIC, May 17.

IT (IT Corporation). 1994. *Status Report Pilot-Scale Thermal Treatment Demonstration, Lower East Fork Poplar Creek.* Prepared for Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, April 29.

Jernelov, A. 1970. "Release of Methyl Mercury from Sediments with Layers Containing Inorganic Mercury at Different Depths," *Limnol. Oceanogr.* 15:958-960.

Johnson, R.M. 1964. *Herpetofauna of the Oak Ridge Area.* ORNL/3653, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Jonasson, I.R., and R.W. Boyle. 1972. "Geochemistry of Mercury and Origins of Natural Contamination of the Environment," *The Canadian Mining and Metallurgical Bulletin*, January, pp. 1-8.

Jones, B. 1993. Personal communication from B. Jones, Safety/Security Director, Methodist Medical Center, Oak Ridge, Tennessee, to M.R. Zanotti, SAIC, February 17.

Kessler, F.M., P.D. Schomer, R.C. Chanaud, and E. Rosendahl. 1978. *Construction-Site Noise Control Cost-Benefit Estimation Technical Background.* CERL-TR-N-37. Technical Report N-37, Construction Engineering Research Laboratory, Champaign, Illinois, January.

Kettelle, R.H. and D.D. Huff. 1984. *Site Characterization of the West Chestnut Ridge Site.* ORNL/TM-9229. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Kitchings, T., and L.K. Mann. 1976. *A Description of the Terrestrial Ecology of the Oak Ridge Environmental Research Park.* ORNL/TM-5073. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Knisel, W.G., ed. 1980. *CREAMS: A Field-Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems.* Conservation Research Report No. 26. U.S. Department of Agriculture Science and Education Administration, Washington, D.C. 643 pp.

Knisel, W.G., G.R. Foster, and R.A. Leonard. 1963. "CREAMS: A System for Evaluating Management Practices," pp. 178-199 in *Agricultural Management and Water Quality,* ed. F.W. Schaller and G.W. Bailey, Iowa State University Press, Ames, Iowa.

Knisel, W.G., F.M. Davis, and R.A. Leonard. 1992. *GLEAMS Version 2.0: Part III - User Manual.* U.S. Agricultural Research Service, Southeast Watershed Research Station, Tifton, Georgia.

Kornegay, F.C. 1992. *Oak Ridge Reservation Environmental Report for 1991.* Vols. 1 and 2, ES/EH-22/V1&V2. Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee.

Kroodsma, R.L. 1987. *Resource Management Plan for the Oak Ridge Reservation, Volume 24: Threatened and Endangered Animal Species*. ORNL/ESH-1/V24. Oak Ridge National Laboratory, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee, January.

Lane, L.J., and V.A. Ferreira. 1980. "Sensitivity Analysis," in *CREAMS: A Field-Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems*, ed. W.G. Knisel, Conservation Research Report No. 26, U.S. Department of Agriculture, Science and Education Administration, Washington, D.C.

Lee, R.R., and R.H. Ketelle. 1989. *Geology of the West Bear Creek Valley Site*, ORNL/TM-10887. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Lee Wan and Associates, Inc. (LWA). 1990. *Draft East Fork Poplar Creek - Sewerline Beltway Integrated RCRA/CERCLA/NEPA Assessment - Phase Ia, Parts 1 and 2*. DOE/OR-930 and LWA/90-006. Oak Ridge, Tennessee.

Leonard, R.A., W.G. Knisel, and D.A. Still. 1987. "GLEAMS: Groundwater Loading Effects of Agricultural Management Systems," *Transactions of the American Society of Agricultural Engineers* 30(5):1403-1418.

Leonard, R.A., W.G. Knisel, F.M. Davis, and A.W. Johnson. 1988. "Modeling Pesticide Metabolite Transport with GLEAMS," pp. 255-262 in *Proceeding on Planning Now for Irrigation and Drainage*, IR/Div./ASCE, Lincoln, Nebraska.

Levine, M.B., E.D. Smith, F.E. Sharples, and K.D. Eddlemon. 1990. *Integration of NEPA and CERCLA Requirements during Remedial Responses at DOE Facilities*. ORNL/TM-11564. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Life Systems, Inc. 1987. *Toxicological Profile for Arsenic*. Prepared for Agency for Toxic Substances and Disease Registry.

Lind, O.T. 1979. *Handbook of Common Methods for Limnology*. C.V. Mosby, St. Louis.

Little, L. 1993. Personal communication from L. Little, ERWM Programs, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee, to J.C. Morrissey, SAIC, March 3.

Loar, J.M., ed. 1992. *First Report on the Oak Ridge Y-12 Plant Biological Monitoring and Abatement Program for East Fork Poplar Creek*. Y/TS-886. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Lorber, M.N., and L.A. Mulkey. 1981. "An Evaluation of Three Runoff Loading Models," *Journal of Environmental Quality* 11:519-529.

McCartney, L. 1992. Personal communication from L. McCartney to D. Combs, SAIC, Oak Ridge, Tennessee, September 17. [Appendix R, RI report (SAIC 1993).]

McComish, M.F., and J.H. Ong. 1988. "Trace Metals," in *Environmental Inorganic Chemistry: Properties, Processes, and Estimation Methods*. Pergamon Press, New York.

McElroy, A.D., S.Y. Chiu, J.W. Nebgen, A. Aleti, and F.W. Bennett. 1976. *Loading Functions for Assessment of Water Pollution for Nonpoint Sources*. EPA 600/2-76/151. U.S. Environmental Protection Agency, Office of Air, Land, and Water Use, Washington, D.C.

McLeod, L. 1993. Personal communication from L. McLeod, Organizer, Save Our Cumberland Mountains, Lake City, Tennessee, to Janice Morrissey, SAIC, December 17.

McMaster, W.M., 1967. *Hydrologic Data for the Oak Ridge Area, Tennessee*. U.S. Geological Survey Water Supply Paper No. 1838-N, U.S. Government Printing Office, Washington, D.C.

Melton, W.L. 1967. "Lithostratigraphy of the Conasauga Group Between Rogersville and Kingsport, Tennessee," Ph.D. Dissertation, The University of Tennessee, Knoxville.

Merritt, R.W., and K.W. Cummings, eds. 1984. *An Introduction to the Aquatic Insects of North America*. Kendall/Hunt Publishing Co., Dubuque, Iowa.

Moneymaker, R.H. 1981. *Soil Survey of Anderson County, Tennessee*. U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C.

Moore, G.K. 1988. *Concepts of Groundwater Occurrence and Flow Near Oak Ridge National Laboratory, Tennessee*. ORNL/TM-10969. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Moore, J.W., and S. Ramamoorthy. 1983. *Heavy Metals in Natural Waters: Applied Monitoring and Impact Assessment*. Springer Verlag, New York.

Mueller, T.C., R.E. Jones, P.B. Bush, and P.A. Banks. 1992. "Hazard Assessment: Comparison of PRZM and GLEAMS Computer Model Predictions with Field Data for Aroclor, Metribuzin and Norflurazon Leaching," *Environ. Toxicol. Chem.* 11:427-436.

Mullins, J. 1993. Personal communication from J. Mullins, Agent, Volunteer Realty, Commercial Office, Knoxville, Tennessee, to J.C. Morrissey, SAIC, May 21.

National Academy of Sciences. 1977. *Guidelines for Preparing Environmental Impact Statements on Noise*. Committee on Hearing Bioacoustics and Biomechanics, Working Group No. 69, Washington, D.C.

Nelson, L., Jr., and F.W. Clark. 1973. "Correction for Spring Traps in Catch/Effort Calculations of Trapping Results," *J. Mammalogy* 54:295-298.

Nephew, E. 1993. Personal communication from E. Nephew, Mayor, City of Oak Ridge, Oak Ridge, Tennessee, to J.C. Morrissey, SAIC, April 22.

Newby, S. 1993. Memorandum from Steven Newby, SAIC, to Calvin R. Wenzel, SAIC. Telephone conversation with Tennessee Wildlife Resources Agency personnel, June 29.

NOAA (National Oceanic and Atmospheric Administration). 1991. *Local Climatological Data. Annual Summary with Comparative Data*. National Climate Data Center, Asheville, N.C.

Noey, L. 1993. Personal communication from L. Noey, Oak Ridge Planning Commission and Oak Ridge City Council, Oak Ridge, Tennessee, to J.C. Morrissey, SAIC, May 18.

Noggle, C.C. 1978. "Behavioral, Physiological, and Lethal Effects of Suspended Sediments on Juvenile Salmonids." M.S. Thesis, University of Washington, Seattle, Washington.

Norris, M.J. 1994. *Integrated Mercury Remediation Team Presentation for LEFPC Citizens' Working Group*. Visuals for presentation to the Citizens' Working Group, Garden Plaza Hotel, Oak Ridge, Tennessee, January 26.

Odum, E.P. 1983. *Basic Ecology*. Saunders College Publishing, New York, pp. 613.

Ohio EPA (Ohio Environmental Protection Agency). 1988a. *Biological Criteria for the Protection of Aquatic Life: Volume II: Users Manual for Biological Field Assessment of Ohio Surface Waters*. Division of Water Quality Monitoring and Assessment, Columbus, Ohio.

Ohio EPA, 1988b. *Biological Criteria for the Protection of Aquatic life; Volume 1: The Role of Biological Data in Water Quality Assessment*. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio.

Olsson, T.I., and B.G. Persson. 1988. "Effects of Deposited Sand on Ova Survival and Alevin Emergence in Brown Trout, *Salmo trutta*," *Arch. Hydrobiol.* 113(4): 621-627.

Opresko, D. M., B. E. Sample, and G. W. Suter. 1993. *Toxicological Benchmarks for Wildlife*, ES/ER/TM-86, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

ORNL (Oak Ridge National Laboratory). 1988. *Data Package for the Low-Level Waste Disposal Development and Demonstration Program.* ORNL/TM-10939. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

ORNL. 1992a. *Environmental Assessment: Steam Plant Ash Disposal Facility and Industrial Landfill at the Y-12 Plant, Anderson County, Tennessee*. DOE/EA-0564. Prepared for the Y-12 Plant, Oak Ridge, Tennessee, managed by Martin Marietta Energy Systems for the U.S. Department of Energy, February.

ORNL. 1992b. *Toxicity Summary for Mercury*. Prepared by R.A. Young, Chemical Hazard Evaluation and Communication Group, Biomedical and Environmental Analysis Section, Health and Safety Research Division, Oak Ridge National Laboratory, for Oak Ridge Reservation Environmental Restoration Program, November 1991.

Parr, P.D. 1984. *Resource Management Plan for the U.S. DOE ORR, Vol. 4: Endangered and Threatened Plant Species*. ORNL-6026/V4. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Peele, R. 1993. Personal communication from R. Peele, Roane County Commission, Kingston, Tennessee, to John Rush, SAIC, August 5.

Phillips, R.W., R.L. Lantz, E.W. Claire, and J.R. Moring. 1975. "Some Effects of Gravel Mixtures on Emergence of Coho Salmon and Steelhead Trout Fry," *Trans. Am. Fish. Soc.* 104(3): 461-466.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. *Rapid Bioassessment Protocols for Use in Streams and Rivers. Benthic Macroinvertebrates and Fish.* EPA 440/4-89/001. U.S. Environmental Protection Agency, Washington, D.C.

Platts, W.S., 1974. *Geomorphic and Aquatic Conditions Influencing Salmonids and Stream Classification - with Application to Ecosystem Management.* U.S. Department of Agriculture SEAM Program, Billings, Montana.

Platts, W.S., W.F. Megahan, and G.W. Minsall. 1983. *Methods for Evaluating Stream, Riparian, and Biotic Conditions.* General Technical Report INT-138. U.S. Department of Agriculture, U.S. Forest Service, Ogden, Utah.

Platts, W.S., C. Armour, G.D. Booth, M. Bryant, J.L. Bufford, P. Cuplin, S. Jensen, G.W. Lienkaemper, G.W. Minshall, S.B. Monsen, R.L. Nelson, J.R. Sedell, and J.S. Tuhy. 1987. *Methods for Evaluating Riparian Habitats with Applications to Management.* General Technical Report INT-221. U.S. Department of Agriculture, Forest Service, Information Research Station, Ogden, Utah, February.

Purves, D. 1985. *Trace Element Contamination of the Environment (Fundamental Aspects of Pollution Control and Environmental Science, Vol. 7).* Elsevier Science Publishers, New York.

Radian (Radian Corporation). 1991. *Initial Screening of Alternatives for East Fork Poplar Creek and the Sewer Line Beltway.* DOE/OR/992D1. Oak Ridge, Tennessee, October.

Radian. 1993a. *Treatability Study Report for Mercury in East Fork Poplar Creek, Oak Ridge, Tennessee.* DOE/OR/02-1221&D1, Prepared for U.S. Department of Energy under Contract DE-AC05-90OR21851, Oak Ridge, Tennessee, September.

Radian. 1993b. *Low-Temperature Thermal Desorption, Phase 2 Study* (Draft). Prepared for U.S. Department of Energy under contract DE-AC05-90OR21851, Oak Ridge, Tennessee, July.

Regional Economic Information System. 1992a. *Full-time and Part-time Employees by Major Industry for Counties and Metropolitan Areas (Thousands of Dollars).* Table CA25 (on Diskette). Bureau of Economic Analysis, April.

Regional Economic Information System. 1992b. *Personal Income by Major Source and Earnings by Industry for Counties and Metropolitan Areas (Thousands of Dollars).* Table CA5 (on Diskette). Bureau of Economic Analysis, April.

Revis, N.W., T.R. Osborne, G. Holdsworth, and C. Hadden. 1989a. "Distribution of Mercury Species in Soil from a Mercury-Contamination Site," *Water, Air, and Soil Pollution* 45:105-113.

Revis, N.W., G. Holdsworth, G. Bingham, A. King, and J. Elmore. 1989b. *An Assessment of Health Risk Associated with Soil and Sediment from East Fork Poplar Creek, Oak Ridge, Tennessee.* Oak Ridge Research Institute, Oak Ridge, Tennessee. Final Report. pp. 1-58.

Rowley, D.L., P. Turri and D.C. Paschal. 1985. *A Pilot Study of Mercury Levels in Oak Ridge, TN.* Tennessee Department of Health and Environment and the U.S. Public Health Service, Centers for Disease Control. Tennessee Department of Health and Environment, Nashville, Tennessee.

Ryon, M. 1993. Personal communication from M. Ryon, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

SAIC (Science Applications International Corporation). 1994. *East Fork Poplar Creek Transport Calculations of Contaminated Soil.* Golden, Colorado, August 9.

Scheuhammer, A. M. 1988. "Chronic Dietary Toxicity of Mehtylmercury in the Zebra Finch, Poephilaguttata," Bull. Environ. Contam. Toxicol, 40: 123-130.

SCS. 1984. *User's Guide for the CREAMS Computer Model, Washington Computer Center Version.* Technical Release 72. U.S. Department of Agriculture, Soil Conservation Service, Engineering Division, Washington, D.C.

SCS. 1991. *Hydric Soils of the United States.* 3rd ed. USDA-SCS Miscellaneous Publication 1491, U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C.

SCS (Soil Conservation Service). 1993. "List of Important Farmlands in Tennessee." Personal communication from N. Johnson, USDA-SCS State Conservationist's Office, Nashville, Tennessee, to J.P. Groton, Jr., SAIC, January 25.

Sides, A. 1993. Personal communication from A. Sides, Director, Oak Ridge Girls' Club, Oak Ridge, Tennessee, to J.C. Morrissey, SAIC, February 19.

Sledge, J.J., and D.D. Huff. 1981. *Computer Model for Determining Fracture Porosity and Permeability in the Conasauga Group.* ORNL/TM-7695. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Sloca, P. 1993a. "DOE Revises Cleanup Proposal for Oak Ridge Site after Public Input," *The Oak Ridger,* Oak Ridge, Tennessee, Wednesday, March 17, p. 1.

Sloca, P. 1993b. "First Health Studies Report Given," *The Oak Ridger,* Oak Ridge, Tennessee, Monday, April 26, p. 1.

Sloca, P. 1993c. "Health Panel Report Seeks Further Y-12 Study," *The Oak Ridger,* Oak Ridge, Tennessee, Wednesday, May 26.

Smallridge, R. 1993. Personal communication from R. Smallridge, Superintendent, Oak Ridge Public Schools, Oak Ridge, Tennessee, to J.C. Morrissey, SAIC, May 20.

Smith, E. 1993a. Personal communication from E. Smith, Vice-Chairperson, Environmental Quality Advisory Board, Oak Ridge, Tennessee, to J.C. Morrissey, SAIC, June 9.

Smith, E. 1993b. Letter from E. Smith, Vice-Chairperson, Environmental Quality Advisory Board, Oak Ridge, Tennessee, to J.J. Broughton, City Manager, Oak Ridge, Tennessee, April 6.

Southard, T. 1993. Personal communication from T. Southard, Chairman, Oak Ridge Housing Development Corporation, Oak Ridge, Tennessee, to J.C. Morrissey, SAIC, May 24.

Steinberg, J. 1993. "Mercury Cleanup Leaves Disruption Fear in City," *The Oak Ridger* (New York Times News Service), Oak Ridge, Tennessee, Sunday, April 18, p. 1D.

Steinman, A.D., and C.D. McIntire. 1990. "Recovery of Lotic Periphyton Communities After Disturbance," *Environ. Management* 14(5):589-604.

Sullivan, T.D. 1993. *Site Impact Traffic Evaluation: K-25 Credit Union, Shopping Center and Oak Ridge Associated Universities Complex, South Illinois Avenue, Oak Ridge, Tennessee.* Prepared by T. Darcy Sullivan, Transportation Consultant, November.

Suter, G.W., II, and J.M. Loar. 1992. "Weighing the Ecological Risk of Hazardous Waste Sites," *Environ. Sci. Technol.* 26:432-438.

Suter, G.W., M.E. Will, and C. Evans. 1993. *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Terrestrial Plants,* ES/ER/TM-85, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Swabe, R. 1993. Personal communication from R. Swabe, TEMA Oak Ridge Oversight Coordinator, Alcoa, Tennessee, to M.R. Zanotti, SAIC, February 16.

Swann, M.E., W. Roberts, E. H. Hubbard, and H.C. Potter. 1942. *Soil Survey of Roane County, Tennessee.* U.S. Department of Agriculture, Bureau of Plant Industry.

Tennessee Department of Conservation. 1991. Letter from A. Shea, Data Manager, Division of Ecological Services, Tennessee Department of Conservation, Nashville, Tennessee, to M. Cunningham, SAIC, September 24.

Travis, C.C., F.O. Hoffman, B.G. Blaylock, K.L. Daniels, C.S. Gist, and C.W. Weber. 1986. *Preliminary Review of TVA Fish Sampling and Analysis Report.* Report of the Task Group Five. Martin Marietta Energy Systems, Oak Ridge, Tennessee.

Travis, C.C., B.G. Blaylock, K.L. Daniels, C.S. Gist, F.O. Hoffman, R.J. McElhaney, and C.W. Weber. 1989. *Final Report of the Oak Ridge Task Force Concerning Public Health Impacts of the Off-Site Contamination in East Fork Poplar Creek and Other Streams.* ORNL/TM-11242. Oak Ridge National Laboratory, Environmental Science Division, Oak Ridge, Tennessee.

Turner, R.R., and M. Bogle. 1992. *Mercury in Ambient Air over the Floodplain of East Fork Poplar Creek, Oak Ridge, Tennessee.* Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Turner, R.R., G.R. Southworth, M.A. Bogle, M.J. Peterson, and N.S. Bloom. 1992. *Availability of Sediment-Bound Mercury for Methylation and Bioaccumulation in Upper East Fork Poplar Creek: Preliminary Results.* Y/ER-108. Draft report to SAIC, October. (SAIC Accession # 380.930318.005.)

TVA (Tennessee Valley Authority). 1985. *Instream Contaminant Study, Task 1: Water Sampling and Analysis; Task 2: Sediment Characterization; Task 3: Sediment Transport; Task 4: Fish Sampling and Analysis; Task 5: Summary Report.* Prepared for U.S, Department of Energy, Oak Ridge, Tennessee, under Interagency Agreement No. DE-AI05-84OR21444, January.

TVA. 1991. *Flood Analysis for Department of Energy Y-12, ORNL, and K-25 Plants.* Water Resources Division (Interagency Agreement No. DE-AI05-91OR21979), December.

U.S. Bureau of the Census. 1982a. *County Business Patterns, 1980, Tennessee.* CBP-80-44. U.S. Department of Commerce, Washington, D.C., May.

U.S. Bureau of the Census. 1982b. *1980 Census of Housing, Volume 1, Characteristics of Housing Units, Chapter A, General Housing Characteristics, Part 44, Tennessee.* HC80-1-A44. U.S. Department of Commerce, Washington, D.C., August.

U.S. Bureau of the Census. 1991. *1990 Census of Population and Housing, Summary Population and Housing Characteristics, Tennessee.* 1990CPH-1-44. U.S. Department of Commerce, Washington, D.C., August.

U.S. Bureau of the Census. 1992a. *County Business Patterns, 1990, Tennessee.* CBP-90-44. U.S. Department of Commerce, Washington, D.C., September.

U.S. Bureau of the Census. 1992b. *Statistical Abstract of the United States, 1992.* 112th edition, Table 750, p. 480. U.S. Department of Commerce, Washington, D.C.

USDA (U.S. Department of Agriculture). 1984. *User's Guide for CREAMS Computer Model, Washington Computer Center Version.* USDA Soil Conservation Service, Engineering Division, Technical Release 72.

USDL (U.S. Department of Labor). 1992. *Survey of Occupational Injuries and Illnesses, 1991.* Bureau of Labor Statistics.

United States League of Savings Institutions. 1989. *Special Management Bulletin,* S-286, July 3.

Van Winkle, W., R.W. Counts, J.G. Dorsey. J.W. Elwood, V.W. Lowe, Jr., R. McElhaney, S.D. Schlotzhauer, F.G. Taylor, Jr., and R.R. Turner. 1984. *Mercury Contamination in East Fork Poplar Creek and Bear Creek.* ORNL/TM-8894. Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Watson, K.W., and J.R. Luxmoore. 1986. "Estimating Macroporosity in a Forest Watershed by Use of a Tension Infiltrometer," *Soil Science Society of America Journal* 50:578-582.

Weast, R.C. ed. 1984. *CRC Handbook of Chemistry and Physics.* CRC Press, Inc., Boca Raton, Florida.

Webster, D.A. 1976. *A Review of the Hydrologic and Geologic Conditions Related to the Radioactive Solid Waste Burial Grounds at Oak Ridge National Laboratory, Tennessee.* USGS Open File Report 76-727. U.S. Geological Survey, Knoxville, Tennessee.

Welch, S.H. 1987. *RCRA Facility Investigation Plan, General Document, Y-12 Plant.* Y/TS- Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.

Welch, S.H., 1989. *RCRA Facility Investigation Plan for East Fork Poplar Creek and the Oak Ridge Sewer Line Beltway, Oak Ridge Y-12 Plant, Oak Ridge Tennessee.* Y/TS-366/R1. U.S. Department of Energy, Environmental Management Department, Health, Safety, Environment and Accountability Division, Oak Ridge, Tennessee.

Welch, S.H., C.S. Haase, C.W. Kimbrough, and T.M. Mercier. 1987. *Solid Waste Management Unit Information for Y-12 Plant RCRA 3004(u) Facility Assessment.* Y/TS-273/SUP.1. Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.

White, S. 1993. Personal communication from S. White, Civil Design, Martin Marietta Energy Systems, Oak Ridge, Tennessee, to T. Hanrahan, SAIC, May 13. 138C.930513.004.

Woodward-Clyde Consultants. 1984. *Subsurface Characterization and Geohydrologic Site Evaluation. West Chestnut Ridge Site.* Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Worline, B. 1993. Personal communication from B. Worline, President, Residents' Association, Oak Ridge Housing Authority, Oak Ridge, Tennessee, to J.C. Morrissey, SAIC, May 18.

Yeh, G.T. 1983. *CHNTRN: A CHaNnel TRaNsport Model for Simulating Sediment and Chemical Distribution in a Stream/River Network.* ORNL-5582. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Young, L. 1993. Personal communication from L. Young, Vice President of Economic Development, Oak Ridge Chamber of Commerce, Oak Ridge, Tennessee, to J.C. Morrissey, SAIC, May 20.

YWCA (Young Women's Christian Association). 1991. *Annual Report, YWCA of Oak Ridge,* Oak Ridge, Tennessee.

Ziemer, P.L. 1992. "Finding of No Significant Impact, Steam Plant Ash Disposal Facility and Industrial Landfill at the Oak Ridge Reservation's Y-12 Plant, Anderson County, Tennessee." Attachment to Memorandum from P.L. Ziemer, Assistant Secretary, Environmental, Safety and Health, to L.P. Duffy, Assistant Secretary for Environmental Restoration and Waste Management, U.S. Department of Energy, Washington, D.C., April 16.

Zoning Ordinance, Oak Ridge, Tennessee, As Originally Passed June 17, 1959, with Amendments to May 1989. Oak Ridge City Council and Oak Ridge Regional Planning Commission, Oak Ridge, Tennessee.

8. LIST OF PREPARERS

This FS report was prepared by DOE with contractual assistance from SAIC and Radian Corporation. The following SAIC and Radian staff members contributed to the preparation of this report.

Name	Degree/discipline	Professional experience	Responsibility
Rob Adkison, P.E.	M.S. Environmental Engineering B.S. Civil Engineering	20 years of experience in civil engineering in nuclear power, environmental engineering, and remediation planning	Cost estimating; FS technical support
Richard Ambrose	Ph.D. Zoology M.S. Zoology B.S. Ecology	25 years of experience in environmental impact assessment; 16 years of experience in EIS preparation	Coordinator of nature and extent analysis
Cassandra Anthony	B.S. Civil Engineering	9 years of experience in civil engineering; 3.5 years of experience in alternative evaluations and feasibility study preparation	FS technical support
Judy Blair	B.S. Chemistry	10 years of experience in hazardous and toxic waste management, technical oversight, and laboratory analysis; 2.5 years of experience in RI/FS-EIS preparation	FS technical support
Lawrence Cain	M.S. Environmental Health and Policy	12 years of experience in health effects analysis and related field	Human health risk assessment
Teresa Carleton	M.E.M. Ecotoxicology B.S. Wildlife Sciences	2 years of experience in contaminant fate and transport modeling and analysis	Contaminant fate and transport analysis

Name	Degree/discipline	Professional experience	Responsibility
Danny Christodoss	Ph.D. Civil Engineering (Environmental) M.S. Civil-Public Health Engineering B.S. Civil Engineering	11 years of experience in waste water and hazardous waste treatment	ARARs compliance
Barney Cornaby	Ph.D. Ecology/Entomology M.S. Zoology/Statistics	20 years of environmental assessment experience including physical, radiological/chemical, and biological stressors on all aspects of the built-up and natural environments	Ecological resources; Ecological risk assessment
Maureen Cunningham	M.S. Botany B.A. Botany	7 years of experience in environmental impact assessment and rare species surveys; 3 years of experience in EIS preparation; 2 years of experience in integrated FS-EIS preparation	Threatened and endangered species; Overall protection evaluation; Comparative analysis
Michael Deacon	B.S. Environmental Studies B.S. Environmental Health	2 years of experience in environmental impact assessment and EIS preparation	Ecological resources; Transportation noise
Elizabeth L. Etnier	M.S. Zoology B.S. Fish and Wildlife Management	7 years of experience in developing ARARs for Army and DOE National Priorities List sites; Energy Systems-ER ARARs coordinator	Development of ARARs
Julia Gartseff	M.A. Biology B.S. Environmental Biology	11 years of experience in regulatory analysis and compliance	FS technical support
James P. Groton, Jr.	M.S. Forestry B.S. Natural Resources	15 years of experience in environmental impact assessment; 5 years of experience in EIS preparation	Floodplains and wetlands assessment; soil resources analysis

Name	Degree/discipline	Professional experience	Responsibility
Colleen Kadir	M.S. Environmental Engineering B.S. Chemistry	2 years of experience in treatment technology screening	FS technical support
Tom Hanrahan, P.E.	M.S. Business Administration B.S. Mechanical Engineering	21 years of experience in engineering and management; 13 years of experience in radioactive and hazardous waste treatment and disposal	FS technical support and public involvement
Scott Lane	B.S. Geology	5 years of experience in air quality compliance and evaluations	Air quality impact analysis
Ruth Maddigan	D.B.A. Business Economics/ Quantitative Business Analysis M.S.B.A. Management B.S. Mathematics A.B. Economics	14 years of experience in economic impact analysis; 4 years of experience in EIS preparation	Economic and demographic resources
Carol Mason	M.S. Chemical Engineering B.S. Chemical Engineering	23 years of experience in system reliability and risk assessment	Detailed analysis of toxicity, mobility, and volume through treatment
Linda Meredith	B.A. Chemistry	6 years of experience in RI/FS work and human health risk assessment	Human health risk assessment
Robert Milazzo	B.S. Chemical Engineering	13 years of experience as a chemical engineer in remediation planning and radioactive material processing	FS task manager

Name	Degree/discipline	Professional experience	Responsibility
Stephen Mitz	M.S. Aquatic Toxicology B.S. Wildlife Biology	12 years of experience in environmental impact analysis, emphasizing fate and effects of contaminants in aquatic ecosystems; 3 years of experience in EIS preparation	Aquatic/riparian ecological resources
Janice Morrissey	Ph.D. Sociology (in progress) M.A. Sociology B.A. Behavioral Science	8 years of experience in social impact assessment and environmental impact assessment; 8 years of experience in EIS preparation	Institutional analysis; Public services and facilities
Duncan Moss	Ph.D. Geochemistry B.A. Geology	8 years of experience in research and exploration geochemistry; 3 years of experience in hydrogeology	Groundwater
Tim Myrick	B.S. Nuclear Engineering M.E. Environmental Engineering	15 years of experience in environmental restoration and waste management on the ORR	Senior technical reviewer
Will Robinson, P.E.	B.S. Civil Engineering	5 years of experience in civil and environmental engineering	Implementability
John Rush	M.S. Planning B.A. Sociology/Psychology	5 years of experience in environmental impact assessment and environmental impact statement preparation	Land use; Archaeological, cultural, and historical resources
Patrick Ryan	Ph.D. Environmental Sciences	8 years of experience in water quality modeling and analysis	Surface water
Joe Skibinski	B.S. Chemistry	5 years of experience in RI/FS work	Human health risk assessment
Pam Stevens	B.A. Biology	7 years of experience in environmental compliance	FS technical support

Name	Degree/discipline	Professional experience	Responsibility
Wayne Tolbert	Ph.D. Ecology M.S. Ecology B.S. Biology	24 years of experience in environmental compliance and project management	SAIC Program Manager
John Weeks	M.F. Forest Resource Management M.S. Biostatistics, Population Biology B.S. Biology	15 years of experience in contaminant transport and fate modeling and analysis and environmental impact assessment	Contaminant transport and fate analysis
Calvin Wenzel	B.S. Biology	18 years of experience in environmental impact assessment and environmental impact statement preparation	Terrestrial ecological resources
Marialice Wilson	M.S.L.S. Biomedical Information B.S. Biology	16 years of experience in risk assessment, toxicology, and environmental assessments/environmental impact statements	Coordination of detailed analysis of alternatives
Robert L. Yust, P.E.	B.S. Environmental Engineering	16 years of experience in environmental engineering, hazardous materials and waste management, CERCLA project management	FS senior reviewer; technical support
Fred Zafran	M.S. Environmental Science/ Toxicology B.S. Zoology	17 years of experience in risk assessment and toxicology	Human health risk assessment and senior reviewer

9. LIST OF RECIPIENTS

Mr. Tony Able (8 copies)
U.S. Environmental Protection Agency
Region IV
345 Courtland Street, N.E.
Atlanta, Georgia 30365

Mr. Doug McCoy (3 copies)
U.S. Department of Energy
Oversight Division
Tennessee Department of
Environment and Conservation
761 Emory Valley Road
Oak Ridge, Tennessee 37830-7072

Jill Bilyeu (5 copies)
U.S. Department of Energy
EM-423
19901 Germantown Road
Germantown, Maryland 20874-1290

Jerome Miller
Martin Marietta Energy Systems
P. O. Box 2009
9983-AH; MS 8247
Oak Ridge, Tennessee 37831-2009

Debbie Matteo
Martin Marietta Energy Systems
P. O. Box 2003
1330; MS 7256
Oak Ridge, Tennessee 37831-2003

Richard Olson
Martin Marietta Energy Systems
P. O. Box 2008
1505; MS 6035
Oak Ridge, Tennessee 37831-2008

Lesley Cusick
Martin Marietta Energy Systems
P. O. Box 2003
1001; MS 7191
Oak Ridge, Tennessee 37831-2003

Central Records

Patty Phillips
DOE-ORO
P. O. Box 2001
Oak Ridge, Tennessee 37831-2001

D.G. Page
EW-913
ORO

C. Watson
Jacobs Engineering
125 Broadway Avenue
Oak Ridge, Tennessee 37831

T. Swor
U.S. Army Corps of Engineers
Estes Kefauver Building
801 Broadway
Nashville, Tennessee 37202

Allen Robinson
U.S. Fish and Wildlife Service
446 Neal Street
Cookeville, Tennessee 38501

David Young
Tennessee Wildlife Resources Agency
216 E. Penfield Street
Crossville, Tennessee 38555

Jack Hanley
Agency for Toxic Substances
Disease Registry
1600 Clifton Road MS E56
Atlanta, Georgia 30333

Bob Pryor
Tennessee Valley Authority
400 West Summit Hill Drive
Knoxville, Tennessee 37902

940901.0002
c.1
DOE/OR/02-1185&D2&V2

RECEIVED
AUG 31 1994
INFORMATION
RESOURCE CENTER

Feasibility Study for the East Fork Poplar Creek —Sewer Line Beltway

CLEARED FOR
PUBLIC RELEASE

ChemRisk Document No. 1841
Vol 2

RECEIVED
AUG 31 1994
INFORMATION
RESOURCE CENTER

DOE/OR/02-1185&D2&V2

1331.940819.008

Feasibility Study for the East Fork Poplar Creek - Sewer Line Beltway

Volume 2

August 1994

prepared by
U.S. Department of Energy, Oak Ridge Operations Office

with technical assistance from
Science Applications International Corporation
under Contract No. DE-AC05-90OR21851

93-008P/072194

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

contributed to the preparation of this document and should not be considered an eligible contractor for its review.

VOLUME 2
CONTENTS

APPENDIX A	GLOSSARY	A-1
APPENDIX B	COPIES OF CORRESPONDENCE	B-1
APPENDIX C	DOCUMENTATION OF ARARs	C-1
APPENDIX D	COST	D-1
APPENDIX E	METHODOLOGY FOR SOCIOECONOMICS	E-1
APPENDIX F	HUMAN HEALTH RISK ASSESSMENT	F-1
APPENDIX G	ECOLOGICAL RISK ASSESSMENT	G-1
APPENDIX H	LAND USE MAPS	H-1
APPENDIX I	COMMUNITY AND PUBLIC INVOLVEMENT PROGRAM FOR EAST FORK POPLAR CREEK	I-1
APPENDIX J	FLOODPLAINS AND WETLANDS ASSESSMENT FOR REMEDIATION OF EFPC	J-1
APPENDIX K	FLOODPLAIN STATEMENT OF FINDINGS FOR EFPC	K-1

APPENDIX A

GLOSSARY

APPENDIX A

GLOSSARY

absorption: Taking up, incorporating, or assimilating a material.

action-specific requirements: Technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes.

adsorption: Attachment of molecules of a gas or molecules in solution to the surface of solid materials with which they come in contact.

aerobic: Living, active, or occurring only in the presence of free oxygen; characterized by the presence of free oxygen (aerobic conditions).

alluvium: Unconsolidated sediments (including clay, sand, silt, and gravel) deposited by running water (e.g., streams). The deposits generally occur on the floodplains of streams or as alluvial fans or cones at places where streams from mountains lose velocity and deposit sediments on a valley floor.

anaerobic: Occurring in or capable of maintaining life in the absence of free oxygen; characterized by the absence of free oxygen.

applicable or relevant and appropriate requirements (ARARs): Requirements or standards under federal or more stringent state environmental laws that are applicable or relevant and appropriate to the hazardous substances or particular circumstances at a CERCLA site and with which remedial actions must comply to protect human health and the environment. **Applicable requirements** are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental, state environmental, or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable. **Relevant and appropriate requirements** are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental, state environmental, or facility siting laws that, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.

aquatic: Growing, living in, or frequenting water.

aquifer: A water-bearing stratum of permeable rock, sand, or gravel capable of supplying usable quantities of water to wells or springs.

area of contamination: A continuous (significant) extent of contamination at a Superfund site. For the purposes of ARARs, an area of contamination is used as the equivalent of a RCRA-based land unit to determine whether disposal will occur.

assessment endpoints: Goals or objectives, based on policy goals developed within the context of EPA guidance, for environmental values to be protected during the remediation process.

A-weighted (A-scale) sound level: A measurement of sound approximating the sensitivity of the human ear; used in sound analysis systems to note the intensity or annoyance level of sounds.

barrow: A large mound of earth or stones.

base flow: Stream flow supplied by groundwater that emerges as springs or other see pages along the stream channel and is responsible for the low flow or dry season flow of most perennial streams.

baseline risk assessment: Characterization of current and potential future risks to human health and the environment that may be posed by contaminants released to and/or migrating within environmental media at a site, using concentrations of COCs measured in the environmental media (soils, surface water/sediments, groundwater, air) to predict concentrations to which individuals might be exposed if the site were not remediated.

beneficial reuse: Use of soil that has undergone treatment to reduce residual contamination to acceptable levels for beneficial purposes (e.g., landfill cover, backfill in areas of excavation, roadway/runway fill, fill material on the ORR, or land spreading).

benthic: Referring to the bottom of a body of water; bottom-dwelling.

benthic macroinvertebrates: Macroscopic invertebrates found on or near the bottom of a stream, lake, or ocean.

berm: A narrow shelf, edge, or path along a bank providing support and bank stabilization.

bioaccumulation: Increase in the concentration of a substance (e.g., a contaminant) within living organisms as they take in food, water, or air containing the substance.

bioassay: Determination of the relative potency of a drug or other substance (e.g., a contaminant) by comparing its effect on a test organism with the effect of a standard preparation.

bioconcentration factor: Factor predicting extent of concentration of a substance in tissue as it moves up the food chain.

biodegradation: Breakdown or decomposition of a substance by the action of living organisms (e.g., by enzymes produced by microorganisms).

Biological Monitoring and Abatement Program (BMAP): Program initiated in 1985 as part of NPDES permit requirements to document ecological effects of implementing a water pollution control program at the Oak Ridge Y-12 Plant. The BMAP includes ambient toxicity testing, bioaccumulation studies, biological indicator studies, and ecological surveys of stream communities, including fish, macroinvertebrates, and periphyton.

biomagnification: Process whereby certain substances (e.g., pesticides, heavy metals) move up the food chain; enter a river, lake, or stream; and are ingested by aquatic organisms such as fish, which in turn are ingested by large birds, other animals, or humans. The substances become concentrated in tissues as they move up the food chain.

biomass: Total weight of all organisms (or of a particular species or group of organisms) per unit area or volume of habitat.

biota: The flora and fauna of an area.

biotransfer factor: Factor predicting biotransfer of a contaminant from soil to plant or animal tissue.

biotransformation: Transformation of chemical compounds within a living system.

body burden: Measured concentration of a contaminant in the tissues of an indicator organism.

borrow soil: Soil taken from one location to be used as fill at another location.

bottomland hardwood forest: Forest dominated by tree species well adapted to growth in deep alluvial soil along a stream subject to periodic flooding.

brickmaking: Treatment technologies in which soil containing contaminants is formed and compressed into bricks using conventional brickmaking technology.

cancer slope factor: Plausible upper-bound estimate of the slope of the dose-response curve in the low-dose range, representing the probability of a response per unit intake of a chemical over a lifetime. Used to estimate an upper-bound probability that an individual will develop cancer as a result of a lifetime of exposure to a particular level of a particular carcinogen. For known or suspected carcinogens, acceptable exposure levels are those concentrations that represent an upper-bound excess lifetime cancer risk to an individual of 10^{-6} to 10^{-4} (1 in 1,000,000 to 1 in 10,000) as determined by the dose-response relationship.

capping: Containment action that involves covering an area containing contaminated soils with a low-permeability material to reduce migration of contaminants by free release to the atmosphere, provide a barrier between the contaminated medium and human and environmental receptors, and reduce infiltration of surface water through contaminated soils to groundwater. Also: Placing a layer of clay or other highly impermeable material over the top of a closed landfill to prevent entry of rainfall and minimize the production of leachate.

carcinogen: A substance that can cause or contribute to the production of cancer.

carcinogenic: Producing or associated with cancer.

channelization: An engineering technique to straighten, widen, deepen, or otherwise modify a natural stream channel so that water will move faster.

chemical-specific requirements: Health- or risk-based numerical values (or methodologies that, when applied to site-specific conditions, result in establishment of numerical values) specifying acceptable concentrations of a chemical that may be present in or discharged to the environment.

chlordane: A highly chlorinated, viscous, volatile liquid insecticide ($C_{10}H_6Cl_8$).

circulating bed incineration: Combustion method for waste treatment using high turbulence within the incineration bed; allows efficient destruction of halogenated hydrocarbons.

Clean Water Act: A federal law that amends the Federal Water Pollution Control Act to provide for additional authorizations and establishes a reasonableness test for effecting new controls on conventional pollutants. Requires the control of toxic chemicals at industrial sites through best management practices and provides for wetlands protection.

cleanup: Actions taken to deal with a release or threat of release of a hazardous substance that could affect human health or the environment; sometimes used interchangeably with the terms remedial action, removal action, response action, or corrective action.

clear cut: A forest management technique that involves harvesting all trees in an area at one time.

climax community: Type of community whose composition is more or less stable, in equilibrium with existing natural environmental conditions; final community in a successional series.

COLEX: Column exchange process used in product-scale separation of lithium isotopes at the Y-12 Plant from 1950 to 1963; mercury was a by-product present in the process effluent.

community: Ecological term for any naturally occurring mutually sustaining and interdependent group of different organisms inhabiting a common environment, interacting with each other (especially through food relationships), and relatively independent of other groups.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA): A federal law that authorizes EPA to finance the cleanup of abandoned hazardous waste sites and provides the agency with the legal means to recover cleanup costs.

confluence: The flowing together of two or more streams; the point at which two or more streams come together.

containment: Confining wastes within prescribed boundaries.

containment actions: Actions consisting of technologies that confine contaminated media at their current locations. Containment reduces contaminant mobility and the associated potential for exposure but does not reduce contaminant toxicity or volume.

contaminant: Any element, substance, compound, or mixture (including disease-causing agents) that, after release into the environment and uptake by any organism (e.g., by ingestion, inhalation, or assimilation either directly from the environment or indirectly via food chains),

causes (or may reasonably be expected to cause) adverse effects (including death, disease, behavioral abnormalities, cancer, genetic mutation, physiological malfunctions, or physical deformation) in such organisms or their offspring.

contaminant of concern (COC): A contaminant that is potentially site-related and for which data are available that are of sufficient quality for use in quantitative risk assessment.

contaminant transport: Movement of contaminant(s) via pathways represented by environmental media (soil, groundwater, surface water/sediments, air, biota).

Contract Laboratory Program (CLP): EPA analytical program developed for Superfund site samples to meet the need for legally defensible analytical results supported by a high level of quality assurance and documentation.

Contract Laboratory Program statements of work (CLP SOWs): Documents specifying instrumentation, sample handling procedures, analytical parameters and procedures, required quantitation limits, QC requirements, and reporting format to be used by CLP laboratories in analysis for organic and inorganic chemical constituents.

CREAMS (Chemicals, Runoff, and Erosion from Agricultural Management Systems) model: Computerized mathematical model developed by USDA to evaluate floodplain erosion and runoff and the movement and degradation of chemicals within the plant root zone under various crop management systems.

culvert: A transverse drain or waterway (e.g., under a road or railroad).

data quality objectives: Criteria for data quality (as determined by evaluation of PARCC parameters) established in the sampling and analysis plan based on the intended use of the data.

data validation: Systematic technical review of data by examining all analytical results and laboratory documentation, following appropriate functional guidelines.

decibel (dB): A unit of sound measurement. In general, a sound doubles in loudness for every 10-dB increase.

default value: Value assigned to a given parameter in the absence of specific empirical data for that parameter.

demography: Study of human populations including size, density, distribution, and vital statistics (e.g., age, sex, etc.).

density: Total number of organisms (e.g., of a given species, family, etc.) collected per area sampled.

dermal exposure: Exposure via absorption through the skin.

desorption: Removal of a sorbed substance from a surface by a process that is the reverse of sorption.

discharge: In groundwater hydrology, water that issues naturally or is withdrawn from an aquifer.

disposal: Waste emplacement designed to ensure isolation of waste from the biosphere, with no intention of retrieval for the foreseeable future, requiring deliberate action to regain access to the waste. Final placement or destruction of toxic, radioactive, or other wastes; surplus or banned pesticides or other chemicals; contaminated soils; or drums containing hazardous materials from removal actions or accidental releases.

disposal action: Permanent and final placement of waste material, either on site or off site, in a manner that protects human health and the environment.

distribution coefficient (K_d): Ratio of the concentration of a constituent adsorbed on soil particles to the concentration of the dissolved constituent in water.

diversity index: Ratio between number of species and number of individuals in a community.

dominant species: The species most characteristic of a particular plant or animal community, to a large extent governing the type and abundance of other species in the community.

ecological succession: Orderly and therefore often predictable progression of changes in community composition, from initial colonization to attainment of the climax community characteristic of the geographical area, that results from modification of the physical environment by the resident organisms and culminates in the establishment of an ecosystem that is as stable as is biologically possible (climax state).

ecology: Study of relationships between organisms and their environments.

ecosystem: The complex of a community and its environment, functioning as an ecological unit.

ecotone: A transitional area between two adjacent ecological communities (e.g., forest and grassland), usually exhibiting competition between organisms common to both communities.

effluent: Liquid, gaseous, or solid discharges into the environment generated by a process or procedure; wastewater (treated or untreated) that flows out of a treatment plant, sewer, or industrial outfall. Generally refers to wastes discharged into surface waters.

effluent streams: Streams in which flow is maintained during the dry season by groundwater seepage into the channel. Effluent streams tend to be perennial.

endangered species: A species in danger of extinction throughout all or a significant portion of its range.

environmental impact statement (EIS): A document required of federal agencies by NEPA for major projects or legislative proposals affecting the environment. The EIS describes positive and negative impacts of the undertaking and lists alternative actions.

erosion: Wearing away of land surface by wind or water. Erosion occurs naturally from weathering or runoff but can be intensified by land-clearing practices related to farming, residential or industrial development, road construction, or timber cutting.

evapotranspiration: Loss of water from the soil both by evaporation from the surface and by transpiration from plants growing in the soil.

exposure: Lifetime average daily intake or dose of a contaminant sustained by an individual.

exposure pathway: The means by which contaminants move to reach receptors. Potential pathways include soil, groundwater, surface water/sediments, air, and biota (plants and animals).

exposure unit: Geographic area within which a receptor would realistically be expected to spatially and temporally aggregate exposure to contaminants.

fauna: Animals characteristic of a particular region, locality, or habitat.

feasibility study (FS): Superfund study that follows the remedial investigation. The FS identifies, develops, evaluates, and selects for recommendation remedial action alternatives for sites on the National Priorities List.

Federal Facilities Agreement: Cooperative agreement under which DOE, EPA, and state environmental agencies (e.g., TDEC) coordinate assessment and remediation activities at CERCLA sites to comply with CERCLA, RCRA, and NEPA requirements. The Federal Facilities Agreement establishes a procedural framework and schedule for developing, implementing, and monitoring appropriate response actions in accordance with CERCLA, RCRA, NEPA, appropriate guidance and policy, and state law.

floodplain: The portion of a river or stream valley that periodically is inundated. The 100-year floodplain is the area that is likely to be inundated once in 100 years. Floodplains are characterized by flat topography adjacent to a stream in a river valley that has been produced by the combination of overbank flow and lateral migration of meander bends.

floodwall: A wall built to protect against inundation by high water.

floodway district: The portion of a channel and floodplain of a stream designated to provide passage of the 100-year regulatory flood without increasing the elevation of the flood by more than 0.3 m (1 ft). The floodway district is a special zoning district established for areas in 100-year floodplains to ensure that waterways (e.g., EFPC) can carry abnormal flows of water during floods, to prevent increases in flood height and damage, and to prevent loss of life and excessive property damage. (The 100-year flood has a 1% chance of being equalled or exceeded in any given year.)

floodway fringe district: Land located between the floodway district and the maximum elevation subject to flooding by the 100-year regulatory flood. The floodway fringe district includes the portions of the area outside the floodway district that are within the limits of the 500-year flood.

flora: Plants characteristic of a particular region, locality, or habitat.

fluidized bed incineration: Injection of waste into a hot, agitating bed of sand where combustion occurs.

food chain: A sequence of organisms in an ecological community, each of which uses the next-lowest member of the sequence as a food source.

food web: The totality of interacting food chains in an ecological community.

gabion: A hollow cylinder of wickerwork or strap iron (resembling a basket without a bottom) that is filled with earth and used in building fieldworks or in mining as revetments. Also: A contrivance like a gabion filled with stones and sunk to assist in forming a bar, dike, or similar structure (e.g., in harborworks).

geological repository: A system that is intended to be or may be used for the disposal of radioactive wastes in excavated geologic media. The geologic repository includes (1) the geologic repository operations area and (2) the portion of the geologic setting that provides isolation of the radioactive waste.

general response actions: Activities that directly affect the source of contaminants or contaminated materials at the site to minimize the potential hazard to human health and the environment. Each general response action may include several technology options.

GLEAMS (Groundwater Loading Effects of Agricultural Management Systems) model: Computerized mathematical model developed by USDA Agricultural Research Service for field-size areas to evaluate movement and degradation of chemicals within the plant root zone under various crop management systems. The hydrology and erosion components of GLEAMS are essentially similar to those of the CREAMS model, but GLEAMS included new emphasis on prediction of chemical losses through leaching to groundwater and more sophisticated handling of irrigation.

gradient: Slope; change in the value of a quantity per unit distance in a given direction.

gravel: Unconsolidated, generally rounded fragments of rocks and minerals >2 mm (0.08 in.) in diameter.

grizzly screen: Screen made of heavy fixed bars, used in the removal of oversized stones, stumps, etc.

groundwater: Water beneath the earth's surface that fills pores between materials such as sand, soil, and gravel; occurs usually in aquifers; and is often used to supply wells and springs.

grubbing: Removal of roots or stumps from or breaking up the surface of an area by digging.

habitat: The place where a population lives and its surroundings, both living and nonliving.

half-life: The time required for half the atoms of a radioactive substance initially present to undergo disintegration (decay); the time required for half the amount of a substance (e.g., a drug or radioactive tracer) in or introduced into a living system to be eliminated by excretion,

metabolic decomposition, or other natural process; the time required for a pollutant to lose half its effect on the environment.

hardwood plantation: Planted forest of nonconiferous trees, with understory varying depending on the degree of canopy closure.

hazard index (HI): Measure of the total potential risk for adverse noncarcinogenic effects to a receptor from exposure to all chemical contaminants of concern via a given pathway or pathways, defined as the sum of the hazard quotients for the individual contaminants.

hazard quotient (HQ): Measure of the potential risk for adverse noncarcinogenic effects to a receptor from exposure to an individual chemical contaminant, defined as the ratio of the single-substance exposure level via a given pathway (or pathways) over a specified time to a reference dose for that substance derived from a similar exposure period.

headwaters: The source and upper part of a stream.

HEC-6 model: Computer model developed by COE to model interaction between a water-sediment mixture, sediment material forming at a stream's boundary, and the hydraulics of flow. The model simulates transport of sediment in streams and can be used to estimate changes in volume and location of sediment deposits.

HEC-2 model: Computer model used by TVA and COE to calculate water surface profiles and determine floodplain extent.

Henry's Law constant: Constant of proportionality in the relationship defined by Henry's Law, which states that the solubility of a gas is directly proportional to the partial pressure exerted by the gas.

herbicide: An agent used to destroy or inhibit plant growth; a selective weed-killer that is not injurious to crop plants.

herbivore: An animal that feeds on plants.

herpetofauna: Reptiles and amphibians.

high-level radioactive waste: Highly radioactive material (containing fission products, traces of uranium and plutonium, and other transuranic elements) that results from chemical reprocessing of spent fuel. Originally produced in liquid form, high-level waste must be solidified before disposal.

homoiotherm: An organism that is warm-blooded (i.e., an organism that maintains a relatively uniform body temperature nearly independent of the environmental temperature).

horizons (soil): Layers in soil (A, B, C) that differ from each other in chemical, physical, and biological properties.

hydraulic conductivity: The quantity of water that will flow through a unit cross-sectional area of porous material per unit time under a hydraulic gradient of 100 at a specific temperature.

hydraulic gradient: Change in static head per unit of lateral distance in a given direction.

hydric: Characterized by, relating to, or requiring an abundance of moisture.

hydrocarbons: Organic compounds consisting of carbon and hydrogen.

hydrology: Study of the properties, distribution, and circulation of water on the surface of the land, in the soil and underlying rocks, and in the atmosphere.

hydrolysis: A chemical reaction between water and another reactant in which a bond in the other reactant is split and hydrogen and hydroxyl groups are added, usually resulting in the formation of two or more new compounds.

impacts: Effects and their significance.

implementability: The technical and administrative feasibility of an action as well as the availability of needed materials and services.

incineration: Reduction of combustible waste to inert residue by burning at high temperatures [900 to 1000°C (1652 to 1832°F)]; achieves 75-95% volume reduction.

indicator species: Species representative of a particular habitat. Measured effects of a given contaminant on indicator species from each major aquatic or terrestrial habitat can be extrapolated to predict overall effects of the contaminant on the ecosystem. For this FS/PP-EIS, aquatic indicator species included fish (stonerollers, redbreast sunfish, and largemouth bass); sediment-dwelling invertebrates (benthic macroinvertebrates and crayfish); and periphyton (algae and heterotrophic microbes). Terrestrial indicator species included small mammals (shorttail shrew and white-footed mouse); birds (wren and heron); invertebrates (earthworms and adult terrestrial insects) living in or on the soil; and plants (e.g., grasses).

influent streams: Streams that are everywhere above the groundwater table and flow in direct response to precipitation. Water from the channel moves down through the water table, forming a recharge mound. Influent streams may be intermittent or ephemeral in that they flow only part of the year.

in situ: In place; in the natural or original position.

institutional actions: Measures that preclude or minimize exposure by limiting access to or use of contaminated areas. Institutional actions do not reduce contaminant toxicity, mobility, or volume, but they do reduce the potential for exposure to contaminated material. Under the National Contingency Plan, institutional actions may not substitute for active response measures as the sole remedy unless active measures are determined not to be practicable, but institutional actions may be combined with other actions to prevent exposure to residual contamination (e.g., by restricting access to contaminated media via fencing, site security, posting signs, and/or deed or land use restrictions).

institutional control: Management by any governmental or other organized body. Institutional controls may include record keeping, limitations on land ownership and use, maintenance and security activities, monitoring, or other enforced restrictions.

Integrated Risk Information System (IRIS): An EPA data base containing verified RfDs and cancer slope factors and up-to-date health risks and EPA regulatory information for numerous chemicals. IRIS is EPA's preferred source for toxicity information for Superfund.

interim remedial actions: Operations for which monitoring and human control are provided and subsequent action involving treatment, transportation, or final disposition is expected.

isohyetal map: Map indicating lines of equal rainfall.

landfill: (RCRA definition) Any land disposal unit that does not meet the regulatory definition of any other land disposal unit and thus is interpreted by EPA in the National Contingency Plan as including nondiscrete land areas in which there is generally dispersed contamination (55 *FR* 8760).

leaching: Removal or separation of soluble components from a solid by contact with water or other liquids.

levee: An embankment designed to prevent flooding.

limnology: The study of the physical, chemical, meteorological, and biological aspects of fresh water.

location-specific requirements: Restrictions placed on the concentrations of hazardous substances or the conduct of activities based on the fact that they occur in specific locations.

lowest observed adverse effect level (LOAEL): In dose-response experiments, the experimental exposure level representing the lowest level tested at which adverse effects were observed.

low-level radioactive waste: Radioactive material containing low levels of contamination that present significantly less health risk than wastes generated by a nuclear reactor. Low-level wastes include radioactively contaminated construction debris or materials generated by hospitals, research laboratories, and certain industries; disposal is usually by shallow land burial. Responsibility for management of low-level radioactive wastes is shared by DOE, the Nuclear Regulatory Commission, and EPA.

low-temperature thermal desorption: Thermal treatment method using moderate temperature [93 to 315°C (200 to 600°F)] vaporization using rotary drums or pug mill to separate volatile metals (including arsenic and mercury) from soil.

maximum contaminant level: The maximum permissible level of a contaminant in water delivered to any user of a public water supply system that serves 15 or more connections and 25 or more people. The standards set as maximum contaminant levels take into account the feasibility and cost of attaining the standard. Maximum contaminant levels are enforceable standards under the Safe Drinking Water Act.

maximum contaminant level goal: A nonenforceable goal established under the Safe Drinking Water Act for drinking water that considers only health-based factors.

meander: Bend in a stream channel that migrates back and forth across the floodplain, depositing sediment on the inside of the bends and eroding the outside of the bends.

mesic: Characterized by a moderate amount of moisture.

metal: An element generally characterized chemically by the ability to form cations by the loss of one or more electrons from each atom and to form basic oxides and hydroxides; metals include >75% of the known chemical elements (rubidium, cobalt, gallium, and mercury) and are crystalline solids at or near room temperature.

mixed waste: Waste containing both radioactive and RCRA-regulated hazardous waste.

monitoring: Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or contaminant levels in various environmental media (soil, groundwater, surface water, sediments, air) or in humans or other organisms.

Monte Carlo simulation: Method used to generate probabilistic estimates of risk distribution by using probability density functions reflecting the inherent variability in the exposure factors to characterize exposure variables.

most likely exposure (MLE): The most probable exposure (lifetime average daily intake or dose) expected to occur for a given exposure pathway at a site, estimated as the arithmetic mean of the measured concentrations of the contaminant in the environmental medium.

National Oil and Hazardous Substances Pollution Contingency Plan: The federal regulation guiding the determination of sites to be corrected under the Superfund program and the program to prevent or control spills into surface waters or other portions of the environment. The National Contingency Plan outlines the responsibilities and authorities for responding to releases into the environment of hazardous substances and other pollutants and contaminants under the statutory authority of CERCLA and Section 311 of the Clean Water Act.

National Environmental Policy Act (NEPA): Federal law establishing a framework for the government to assess environmental effects of its actions. NEPA requires federal agencies to prepare environmental impact statements to assess environmental effects of proposed projects and legislation and created the President's Council on Environmental Equality to advise the President and prepare an annual environmental quality report for Congress.

National Pollutant Discharge Elimination System (NPDES): A provision of the Clean Water Act that prohibits discharge of pollutants into waters of the United States without a special permit issued by EPA, a state, or (where delegated) a tribal government on an Indian reservation.

National Priorities List: EPA's list of the most serious uncontrolled or abandoned hazardous waste sites identified for possible long-term remedial action under Superfund. A site must be on the National Priorities List to receive money from the Trust Fund (Superfund) for remedial

action. The list is based primarily on the score received by the site from the Hazard Ranking System. EPA is required to update the National Priorities List at least once a year.

neutron activation analysis: Method of trace element analysis in which a sample and standard are irradiated and radioassayed under the same conditions; the ratio of count rates for sample and standard equals the ratio of the masses of the element of interest. Neutron activation analysis requires no chemical separation or extraction. This method was used for total Hg analysis in the EFPC RI.

No Action alternative: Remedial action alternative under which no implementation of remedial technologies occurs and no further action is taken with the exception of periodic environmental monitoring of existing conditions. Evaluation of the No Action alternative is required by CERCLA and NEPA to provide a baseline for comparison with other alternatives.

nonconformance report: Report documenting quality deficiencies identified during an audit or surveillance.

nonpoint source: Contaminant source that is diffuse and does not have a single point of origin or is not introduced into a receiving stream from a specific outlet. The contaminants are generally carried off the land by stormwater runoff. Categories of nonpoint sources include agriculture, urban, mining, construction, dams and channels, land disposal, and saltwater intrusion.

no observed adverse effect level (NOAEL): In dose-response experiments, the experimental exposure level representing the highest level tested at which no adverse effects were observed.

old field: Former agricultural or pasture lands dominated by grasses and forbs. Tree and shrub seedlings typically are also present. Old fields are neither grazed nor mowed.

old field succession: The progressive changes in vegetation and animal species structure and community processes that follow the abandonment of cropland or pasture.

omnivore: An organism that feeds on both plant and animal life or products of metabolism.

on-site: "The areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementing the response action" (CERCLA definition, 40 CFR 300.5).

operable unit (OU): Term for each of a number of separate activities undertaken as part of a Superfund site cleanup. Depending on the complexity of problems associated with the site, cleanup can be divided into a number of OUs, which may address different geographical portions of the site, specific site problems, or initial phases of an action or may consist of a set of actions that are performed over time or are performed concurrently but located in different parts of the site.

operation and maintenance: Measures required to maintain the effectiveness of response actions; activities conducted at a site after a response action is completed to ensure that the cleanup or containment system is functioning properly.

organic carbon partition coefficient (K_{oc}): Equilibrium binding constant describing the strength of binding of nonpolar organic compounds to the organic carbon fraction of soils or sediments.

outfall: The location where an effluent is discharged into receiving waters.

oxidation-reduction (redox) reaction: A chemical reaction in which one or more electrons are transferred from one atom or molecule to another.

oxidation-reduction potential (Eh): The potential at which oxidation occurs at the anode and reduction occurs at the cathode in an electrochemical cell.

PARCC (precision, accuracy, representativeness, completeness, and comparability) parameters: Parameters used to evaluate the quality of data obtained from sampling and analysis. Precision is a measure of the reproducibility of measurements under constant conditions. Accuracy is a measure of the agreement between an observed result and the true value for the sample analysis. Representativeness describes the degree to which sampling data reflect the population sampled. Completeness is assessed by determining the percentage of measurements that resulted in valid data. Comparability is a measure of the confidence with which one data set can be compared with another.

pasture: Open, grassy areas used for grazing by cattle or horses.

perennial stream: A stream that is present during all seasons of the year.

periphyton: Complex matrix of algae and heterotrophic microbes attached to submerged surfaces and serving as a major food source for many stream invertebrates and herbivorous fish.

permeability: The measure of the ability of a material to transmit fluids (e.g., water).

pesticide: Chemical agent used to kill or inhibit the growth of insects or other pests.

pH: A measure of acidity or alkalinity, defined as the negative logarithm of the hydrogen ion concentration and ranging quantitatively from 0 to 14 (pH units).

photolysis: Chemical decomposition or dissociation by the action of radiant energy (e.g., light).

phytoplankton: Minute plants suspended in the water of an aquatic habitat.

piezometric surface: The surface defined by the levels to which groundwater will rise in tightly cased wells that tap an artesian aquifer.

pine plantation: Planted forest of pine trees (typically loblolly and white pine); understory is typically sparse in mature stands but more diverse if some areas have been harvested without replanting.

piscivorous: Feeding on fish.

plankton: Passively floating or weakly swimming animal and plant life of a body of water consisting chiefly of minute plants (e.g., diatoms, blue-green algae) and animals (e.g., protozoa, rotifers, larvae of insects and other invertebrates).

point source: A stationary location, fixed facility, or any other single identifiable source from which contaminants are discharged or otherwise originate.

pollutant: Any substance introduced into the environment that adversely affects the usefulness of a resource.

pollution: The presence of matter or energy whose nature, location, or quantity produces undesired environmental effects.

polychlorinated biphenyl (PCB): Any of several synthetic organic compounds that are produced by replacing hydrogen atoms in biphenyl with chlorine. PCBs were formerly widely used in various industrial applications (e.g., electrical equipment, heat transfer systems, specialized hydraulic systems)
and are environmental pollutants that tend to accumulate in animal tissues.

polycyclic aromatic hydrocarbon (PAH): A hydrocarbon that contains two or more fused rings in the structure of the molecule.

pool: Stream section characterized by relatively deep, slow-moving water that occurs in areas of relatively flat gradients, usually at bends in a channel. Pools generally have well defined boundaries with bowl-shaped bottom areas on which silt and other suspended materials are deposited, forming a suitable substrate for burrowing worms and nekton.

population density: Biomass or number of individuals per unit area or per unit volume.

porosity: The percentage of void or empty space in soil or rock.

predator: An animal that obtains its food primarily by killing and consuming other animals (prey); predation reduces the size of the prey population, which responds by more rapid population growth.

propagule pool: The physical source of individuals potentially available to colonize a new substrate.

pyrolysis: Chemical decomposition or other chemical change brought about by the action of heat.

quality assurance/quality control (QA/QC): A system of procedures, checks, audits, and corrective actions to ensure that all research design and performance, environmental monitoring and sampling, analytical, and other technical and reporting activities are of the highest achievable quality.

quotient method: Method of ecological risk analysis in which observed contaminant concentrations are compared with numerical criteria (e.g., assessment endpoints) for protection

of ecological resources. The ratio of the observed concentration to the protection criterion indicates the severity of the impact or risk, with larger quotients indicating greater potential impact or risk.

radionuclide: An unstable isotope of an element that undergoes radioactive decay.

reasonable maximum exposure (RME): Defined by EPA as the highest exposure (lifetime average daily intake or dose) that could reasonably be expected to occur for a given exposure pathway at a site, estimated as the upper 95% confidence limit on the mean of the concentrations of the contaminant measured in the environmental medium under consideration.

receiving waters: A river, lake, ocean, stream, or other watercourse into which wastewater or treated effluent is discharged.

receptor: Hypothetical individual member of a population at potential risk from exposure to a contaminant or contaminants via one or more exposure pathways.

redox: Oxidation-reduction.

recharge: In groundwater hydrology, a source or means for replenishment of water withdrawn or discharged from an aquifer.

reclamation/recycling: Reclaiming concentrated contaminants as commercial products by recycling.

Record of Decision: A public document that explains which cleanup alternatives will be used at National Pririty List sites where, under CERCLA, funds for cleanup are provided by Superfund.

reference concentration (RfC): Acceptable intake value for subchronic and chronic inhalation exposure to a contaminant (noncarcinogenic effects).

reference dose (RfD): Acceptable intake value for subchronic and chronic oral exposure to a contaminant (noncarcinogenic effects).

reference site: Uncontaminated site at which sampling and analysis were conducted as for sites under investigation to provide representative reference data for comparison with observed results.

relative abundance: Percentage of the total number of a given category of organisms collected that is represented by a given subset of the category.

remedial action: The construction or implementation phase that follows the remedial design of the selected cleanup alternative at a site on the National Priorities List.

remedial action objectives: Specific objectives of remedial action based on contaminants of concern, exposure routes, receptors, and acceptable contaminant levels (e.g., remediation goal options) for all contaminated media at a site. Remedial action objectives for a site are based on acceptable risk-based exposure levels that are protective of human health and the environment and

comply with federal and state ARARs.

remedial design: Phase of remedial action that follows the remedial investigation/feasibility study and includes development of engineering drawings and specifications for a site cleanup.

remedial investigation (RI): An in-depth study designed to gather data necessary to determine the nature and extent of contamination at a Superfund site, establish criteria for site cleanup, identify preliminary alternatives for remediation, and support evaluation of technical and cost alternatives.

remedial units (RUs): For this FS/PP-EIS, the units into which the EFPC OU was delineated for evaluating remedial action alternatives. Delineation was based on differences in land uses and associated risks, media (to some extent), COCs, and public accessibility.

Surface Water/Sediments RU: The remedial unit addressing EFPC surface water and sediments.

Commercial RU: RU addressing area used and zoned for commercial purposes (e.g., offices, retail stores, shopping centers, and other commercial establishments).

DOE RU: RU addressing area that includes all properties owned by DOE.

Other RU: RU addressing land classified as open land use, including areas that may have only incidental use (e.g., recreation or trespass).

Residential RU: RU addressing existing residential areas (primarily single-family and multifamily units) and vacant parcels zoned for future residential use.

Agricultural RU: RU addressing areas used for agricultural purposes (e.g., pasture land for livestock grazing, horse ranches, etc.).

remediation goal options: Initial chemical-specific quantitative cleanup limits (developed using results of human health and ecological risk assessment) for each affected environmental medium that are protective of human health and the environment and that comply with ARARs.

Resource Conservation and Recovery Act (RCRA): A federal law that established a regulatory system to track hazardous wastes from generation to disposal. RCRA requires the use of safe and secure procedures for treatment, transportation, storage, and disposal of hazardous wastes and is designed to prevent creation of new, uncontrolled hazardous waste sites. RCRA also regulates the disposal of certain solid waste that may not be considered hazardous.

removal action: Short-term immediate action taken to address releases or threatened releases of hazardous substances that require expedited response. A removal action involves removal of the contaminant source or contaminated materials (e.g., removal of contaminated soil by excavation using earth-moving equipment such as bulldozers, backhoes, front-end loaders, and excavators or manual excavation techniques in areas with limited access).

RESRAD: Model specified in DOE Order 5400.5 for use in estimating radionuclide concentrations in soils that will achieve the dose limits for residual radioactivity.

riffle: A section of stream channel characterized by relatively shallow, turbulent, and fast-moving water, typically occurring in higher gradient reaches. The current velocity is great enough to keep the bottom cleared of silt and other loose materials, providing a fi[redacted]bstrate occupied largely by specialized benthic macroinvertebrates, periphyton, and some fish species.

riparian: Living on, located on, or relating to the bank of a river, stream, or lake.

riparian habitat: Habitat consisting of areas adjacent to rivers and streams that have a high density, diversity, and productivity of plant and animal species relative to nearby uplands.

riprap: A layer of stones, chunks of concrete, etc., emplaced to protect an embankment against erosion.

risk assessment: Qualitative and quantitative evaluation designed to define the risk posed to human health and/or the environment by the presence or potential presence of and exposure to specific contaminants; performed as part of the remedial investigation at a Superfund site.

risk quotient: Ratio of exposure concentration to concentration specified by criteria limiting contaminant concentrations to protect aquatic or terrestrial biota or their predators.

rotary kiln incineration: Combustion in a horizontally rotating cylinder designed for uniform heat transfer.

run: Stream section similar to a riffle but usually lower in velocity and gradient, with a more laminar flow and very little disruption of surface tension. Runs are generally more constant in depth than pools.

runoff: The portion of precipitation (rainfall and melted snow) that does not soak into the ground, does not evaporate immediately, and is not used by vegetation and that therefore flows over the land surface and eventually reaches streams.

Safe Drinking Water Act: Federal legislation setting regulatory standards for levels of organic chemicals and other pollutants in drinking water and establishing programs to prevent contamination of groundwater sources. The Safe Drinking Water Act requires owners and operators of public/industrial water supplies and sources of drinking water to comply with all federal, state, and local requirements; to obtain applicable permits; and to satisfactorily complete required sample analyses and site inspections. Safe Drinking Water Act Primary Drinking Water Standards are frequently used to establish groundwater protection standards pursuant to RCRA and CERCLA.

sampling and analysis plan: Plan for RI sampling and analysis comprising a field sampling plan, which provides guidance for all field work by defining in detail the sampling and data-gathering methodology for the project and a quality assurance project plan, which describes the policy, organization, functional activities, and QA/QC protocols necessary to achieve data quality objectives dictated by the intended use of the data.

sanitary landfill: Land disposal site for nonhazardous solid wastes; the waste is spread in layers and compacted to the smallest practical volume, and cover material is applied at the end of each operating day.

scavenger: An organism that feeds habitually on refuse or carrion.

scouring: Clearing, digging, or removal by a strong current of water.

screens/grizzlies: Vibrating units operated by selectively allowing particles to pass and removing oversized material.

sediments: Soil, sand, and minerals washed from land into water, usually after precipitation events. Sediments accumulate in reservoirs, rivers, and harbors with adverse effects on aquatic habitats (e.g., destruction of fish nesting areas and increased turbidity of the water, which prevents sunlight from reaching aquatic plants).

seral stage: Stage in an ecological sere (a series of ecological communities formed in ecological succession).

sewer: A channel or conduit that carries wastewater and/or stormwater runoff from the source to a treatment plant or receiving stream.

shallow land burial: Disposal of wastes in shallow trenches; commonly used for low-level radioactive wastes. Treated soil buried in trenches must meet land disposal restrictions.

silt: Fine particles of sand or rock [loose sedimentary material with rock particles < 0.05 mm (0.002 in.) in diameter] that can be picked up by air or water and deposited as sediment.

solvent: Substance (usually liquid) capable of dissolving or dispersing one or more other substances.

sorption: The process of taking up or holding by physical or chemical forces or both.

species: A reproductively isolated aggregate of interbreeding populations of organisms.

species richness: Total number of species collected at a site.

storage: Temporary holding of waste pending treatment or disposal. Storage methods include the use of containers, tanks, waste piles, surface impoundments, etc.

stormflow: Surface water flow during flood events.

Superfund: The common name used for CERCLA, also referred to as the Trust Fund. The fund was set up under CERCLA to help pay for cleanup of hazardous waste sites and for legal action to force those responsible for the sites to clean them up.

surface bioreclamation: Addition of nutrients and/or microorganisms to surface soils to enhance the natural degradation of organic contaminants.

surface water: All the waters that are above ground and naturally open to the atmosphere (rivers, lakes, reservoirs, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors that are directly influenced by surface water. Surface water represents the portion of precipitation that dislodges soil and rock particles on impact with the land surface, is rejected from infiltrating, runs overland in rivulets or streams to rivers, physically and chemically picks up minerals, and erodes the earth.

taxon (pl. taxa): Any formal taxonomic unit or category of organisms (e.g., species, genus, family, order, etc.).

threatened and endangered species: Animals, birds, fish, plants, or other organisms threatened with extinction by anthropogenic or natural changes in their environment. Requirements for designation are contained in the Endangered Species Act.

threatened species: A species likely to become endangered throughout all or a significant portion of its range (see endangered species).

to-be-considered criteria: Nonpromulgated advisories or guidance issued by federal or state governments. Although they are not legally binding and do not have the status of ARARs, to-be-considered criteria can be considered with ARARs in determining the necessary level of remediation for protection of human health or the environment.

tolerant species: Species adapted to survival in various conditions of degraded water quality.

total family richness: Total number of families collected at a site.

total EPT richness: Total number of Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) families collected at a site. EPT richness is a biotic indicator of water quality and is lower in degraded streams.

translocation: Transfer of food materials or products of metabolism from one part of a plant body to another.

treatment: Any activity or process designed to change the physical form or chemical composition of hazardous waste to render it nonhazardous.

treatment action: Action involving the use of physical, chemical, biological, thermal, in situ, or dewatering technologies to reduce or eliminate the toxicity, mobility, or volume of contaminants.

treatment, storage, and disposal facility: A site where hazardous substances are treated, stored, or disposed. Treatment, storage, and disposal facilities are regulated by EPA and states under RCRA.

treatment technology: Any unit operation or series of unit operations that alters the composition of a hazardous substance, pollutant, or contaminant through chemical, biological, or physical means, thereby reducing toxicity, mobility, or volume of the contaminated materials being treated. Treatment technologies are an alternative to land disposal of hazardous wastes without treatment.

Physical technologies reduce the volume of the contaminated materials by physical separation techniques and segregation. Examples include soil washing, air stripping, soil flushing, adsorption/absorption, etc.

Chemical technologies alter the chemical structure of the waste constituents to produce a waste residue that is less hazardous than the original waste. Contaminants can also be separated

from solid waste media by chemical extraction or leaching techniques to reduce volume or mobility of the contaminants.

Biological treatment technologies, used mainly for degradation of organically contaminated material, involve such techniques as surface bioreclamation.

Thermal treatment technologies use high temperatures to destroy, detoxify, or physically stabilize hazardous wastes. Examples include incineration, infrared heating, wet air oxidation, pyrolysis, thermal desorption, and vitrification.

Dewatering techniques are used mainly to separate liquids from solids in aqueous waste streams.

trophic level: One of the successive levels in a food web or food chain.

tumulus (pl. tumuli): An earthen mound; an artificial hillock or burial mound.

TVA Instream Contaminant Study: Study (TVA 1985) that examined potential off-site contamination associated with DOE facilities near Oak Ridge; divided into five tasks covering instream water, sediment, fish, and floodplain sampling of several watersheds, including EFPC.

unconfined aquifer: Type of aquifer in which there is no impermeable layer restricting the upper surface of the zone of saturation.

unsaturated zone: The area above the water table where the soil pores are not fully saturated, although some water may be present.

upland forest: Mixed forest growing on the edge of a floodplain or in upland areas adjoining a floodplain.

vitrification: Waste treatment process resulting in production of a glasslike solid within which contaminants are immobilized.

watershed: Drainage basin; area of land that drains into a body of water. Watersheds are separated by divides.

water table: Surface below which all the pore space in rock or soil is saturated with water. The water table represents the upper surface of the zone of saturation in the subsurface at which the water pressure is equal to atmospheric pressure, or the upper surface of an unconfined aquifer.

weight-of-evidence analysis: In ecological risk assessment, evaluation of strength of relationship between stressors and observed effects on indicator species and the implications for assessment endpoints. A causal relationship between a stressor and a response is proposed, and the proposition is then evaluated against a series of criteria and qualitatively ranked based on the level of available evidence.

weir: A dam in a stream to raise the water level or divert its flow; also, a fence or enclosure set in a waterway for taking fish.

wetland: Area characterized by wetland hydrology, hydrophytic vegetation, and hydric soils. Wetlands include swamps, marshes, bogs, and similar areas.

Yang's streampower principle: Basis of the sediment transport relationship for noncohesive material (sand and larger-size particles), which expresses sediment transport capacity of the stream for specific flow conditions and sediment size distribution.

zone of saturation: Zone or layer below the water table in which all the pore space of rock or soil is saturated.

zooplankton: All animals suspended in the water of an aquatic habitat that are not independent of currents and water movements. Most are microscopic and commonly include protozoa, rotifers, and small crustaceans.

APPENDIX B

COPIES OF CORRESPONDENCE

CONTENTS

APPENDIX B: COPIES OF CORRESPONDENCE B-1

Letters and Memoranda:

FWS (U.S. Fish and Wildlife Service). 1991. Letter from R.T. Bay, Acting Field Supervisor, Fish and Wildlife Service, U.S. Department of the Interior, Cookeville, Tennessee, to M. Cunningham, SAIC (August 29) B-1

Tennessee, Department of Conservation. 1991. Letter from A. Shea, Data Manager, Division of Ecological Services, Tennessee Department of Conservation, Nashville, Tennessee, to M. Cunningham, SAIC (September 24) B-3

Personal Communications (including telephone calls/conferences):

Claud, T. 1992. Personal communication from T. Claud, Project Manager, U.S. Army Corps of Engineers, Nashville, Tennessee, to E.L. Etnier, Biomedical and Environmental Information Analysis, Oak Ridge National Laboratory, Oak Ridge, Tennessee (November 16) B-27

Collins, T. 1993. Personal communication from T. Collins, Clean Water Section, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee, to T. Hanrahan, SAIC (May 13) B-37

Hedrick, R. 1993. Personal communication from R. Hedrick, COE Regulatory Branch, to J. Groton, SAIC (August 12) B-38

Stringer, B. 1993. Personal communication from R. Swabe, TEMA Oak Ridge Oversight Coordinator, Alcoa, Tennessee, to M.R. Zanotti, SAIC (February 16) B-39

White, S. 1993. Personal communication from S. White, Civil Design, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee, to T. Hanrahan, SAIC (May 13) B-40

Currier, B. 1993. Personal communication from B. Currier, Assistant Superintendent, Wastewater Operations, City of Oak Ridge, Tennessee, to S. Mitz, Environmental Scientist, SAIC, (December 16) B-41

Bunting, L. 1994. Personal communication from L. Bunting, TDEC Water Pollution Control, Nashville, Tennessee, to Tom Hanrahan, SAIC, July 11 . . . . . B-42

United States Department of the Interior
FISH AND WILDLIFE SERVICE
Post Office Box 845
Cookeville, TN 38503

TAKE PRIDE IN AMERICA

August 29, 1991

Ms. Maureen Cunningham
Science Applications
Internation Corporation
P.O. Box 2501
Oak Ridge, Tennessee 37831

Dear Ms. Cunningham:

This responds to your letter of August 9, 1991, in which you requested a list of threatened and endangered species in the watershed of the East Fork of Poplar Creek (EFPC). Enclosure 1 lists all threatened and endangered species in Anderson and Roane Counties, Tennessee. Because 17 of the 21 species are aquatic, the subject restoration has significant, potentially positive effects for any of these species which occur in the EFPC.

We appreciate the opportunity to provide you with the requested information, and look forward to ongoing cooperation between our offices on the EFPC project. If you need additional information, please contact Jodi Jenkins at (615) 528-6481.

Sincerely,

Robert T. Bay

Robert T. Bay
Acting Field Supervisor

Enclosure
xc:
TDWPC/Robbie Baker

ENCLOSURE 1

East Fork Poplar Creek Environmental Restoration

Listed species		Status
Alabama lamp pearly mussel	(*Lampsilis virescens*)	ENDANGERED
Alabama monkeyface pearly mussel	(*Quadrula sparsa*)	ENDANGERED
American hart's tongue fern	(*Phyllitis scolopendrium* var. *americana*)	THREATENED
Birdwing pearly mussel	(*Conradilla caelata*)	ENDANGERED
Cumberland monkeyface pearly mussel	(*Quadrula intermedia*)	ENDANGERED
Dromedary pearly mussel	(*Dromus dromas*)	ENDANGERED
Fine-rayed pigtoe pearly mussel	(*Fusconaia cuneolus*)	ENDANGERED
Gray bat	(*Myotis grisescens*)	ENDANGERED
Green-blossom pearly mussel	(*Epioblasma torulosa gubernaculum*)	ENDANGERED
Orange-footed pearly mussel	(*Plethobasus cooperianus*)	ENDANGERED
Pink mucket pearly mussel	(*Lampsilis orbiculata*)	ENDANGERED
Red-cockaded woodpecker	(*Picoides borealis*)	THREATENED
Rough pigtoe pearly mussel	(*Pleurobema plenum*)	ENDANGERED
Shiny pigtoe pearly mussel	(*Fusconaia edgariana*)	ENDANGERED
Slender chub	(*Hybopsis cahni*)	THREATENED
Spotfin chub	(*Hybopsis monacha*)	THREATENED
Turgid-blossom pearly mussel	(*Epioblasma turgidula*)	ENDANGERED
Virginia spiraea	(*Spiraea virginiana*)	THREATENED
White wartyback pearly mussel	(*Plethobasus cicatricosus*)	ENDANGERED
Yellow-blossom pearly mussel	(*Epioblasma florentina florentina*)	ENDANGERED
Yellowfin madtom	(*Noturus flavipinnis*)	THREATENED

Division of Ecological Services
TENNESSEE DEPARTMENT OF CONSERVATION
Nashville, Tennessee 37243-0447

September 24, 1991

Maureen Cunningham
SAIC
P.O. Box 2501
800 Oak ridge Turnpike
Oak Ridge, TN 37831

Dear Maureen,

Enclosed is the information that you requested. I included all of the records within the East Fork Poplar Creek Drainage as well as a list of the records for the Bethel Valley Quad. The other quads had no records for species in the drainage. We have a Protection Site, East Fork Ridge, in the area. As stated on the printout, there are no endangered species at this site. I have enclosed a crude map with the approximate site boundaries drawn in orange. If you have further questions please call me at (615)742-6550.

Sincerely,

Andrea Shea
Data Manager
Ecological Services Division

LIST OF RARE AND ENDANGERED SPECIES FOR [redacted]R) QUAD
23 SEP 1991 Bethel Valley

IENTIFIC NAME	COMMON NAME	FEDERAL STATUS	STATE STATUS	ESO STATUS
VERTEBRATES				
FLUVIALIS	SPINY RIVERSNAIL	C1		E
MPSILIS ABRUPTA	PINK MUCKET	LE	E	E
ANTS				
REX OXYLEPIS VAR PUBESCENS	A SEDGE		S	
NICIFUGA RUBIFOLIA	APPALACHIAN BUGBANE	C2	T	T
LPHINIUM EXALTATUM	TALL LARKSPUR	C2	E	
ONYMUS OBOVATA	RUNNING STRAWBERRY-BUSH		S	
THERGILLA MAJOR	MOUNTAIN WITCH-ALDER		T	
LIUM CANADENSE	CANADA LILY		T	
NAX QUINQUEFOLIUS	AMERICAN GINSENG	3C	T	
ATANTHERA FLAVA VAR FLAVA	SOUTHERN REIN-ORCHID	3C	S	
XIFRAGA CAREYANA	CAREY SAXIFRAGE	3C	S	
IRANTHES OVALIS	LESSER LADIES'-TRESSES		S	
RTEBRATES				
CIPITER STRIATUS	SHARP-SHINNED HAWK		T	E
KOPHILA AESTIVALIS	BACHMAN'S SPARROW	C2	E	E
EIDES AENEUS	GREEN SALAMANDER °	C23C	D	S
ENIDOPHORUS SEXLINEATUS	SIX-LINED RACERUNNER •		D	S
RAGYPS ATRATUS	BLACK VULTURE		D	S
REX LONGIROSTRIS	SOUTHEASTERN SHREW •		D	S
ACHEMYS SCRIPTA TROOSTII	CUMBERLAND SLIDER •		D	S

Records Processed

[illegible]
AIMOPHILA AESTIVALIS

ertitiers:
Elcode EO# State:
CODE: ABPBX91050*009*TN FONUM: IDENT: [illegible]
AME: AIMOPHILA AESTIVALIS
OMNAME: BACHMAN'S SPARROW
EMENT RANKS: GRANK: G3 NRANK: SRANK: S[illegible]

cators:
TION: US SITECODE:
TENAME:
RVEYSITE:

ECISION: S

COUNTYCODE: COUNTYNAME LOCALJURIS:
TNROAN Roane

	QUAD CODE:	MARG NUM:	DOT NUM:	TEN TEN:
JADNAME: ETHEL VALLEY	3508483	15		03.06

LAT: 355605N S:
LONG: 0842048W N:
E:
W:

OWNRANGE: SECTION: MERIDIAN:
RSCOM:

Hwy 95

RECTIONS: 0.3 MI W OF JCT OF BEAR CREEK RD AND WHITE WING RD. IN POWER LINE RIGHT OF WAY.

HYSPROV: RV WATERSHED: 06010207

tus:
URVEYDATE: LASTOBS: 1975-06-20 FIRSTOBS: 1975
ORANK: EORANKDATE:
ORANKCOM:

ODATA: TERRITORIAL PAIR OBS 18 JUNE AND SINGLE BIRD OBS 20 JUNE. SOURCE TITLE: THE BACHMAN'S SPARROW IN TENNESSEE.

ONTACT:

ONTACTNUM:

Description:
OTYPE:
GENDESC:

LEV: 850 SIZE:

Protection:
HACODE: MANAME: CONTAINED:
M.USTNHP*128 OAK RIDGE RESERVATION

ISLAND: MGMTPROT: MGREMGMT: TWOINVOLVE:

MTCOM:

OTCOM:

Ownership:
OWNER: DOE OWNERINFO:
OWNCOM: 01

General Comments:
COMMENTS:

Optional Fields:
OPR.OPT1: 649
OPR.OPT2: 19C
OPR.OPT3: TC02
OPR.OPT4:
OPR.OPT5:
OPR.OPT6:
OPR.OPT7:
OPR.OPT8: C
OPR.OPT9:
OPR.OPT10:

Documentation and Maintenance:
PHASENS: BOUNDARIES: PHOTOS:
DATSOURCE: NICHOLSON, CP, 1976, MIGRANT, 47 53-60

SUBSCRIBR: 91-09- CDREV: SOURCECODE:

TAPEP: OC:

STAREP:
UPDATE: 91-02-27 HSB

EAST FORK RIDGE

entifiers:

ID: COUNTER:

TECODE: S.USTNHP * 204

TENAME: EAST FORK RIDGE

TE.CLASS: SS OLDCODE: USTNSSEAST01

TEALIAS:

MCSITECODE: MCSITENAME:

MGSITECODE: MGSITENAME:

ocators:

ATION: US STATE: TN SITERESP:

OUNTYCODE: COUNTYNAME: QUADNAME: QUADCODE:

TNANDE Anderson WINDROCK

BETHEL VALLEY

OCALJURIS: OAK RIDGE

OWNRANGE: SECTION: MERIDIAN:

SCOM:

T: 360000N LONG: 0841700W

: 360044N N: 360023N E: 0841553W W: 0841741W

IRECTIONS: GO W ON SR-95 FROM JCT OF SR-95 & SR-62. THE RIDGE IS S OF SR-95.

ite Description/Design:

ITEDESC: FOREST OF MIXED MESOPHYTIC TYPE WITH HIGH DIVERSITY OF NATIVE TREE, SHRUB, HERB SPECIES. 2ND GROWTH OAK-HICKORY FORESTS ON UPPER CREST,S-FACING SLOPES. 2 PARALLEL SIDE HOLLOWS RUN OFF MILL CREEK. STEEP N-FACING SLOPE SUPPORT DENSE THICKETS

ITEMAP: Y MAPDATE: 90-06-21

ESIGNER: GHANSAH, EMMANUEL.

OUNDJUST: THE AREA PROPOSED FOR PROTECTION IS EASTERMOST PORTION OF E FORK RIDGE BOUNDED BY E FORK POPLAR CREEK ON N & MILL CREEK ON W.

RISECACRE: PRIMEACRES: 700.00 SITETLACRES:

ITECOM: LOWER SLOPES UNDERLAIN BY ORDOVICIAN LIMESTONE OF CHREAMANGA GROUP: ABOVE THIS IS SEQUATCHIE THEN ROCKWOOD FORMATIONS.

ite Significance:

LDRATING:

ATINGCOM:

IODIVSIG:

IODIVCOM:

HERVALEUS:
HERVALUCOM:

OTURGENCY:
OTURGCOM:

MTURGENCY:
MTURGCOM:

Land Estate and Protection:
INSINTENT: NO RARE SPECIES ARE KNOWN FROM AREA, BUT THE DIVERSITY & QUALITY OF FOREST WOULD MAKE IT WORTHWHILE TO PROTECT.

UMTRACTS: ESTPROTCOST:

DESIG.CODE: DESIGNATION:

POTCOM: TIMBERING & HOUSING DEV. ARE POTENTIAL THREATS TO AREA. CURRENT ABUSES INCLUDE WILDFLOWER DIGGING & OFF-ROAD VEHICLE USE

Stewardship:
ANDUSECOM:

ATHAZCOM:

NOTICCOM:

OFFSITE:

OFONEEDS:

SMTNEEDS: SITE POSSESSES OUSTANDING EXAMPLE OF MATURE MIXED MESOPHYTIC FOREST IN THE RIDGE & VALLEY PHYSIOGRAPHIC PROVINCE. IT INCLUDES A PORTION OF THE OAK RIDGE GREENBELT . WHICH WAS ESTABLISHED SHORTLY AFTER THE CITY WAS FOUNDED.

TCOM:

Optional Fields:
SR.OPT1:

SR.OPT2:

SR.OPT3:

SR.OPT4:

SR.OPT5:

Element Occurrence Information:
ECODE: SNAME: SCOMNAME: GRANK: GRAN

Record Maintenance:
EADRESP:

Change History:

OFFICE:	INITIALS:	CHANGE.DATE:	CHANGE.FIELD:
USTNHP	EG	90-06-21	

MANUAL.FILE.NOTE:

[illegible]
LILIUM CANADENSE

entifiers:
Elcode EO# State:
CODE: PMLIL1A030*008*TN FONUM: IDENT:
AME: LILIUM CANADENSE
OMNAME: CANADA LILY
EMENT RANKS: GRANK: G5 NRANK: SRANK: S2

cators:
TION: US SITECODE:
ITENAME:
URVEYSITE:

RECISION:

COUNTYCODE: COUNTYNAME LOCALJURIS:
TNANDE Anderson

	QUAD CODE:	MARG NUM:	DOT NUM:	TEN TEN:
UADNAME:				
ETHEL VALLEY	3508483	24		03.04

LAT: 355741N S:
LONG: 0842032W N:
E:
W:

OWNRANGE: SECTION: MERIDIAN:
RCOM:

IRECTIONS:

KYSPROV: RV WATERSHED: 06010207

[illegible]
RVEYDATE: LASTOBS: 1976-00-00 FIRSTOBS:
RANK: EORANKDATE:
ORANKCOM:

ODATA: OBSERVED GROWING IN A DENSE ROADSIDE HONEYSUCKLE THICKET ABO
UT 50 FEET FROM STREAM. ONLY ONE PLANT OBSERVED.

INTACT:

ONTACTNUM:

escription:
OTYPE:
ENDESC:

LEV: 880 SIZE:

Location:
CODE: MANAME: CONTAINED:
USTNHP*128 OAK RIDGE RESERVATION

PELAND: MOREPROT: MOREMGMT: TNCINVOLVE:

MTCOM:

OTCOM: 2

Ownership:
WNER: OWNERINFO:
WNERCOM:

General Comments:
MMENTS:

Optional Fields:
OR.OPT1: G49
OR.OPT2: 19C
OR.OPT3: TC02
OR.OPT4:
OR.OPT5:
OR.OPT6:
OR.OPT7:
OR.OPT8:
OR.OPT9:
OR.OPT10:

Documentation and Maintenance:
TASENS: BOUNDARIES: PHOTOS:
ESTSOURCE: MANN, LINDA K. ORNL

TRANSCRIBR: 78-07- *** COREV: SOURCECODE:

APPER: QC:

STARESP:
DATE: 91-02-27 HSB

Element Collected Spec
PLATANTHERA FLAVA VAR FLAVA

entifiers:
Elcode EO# State:
CODE: PMORC1Y031*012*TN FONUM: IDENT: 1
AME: PLATANTHERA FLAVA VAR FLAVA
OMNAME: SOUTHERN REIN-ORCHID
MENT RANKS: GRANK: G4T3? NRANK: SRANK: S2

ators:
TION: US SITECODE:
TENAME:
RVEYSITE:

ECISION: S

COUNTYCODE: COUNTYNAME LOCALJURIS:
TNROAN Roane

QUAD MARG DOT TEN
ADNAME: CODE: NUM: NUM: TEN:
ETHEL VALLEY 3508483 19 02.05

LAT: 355633N S:
LONG: 0842112W N:
E:
W:

OWNRANGE: SECTION: MERIDIAN:
COM:

ECTIONS:

YSPROV: FV WATERSHED: 06010207

ing:
RVEYDATE: LASTOBS: 1900-00-00 FIRSTOBS:
RANK: EORANKDATE:
RANKCOM:

DATA: BOTTOMLAND HARDWOODS DISSECTED BY SPRINGFED STREAMS. SIGHTRE CORD. PLOTTED FROM MAP RECEIVED FROM LINDA MANN ON 18 DECEMB ER 1979.

NTACT:

NTACTNUM:

escription:
OTYPE:
ENDESC:

LEV: 880 SIZE:

otection:
ACODE: MANAME: CONTAINED:
USTNHP*128 OAK RIDGE RESERVATION

RELAND: MOREPROT: MOREMGMT: INCIDSOLVE:

MTCOM:

OTCOM:

nership:
INER: OWNERINFO:
INERCOM:

neral Comments:
OMMENTS:

ptional Fields:
OR.OPT1: 649
OR.OPT2: 19C
OR.OPT3: TC02
OR.OPT4:
OR.OPT5:
OR.OPT6:
OR.OPT7:
OR.OPT8: C
OR.OPT9:
OR.OPT10:

ocumentation and Maintenance:
ATASENS: BOUNDARIES: PHOTOS:
ESTSOURCE: MANN, LK, OAK RIDGE NATIONAL LABORATORY, ENVIRONMENTAL SCIENCES DIVISION

RANSCRIBR: 92-02- COREV: SOURCECODE:

APPER: QC:

ATARESP:
PDATE: 91-02-27 H39

PHOXINUS OREAS

entifiers:

	Elcode	EO#	State:		
CODE:	AFCJB31050*001*TN			SFONUM:	IDENT: Y
AME:	PHOXINUS OREAS				
OMNAME:	MOUNTAIN REDBELLY DACE				
EMENT RANKS:	GRANK: G5		NRANK:		SRANK: S?

ations:

TION:	US	SITECODE.
TENAME:		
RVEYSITE:		

ECISION: S

COUNTYCODE:	COUNTYNAME	LOCALJURIS:
TNROAN	Roane	

QUADNAME:	QUAD CODE:	MARG NUM:	DOT NUM:	TEN TEN:
THEL VALLEY	3508483	21		03,05

LAT: 355640N S:
LONG: 0842056W N:
E:
W:

OWNRANGE: SECTION: MERIDIAN:
SCOM:

RECTIONS: TRIB TO BEAR CREEK AT TN HWY 95

YSPROV: RV WATERSHED: 06010207

atus:

RVEYDATE: LASTOBS: 1971-04-20 FIRSTOBS: 1971
RANK: EORANKDATE:
RANKCOM:

DATA: 49 SPECIMENS, UT CAT. NO. 44.745; ALSO 7 SPECIMENS, UT CAT. NO. 44.992, 2 DEC, 1974.

NTACT:

NTACTNUM:

escription:

TYPE:
ENDESC:

EV: 780 SIZE:

[illegible]:
CODE: MANAME: CONTAINED:
[illegible] OAK RIDGE RESERVATION

[illegible]RELAND: MOREPROT: MOREMGMT: TNCINVOLVE:

[illegible]MTCOM:

OTCOM:

[illegible]nership:
[illegible]NER: OWNERINFO:
[illegible]NERCOM:

[illegible]neral Comments:
[illegible]MMENTS:

[illegible]tional Fields:
[illegible]R.OPT1: G49
[illegible]R.OPT2: 19C
[illegible]R.OPT3: TC02
[illegible]R.OPT4:
[illegible]R.OPT5:
[illegible]R.OPT6:
[illegible]R.OPT7:
[illegible]R.OPT8:
[illegible]R.OPT9:
[illegible]R.OPT10:

[illegible]cumentation and Maintenance:
[illegible]TASENS: BOUNDARIES: PHOTOS:
[illegible]STSOURCE: UNIVERSITY OF TENNESSEE ICHTHYOLOGICAL COLLECTION.
KNOXVILLE, TN

[illegible]ANSCRIBR: 91-09- COREV: SOURCECODE:

[illegible]PPER: QC:

[illegible]TARESP:
[illegible]DATE: 91-02-27 HSB

Element Occurrence Report
PANAX QUINQUEFOLIUS

Identifiers:

	Elcode	EO#	State:		
CODE:	PDARA09010*038*TN			FONUM:	IDENT: Y
AME:	PANAX QUINQUEFOLIUS				
OMNAME:	AMERICAN GINSENG				
EMENT RANKS:	GRANK: G4		NRANK:		SRANK: S3

Locators:

TION:	US	SITECODE:	
TENAME:			
RVEYSITE:			

ECISION: S

COUNTYCODE:	COUNTYNAME	LOCALJURIS:
TNROAN	Roane	

	QUAD CODE:	MARG NUM:	DOT NUM:	TEN TEN:
ADNAME:				
ETHEL VALLEY	3508483	17		03,06

LAT: 355614N S:
LONG: 0842057W N:
E:
W:

WNRANGE:	SECTION:	MERIDIAN:
SCOM:		

IRECTIONS: CA 0.5MI NW OF INTERSECT. OF HWY95 & BEAR CR RD, NE-FACING S LOPE OF SECONDARY RIDGE TO PINE RIDGE

YSPROV: RV WATERSHED: 06010207

Notes:

URVEYDATE:	LASTOBS: 1977-00-00	FIRSTOBS:
RANK:	EORANKDATE:	
RANKCOM:		

DATA: CHAPMAN RIDGE 55. POPULATION OF 30 OR MORE IN 1975.

NTACT:

NTACTNUM:

Description:

OTYPE:
ENDESC:

LEV: 880 SIZE:

Location:
CODE: MANAME: CONTAINED:
USTNHP*128 OAK RIDGE RESERVATION

PRELAND: MOREPROT: MOREMGMT: TNCINVOLVE:

IMTCOM:

OTCOM: 3

Ownership:
OWNER: US OWNERINFO:
OWNERCOM:

General Comments:
COMMENTS:

Optional Fields:
OPR.OPT1: G49
OPR.OPT2: 19C
OPR.OPT3: TC02
OPR.OPT4:
OPR.OPT5:
OPR.OPT6:
OPR.OPT7:
OPR.OPT8: C
OPR.OPT9:
OPR.OPT10:

Documentation and Maintenance:
STASENS: BOUNDARIES: PHOTOS:
ESTSOURCE: HEDGE CLOYCE, UNIV TENN ECOL PROGR. (NO SPECIMEN) HEDGE 0077

TRANSCRIBR: 78-05- *** CDREV: SOURCECODE:

UPPER: QC:

STARESP:
UPDATE: 91-02-27 HSB

Element Occurrence Field
PANAX QUINQUEFOLIUS

entifiers:
Elcode EO# State:
CODE: PDARA09010*038*TN FONUM: IDENT: Y
AME: PANAX QUINQUEFOLIUS
OMNAME: AMERICAN GINSENG
EMENT RANKS: GRANK: G4 NRANK: SRANK: S3

cators:
TION: US SITECODE:
TENAME:
RVEYSITE:

ECISION: S

COUNTYCODE: COUNTYNAME LOCALJURIS:
TNROAN Roane

QUAD MARG DOT TEN
ADNAME: CODE: NUM: NUM: TEN:
ETHEL VALLEY 3508483 17 03.06

LAT: 355614N S:
LONG: 0842057W N:
E:
W:

OWNRANGE: SECTION: MERIDIAN:
SCOM:

IRECTIONS: CA 0.5MI NW OF INTERSECT. OF HWY95 & BEAR CR RD. NE-FACING S
LOPE OF SECONDARY RIDGE TO PINE RIDGE

YSPROV: RV WATERSHED: 06010207

cious:
RVEYDATE: LASTOBS: 1977-00-00 FIRSTOBS:
PANK: EORANKDATE:
RANKCOM:

DATA: CHAPMAN RIDGE 55. POPULATION OF 30 OR MORE IN 1975.

NTACT:

NTACTNUM:

escription:
OTYPE:
ENDESC:

EV: 880 SIZE:

Protection:
CODE: MANAME: CONTAINED:
USTNHP'123 OAK RIDGE RESERVATION

PRELAND: MOREPROT: MOREMGMT: TNCINVOLVE:

MTCOM:

OTCOM: 3

Ownership:
OWNER: US OWNEDINFO:
OWNERCOM:

General Comments:
COMMENTS:

Optional Fields:
OR.OPT1: G49
OR.OPT2: 19C
OR.OPT3: TC02
OR.OPT4:
OR.OPT5:
OR.OPT6:
OR.OPT7:
OR.OPT8: C
OR.OPT9:
OR.OPT10:

Documentation and Maintenance:
DATASENS: BOUNDARIES: PHOTOS:
DESTSOURCE: HEDGE CLOYCE, UNIV TENN ECOL PROGR. (NO SPECIMEN) HEDGE 0077

TRANSCRIBR: 78-05- *** CDREV: SOURCECODE:

APPEF: QC:

STARESP:
PDATE: 91-02-27 HSB

Element Occurrence Report
PHOXINUS OREAS

Identifiers:

	Elcode	EO#	State:		
SCODE:	AFCJB3105C*002*TN		FONUM:	IDENT:	Y
NAME:	PHOXINUS OREAS				
COMNAME:	MOUNTAIN REDBELLY DACE				
ELEMENT RANKS:	GRANK: G5		NRANK:	SRANK: S?	

Locators:

NATION: US SITECODE:
SITENAME:
SURVEYSITE:

PRECISION: S

COUNTYCODE:	COUNTYNAME	LOCALJURIS:
TNROAN	Roane	

QUADNAME:	QUAD CODE:	MARG NUM:	DOT NUM:	TEN TEN:
ETHEL VALLEY	3508483	18		03.05

LAT: 355616N S:
LONG: 0842028W N:
E:
W:

TOWNRANGE: SECTION: MERIDIAN:
USCOM:

DIRECTIONS: BEAR CREEK AT HWY 95 BRIDGE

PHYSPROV: RV WATERSHED: 06010207

Status:

SURVEYDATE: LASTOBS: 1975-09-12 FIRSTOBS: 1975
SRANK: EORANKDATE:
SRANKCOM:

SDATA: 2 SPECIMENS, UT CAT. NO. 44.1250.

CONTACT:

CONTACTNUM:

Description:

GTYPE:
GENDESC:

ELEV: 800 SIZE:

Protection:

LACODE:	MANAME:	CONTAINED:
*.USTNHP*128	OAK RIDGE RESERVATION	

PMORELAND: MOREPROT: MOREMGMT: TNCINVOLVE:

MTCOM:

OTCOM:

nership:
NER: OWNERINFO:
NERCOM:

neral Comments:
MMENTS:

tional Fields:
R.OPT1: G49
R.OPT2: 19C
R.OPT3: TC02
R.OPT4:
R.OPT5:
R.OPT6:
R.OPT7:
R.OPT8: C
R.OPT9:
R.OPT10:

cumentation and Maintenance:
TASENS: BOUNDARIES: PHOTOS:
ESTSOURCE: UNIVERSITY OF TENNESSEE ICHTHYOLOGICAL COLLECTION,
KNOXVILLE, TN

ANSCRIBR: 81-09- CORE: SOURCECODE:

PPER: QC:

TARESP:
DATE: 91-02-27 HSB

Element Occurrence Rec
LILIUM CANADENSE

Identifiers:

	Elcode	EO#	State:		
SCODE:	PMLIL1A030	004	TN	FONUM:	IDENT: J
NAME:	LILIUM CANADENSE				
COMNAME:	CANADA LILY				
LEMENT RANKS:	GRANK: G5		NRANK:		SRANK: S2

Locators:

NATION: US SITECODE:
SITENAME:
SURVEYSITE:

PRECISION: S

COUNTYCODE:	COUNTYNAME	LOCALJURIS:
TNROAN	Roane	

	QUAD CODE:	MARG NUM:	DOT NUM:	TEN TEN:
QUADNAME:				
ETHEL VALLEY	3508483	23		06.04

LAT: 355718N S:
LONG: 0841836W N:
E:
W:

OWNRANGE: SECTION: MERIDIAN:
PSCOM:

DIRECTIONS:

PHYSPROV: RV WATERSHED: 06010207

Status:

SURVEYDATE: LASTOBS: 1900-00-00 FIRSTOBS:
SRANK: EORANKDATE:
SRANKCOM:

GENDATA: VERY SMALL POPULATION. SIGHT RECORD. PLOTTED FROM MAP RECEIV
ED FROM LINDA MANN ON 18 DECEMBER 1979.

CONTACT:

CONTACTNUM:

Description:

GTYPE:
GENDESC:

ELEV: 880 SIZE:

Identification:
CODE: MANAME: CONTAINED:
USTNHP*128 OAK RIDGE RESERVATION

RELAND: MOREPROT: MOREMGMT: TNCINVOLVE:

MTCOM:

OTCOM:

Ownership:
JNER: OWNERINFO:
:NERCOM:

General Comments:
OMMENTS:

Optional Fields:
OR.OPT1: G49
OR.OPT2: 19C
OR.OPT3: TC02
OR.OPT4:
OR.OPT5:
OR.OPT6:
OR.OPT7:
OR.OPT8: C
OR.OPT9:
OR.OPT10:

Documentation and Maintenance:
ATASENT: BOUNDARIES: PHOTOS:
ESTSOURCE: MANN, LK, OAK RIDGE NATIONAL LABORATORY,ENVIRONMENTAL SCIENCES DIVISION

RANSCRIBE: 82-02- CDREV: SOURCECODE:

APPER: QC:

STARESP:
DATE: 91-03-27 HSB

Element Occurrence Record
FOTHERGILLA MAJOR

Identifiers:

	Elcode	EO#	State:
CODE:	PDHAM01020*011*TN	FONUM:	IDENT:
AME:	FOTHERGILLA MAJOR		
OMNAME:	MOUNTAIN WITCH-ALDER		
EMENT RANKS:	GRANK: G3	NRANK:	SRANK: S2

Locators:

TION:	US	SITECODE:	
TENAME:			
URVEYSITE:			

ECISION: S

COUNTYCODE:	COUNTYNAME	LOCALJURIS:
TNANDE	Anderson	

	QUAD	MARG	DOT	TEN
JADNAME:	CODE:	NUM:	NUM:	TEN:
ETHEL VALLEY	3508483	26		07,02

LAT:	355849N	S:
LONG:	0841717W	N:
		E:
		W:

DWNRANGE:	SECTION:	MERIDIAN:
RSCOM:		

DIRECTIONS:

HYSPROV: RV WATERSHED: 06010207

Status:

RVEYDATE:	LASTOBS: 1979-00-00	FIRSTOBS:
RANK:	EORANKDATE:	
RANKCOM:		

ODATA: A DOZEN PLANTS. PHOTOGRAPHED. SIGHT RECORD. PLOTTED FROM MAP RECEIVED FROM LINDA MANN ON 18 DECEMBER 1979.

ONTACT:

ONTACTNUM:

Description:

OTYPE:

ENDESC:

LEV: 1080 SIZE:

otection:
CODE: MANAME: CONTAINED:
.USTNHP*128 OAK RIDGE RESERVATION

ORELAND: MOREPROT: MOREMGMT: TNCINVOLVE:

GMTCOM:

ROTCOM:

wnership:
WNER: OWNERINFO:
WNERCOM:

eneral Comments:
OMMENTS:

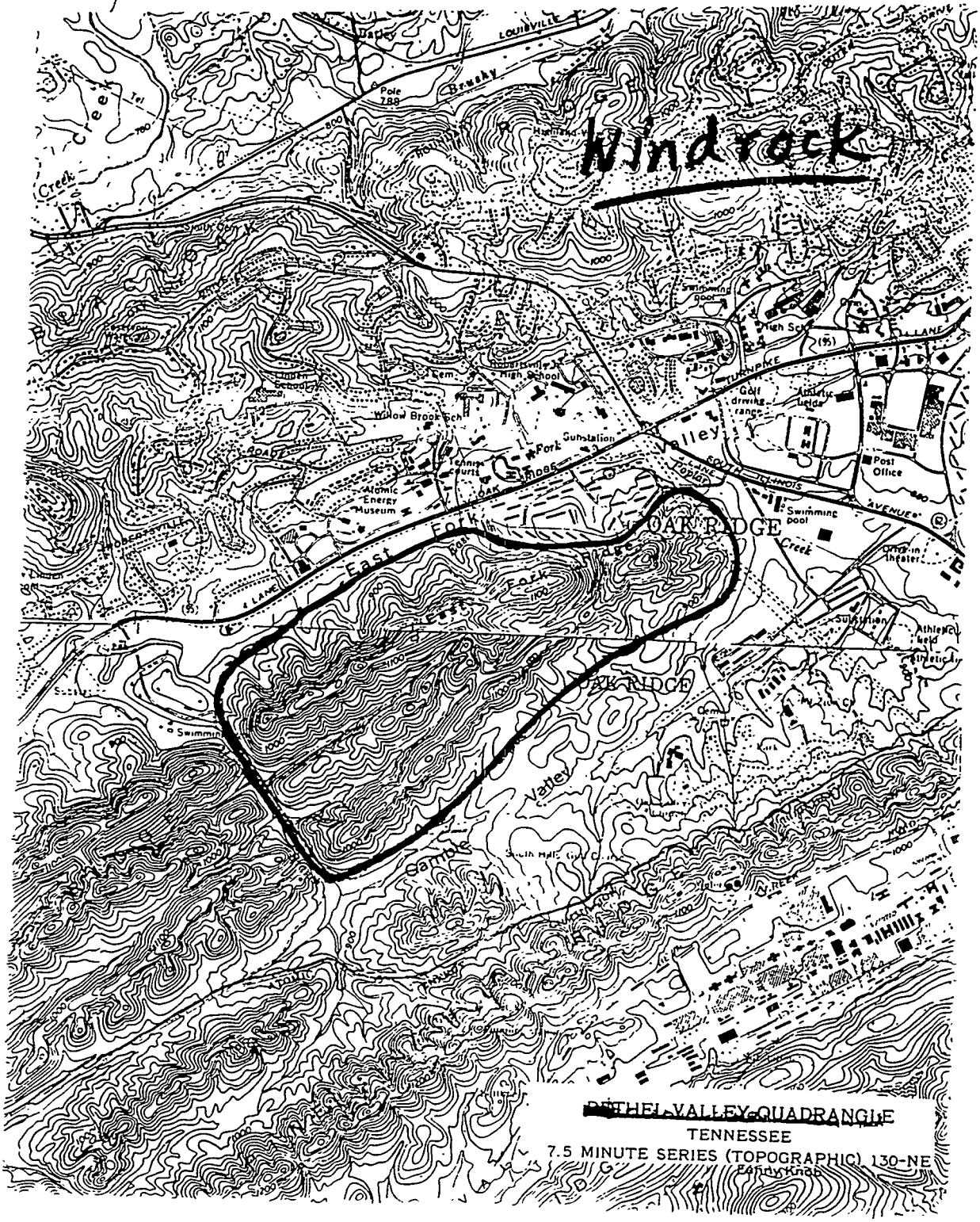
ptional Fields:
OR.OPT1: G49
OR.OPT2: 19C
OR.OPT3: TC02
OR.OPT4:
OR.OPT5:
OR.OPT6:
OR.OPT7:
OR.OPT8: C
OR.OPT9:
OR.OPT10:

ocumentation and Maintenance:
ATASENS: BOUNDARIES: PHOTOS:
ESTSOURCE: MANN. LK. OAK RIDGE NATIONAL LABORATORY.ENVIRONMENTAL SCIENCES DIVISION

RANSCRIBR: 82-02- CDREV: SOURCECODE:

APPER: QC:

ATARESP:
PDATE: 91-02-27 HSB



BETHEL VALLEY QUADRANGLE
TENNESSEE
7.5 MINUTE SERIES (TOPOGRAPHIC) 130-NE

Record of Conversation

This is to document the discussion between E.L. Etnier and Travis Claud, Project Manager, U.S. Army Corps of Engineers, Nashville, Tennessee (615-736-5181) on November 16, 1992

The COE requires permits for structures or work in or affecting navigable waters of the U. S. under § 10 of the Rivers and Harbors Act. In addition, the discharge of dredged or fill material into waters of the U.S. or navigable waters is regulated under CWA § 404 and implemented through 33 CFR 320-330 and 40 CFR 230. 33 CFR §§ 322.2 and 328 define "waters of the United States" as those waters of the U. S. that are subject to the ebb and flow of the tide toward the mean high water mark and which have been at any time, or may be, used for interstate commerce. This definition includes all impoundments of such waters [40 CFR 328.3(a)(4)]. The COE has established the ordinary high water mark for impoundments to be the normal summer pool elevation (elev. 741 for the Watts Bar impoundment), which includes any slackwater areas. Any upland activity above this elevation would not require approval pursuant to § 10 of the Rivers and Harbors Act. The COE published a public notice (ORNOR-F, 86-23), dated May 8, 1986, of all "navigable waters" within the Nashville District; Poplar Creek from its mouth to River Mile 18.3 has been designated a navigable water. However, no tributaries to Poplar Creek have received such a designation (Claud 1992).

Travis W. Claud

22 February 1993

U. S. Army Corps of Engineers

List of Navigable Waters of the United States pursuant to the Rivers and Harbors Act of 1899

Navigable Waters Within the Memphis District

I. Forked Deer River - Mouth to Mile 25 (confluence with North and South Forks).

A. North Fork Forked Deer River (FDRM 25) - Mouth to Mile 6 (Dyersburg, TN).

B. South Fork Forked Deer River (FDRM 25) - Mouth to Mile 94 (Jackson, TN).

II. Hatchie River - Mouth to Mile 140 (Bolivar, TN).

III. Obion River - Mouth to Mile 69.1 (Obion, TN).

IV. Wolf River - Mouth to Mile 15 (Raleigh, TN).

Navigable Waters Within the Nashville District

CUMBERLAND RIVER AND TRIBUTARIES

I. Cumberland River (CR) - Mouth to Mile 694.2 (Head of River, Confluence of Poor Fork and Clover Fork, at Harlan, Kentucky).

A. Little River (CRM 59.0) - Mouth to Mile 60.9 (Confluence of the North and South Forks).

B. Red River (CRM 125.3) - Mouth to Mile 76.5 (Prices Mill Dam).

1. West Fork Red River (Red River Mile 1.2) - Mouth to Mile 7.4 (Head of Slackwaters of Barkley Lake).

2. Sulphur Fork Red River (Red River Mile 25.5) - Mouth to Mile 26.6 (Road Bridge 1.5 Miles Northeast of Springfield, Tennessee).

3. Elk Fork Red River (Red River Mile 33.8) - Mouth to Mile 8.7 (Road Bridge Near Darnell, Kentucky).

4. Whippoorwill Creek (Red River Mile 54.9)- Mouth to Mile 11 (Head of Slackwaters of Lickskillet Mill Dam).

5. South Fork Red River (Red River Mile 56.9) - Mouth to Mile 7.9 (Tennessee-Kentucky State Line).

C. Harpeth River (CRM 152.9) - Mouth to Mile 114.5 (US Highway 41A Bridge).

1. Jones Creek (Harpeth River Mile 10.6) Mouth to Mile 14.4, (Tennessee Highway 47 Bridge).

2. Turnbull Creek (Harpeth River Mile 35.1) Mouth to Mile 13.1, (Tennessee Highway 96 Bridge).

3. South Harpeth River (Harpeth River Mile 43.4) Mouth to Mile 8.4, (Old Harding Pike Bridge).

4. West Harpeth River (Harpeth River Mile 78.7) Mouth to Mile 8.6 (Confluence with Leipers Fork).

D. Stones River (CRM 205.6) - Mouth to Mile 38.6 (Confluence of East and West Forks, Stones River).

1. East Fork, Stones River - Mouth to Mile 38.2 (Confluence of Carson Fork).

2. West Fork, Stones River - Mouth to Mile 21.8 (Confluence of Middle Fork Stones River).

E. Caney Fork River (CRM 309.2) - Mouth to Mile 134.2 (Cumberland County Highway Bridge).

1. Smith Fork Creek (Caney Fork Mile 15.9) Mouth to Mile 30.5 (DeKalb County Highway Bride near Cottage Home, Tennessee).

2. Falling Water River (Caney Fork Mile 53.4) Mouth to Mile 10.2 (Head of Slackwaters of Center Hill Lake).

3. Collins River (Caney Fork Mile 91.2) Mouth to Mile 55.2 (Confluence with Big Creek).

a. Barren Fork (Collins River Mile 21.5) Mouth to Mile 23.1 (Warren County Highway Bridge near Trousdale, Tennessee).

ORNOR-F 86-23

(1) Hickory Creek (Barren Fork Mile 10.5) Mouth to Mile 12.6, (Confluence with West Fork).

4. Rocky River (Caney Fork Mile 92.6) Mouth to Mile 9.6, (Head of Slackwaters of Great Falls Lake).

5. Calfkiller River (Caney Fork Mile 104.6) Mouth to Mile 23.3, (Confluence with Cherry Creek).

6. Cane Creek (Caney Fork Mile 108.8) Mouth to Mile 10.8, (Confluence with Indian Camp Branch).

F. Roaring River (CRM 357.8) Mouth to Mile 22.3 (Site of Johnson Falls).

1. Spring Creek (Roaring River Mile 12.0) Mouth to Mile 8.6, (Site of Waterloo Falls).

2. Blackburn Fork (Roaring River Mile 8.0) Mouth to Mile 14.3, (Site of Cummins Falls).

G. Obey River (CRM 380.9) - Mouth to Mile 58.2 (Confluence of East Fork and West Fork Obey River).

1. East Fork Obey River - Mouth to Mile 29.6 (Confluence with Hurricane Creek).

2. West Fork Obey River - Mouth to Mile 20.0 (Confluence with Dry Hollow Branch).

3. Wolf River (Obey River Mile 31.1) - Mouth to Mile 35.6 (Confluence with Rotten Fork).

H. Big South Fork Cumberland River (CRM 516.0) - Mouth to Mile 77.0 (Confluence of Clear Fork River and New River).

1. Little South Fork (BSF River Mile 26.1) - Mouth to Mile 31.5 (at Parmleysville, Kentucky).

2. Rock Creek (BSF River Mile 40.9) - Mouth to Mile 3.6 (at White Oak Junction, Kentucky).

3. North Whiteoak Creek (BSF River Mile 71.5) - Mouth to Mile 6.5 (at Zenith, Tennessee).

4. New River - Mouth to Mile 36.0 (Confluence with Smoky Creek).

5. Clear Fork River - Mouth to Mile 25.8 (at Gatewood's Bridge).

a. Whiteoak Creek (Clear Fork River Mile 9.4) - Mouth to Mile 5.6 (Tennessee Highway 52 Bridge).

I. Buck Creek (CRM 533.8) - Mouth to Mile 45.0 (Kentucky Highway 70 Bridge).

J. Rockcastle River (CRM 546.4) - Mouth to Mile 53.2 (Confluence of Middle and South Forks).

1. South Fork Rockcastle River - Mouth to Mile 8.5, (Confluence with Pond Creek).

2. Middle Fork Rockcastle River - Mouth to Mile 7.8, (Confluence of Indian Creek and Laurel Fork).

3. Roundstone Creek (Rockcastle River Mile 43.1) - Mouth to Mile 13.4, (Confluence with Renfro Creek).

K. Laurel River (CRM 552.1) - Mouth to Mile 30.5 (Head of Slackwaters of Dorethea Lake).

L. Clear Fork of Cumberland River (CRM 592.3) - Mouth to Mile 33.0 (Confluence with Tackett Creek).

1. Hickory Creek (Clear Fork of Cumberland River Mile 28.2) - Mouth to Mile 9.8 (Confluence with Stinking Creek).

M. Poor Fork of Cumberland River (CRM 694.2) - Mouth to Mile 39.9 (Confluence with Franks Creek).

N. Clover Fork of Cumberland River (CRM 694.2) - Mouth to Mile 11.0 (Mouth of Bailey Creek).

1. Martins Fork of Cumberland River (Clover Fork of Cumberland River Mile 1.6) - Mouth to Mile 19.5. (Head of Slackwaters of Martins Fork Lake).

TENNESSEE RIVER AND TRIBUTARIES

II. Tennessee River (TR) - Mouth to Mile 652.1 (Head, Confluence of French Broad and Holston Rivers).

A. Clarks River (TRM 4.3) - Mouth to Mile 20.2 (ELVA Bridge).

1. West Fork Clarks River (Clarks River Mile 12.7) - Mouth to Mile 11.9 (Kahler Bridge).

B. Blood River (TRM 50.7) - Mouth to Mile 9.7 (Kentucky Highway 121 Bridge).

C. Big Sandy River (TRM 67.0) - Mouth to Mile 52.6 (Carroll County Highway Bridge near Wildersville, Tennessee).

1. West Fork Big Sandy River (Big Sandy River Mile 8.8) - Mouth to Mile 8.2 (Tennessee Highway 69 Bridge).

D. Duck River (TRM 110.8) - Mouth to Mile 262.8 (Head of Slackwaters of Normandy Lake).

1. Buffalo River (Duck River Mile 15.4) - Mouth to Mile 116.7 (Lawrence County Highway Bridge at Henryville, Tennessee).

E. Beech River (TRM 135.7) - Mouth to Mile 21.6 (Henderson County, Highway Bridge near Chesterfield, Tennessee).

F. Yellow Creek (TRM 215.1) - Mouth to Mile 32.1 (Head, Tennessee Valley Divide).

G. Bear Creek (TRM 224.7) - Mouth to Mile 130.0 (Head of Slackwaters of Upper Bear Creek Lake).

1. Cedar Creek (Bear Creek Mile 27.7) - Mouth to Mile 38.3 (Head of Slackwaters of Cedar Creek Lake).

a. Little Bear Creek (Cedar Creek Mile 14.9) - Mouth to Mile 23.1 (Head of Slackwaters of Little Bear Creek Lake).

H. Cypress Creek (TRM 255.0) - Mouth to Mile 17.6 (Lauderdale County Highway Bridge).

1. Little Cypress Creek (Cypress Creek Mile 10.2) - Mouth to Mile 8.0 (Head of Slackwaters of Sharps Mill Lake).

I. Shoal Creek (TRM 264.3) - Mouth to Mile 56.0 (Confluence with Little Shoal Creek).

1. Factory Creek (Shoal Creek Mile 28.6) - Mouth to Mile 9.7 (Wayne County Highway Bridge 0.1 Mile Upstream of Couch Branch).

J. Elk River (TRM 284.3) - Mouth to Mile 194.1 (US Highway 41 Bridge).

1. Richland Creek (Elk River Mile 42.6) - Mouth to Mile 48.6 (Confluence with Clear Creek).

K. Flint Creek (TRM 308.4) - Mouth to Mile 28.2 (Huckaba Bridge).

L. Limestone Creek (TRM 310.7) - Mouth to Mile 32.0 (Confluence with Little Limestone Creek).

M. Flint River (TRM 339.1) - Mouth to Mile 51.2 (Madison County Highway Bridge Due East of Fisk, Alabama).

N. Paint Rock River (TRM 343.2) - Mouth to Mile 60.0 (Confluence of Estill Fork and Hurricane Creek).

1. Estill Fork (Paint Rock River Mile 60.0) - Mouth to Mile 10.0 (Confluence of Keller and Dry Creeks).

2. Hurricane Creek (Paint Rock River Mile 60.0) - Mouth to Mile 7.4 (John Gifford Hollow).

O. Town Creek (TRM 360.8) - Mouth to Mile 14.0 (High Falls).

P. Short Creek (TRM 360.8) - Mouth to Mile 6.5 (Short Creek Falls).

Q. Crow Creek (TRM 401.1) - Mouth to Mile 33.7 (Confluence with Dry Creek).

R. Sequatchie River (TRM 422.7) - Mouth to Mile 86.3 (Site of Cooper Mill Dam).

1. Little Sequatchie River (Sequatchie River Mile 8.0) Mouth to Mile 8.0 (One Mile North of Coppinger Chapel).

S. South Chickamauga Creek (TRM 468.2) - Mouth to Mile 17.3) (Tennessee-Georgia State Line).

1. West Chickamauga Creek (South Chickamauga Creek Mile 13.2) Mouth to Mile 3.2 (Tennessee-Georgia State Line).

T. North Chickamauga Creek (TRM 470.9) - Mouth to Mile 17.4 (U.S. Highway 27 Bridge).

U. Hiwassee River (TRM 500.3) - Mouth to Mile 65.8 (Tennessee-North Carolina State Line).

1. Ocoee River (Hiwassee River Mile 34.4) - Mouth to Mile 38.8 (Tennessee-Georgia State Line).

V. Piney River (TRM 532.5) - Mouth to Mile 8.9 (Confluence with Soak Creek).

W. Clinch River (TRM 567.7) - Mouth to Mile 202.1 (Tennessee-Virginia State Line).

1. Emory River (Clinch River Mile 4.4) - Mouth to Mile 45.3 (Site of Macedonia Church).

a. Obed River (Emory River Mile 28.4) - Mouth to Mile 34.5 (U.S. Highway 127 Bridge).

ORNOR-F 86-23

(1) Clear Creek (Obed River Mile 4.4) - Mouth to Mile 29 (U.S. Highway 127 Bridge).

(a) White Creek (Clear Creek Mile 8.8) - Mouth to Mile 6.9 (Twin Bridges).

(2) Daddys Creek (Obed River Mile 9.1) - Mouth to Mile 33.9 (Tennessee Highway 28 Bridge).

2. Poplar Creek (Clinch River Mile 12.0) - Mouth to Mile 18.3 (Tennessee Highway 61 Bridge).

3. Powell River (Clinch River Mile 88.8) - Mouth to Mile 115.7 (Tennessee-Virginia State Line).

X. Little Tennessee River (TRM 601.3) - Mouth to Mile 49.4 (Tennessee-North Carolina State Line).

1. Tellico River (Little Tennessee River Mile 19.2) - Mouth to Mile 37.0 (One mile downstream of Bald River Falls).

Y. Little River (TRM 635.6) - Mouth to Mile 50.5 (At Elkmont, Tennessee).

Z. Holston River (TRM 652.1) - Mouth to Mile 142.2 (Head, Confluence of North and South Fork Holston River).

1. North Fork Holston River (Holston River Mile 142.2) - Mouth to Mile 5.0 (Tennessee-Virginia State Line).

2. South Fork Holston River (Holston River Mile 142.2) - Mouth to Mile 73.7 (Head of Slackwaters of South Holston Lake).

a. Watauga River (South Fork Holston River Mile 19.9) - Mouth to Mile 55.1 (Tennessee-North Carolina State Line).

(1) Doe River (Watauga River Mile 26.4) Mouth to Mile 22.7, (1.4 miles SSW of Roan Mountain).

(2) Elk River (Watauga River Mile 46.8) Mouth to Mile 14.5 (Tennessee-North Carolina State Line).

b. Middle Fork Holston River (South Fork Holston River Mile 72.3) - Mouth to Mile 1.3 (Head of Slackwaters of South Holston Lake).

AA. French Broad River (TRM 652.1) - Mouth to Mile 102.6 (Tennessee-North Carolina State Line).

1. Little Pigeon River (French Broad River Mile 27.4) - Mouth to Mile 25.5 (Highway 73 Bridge).

a. West Prong, Little Pigeon River (Little Pigeon River Mile 4.7) Mouth to Mile 12.3, (Champmans Highway Bridge).

b. East Fork Little Pigeon River (Little Pigeon River Mile) Mouth to Mile 11.0 (Confluence of Long Branch and Dunn Creek).

2. Nolichucky River (French Broad River Mile 69.1) - Mouth to Mile 100.8 (Tennessee-North Carolina State Line).

a. Lick Creek (Nolichucky River Mile 16.0) - Mouth to Mile 49.8 (Lick Creek Mill).

3. Pigeon River (French Broad River Mile 73.8) - Mouth to Mile 25.9 (Tennessee-North Carolina State Line).

In addition, embayments and tributary streams of all impounded reservoirs of navigable waters of the United States are also considered navigable waters of the United States to the extent of slackwaters, and jurisdiction will be exercised accordingly.

SAIC/OAK RIDGE CONTACT LOG

CC: EFPC Isotain Analysis

DISTRIBUTION:	CONTACT TYPE:	DATE: 5-13-93
· MILA220 · WOEICS · RYAN	PHONE (circled) MEETING CORRESPONDENCE OTHER	TIME:

138C.930513.004

PERSON(S) CONTACTED:
NAME STEVE WHITE - 576-6492 ~~COMPANY~~
~~NAME~~ Civil Design - MMES
NAME
NAME Tom Collins - 574-8886 m/s 8098, Bldg 9116
PHONE# Clean Water Section ~~TITLE~~

> separate conversations

ADDRESS

PERSON(S) CONTACTING: NAME Tom HANRAHAN - 481-4622

SUMMARY OF DISCUSSION, ACTION, OR DATA EXCHANGED:

RE: INCREASE in EFPC base flow.

Purpose of increase - ① meet anticipated NPDES permit level for various TREATMENT facilities ② secondarily to assist OR sewage treatment plant in meeting their discharge req'ts

STATUS: General agreement by STATE (TDEC), city for need. will need STATE Approval. Budget committed at FY 17 in agreement. Preliminary proposal being written - will go to DOE for funding. Expect FY 94 funding. Currently at conceptual design stage. If approvals & funding in place, construction could be early 1994 & operational by mid 194

Description: will pump WATER from Clinch river to Upper EFPC to maintain a minimum flow at the N-S pipe. of 5 mil. gal/day. Current flow approx. 2.9 mil gal/day. pumping will cut back during STORM conditions. Reportedly very little flow difference between STATION 8 near N-S pipe and STATION 17, downstream of Lake Reality. Raw water will be chlorinated near pumping STATION & dechlorinated at N-S pipe

~~ACTION(S) REQUIRED~~: to reduce build up in piping.

ACTION COMPLETED:

Additional Information:

For more info the following maybe contacted directly -

Tom Collins - 574-8886
Elliot Bennet -
Steve White - 576-6492

SAI/OAK RIDGE CONTACT LOG

DISTRIBUTION: Cornaby, Milazzo, Ambrose

CONTACT TYPE: (PHONE) MEETING CORRESPONDENCE OTHER

DATE: Aug 12, 1993

TIME: 3:15 PM

PERSON(S) CONTACTED:
NAME Ray Hedrick
NAME
NAME
NAME
PHONE # 615 / 736-5026
ADDRESS Nashville, TN

COMPANY U.S. Army Corps of Engineers
TITLE Environmental Scientist (Wetlands)

PERSON(S) CONTACTING: NAME James Graton

SUMMARY OF DISCUSSION, ACTION, OR DATA EXCHANGED:

Requesting generic info about wetlands mitigation requirements from Regulatory staff w/COE. Mitigation ratios depend somewhat on the quality of the wetland(s) to be taken. Regulatory seldom accepts a mitigation ratio < 2:1. ~~As~~ as a rule.

ACTION(S) REQUIRED:

None

ACTION COMPLETED:

380.930812.008

Science Applications International Corporation

OAK RIDGE CONTACT LOG

DISTRIBUTION:	CONTACT TYPE: PHONE	DATE: March 22, 1993
	MEETING CORRESPONDENCE	
EFPC Distribution	OTHER _____	TIME: 10:00 AM

PERSON(S)
CONTACTED: NAME Barry Stringer COMPANY Gundle Lining Systems, Inc.
NAME Scott Ortolon
NAME _____
NAME _____
PHONE # (800) 435-2008 TITLE _____

ADDRESS 1910 Gundle Road, Houston, TX 77073

PERSON(S)
CONTACTING: NAME Rob Adkison

SUMMARY OF DISCUSSION, ACTION, OR DATA EXCHANGED:

I contacted Mr Stringer to determine the feasibility of using a permeable liner below a soil cover containment system that would prevent the intrusion of vermin. He said that their product called GUNDNET ™ XL-14 would deter the intrusion of burrowing animals. He said that the net is made of high density polyethylene (HDPE) which animals may gnaw on, but usually do not penetrate because the material is tough and not very tasty. The material comes in 14 ft. wide by 100 ft. rolls. The net can be placed over an area that has been rough graded and the rolls are tied at 6 ft. intervals with plastic ties. A rubber-tired grader, backhoe, or bobcat could place the soil cover over the netting 12 to 18 inches thick. The basic material cost is roughly 20¢ per sq. ft. A 7 to 8 man crew can place ½ to 1 acre a day. He estimated the total cost (material, equipment, and labor) at 50¢ per sq. ft. based on 50 acres.

ACTIONS(S) REQUIRED:	ACTION COMPLETED:
Mr. Stringer said he would provide a firmer cost estimate based on 50 acres of coverage.	

SAIC/OAK RIDGE CONTACT LOG

CC: EFPC Location Analysis

DISTRIBUTION:	CONTACT TYPE:	DATE:
· MILAZZO · WOEICS · RYAN	PHONE (circled) MEETING CORRESPONDENCE OTHER	5-13-93 TIME:

138C.930513.004

PERSON(S) CONTACTED:
NAME: STEVE WHITE - 576-6492 ~~COMPANY~~
~~NAME~~: Civil Design - MMES
NAME:
NAME: Tom Collins - 574-8886 M/S 8098, Bldg 9116
PHONE#: Clean Water Section ~~TITLE~~
ADDRESS:

> separate conversations

PERSON(S) CONTACTING:
NAME: Tom HANRAHAN - 481-4622

SUMMARY OF DISCUSSION, ACTION, OR DATA EXCHANGED:

RE: INCREASE in EFPC base flow.

Purpose of increase - ① meet anticipated NPDES permit level for various treatment facilities ② secondarily to assist OR sewage treatment plant in meeting their discharge req'ts

STATUS: General agreement by STATE (TDEC), city for need. will need STATE Approval. Budget committed at FY 17 in agreement. Preliminary proposal being written - will go to DOE for funding. Expect FY 94 funding. Currently at conceptual design stage. If approvals & funding in place, construction could be early 1994 & operational by mid 194

Description: will pump WATER from Clinch river to Upper EFPC to maintain a minimum flow at the N-S pipe. of 5 mil. gal/day. Current flow approx. 2.9 mil gal/day. pumping will cut back during STORM conditions. Reportedly very little flow difference between STATION 8 near N-S pipe and STATION 17, downstream of Lake Reality. Raw water will be chlorinated near pumping STATION & dechlorinated at N-S pipe

~~ACTION(S) REQUIRED~~: to reduce build up in piping.

ACTION COMPLETED:

Additional Information:

For more info the following may be contacted directly -

Tom Collins - 574-8886
Elliot Bennet -
Steve White - 576-6492

CITY OF
OAK RIDGE

380.931221.006

POST OFFICE BOX 1 • OAK RIDGE, TENNESSEE 37831-0001

December 16, 1993

Steve Mitz
Environmental Scientist
NAIC
800 Oak Ridge Turnpike
P.O. Box 2502
Oak Ridge, TN. 37831

REFERENCE: Request for Effluent Flow Data and NPDES Constituents

Dear Mr. Mitz,

In response to your letter dated December 7, 1993 we are providing the following:

The average daily flow in Million Gallons per Day (MGD) for the years 1988 thru 1993.

1988 5.2 MGD, 1989 6.2 MGD, 1990 5.5 MGD, 1991 6.1 MGD, 1992 5.7 MDG, and 1993 5.6 MGD.

The City of Oak Ridge NPDES permit Requires analyses of the plant effluent that include the following constituents;

BOD, Total Suspended Solids, Settleable Solids, Ph, DO, Fecal Coliform, Chlorine residual, Ammonia, as N, Lead, and Biomontoring.

Please do not hesitate to call me at 482-8342 if you have any questions or require further assistance.

Respectfully yours,

Bob Currier

Bob Currier
Wastewater Operations
Assistant Superintendent

cc: Gary M. Cinder
Director of Public Works

SAIC

CONTACT REPORT

Ref. No.

Originator: Tom Hanrahan	DISTRIBUTION	INFO	ACTION
Date Contacted: 7/11/94	1. Mary Alice Wilson		
Telecon: ☒ Visit: ☐	2.		
	3.		
	4.		
	5.		
	6.		

Individual Contacted, Title, Phone: Larry Bunting 615-532-0665

Organization: TOEC - WATER Pollution Control

Address: City: Nashville State: Zip:

Subject: EFPC & NPDES Permit

Comments, Action, Dates

Discussion:

(1) Permit Status - expected issuance this year - maybe as soon as this month

(2) In 1993 Avg daily non-storm WATER flow was between 3 and 4½ mgd NPDES will require 7 mgd at station 17 (downstream of Lake Reality) before 3/1/97

(3) NPDES will require by 12/31/98 that total loading be reduced to 5g/day

(4) Avg Hg conc that he has are

1989	1.63 µg/L (ppb)	
1990	1.70	
1991	1.39	
1992	1.35	
1993	0.90 (1st 6 mo)	
1994	0.91 (almost 1st 6 mo)	

SAIC/OAK RIDGE CONTACT LOG

DISTRIBUTION: W. Tolbert T. Hanrahan L. McCartney	CONTACT TYPE: Meeting	DATE: 5/21/93

PERSON(S) CONTACTED: NAME: Rex Allen Gass

AFFILIATION: Pres., Clinch Valley Association of Realtors; Managing Broker, Oak Ridge Office, Volunteer Realty; State Certified Real Estate Appraiser #CR-925.

PHONE #: 483-1111

TITLE:

ADDRESS: 162 Talmeda Rd, Oak Ridge 37830-6920

PERSON(S) CONTACTING: Janice Morrissey

SUMMARY OF DISCUSSION, ACTION, OR DATA EXCHANGED:

I contacted Mr. Gass for perspective of real estate industry on social impacts of EFPC. He explained that his experience has been that those aware of contamination associated with EFPC are very wary. In appraising land for Cappiellos, could not determine specific impact of environmental toxins with regard to EFPC. He can recall a few cases where prospective buyers have raised questions about contaminants in Oak Ridge. He described one case where people requested soil test for toxins on property off Gallaher Road below K-25. The cost was $2,000, and they backed out of deal to look for property out of impact area of OR. He currently has another potential buyer (from Oregon) coming to work in OR, whose wife is reluctant to live in OR due to children's health. They are now looking in West Knoxville. Unless property is actually in the floodplain, agency does not discuss contamination. Most people who may be interested in buying a home in OR have knowledge that it is a huge nuclear facility before contacting real estate agencies. Others have access to public information on Oak Ridge through a variety of sources (library, chamber, telephone book).

His agency has a policy to inform people of any hazard we have knowledge of. Any property close to or adjacent to EFPC, make disclosure statement. This is highly recommended as standard practice. National Assoc of Realtors subscribes to Code of Ethical conduct. Emphasis on policing ourselves. Approximately 50% of real estate agents belong to Natl Assoc of Realtors. If agent had knowledge and did not inform buyer, violation of Code of ethics. Natl Ass of R sent members a sample form for Property Environmental Information Disclosure three years ago (attached). Volunteer Realty uses this when somebody specifically asks about environmental disclosure. Volunteer uses a standard form for general disclosure in all cases; it includes questions about soil problems, floodplain, and "any condition of the property which materially affects the phyhsical health or safety of an individual." He believed that the issue of mandated agency disclosure is currently before the legislature.

He noted that the signs may have affected ability to sell some homes, such as a townhome in Grandcove area that sat for 3 years, and a sign is located immediately behind it. He suggested calling Mildred Cappiello, of Cappiello Land Development Co.

He believes excavation would have a temporary effect on real estate - he would probably recommend not marketing until excavation is completed near a property. Prospective buyers inquire about remodeling or excavation work going on nearby. Luckily not a lot of housing backs up to the creek.

He suggested evaluating impact to value by looking at records of sales of taxable real estate in property assessor's office. I told him I would rely upon qualitative methods that suggest property value impacts.

ACTION(S) REQUIRED:	ACTION COMPLETED:

APPENDIX C

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

CONTENTS

TABLES . . . . . C-v
ACRONYMS . . . . . C-vii

APPENDIX C: APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) C-1

C.1 CHEMICAL-SPECIFIC ARARs C-3
C.1.1 Contaminated Soil/Sediment C-3

C.2 RADIATION PROTECTION STANDARDS C-4
C.2.1 EPA Regulations C-4
C.2.2 DOE Orders C-4

C.3 LOCATION-SPECIFIC ARARs C-6
C.3.1 Aquatic Resources and Natural Areas C-6
C.3.2 Historic Sites and Archaeological Findings C-6
C.3.3 Rare, Threatened, or Endangered Species C-7

C.4 ACTION-SPECIFIC ARARs C-7
C.4.1 No Action Alternative C-8
C.4.2 General Response Activities for All Remedial Alternatives C-8
C.4.2.1 On-site excavation and construction activities C-8
C.4.2.2 Treatment of decontamination water C-10
C.4.2.3 Disposal of decontamination water C-10
C.4.2.4 Disposal of waste materials C-11
C.4.2.5 Transportation C-11
C.4.3 Specific Response Activities C-12
C.4.3.1 Institutional controls C-12
C.4.3.2 Containment C-13
C.4.3.3 Removal C-13
C.4.3.4 On-site treatment C-13
C.4.3.5 Beneficial reuse C-15
C.4.3.6 Property acquisition C-15

REFERENCES C-16

TABLES

C.1 DOE Order 5400.5, "Radiation Protection of the Public and the Environment" . . C-19

C.2 Location-specific ARARs for all alternatives for EFPC C-22

C.3 Chemical-, radionuclide-, and action-specific ARARs and to-be-considered guidance for the No Action alternatives at EFPC C-28

C.4 Chemical-, radionuclide-, and action-specific ARARs and to-be-considered guidance for general activities for all alternatives at EFPC C-30

C.5 Chemical-, radionuclide-, and action-specific ARARs and to-be-considered guidance for institutional controls at EFPC C-39

C.6 Chemical-, radionuclide-, and action-specific ARARs and to-be-considered guidance for containment at EFPC C-40

C.7 Chemical-, radionuclide-, and action-specific ARARs and to-be-considered guidance for treatment of contaminated EFPC soils C-42

C.8 Compliance with ARARs for EFPC C-44

ACRONYMS

ALARA	as low as reasonably achievable
APC	Air Pollution Control
ARAP	aquatic resources alteration permit
ARAR	applicable or relevant and appropriate requirement
BMAP	Biological Monitoring and Abatement Program
CAMU	corrective action management unit
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	contaminant of concern
COE	U.S. Army Corps of Engineers
CWA	Clean Water Act
DCG	derived concentration guide
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
DOT	U.S. Department of Transportation
EFPC	East Fork Poplar Creek
Energy Systems	Martin Marietta Energy Systems, Inc.
EPA	U.S. Environmental Protection Agency
FFCA	Federal Facilities Compliance Agreement
FR	Federal Register
FS	feasibility study
FUSRAP	Formerly Utilized Sites Remedial Action Program
FWS	U.S. Fish and Wildlife Service
GOCO	Government Owned Contractor Operated
NEPA	National Environmental Policy Act
NERP	National Environmental Research Park
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NPDES	National Pollutant Discharge Elimination System
ORR	Oak Ridge Reservation
OSHA	Occupational Safety and Health Administration
PCB	polychlorinated biphenyl
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RI	remedial investigation
RU	remedial unit
SARA	Superfund Amendments and Reauthorization Act
SCS	U.S. Soil Conservation Service
SEN	Secretary of Energy Notice
SFMP	Surplus Facilities Management Program
SWA	sitewide alternative
TCA	Tennessee Code Annotated
TCLP	toxicity characteristic leaching procedure
TDEC	Tennessee Department of Environment and Conservation
TGCA	Tennessee General Cemetery Act
TLV	threshold limit value
TSCA	Toxic Substances Control Act
TU	temporary unit
USC	United States Code

APPENDIX C

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 was passed by Congress and signed into law on December 11, 1980 (Public Law 96-510). This act was intended to provide for "liability, compensation, cleanup, and emergency response for hazardous substances released into the environment and the cleanup of inactive waste disposal sites." The Superfund Amendments and Reauthorization Act (SARA), adopted on October 17, 1986 (Public Law 99-499), did not substantially alter the original structure of CERCLA but provided extensive amendments to it.

In particular, §121 of CERCLA specifies that remedial actions for cleanup of hazardous substances must comply with requirements or standards under federal or more stringent state environmental laws that are applicable or relevant and appropriate to the hazardous substances or particular circumstances at a site. Inherent in the interpretation of applicable or relevant and appropriate requirements (ARARs) is the assumption that protection of human heath and the environment is ensured.

The purpose of this appendix is to supply a preliminary list of available federal and state chemical-, location-, and action-specific ARARs that might be considered for remedial actions taken at East Fork Poplar Creek (EFPC). Remedial alternatives for EFPC have been developed for six remedial units (RUs) as described in Sect. 4.2; seven sitewide alternatives for remediation of soils or sediments in each of the RUs are described in Sect. 4.3 The first sitewide alternative (SWA 1) is a No Action alternative; the remaining six sitewide alternatives are made up of a variety of component parts, including property acquisition, institutional controls, containment, removal, treatment, and disposal. Beneficial reuse is considered a disposal option.

Rather than attempt to organize the following discussion of ARARs by the complex remedial alternatives described in Sect. 4.3, ARARs are first organized and discussed according to general activities for all remedial components and then are discussed for each component part. A brief summary of each ARAR appears in the text, with specific requirements outlined in the attached tables (Tables C.1 through C.8). Remediation of contaminated surface water and groundwater is not addressed in this feasibility study (FS); therefore, ARARs for cleanup of these media are not addressed here.

It is understood that the U.S. Department of Energy (DOE) will comply with the National Environmental Policy Act (NEPA) as specified in DOE Order 5440.1D (*National Environmental Policy Act Compliance Program*). Further, DOE Order 5400.4 (*Comprehensive Environmental Response, Compensation, and Liability Act Requirements*) calls for integration of NEPA values and CERCLA requirements for DOE remedial actions at CERCLA sites. This issue was reaffirmed in the Federal Facilities Agreement §I(A)(3) and §III(A)(2) and Secretary of Energy Notice (SEN) of February 5, 1990 (SEN-15-90), which was issued to ensure that DOE's NEPA activities are carried out in a centralized and uniform manner. Therefore, the regulations found in NEPA will not be addressed as ARARs. However, the requirements that are triggered by the presence of environmental resources are discussed as "location-specific" ARARs.

Similarly, DOE addresses occupational safety in DOE Orders 5480.11 (*Radiation Protection for Occupational Workers*); 5480.4 (*Environmental Protection, Safety, and Health Protection Standards*); 5483.1A [*Occupational Safety and Health Program for Contractors at Government Owned Contractor Operated (GOCO) Facilities*]; 5480.9 (*Construction Safety and Health Program*); and 5480.10 (*Contractor Industrial Hygiene Program*). However, ARARs apply to those federal and state regulations that are designed to protect the environment and do not generally apply to occupational safety regulations. The U.S. Environmental Protection Agency (EPA) requires compliance with the OSHA standards in §300.150 of the National Oil and Hazardous Substance Contingency Plan, not through the ARARs process. Therefore, neither the regulations promulgated by OSHA nor the DOE Orders related to occupational safety are addressed as ARARs; the regulations are discussed in the site-specific Health and Safety Plan.

The following is a listing of the definitions of terms used throughout this report:

Applicable requirements are "those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site" (40 *CFR* 300.5).

Relevant and appropriate requirements are "those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting law that, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site" (40 *CFR* 300.5).

Requirements under federal or state law may be *either* applicable *or* relevant and appropriate to CERCLA cleanup actions, but not both. However, requirements must be *both* relevant *and* appropriate for compliance to be necessary. In the case where a federal and a state ARAR are available, or where there are two potential ARARs addressing the same issue, the more stringent regulation must be selected. However, CERCLA §121(d)(4) provides several ARAR waiver options that may be invoked, provided that the basic premise of protection of human health and the environment is not ignored. A waiver is available for state standards that have not been applied uniformly in similar circumstances across the state. In addition, CERCLA §121(d)(2)(C) forbids state standards that effectively prohibit land disposal of hazardous substances.

To-be-considered criteria include nonpromulgated advisories or guidance issued by federal or state governments; to-be-considered criteria are not legally binding and do not have the status of potential ARARs. [See *CERCLA Compliance with Other Laws Manual* (Draft Guidance) EPA/540/G-89/006, August 1988.]

CERCLA on-site remedial response actions must only comply with the substantive requirements of a regulation and not the administrative requirements to obtain federal, state, or local permits [CERCLA §121(e) and Federal Facilities Agreement §XXII]. To ensure that CERCLA response actions proceed as rapidly as possible, EPA has reaffirmed this position in the final National Contingency Plan (55 *FR* 8756, March 8, 1990). **Substantive requirements** pertain directly to the actions or conditions at a site, while **administrative requirements** facilitate

their implementation. EPA recognizes that certain of the administrative requirements, such as consultation with state agencies, reporting, etc., are accomplished through the state involvement and public participation requirements of the National Contingency Plan. These administrative requirements should be observed if they are useful in determining cleanup standards at the site (55 *FR* 8757).

CERCLA defines "on-site" to mean "the areal extent of contamination and all suitable areas in very close proximity" (40 *CFR* 300.5); therefore, for this ARAR summary, all remedial actions performed at EFPC are assumed to be on-site actions that do not require permitting.

C.1 CHEMICAL-SPECIFIC ARARs

"Chemical-specific requirements set health or risk-based concentration limits or discharge limitations in various environmental media for specific hazardous substances, pollutants, or contaminants" (53 *FR* 51437). These requirements generally either set protective cleanup levels for the chemicals of concern in the designated media or indicate a safe level of discharge that may be incorporated when considering a specific remedial activity.

Over the years, various amounts of both treated and untreated waste water from the Y-12 Plant have been discharged to EFPC, which originates as a surface water drainage ditch on the Y-12 Plant. These waste waters resulted from normal operations at the facility and were radioactive and/or chemically hazardous in nature. However, it is impossible to determine the actual source of the wastes present in EFPC; therefore, pursuant to the National Contingency Plan (44 *FR* 8758), it may be assumed that the waste is not a Resource Conservation and Recovery Act (RCRA-) listed waste. In addition, none of the soils tested have proven to be RCRA-characteristic wastes. The contaminant of concern (COC) for human health and the environment identified for EFPC is mercury (see Sect. 3.1.2 of this report). Radionuclides have been identified in the soils, including uranium and thorium (see Sect. 2.3 of this report). However, concentrations of the uranium isotopes were found to be relatively low across the EFPC floodplain, with little discernable pattern of distribution (Sect. 2.3.1.1). Risk of exposure to radionuclides through direct ingestion and inhalation was evaluated during the remedial investigation (RI) and determined to be of no concern.

C.1.1 Contaminated Soil/Sediment

There are no chemical-specific ARARs for cleanup of contaminated soils. The Tennessee Department of Environment and Conservation (TDEC) Rule 1200-4-3 specifies 0.012 μg/L as the ambient water quality criterion continuous concentration for mercury. TDEC has proposed a new Chapter 1200-1-13 (*Hazardous Substance Site Remedial Action*) to the Rules of the TDEC, which is currently undergoing revisions based on public comments. This proposed rule states that, where numerical standards or background levels are not available for cleanup of soils at hazardous waste sites, soil cleanup levels shall be developed using a human health or environmental risk assessment. This assessment shall be based on methods approved or determined by TDEC, or by using a site-specific risk assessment approved by TDEC [1200-1-13-.08(3)(b)].

Based on the use of EPA's reference dose (RfD) for mercury as to-be-considered guidance, a remediation goal option of 58.8 ppm mercury has been calculated for protection of human

health in the Residential and Agricultural RUs. Remediation goal options for the Commercial, DOE, and Other RUs have been calculated based on ecological considerations. Section 7 of the RI Report for EFPC discusses the derivation of the remediation goal options for each of the RUs (DOE 1994a).

C.2 RADIATION PROTECTION STANDARDS

Very few applicable standards are available for the cleanup of radioactively contaminated CERCLA sites. The Atomic Energy Act of 1954 and its amendments delegated authority for control of nuclear energy to DOE, the U.S. Nuclear Regulatory Commission, and EPA.

DOE is authorized to control all types of nuclear materials at sites under its jurisdiction and is exempt from the Nuclear Regulatory Commission licensing and regulatory requirements. Therefore, Nuclear Regulatory Commission regulations are not generally considered to be applicable for CERCLA cleanup at DOE facilities. The DOE regulations for handling and cleanup of radioactive materials are outlined in a series of internal DOE Orders that are legally binding to DOE contractors but are not considered by EPA to be ARARs. The DOE Orders, however, are functionally equivalent to the Nuclear Regulatory Commission requirements and include all "appropriate" requirements from the Nuclear Regulatory Commission regulations. For the purposes of developing ARARs, DOE Orders rather than the Nuclear Regulatory Commission regulations will be treated as to-be-considered guidance. Sections of the Nuclear Regulatory Commission regulations may be relevant and appropriate or to-be-considered in situations where the DOE Orders do not adequately address a specific situation at a site; these will be considered, if warranted, after selection of final alternatives.

C.2.1 EPA Regulations

Subpart H of 40 *CFR* 61 addresses atmospheric radionuclide emissions from DOE facilities and may be applicable to airborne emissions during remedial activities. EPA has issued a final National Emission Standards for Hazardous Air Pollutants (NESHAP) rule (54 *FR* 51654, December 15, 1989) that limits emissions of radionuclides to the ambient air from DOE facilities to amounts that would not cause any member of the public to receive an effective dose equivalent of 10 mrem/year (40 *CFR* 61.92).

C.2.2 DOE Orders

Radiation exposure limits for the general public defined in DOE Order 5400.5 (*Radiation Protection of the Public and the Environment*, February 8, 1990) are: an effective dose equivalent of 100 mrem/year from all exposure pathways and all DOE sources of radiation and a dose of <500 mrem/year as a temporary maximum exemption under specially permitted and DOE-approved circumstances. The overriding principle of the DOE Order is that all releases of radioactive material shall be "as low as reasonably achievable" (ALARA). These dose limits are listed as to-be-considered guidance in Tables C.3 through C.6. Doses to individuals using property released to the public must be well below the primary dose limits, and the ALARA process must be applied no matter how small the dose. Table C.1 lists the requirements of DOE Order 5400.5.

DOE Order 5400.5, Chap. II, lists derived concentration guides (DCGs) for radionuclides based on a committed effective dose equivalent of 100 mrem/year for ingestion of air or water. For liquid wastes containing radionuclides that are discharged to surface waters, the best available technology must be used if the receiving water, at the point of discharge, would receive radioactive material at a concentration greater than the DCG. Guidelines for selecting the best available technology are given. Implementation of the best available technology process is not required if annual releases to surface water are below the DCG. In the case of releases of multiple radionuclides, the sum of the fractional DCGs must not exceed unity. In addition, effluent releases to surface water must not result in exposures to aquatic organisms that exceed an absorbed dose of 1 rad/d.

DOE Order 5400.5, Chap. IV, presents guidelines for cleanup of residual radioactive material and management of sites with residual radioactivity above the specified guidelines. The Order provides basic dose limits and guidelines for residual radioactivity, as well as criteria for interim storage and interim and long-term management of properties where residual radioactivity above the guidelines is left in place. Supplemental limits and exceptions may be established for a site as described in Chap. IV.7. An exception may be made in instances where residual radioactive material is inaccessible, such as under hard-surfaced public roads and sidewalks, around public sewer lines, or in fence post foundations. Information on application of the guidelines and requirements presented in the Order, including procedures for deriving specific property guidelines for allowable levels of residual radioactive material from basic dose limits (i.e., the RESRAD model), is contained in DOE/CH 8901, "A Manual for Implementing Residual Radioactive Material Guidelines, A Supplement to the U.S. Department of Energy Guidelines for Residual Radioactive Material at FUSRAP and SFMP Sites," June 1989 [5400.5(IV.2)]. In these situations, administrative controls with an effective life of 25 years are required for interim management.

Although DOE Order 5400.5 specifies use of the RESRAD model to estimate concentrations in soils that will achieve the dose limits for residual radioactivity, the Nuclear Regulatory Commission criterion of 30 pCi/g for unrestricted disposal of slightly enriched uranium is often used as a standard for unrestricted use of contaminated media. This Nuclear Regulatory Commission value may be considered to-be-considered for cleanup of EFPC soils or beneficial reuse of treated soils.

DOE has proposed the radiation protection standards for the public and the environment specified in DOE Order 5400.5 for codification at 10 *CFR* 834 (58 *FR* 16268, March 25, 1993). A final rule is expected in September 1994 (Houlberg et al. 1993); when final, these standards will be legally applicable for cleanup at DOE sites.

DOE Order 5820.2A (*Radioactive Waste Management*, September 9, 1988) states that the management of low-level radioactive waste must ensure that external exposure to the waste and concentrations of radioactive material that may be released into surface water and soil does not exceed 25 mrem/year to any member of the public. Releases to the atmosphere shall not exceed 10 mrem/year. Reasonable effort should be made to maintain releases to the environment at ALARA levels. The Order pertains to the management of radioactive waste; the requirements in this Order are to-be-considered for disposal of soils or treatment residuals contaminated with low-level waste.

C.3 LOCATION-SPECIFIC ARARs

Location-specific requirements "set restrictions upon the concentration of hazardous substances or the conduct of activities solely because they are in special locations" (53 *FR* 51394). Table C.2 lists the major federal and state location-specific ARARs that might be pertinent to remedial actions at EFPC.

C.3.1 Aquatic Resources and National Areas

The Oak Ridge Reservation (ORR) is located within the Clinch River Drainage basin and is bounded on the south and west by the Clinch River. EFPC, situated primarily in the valley between East Fork Ridge and Black Oak Ridge, is located in the EFPC watershed. In addition to floodplains, 17 wetland areas have been identified within the EFPC floodplain (DOE 1994a).

If any remedial alternatives that would affect floodplains are selected, the requirements found in Executive Order 11988, 40 *CFR* 6.302(b), 40 *CFR* 6 (Appendix A), and 10 *CFR* 1022 would provide applicable requirements for EFPC. If wetlands are affected, consideration should be given to Executive Order 11990, 40 *CFR* 6.302(a), 40 *CFR* 6 (Appendix A), 10 *CFR* 1022, CWA §404, 40 *CFR* 230, and 33 *CFR* 320-330 for applicable requirements.

There are no designated wilderness areas, wildlife refuges, or scenic rivers on ORR. However, portions of ORR, including part of EFPC, have been designated as Tennessee and DOE National Environmental Research Park (NERP) National Areas and Reference Areas. Approximately the last 4.8 km (3 miles) of EFPC, before it converges with Poplar Creek, is within the DOE NERP. In addition, two areas on EFPC have been designated as Reference Areas, Biological Monitoring and Abatement Program (BMAP) sites.

If remedial actions that would affect the National Areas or Reference Areas are contemplated, the Tennessee Natural Areas Preservation Act of 1971 may provide ARARs. In addition, if any remedial action is taken to alter EFPC, because of its designation for protection of fish and aquatic life, recreation, irrigation, livestock watering, etc., the Fish and Wildlife Coordination Act and the TDEC Water Quality Control Act [Tennessee Code Annotated (TCA) 69-3-101 *et seq.*] may be applicable (see Table C.2).

C.3.2 Historic Sites and Archaeological Findings

Section 2.1.1.2 of the EFPC RI Report (DOE 1994a) discusses the probability of discovering archaeological resources on the EFPC floodplain. Although the potential is low, if any remedial action is taken which would cause irreparable harm, loss, or destruction to any historic or archaeological site, the provisions of the Archaeological Resources Recovery Act (16 USC 470aa-ll), 43 *CFR* 7, the Archaeological and Historic Preservation Act (16 USC 469a-c), and 40 *CFR* 6.301, as well as Executive Order 11593, 40 *CFR* 6.301, and 36 *CFR* 800 *et seq.* may be applicable. Finally, should any cemeteries be located on the EFPC remedial site, the Tennessee Cemetery Protection Act (TCA 46-1-101 *et seq.*), which prohibits the destruction or degradation thereof, may apply.

C.3.3 Rare, Threatened, or Endangered Species

If a site investigation reveals the presence of any rare, threatened, or endangered animals or plants or any designated critical habitats at EFPC, the Endangered Species Act of 1973 and the Tennessee Non-Game and Endangered or Threatened Wildlife Species Act of 1974 may be applicable (Table C.2). Habitat modifications impacting any species designated by the state as "in need of management" (Tennessee Wildlife Resources Commission Proclamation 86-29, 1991) may trigger the state endangered species act, because it is unlawful for any person to knowingly destroy the habitat of wildlife "in need of management" [TCA 70-8-104(b)(1)]. Exceptions to this regulation may be allowed where necessary to protect human health and safety.

Although the Tennessee Rare Plant Protection and Conservation Act of 1985 (TCA 11-26-201) is designated to protect and conserve rare plants throughout the state, the prohibition on knowingly disturbing, damaging, or destroying any state-listed endangered plant species does not apply to any employee or contractor of the federal government (TCA 11-26-209). However, this exclusion does not apply to federally listed endangered plants nor to the ginseng plant (*Panax quinquefolius*) (TCA 11-26-214).

C.4 ACTION-SPECIFIC ARARs

Performance, design, or other action-specific requirements set controls or restrictions on particular kinds of activities related to the management of hazardous waste (52 *FR* 32496). Selection of a particular remedial action at a site will involve the appropriate action-specific ARARs that may specify particular performance standards or technologies, as well as specific environmental levels for discharged or residual chemicals.

A complete description of each of the sitewide alternatives is included in Sect. 4 of this report. The activities associated with each alternative are listed briefly below. Regulations are summarized in the text for the general categories of response actions, and regulatory requirements are expanded in Tables C.3 through C.7, with the determination of applicability or relevance and appropriateness listed in the tables. The discussion of general response activities is organized as a chain of events, and the tables list the response actions in alphabetical order. Tennessee state regulations governing waste management, emissions to air or water, etc., are included in the text and tables if promulgated and/or if more stringent than the federal regulations governing the same topic. Table C.8 summarizes the ARARs for all sitewide alternatives and indicates whether each alternative can comply with the requirement, if pertinent for that alternative.

EPA has established two new sections in RCRA Subpart S (*Corrective Action for Solid Waste Management Units*): 40 *CFR* 264.552 [Corrective Action Management Units (CAMUs)] and 40 *CFR* 264.553 [Temporary Units (TUs)] (48 *FR* 8658, February 16, 1993). Both of these units function solely to manage wastes that are generated at a RCRA facility for the purpose of implementing remedial actions (i.e., remediation wastes). The substantive requirements of this rule are expected to be ARARs for remediation of CERCLA sites that involve the management of RCRA hazardous waste. In this context, CAMU designations would be incorporated into CERCLA decision documents (58 *FR* 8679).

Since there is no RCRA-listed or characteristic waste in EFPC floodplain soils, the applicability of the CAMU rule would be limited to storage or disposal of any RCRA wastes generated during treatment. Designation of a CAMU by the EPA Regional Administrator is a lengthy process, involving evaluation of seven decision criteria, public review and comment, and either RCRA permit modification or designation in a CERCLA decision document. Since all treatment residuals other than the high-efficiency particulate air filters and untreated process water are assumed to be the responsibility of a fixed-price contractor, the quantity of remediation wastes requiring disposal by DOE/Martin Marietta Energy Systems, Inc. (Energy Systems) is not expected to be sufficient to warrant involving the CAMU rule. Therefore, this rule will not be addressed further as an ARAR.

C.4.1 No Action Alternative

There are no action-specific ARARs for the No Action alternative (SWA 1). However, leaving the waste in place may violate certain DOE Orders for protection of the public from all sources of radiation. In addition, the policy of the TDEC Water Quality Control Act is to protect waters of the state by abating existing pollution and reclaiming polluted waters [TCA 69-3-102(b)]. Table C.3 summarizes ARARs and to-be-considered guidance for the No Action alternative.

C.4.2 General Response Activities for All Remedial Alternatives

Certain activities are common to some or all of the six "action" alternatives (SWAs 2 through 7). These activities include road construction, removal of vegetation, site grading, surface water controls, and streambed modifications as described below. Table C.4 lists the regulatory requirements for these general site remedial activities.

C.4.2.1 On-site excavation and construction activities

On-site excavation and/or construction activities that will be necessary to prepare the sites for remediation include the development of additional roads for vehicular traffic, removal of vegetation and soils, site grading, and construction activities designed to control surface water runoff. Excavated soils may be loaded into trucks and carried either to staging areas for packaging prior to transportation for disposal or to the treatment facility located at the K-25 Site. Borrow soils used for backfilling the excavated floodplain areas will also be transported by truck from the ORR.

Fugitive Dust Emissions. Airborne pollutants may result from these excavation and construction activities. The primary concern is elevation of particulate concentrations resulting from earth-moving and site-grading activities. The TDEC Division of Air Pollution Control has also promulgated regulations governing fugitive dust emissions (TDEC Rules, Chapter 1200-3-8-.010). These are listed in Table C.4 and are applicable to remedial activities at EFPC.

Construction of Roads. In support of the Clean Water Act (CWA) §404, 33 *CFR* 323.4 specifies that best management practices be applied during construction or maintenance of temporary or permanent farm, forest, or mining roads near wetland areas, including minimization of discharges of dredged or fill material into waters of the United States and minimization of vegetative disturbances. Road crossings must not disrupt the migration or other movement of

aquatic life in the water body, and borrow material must be taken from upland sources whenever feasible. Table C.4 lists the specific requirements of 33 *CFR* 323.4; these may be relevant and appropriate for road construction on the EFPC floodplain.

Steambed Modification. If remedial activities extend near the bank of EFPC, surface control measures, such as piping of the creek or construction of coffer dams, may be implemented as needed to prevent further runoff and/or contamination of the stream from remedial activities. Activities impacting "waters of the state" are protected under the authority of the TDEC Water Quality Control Act of 1977 (TCA 69-3-108). Consultation with TDEC and approval of design plans for rechannelization or coffer dam construction will be necessary to ensure compliance with the intent of TCA 69-3-108.

TDEC issues general permits for alteration of aquatic resources. These general aquatic resource alteration permits (ARAPs) include alteration of wet weather conveyances, major road crossings, utility line crossing, bank stabilization, sand and gravel dredging, and debris removal. Individual permits may be required for other activities. The substantive requirements are that no activities be located in wetlands; no activities be located in any waterway which has been identified by TDEC as having contaminated sediments; and no portion of the activity is located in a known habitat of state or federally listed threatened or endangered species (TDEC Rules, Chapter 1200-4-7 *et seq.*).

Discharge of Dredge and Fill Material. The U.S. Army Corps of Engineers (COE) requires permits for structures or work in or affecting navigable waters of the United States under §10 of the Rivers and Harbors Act. "Waters of the United States" are defined in 33 *CFR* §§322.2 and 328 as those waters of the United States that are subject to the ebb and flow of the tide toward the mean high water mark and which have been at any time, or may be, used for interstate commerce. This definition includes all impoundments of such waters [40 *CFR* 328.3(a)(4)]. The COE has established the ordinary high water mark for impoundments to be the normal summer pool elevation (elev. 741 for the Watts Bar impoundment), which includes any slackwater areas. Any activity above this elevation would not require approval pursuant to §10 of the Rivers and Harbors Act. A Regional survey by the COE identified "navigable waters" in the area; Poplar Creek from its mouth to river mile 18.3 has been designated a navigable water. However, no tributaries to Poplar Creek have received such a designation (Claud 1992).

The requirements for 40 *CFR* 230 *et seq.* are designed to prevent potential impacts on aquatic ecosystems by prohibiting the discharge of dredge or fill material into such ecosystems unless it can be demonstrated that such discharge will have no impact. The guidelines presented in 40 *CFR* 230 are applicable to permit specifications for disposal sites for dredge or fill material. However, the substantive requirements of 40 *CFR* 230, designed to restore and maintain the chemical, physical, and biological integrity of waters of the United States are relevant and appropriate to the actions proposed for modifications to EFPC or discharge of fill material into EFPC. These requirements are predominantly found in Subpart B, *Restrictions on Discharge* (40 *CFR* 230.10) and Subpart H, *Actions to Minimize Adverse Effects*. Table C.4 gives a brief summary of the content of these regulations.

Surface Water Control. Stormwater discharges from activities at industrial sites involving construction operations that result in the disturbance of 5 acres or more total land have been

included in the final rule for National Pollutant Discharge Elimination System (NPDES) permits for stormwater discharges (40 *CFR* 122). Consultation with TDEC is required to ensure compliance with the substantive requirements of the NPDES permitting process for stormwater discharges during construction activities (TDEC Rules, Chapter 1200-4-10-05).

Construction of Waste Piles. The regulations found in RCRA Subpart L, "Waste Piles," apply to owners and operators of facilities that store or treat RCRA hazardous waste in piles. However, design and operation requirements for waste piles may be relevant and appropriate for staging of excavated soils prior to transportation by truck or rail for disposal. TDEC Rules, Chapter 1200-1-11-.06(12)(b), states that the pile must be covered or managed in a manner to control wind erosion and to prevent fugitive dust emissions. Other regulations pertaining to management of waste piles are listed in Table C.4.

C.4.2.2 Treatment of decontamination water

On-site treatment of decontamination water will be in modular treatment units. The ARARs for these units, which will be the same as for the low-temperature thermal desorption process utilized for soil treatment, are described in Sect. C.4.3.4 and listed in Table C.7.

C.4.2.3 Disposal of decontamination water

Decontamination of trucks, backhoes, bulldozers, and other excavation equipment will be implemented using high-pressure decontamination water obtained from EFPC or from Oak Ridge. Following decontamination, water will be sampled for analysis and, if it contains no contaminants, will be returned to the creek; otherwise, it will be drummed and disposed.

Direct Discharge to Surface Water Body. Direct discharge to EFPC of water generated during the dewatering process or decontamination procedures (see Table C.4) is an option provided that the water meets the effluent discharge criteria for radionuclides found in DOE Order 5400.5 and is not considered RCRA-characteristic waste. Direct discharge to EFPC may be implemented if the water meets CWA federal and state water quality criteria for the designated use of the water body. EFPC has the designated use classifications of recreation, fish and aquatic life, irrigation, and livestock watering and wildlife (TDEC Rules, Chapter 1200-4-4). The substantive requirements of the NPDES effluent standards for point source discharge (40 *CFR* 122-125) must also be met. These include discharge limitations, monitoring requirements, and best management practices. Discharge may be to an NPDES-permitted outfall on EFPC, and the permit limitations would regulate the quantity and quality of the water to be discharged.

Discharge to On-site Treatment Facility. Discharge to an on-site treatment facility will generally invoke no further ARARs, assuming that the facility is NPDES permitted for treatment of waste water, TSCA permitted for treatment of polychlorinated biphenyl (PCB)-contaminated media, or RCRA permitted for treatment of hazardous solid waste. Waste Acceptance Criteria for the receiving facility must be met. Transport of the media to the facility may trigger transportation requirements.

C.4.2.4 Disposal of waste materials

The requirements for disposal of contaminated soils or other remediation wastes depend on whether the waste contains RCRA-characteristic waste and/or low-level radioactive waste. Table C.4 lists the regulatory requirements for disposal of each kind of waste, as described below.

Untreated contaminated soils, treatment residuals, or any other waste materials that are not toxicity characteristic leaching procedure (TCLP) toxic or do not contain radionuclides may be disposed of at any permitted solid waste landfill regulated under RCRA Subtitle D. Subtitle D established minimum national performance standards to ensure that "no reasonable probability of adverse effects on health or the environment" will result from solid waste disposal practices. This satisfies the CERCLA requirement of protection of human health and the environment.

Any contaminated, treatment residuals, or other waste materials generated during remedial activities that are tested and do not contain low-level waste but fail the TCLP must be managed as hazardous waste, and disposed of at a RCRA Subtitle C permitted facility. The low-temperature thermal desorption fixed-price contractor is assumed to be responsible for the disposal of all generated waste except the high-efficiency particulate air filters and untreated process water. It is assumed that the fixed-price contractor will comply with all necessary regulations; therefore, no further ARARs apply to this remediation activity.

Contaminated soils, treatment residuals, etc., that contain both RCRA-characteristic waste and low-level waste must be managed as mixed waste according to DOE and Energy Systems waste management procedures. In June 1992 EPA and DOE signed a Federal Facilities Compliance Agreement (mixed waste-FFCA) to bring mixed waste generation and storage facilities on the ORR into compliance with environmental law. Under the agreement, effective immediately, the mixed waste-FFCA allows DOE ORR facilities to continue to generate and store mixed wastes while addressing land disposal restrictions and mixed waste compliance issues. The mixed wastes covered under the mixed waste-FFCA include flammable and corrosive liquids, solvents, paint waste, waste oils and organics, and solid mixed wastes.

DOE has implemented a "no rad added" policy (i.e., the moratorium on low-level waste shipments) which states that no media containing RCRA hazardous waste or TSCA-regulated waste and added radioactivity may be shipped from a DOE facility to an off-site disposal facility without undergoing a thorough review process to ensure proper analysis, recording, and manifesting of waste shipments.

C.4.2.5 Transportation

Removal of RCRA-characteristic waste from a CERCLA site is considered new generation of hazardous wastes. Any generator that transports or offers for transportation hazardous waste for off-site treatment, storage, or disposal must comply with the administrative as well as the substantive requirements detailed in RCRA Subparts B and C at 40 *CFR* 262. The waste must be packaged in accordance with Department of Transportation (DOT) regulations codified in 49 *CFR* Parts 175, 178, and 179. In addition to the manifest and pretransport requirements of 40 *CFR* 262, standards for labeling, marking, and placarding are stated in 49 *CFR* Part 172. These requirements are considered ARARs for hazardous waste if the action meets the

prerequisites as a generator of a hazardous waste, and the transportation of wastes from EFPC to a rail yard or to the K-25 Site for treatment is considered an off-site action. In addition, DOT regulations address shipments of radioactive materials.

The DOT regulations govern "transportation in commerce of hazardous materials." Government agencies offering hazardous materials for transportation in commerce or transporting hazardous materials in furtherance of a commercial enterprise are subject to the regulations. However, the Chief Counsel of the Research and Special Programs Administration under DOT issued an opinion letter for DOE headquarters stating that DOE is not required to comply with the Hazardous Materials Transportation Act when it offers or transports hazardous materials in a government vehicle because those DOE activities are presumed to be for a governmental purpose and thus not in commerce (Kaleta 1991). The DOT requirements would be applicable if DOE does not close off the road to public use during transport; if the transport does not occur in a DOE operated government vehicle; or if access to the roads is not controlled by the use of gates and guards (Kaleta 1991). However, DOE has stated that it will comply with the DOT transportation requirements; therefore, they are briefly summarized here.

The DOT Regulations for Hazardous Materials list general requirements for shipping and packaging at 49 *CFR* 172 and 173 and requirements for carriage by public highway at 49 *CFR* 177. General standards for operating, handling, and loading rail cars are found at 49 *CFR* 174 (Subparts A, B, and C). A hazardous material includes radionuclides, any RCRA-listed or RCRA-characteristic waste, or any CERCLA substance which is in a quantity, in one package, that equals or exceeds the Reportable Quantity, as listed in the Appendix to 49 *CFR* 172.101 (49 *CFR* 171.8).

General requirements for shipping of hazardous materials are defined in 49 *CFR* 172, with specific marking, labeling, and placarding regulations for radioactive materials in 49 *CFR* 172.310, 172.403, and 172.556, respectively. General package design requirements are given in 49 *CFR* 173.411, with specific design requirements for Type A and B packaging found in 49 *CFR* 173.412 and 173.413, respectively.

C.4.3 Specific Response Activities

C.4.3.1 Institutional controls

DOE Order 5400.5, Chapter IV, requires administrative controls for interim management in areas where residual radioactivity is in inaccessible locations and exceeds the guidelines specified in the Order (see Sect. C.2.2). These controls are listed in Table C.5 and include active and passive controls. Use limitations or deed restrictions may be necessary to control exposure to the residual radioactivity left in place. Use limitations could include restrictions on fish consumption, construction permits, and zoning restrictions, which would have to be enacted by the local governments who have jurisdiction over those matters. Deed restrictions could alter future land uses to reduce the potential for exposure but would have to be put on the public record by the current landowner. DOE could impose deed restrictions on any affected parcels it owns.

C.4.3.2 Containment

The RCRA definition of "landfill" in general is assumed to be any land disposal unit that does not meet the regulatory definition of any other land disposal unit and this is interpreted by EPA in the National Contingency Plan as including non-discrete land areas in which there is generally dispersed contamination (55 *FR* 8760). Although the landfill closure requirements are not applicable to containment of wastes left in place at EFPC, the landfill closure requirements of 40 *CFR* 264.310 will be considered as relevant and appropriate for the containment (capping) operations. Table C.6 lists the ARARs for containment at EFPC.

If waste is left in place, a landfill must be covered with a final cover designed and constructed to provide long-term minimization of migration of liquids through the capped area, function with minimum maintenance, promote drainage and minimize erosion or abrasion of the cover, and accommodate settling and subsidence so that the cover's integrity is maintained. The additional requirements to keep water and leachate from collecting in the waste, i.e., that the cap should have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present [40 *CFR* 264.288 (a)(2)(iii); 40 *CFR* 264.310(b)] are listed in Table C.6 and include long-term maintenance of the cover, runon and runoff diversion systems, etc. The use of institutional controls in areas where waste is left in place has been described previously.

TDEC has promulgated NPDES permit requirements for stormwater discharges during industrial activity (Chapter 1200-4-10-.04), and considers closed CERCLA sites to be industrial areas. Therefore, the substantive requirements of this permitting process will be applicable to discharges following closure of the site. The monitoring parameters and reporting levels are listed in Chapter 1200-4-10-.04(e) for: biological oxygen demand, chemical oxygen demand, total suspended solids, ammonia as nitrogen, oil and grease, pH, floating material, color, sheen, and priority pollutants.

C.4.3.3 Removal

Construction and maintenance of access roads, removal of vegetation, construction of surface water controls, temporary modifications to EFPC to reduce runoff into EFPC, and excavation and removal of contaminated soils are discussed in Sect. C.4.2 as components of this action. Contaminated soil will be loaded into trucks for transport to K-25 for thermal treatment. Trucks and equipment will be decontaminated using high pressure decon water obtained from EFPC. The EFPC floodplain will be restored with the use of borrow soil from the ORR, grading, replacement of pavement, and revegetation. ARARs governing removal of floodplain soils are listed as general activities in Table C.4.

C.4.3.4 On-site treatment

Since there is no indication of RCRA-listed or -characteristic waste, none of the RCRA regulations governing treatment are applicable to the waste from EFPC. However, since the intent of CERCLA is to protect human health and the environment, portions of the RCRA treatments standards may be relevant and appropriate. ARARs for the treatment alternative are listed in Table C.7. Soils containing mercury at levels exceeding the remediation goal options will be transported to K-25 Site and treated by low-temperature thermal desorption. Off-gas from the treatment process will be collected and treated.

Miscellaneous Treatment Units. Treatment in a unit may involve biological, chemical, thermal, or physical processes (see Table C.7); however, the 40 *CFR* 264 regulations do not differentiate between these processes, considering them all to be via "miscellaneous treatment units." Standards for the operation and maintenance of miscellaneous units are codified in 40 *CFR* 264.601 (see Table C.7). These standards require location, design, operation, and closure of the unit in a manner that is protective of human health and the environment. Unlike other RCRA units where the general performance objectives are achieved by specified design standards, only generalized environmental performance standards are applied to miscellaneous units. The general environmental performance standards require that the owner demonstrate prevention of releases to groundwater or subsurface media [40 *CFR* 601(a)], surface waters or wetlands [40 *CFR* 601(b)], or air [40 *CFR* 601(c)] that could have adverse effects on human health and the environment. In demonstrating compliance with these standards, the operator must consider both waste and media characteristics.

The postclosure care regulations for miscellaneous treatment units are meant to ensure protection of human health and the environment (40 *CFR* 264.603). The general environmental performance standards for "miscellaneous units" apply to postclosure care (see Table C.7).

Control of Air Emissions. The TDEC Office of Air Pollution Control (APC) requires construction and operating permits for new air contaminant sources (TDEC Rules, Chapter 1200-3-9-.01 and 1200-3-9-.02, respectively). Emissions must be analyzed to determine if they contain hazardous pollutants as defined by Public Law (P.L.) 101-549 (November 15, 1990) or as listed in TDEC Rules, Chapter 1200-3-11. The APC provides guidance for comparing emissions of hazardous pollutants to threshold limit values (TLVs), and requires a construction and operating permit if emissions of carcinogens or noncarcinogens exceed 0.01 times the TLV or 0.1 times the TLV, respectively. If emissions of hazardous pollutants fall below these values, or if emissions of nonhazardous pollutants do not exceed 0.45 kg/h (0.1 lb/h), the APC will exempt a contaminant source from the permitting requirements.

Although permits are not required for CERCLA response actions, the substantive requirements of the APC regulations will be applicable for potential releases of hazardous pollutants from the low-temperature thermal desorption process; modeling should be performed to estimate potential emissions, and the appropriate APC permit applications should be submitted for APC approval.

In addition, compliance with the NESHAPs rule that limits emissions of radionuclides to the ambient air from DOE facilities to amounts that would not cause any member of the public to receive an effective dose equivalent of 10 mrem/year (40 *CFR* 61.92) is applicable for emissions from the low-temperature thermal desorption unit.

Disposal of Treatment Residuals. Analysis of treatment residuals will be performed to determine whether they contain RCRA-toxic waste and/or low-level waste. Based on the results of this analysis, the residuals will be disposed of according to standard DOE/Energy Systems waste management procedures. If they fail the TCLP test, compliance with the RCRA land disposal restrictions must be assured. On-site or off-site disposal must be to a RCRA-permitted facility. See Sect. C.4.2.3 for a further discussion of disposal requirements.

C.4.3.5 Beneficial reuse

Treated soils will be transported by truck from the treatment unit to a staging area for beneficial reuse on the ORR. ARARs cited for general response activities will apply to this remedial action (i.e., control of fugitive dust emissions, waste pile storage requirements, etc.); these are listed in Table C.4. Since treated soil contains contaminants below health-based levels, there are not further ARARs for the beneficial reuse scenario.

C.4.3.6 Property acquisition

In general, ARARs address protection of human health and the environment and as such, property acquisition requirements of this regulation will not be considered as ARARs for the remediation of EFPC. However, the requirements of these regulations may be applicable to the property acquisition phase of SWA 6, and compliance may be required under another authority than CERCLA.

The Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 P.L. 91-646] and its amendments, the Surface Transportation and Uniform Relocation Assistance Act of 1987 (P.L. 100-17), are implemented by regulations promulgated by the DOT. These DOT regulations are the Uniform Relocation and Real Property Acquisition for Federal and Federally Assisted Programs found in 40 *CFR* 25. The purpose of these regulations is to ensure that owners of real property acquired by the federal government for federal or federally assisted projects are treated fairly and consistently, to ensure and expedite acquisition by agreements with such owners, to minimize litigation, and to promote public confidence in federal programs (40 *CFR* 25.1). The implementation of these regulations must be in compliance with other federal laws, including NEPA, the Civil Rights Act, Floodplain Management, the Equal Opportunity and Housing Act, and others (49 *CFR* 25.8).

The basic acquisition policies are delineated in Subpart B (40 *CFR* 25.102) and include requirements for notification, appraisal, offer of compensation, payment, and negotiation procedures. Other sections of this subpart address: criteria for appraisal (40 *CFR* 25.103); review of appraisals (40 *CFR* 25.104); acquisition of tenant-owned improvements (40 *CFR* 25.105); expense incidental to transfer of title (40 *CFR* 25.106); litigation expenses (40 *CFR* 25.107); and donations (40 *CFR* 25.108). Subsequent subparts address general relocation requirements (Subpart C); payments for moving and related expenses (Subpart D); replacement housing payments (Subpart E); mobile homes (Subpart F); and last resort housing (Subpart G).

Compliance with the Farmland Protection Policy Act requires that DOE determine whether there is any potential for project activities to affect land designated with prime or unique farmland status. If such lands exist in the area affected by project activities, DOE should submit soil Conservation Service (SCS) Form AD-1006 to local SCS office(s) in Clinton, (and Kingston), Tennessee. This is a multistep process. Initially, DOE must provide only general information about the project (e.g., acreage affected, etc.). If after review, the SCS determines that the project would not affect prime or unique farmlands, no further action would be required. If such lands are present and would be affected by the project, additional impact evaluation, utilizing subsequent sections of Forms AD-1006, would be required. Guidance for such analysis is given in 7 *CFR* 658.

REFERENCES

Claud, T. May 1, 1992. Project Manager, Regulatory Branch, U.S. Army Corps of Engineers, Nashville, Tennessee, personal communication to E.L. Etnier.

DOE (U.S. Department of Energy). 1994. *East Fork Poplar Creek/Sewer Line Beltway Remedial Investigating Report*. DOE/OR/02-1119&D0. Oak Ridge, Tennessee.

Houlberg, L.M., Hawkins, G.T., and Salk, M.S. 1993. *Environmental Regulatory Update Table, March/April 1993*. ORNL/M-2648/R1. Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, March.

Kaleta, J.S. 1991. Chief Counsel, U.S. Department of Transportation Research and Special Programs Administration. Letter dated April 23, 1991, to Susan H. Denney, Director, Transportation Management Program, Department of Energy, Washington, D.C.

APPENDIX C

TABLES

This page intentionally left blank.

Table C.1. DOE Order 5400.5, "Radiation Protection of the Public and the Environment"

Action	Requirement	Chapter
Planning and performance of all DOE activities	DOE will carry out all DOE activities to maintain radiation doses to individuals at levels as low as reasonably achievable (ALARA).	I.4
Routine DOE activities including remedial action	Exposures to off-site members of the public from all routine DOE activities shall not cause an effective dose equivalent to be >100 mrem (1 mSv) per year.	II.1a
	Exposures to off-site members of the public from radioactivity released into the atmosphere from all routine DOE activities shall not cause an effective dose equivalent to be >10 mrem (0.1 mSv) per year, pursuant to 40 *CFR* 61.	II.1b
Discharge of liquid waste containing radionuclides to surface water	Implementation of best available technology treatment is required if discharge is at an annual average concentration greater than the derived concentration guide (DCG) level listed in Chapter III, *Derived Concentration Guides for Air and Water.*	II.3a(1)
	Discharge of liquid waste containing radionuclides to surface water at an annual average concentration less than the DCG level does not require the implementation of best available technology treatment.	II.3a(2)
	The absorbed dose to native aquatic animal organisms shall not exceed 1 rad/d from exposure to liquid wastes discharged to natural waterways.	II.3a(5)
	Liquid wastes containing concentrations of radioactive materials >5 times the DCG(s) may be discharged to a federal sanitary sewage system that provides liquid waste treatment prior to discharge to surface water according to II.3a(1). ALARA process considerations are required.	II.3d(3)
	If a waste stream contains multiple radionuclides, then the DCG shall be the sum of the fractional DCG values.	II.3a(3)
Demonstration of compliance with the dose limits	DOE shall make appropriate documentation containing information about compliance with dose limits for members of the public in the immediate vicinity and within 80 km of the site; surveillance methods and dose evaluations are discussed in this section.	II.6
Conduct of radiological environmental protection programs	DCG(s) for water ingestion, air inhalation, and immersion in a gaseous cloud are provided as reference values in this chapter. These DCG(s) are based on a committed effective dose equivalent of 100 mrem for the radionuclide taken into the body by ingestion or inhalation during 1 year.	III.2
	The DCG values apply to only one mode of exposure (i.e., either ingestion *or* inhalation).	III.2a

Table C.1 (continued)

Action	Requirement	Chapter
	For known mixtures of radionuclides, the sum of the ratios of the observed concentration of each radionuclide to its corresponding DCG must not exceed 1.0.	III.2c
Cleanup of residual radioactive material and management of resulting wastes or residues	DOE facilities shall develop plans and protocols for the implementation of the guidance found in this chapter.	IV.1 & 2
	Monitoring, cleanup, and control of residual radioactive material are subject to the ALARA policy.	IV.2e
	The basic dose limits for exposure to residual radioactive material is an effective dose equivalent of 100 mrem (1 mSv) annually.	IV.3a
	Under unusual circumstances, a request may be made for a specific authorization for a temporary dose limit for exposure to residual radioactive material >100 (1 mSv) mrem/year but not to exceed 500 (5 mSv) mrem annually.	IV.3b
	Residual radioactive material in soil includes those concentrations in excess of background concentrations averaged over an area of 100 m^2. These derivations are obtained by means of environmental pathway analogies and basic dose limits, using derivations described in DOE/CH-8901, *A Manual for Implementing Residual Radioactive Material Guidelines.*	IV.4a
	Residual concentrations of radionuclides in the air and water shall not exceed 100 mrem (1 mSv) per year.	IV.4e
	Limits for hot spots shall be developed in cases where the average concentration in any surface or below-surface area equal to or < 25 m^2 exceeds the limit or guidelines by a factor of $(100/A)^{0.5}$. Reasonable effort must be made to remove any radionuclide source that exceeds 30 times the limit.	IV.4a(1)
Interim storage of residual radioactivity above the guidelines specified in IV.1-4	Interim storage control and stabilization features shall be planned to have a minimum life of 25 years and, if reasonably achievable, an effective life of 50 years.	IV.6b(1)
	Control features must be designed so that radionuclide concentrations in the groundwater shall not exceed applicable federal and state standards.	IV.6b(3)
	Access to property contaminated by residual radioactive material above guidelines should be controlled through administrative controls designed to provide, to the extent reasonable, an effective life of at least 25 years.	IV.6(b)(4)

Table C.1 (continued)

Action	Requirement	Chapter
Interim management of residual radioactivity above the guidelines specified in IV.1-4	If residual radioactive material is in inaccessible locations and would be unreasonably costly to remove and when residual radioactive material exceeds guideline values, an interim management plan may be arranged to maintain the property.	IV.6c(1)
	Administrative controls for interim management shall include (but are not limited to): • periodic monitoring as appropriate; • appropriate shielding; • physical barriers to prevent access; and • appropriate radiological safety measures.	IV.6c(2)
Long-term management of residual radioactivity above the guidelines specified in IV.1-4	In accordance with legally applicable federal and state standards, DOE facilities shall protect groundwater.	IV.6d(1)(d)
	Use of and access to residual radioactive material shall be controlled through appropriate administrative and physical controls; these controls should be designed to the extent reasonable for at least 200 years.	IV.6d(1)(e)
	Long-term management of other radionuclides shall be controlled by applicable requirements in Chapter III of DOE 5820.2A.	IV.6d(2)

Table C.2. Location-specific ARARs for all alternatives for EFPC[a]

Location characteristic(s)	Requirement(s)	Operating condition(s)	Federal citation(s)	TDEC[b] Rules, Chapter	Comments
		Wetlands			
Presence of wetlands as defined in Executive Order 11990 §7(c) and 40 *CFR*[c] 6, Appendix A §4(j)	Whenever possible, actions must avoid or minimize adverse impacts on wetlands and act to preserve and enhance their natural and beneficial values. New construction in wetlands areas should be particularly avoided unless there are no practicable alternatives. Wetlands protection considerations shall be incorporated into planning, regulating, and decision-making processes.	Agency action which involves: • acquiring, managing, and disposing of lands and facilities; • providing federally undertaken, financed, or assisted construction and improvements; and • conducting federal activities and programs affecting land use	Executive Order 11990; 40 *CFR* 6.302(a); 40 *CFR* 6, Appendix A; 10 *CFR* 1022		Applicable to remedial actions impacting EFPC wetlands areas
Presence of wetlands as defined in 40 *CFR* 230.3(t) and 33 *CFR* 328.3(b)	Action to avoid degradation or destruction of wetlands must be taken to the extent possible. Discharges for which there are practicable alternatives with less adverse impacts or those which would cause or contribute to significant degradation are prohibited. If adverse impacts are unavoidable, action must be taken to enhance, restore, or create alternative wetlands.	Action involving discharge of dredge or fill material into wetlands	Clean Water Act §404; 40 *CFR* 230; 33 *CFR* 323		Applicable to remedial actions impacting EFPC wetlands areas

Table C.2 (continued)

Location characteristic(s)	Requirement(s)	Operating condition(s)	Federal citation(s)	TDEC[b] Rules, Chapter	Comments
		Floodplains			
Within "lowland and relatively flat areas adjoining inland and coastal waters and other floodprone areas such as offshore islands, including at a minimum, that area subject to a one percent or greater chance of flooding in any given year." [Executive Order 11988 §6(c) and 40 *CFR* 6, Appendix A §4(d)]	Action shall be taken to reduce the risk of flood loss, minimize the impact of floods on human safety, health and welfare, and restore and preserve the natural and beneficial values of floodplains.	Action which involves: • acquiring, managing, and disposing of lands and facilities; • providing federally undertaken, financed, or assisted construction and improvements; and • conducting federal activities and programs affecting land use	Executive Order 11988; 40 *CFR* 6.302(b); 40 *CFR* 6 (Appendix A); 10 *CFR* 1022		Applicable to remedial actions impacting EFPC floodplain
	The potential effects of actions in floodplains shall be evaluated and consideration of flood hazards and floodplain management ensured. If action is taken in floodplains, alternatives that avoid adverse effects and incompatible development and minimize potential harms shall be considered.				Applicable to remedial actions impacting EFPC floodplain

Table C.2 (continued)

Location characteristic(s)	Requirement(s)	Operating condition(s)	Federal citation(s)	TDEC[b] Rules, Chapter	Comments
		Aquatic resources and Natural Areas			
Within area encompassing or affecting waters of the State of Tennessee as defined in TCA[d]69-3-103(32) and the presence of wildlife or aquatic life	Discharge of "substances" which "will result or will likely result in harm, potential harm or detriment to the health of animals, birds, fish, or aquatic life" is prohibited.	Action involving the discharge of any pollutants into the waters of the state		Tennessee Water Quality Control Act of 1977 (TCA 69-3-101 *et seq.*);Stream Use Classifications (TDEC Rules, Chap. 1200-4-4)	Applicable to remedial actions resulting in discharges to EFPC
Within area affecting stream or river *-and-* presence of fish or wildlife resources	The effects of water-related projects on fish and wildlife resources must be considered. Action must be taken to prevent, mitigate, or compensate for project-related damages or losses to fish and wildlife resources. Consultation with the FWS[f] and/or appropriate state agency is recommended for actions that alter a resource.	Action which results in the control or structural modification of a natural stream or body of water	Fish and Wildlife Coordination Act (16 USC[e] 661 *et seq.*); 40 *CFR* 6.302(g)		Applicable to remedial activities which alter the stream flow of EFPC
Location encompassing aquatic ecosystem with dependent fish, wildlife, other aquatic life, or habitat	Degradation or destruction of aquatic ecosystems must be avoided to the extent possible. Discharges which cause or contribute to significant degradation of the water of such ecosystem are prohibited.	Action involving the discharge of dredge or fill material into aquatic ecosystem	Clean Water Act §404 40 *CFR* 230; 33 *CFR* 323		Applicable to remedial activities involving the discharge of dredge or fill material into EFPC

Table C.2 (continued)

Location characteristic(s)	Requirement(s)	Operating condition(s)	Federal citation(s)	TDEC[b] Rules, Chapter	Comments
Location encompassing a state-designated natural area	The scientific, scenic, recreational, and educational values of these areas must be preserved and steps taken to prevent impairment thereof.	Presence of Natural Areas as designated by TDEC		TCA 11-14-101 *et seq*	Applicable to remedial activities occurring within the DOE National Environmental Research Park (NERP) or impacting BMAP Research Areas
		Endangered, Threatened, or Rare Species			
Presence of endangered or threatened species *-or-* critical habitat of such species as designated in 50 *CFR* 17, 50 *CFR* 226, or 50 *CFR* 227	Actions that jeopardize species/habitat must be avoided or appropriate mitigation measures taken. Off-site actions that affect species/habitat require consultation with DOI[g], FWS, and/or state agencies, as appropriate, to ensure that proposed actions do not jeopardize the continued existence of the species or adversely modify or destroy critical habitat; consultation is also strongly recommended for on-site actions.	Action which is likely to jeopardize species or destroy or adversely modify critical habitat	Endangered Species Act of 1973 (16 USC 1531 *et seq.*); 50 *CFR* 402; 40 *CFR* 6.302(h); Fish and Wildlife Coordination Act (16 USC 661 *et seq.*)		Applicable if endangered species or critical habitat are discovered

Table C.2 (continued)

Location characteristic(s)	Requirement(s)	Operating condition(s)	Federal citation(s)	TDEC[b] Rules, Chapter	Comments
Presence of endangered or threatened species or critical habitat (see above citation) of same within an aquatic ecosystem as defined in 40 *CFR* 230.3(c)	Dredge or fill material shall not be discharged into an aquatic ecosystem if it would jeopardize such species or would likely result in the destruction or adverse modification of a critical habitat of the species.	Action involving discharge of dredge or fill material into aquatic ecosystem	Clean Water Act §404; 40 *CFR* 230.10(b); 33 *CFR* 323		Applicable if endangered species or critical habitat are discovered
Presence of Tennessee state-listed endangered or threatened animal species as created and amended pursuant to TCA 70-8-105	Protected species may not be taken, harassed, or destroyed, or their habitat destroyed. Certain exceptions may be allowed where necessary to alleviate property damage or to protect human health or safety. These exceptions require a permit if the remedial action or its attendant effects are off site.			Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act of 1974 (TCA 70-8-101 *et seq.*)	Applicable if endangered species or critical habitat are discovered
Presence of Tennessee state-listed species "in need of management"	No person may knowingly destroy the habitat of such species.	Destruction of habitat for such species		Tennessee Wildlife Resources Commission, Proclamation 86-29 (1991)	Applicable if species in need of management are discovered

Table C.2 (continued)

Location characteristic(s)	Requirement(s)	Operating condition(s)	Federal citation(s)	TDEC[b] Rules, Chapter	Comments
Archaeological or Historic Resources					
Presence of archaeological resources on public land	Steps must be taken to protect archaeological resources and sites.	Action which would impact resource	Archaeological Resources Recovery Act of 1979 (16 USC 470aa-ll); 43 *CFR* 7		Applicable if prehistoric, historic, or archaeological data are uncovered during remedial activities
Presence of archaeologic or historic resources	The Secretary of Interior must be advised of the presence of the data. A survey of affected areas for resources and data must be conducted and steps taken to recover, protect, and preserve data therefrom or request that DOI do so.	Action involving dam construction or other alteration of terrain which might cause irreparable loss or destruction of significant scientific, prehistoric, historic, or archaeologic data	Archaeological and Historic Preservation Act (16 USC 469a-c); 40 *CFR* 6.301		Applicable if prehistoric, historic, or archaeological data are uncovered during remedial activities
Cemetery located on property within Tennessee	Destruction or degradation of property in a graveyard or cemetery is prohibited.			Tennessee General Cemetery Act of 1968 (TCA 46-1-101 *et seq.*)	Applicable if remedial activities will impact a cemetery

[a]EFPC = East Fork Poplar Creek.
[b]TDEC = Tennessee Department of Environment and Conservation, Rules, unless otherwise noted.
[c]*CFR* = Code of Federal Regulations.
[d]TCA = Tennessee Code Annotated.
[e]USC = United States Code.
[f]FWS = Fish and Wildlife Service.
[g]DOI = Department of Interior.

Table C.3. Chemical-, radionuclide-, and action-specific ARARs and TBC[a] guidance for the No Action alternative at EFPC[b]

Actions	Requirements	Prerequisites	Federal citation	TDEC[c] Rules, Chapter	Comments
		Chemical-specific			
	Compliance with TDEC ambient water quality criteria	Criterion continuous concentration for mercury >0.012 μg/L		1200-4-3	Applicable for ambient water quality
	Comply with established primary and secondary drinking water standards.	Surface water or groundwater exceeds MCLs or MCLGs.	Safe Drinking Water Act 40 *CFR* 141	Chapter 1200-5-1	May be considered relevant and appropriate if surface water or groundwater is used as a drinking water source.
		Radionuclide-specific			
Protection of the general public from all sources of radiation	The general public must not receive an effective dose equivalent >100 mrem/year	Dose received by the general public from all sources of radiation exposure from routine activities, including remedial action, at a DOE facility	DOE Order 5400.5		TBC guidance for areas that contain low-level waste
	The basic dose limit for exposure to residual radioactive material is an effective dose equivalent of 100 mrem/year	Cleanup of residual radioactive material and management of resulting wastes	DOE Order 5400.5		TBC guidance for areas that contain low-level waste
	All releases of radioactive material must be "as low as reasonably achievable" (ALARA)	Releases of radioactive material from DOE activities	DOE Order 5400.5		TBC guidance for areas that contain low-level waste

Actions	Requirements	Prerequisites	Federal citation	TDEC[c] Rules, Chapter	Comments
		Location-specific			
Protection of waters of the state	To abate existing pollution of the waters of Tennessee, to reclaim polluted waters, to prevent the future pollution of such waters, and to plan for the future use of such waters in an unpolluted state	Pollution of waters of the state		Tennessee Code Annotated 69-3-102(b)	Applicable for contamination in EFPC and surrounding floodplains
		Action-specific			
	None				

[a]TBC = "to be considered" guidance.
[b]EFPC = East Fork Poplar Creek.
[c]TDEC = Tennessee Department of Environment and Conservation, unless otherwise noted.

Table C.4. Chemical-, radionuclide-, and action-specific ARARs and TBC[a] guidance for general activities for all alternatives at EFPC[b]

Actions	Requirements	Prerequisites	Federal citation	TDEC[c] Rules, Chapter	Comments
		Chemical-specific			
Direct discharge to surface water	Compliance with TDEC ambient water quality criteria	Discharges of effluents to surface water bodies		1200-4-3	Applicable to discharges to EFPC from decontamination procedures
		Radionuclide-specific			
Protection of the general public from all sources of radiation	The general public must not receive an effective dose equivalent >100 mrem/year	Dose received by the general public from all sources of radiation exposure from routine activities, including remedial action, at a DOE[d] facility	DOE Order 5400.5		TBC for remedial activities at a DOE facility
	The basic dose limits for exposure to residual radioactive material is an effective dose equivalent of 100 mrem/year	Cleanup of residual radioactive material and management of resulting wastes	DOE Order 5400.5		TBC for remedial activities at a DOE facility
	All releases of radioactive material must be "as low as reasonably achievable" (ALARA)	Releases of radioactive material from DOE activities	DOE Order 5400.5		TBC for remedial activities at a DOE facility
	Compliance with derived concentration guides (DCGs)	Discharge of liquid waste containing radionuclides to surface water	DOE Order 5400.5(II)		TBC guidance for discharges to EFPC from decontamination procedures
	The absorbed dose to native aquatic organisms shall not exceed 1 rad/d	Discharges of liquid waste containing radionuclides to natural water bodies	DOE Order 5400.5(II)		TBC guidance for discharges to EFPC from decontamination procedures
	Releases to the atmosphere must not exceed the NESHAP[e] of 10 mrem/year	Emissions of radionuclides to ambient air from DOE facilities	40 *CFR*[g] 61.92		Applicable for emissions from DOE facilities, the LTTD[f] unit, or remedial activities

Table C.4 (continued)

Actions	Requirements	Prerequisites	Federal citation	TDEC[c] Rules, Chapter	Comments
		Action-specific			
Construction/ Excavation	Reasonable precautions must be taken to prevent particulate matter from becoming airborne.	Handling or transporting of any materials		1200-3-8-.01	Applicable for construction activities (building roads, site grading, clearing of vegetation, soil removal, etc.
	Fugitive dust may not be emitted as visible emissions beyond property boundary lines for >5 min/h or 20 min/d.	Handling or transporting of any materials		1200-3-8-.01	Applicable on DOE property for emissions released during construction activities.
	Compliance with local zoning requirements or construction codes may be required.	Construction activities occurring on public property			Potentially applicable
Construction of roads	Discharges are exempt from regulation under CWA[h] §404 if such roads are constructed in accordance with best management practices (BMP), including: • all roads, temporary or permanent, shall be located sufficiently far from streams or other water bodies (except for portions of roads that must cross water bodies) to minimize discharges of dredge or fill material into waters of the U.S.;	Discharge of fill material resulting from construction of farm roads, forest roads, or temporary roads for moving mining equipment into waters of the U.S.[i]	33 *CFR* 323.4		Applicable for roads built on the EFPC floodplain

Table C.4 (continued)

Actions	Requirements	Prerequisites	Federal citation	TDEC[c] Rules, Chapter	Comments
	• the road shall be bridged, culverted, or otherwise designed to prevent the restriction of expected flood flows; • the fill shall be properly stabilized and maintained during and following construction to prevent erosion; • vegetative disturbance in waters of the U.S. shall be kept at a minimum; • the design, construction, and maintenance of the road crossing shall not disrupt the migration or other movement of those species of aquatic life inhabiting the water body; • borrow material shall be taken from upland sources wherever feasible; • discharges into wetlands shall be avoided if practical alternatives exist; • the discharge shall consist of suitable material free from toxic pollutants in toxic amounts;				

Table C.4 (continued)

Actions	Requirements	Prerequisites	Federal citation	TDEC[c] Rules, Chapter	Comments
	• all temporary fills shall be removed in their entirety and the area restored to its original elevation.				
Direct discharge to surface water body	Must meet CWA federal and state water quality criteria for the designated use	Direct discharge to surface water	40 *CFR* 122.44(d)	1200-4-3	Applicable for direct discharge of decontamination waters into EFPC
	Must meet NPDES[j] permit limitations for permitted outfalls at EFPC	Direct discharge to surface water	40 *CFR* 122.44	1200-4-5	Applicable for point source discharge at permitted outfalls
	Compliance with DCGs	Discharge of liquid waste containing radionuclides to surface water	DOE Order 5400.5(II)		TBC guidance for discharges to EFPC from decontamination procedures
Discharge of dredge and fill material to navigable waters	The four conditions that must be satisfied before dredge and fill is an allowable alternative are:	Specifications for disposal sites for discharges of dredge and fill material into waters of the U.S. to be used for permitting purposes	40 *CFR* 230.10		Applicable although not necessary to secure permits. Under CERCLA, only substantive provisions apply.
	• There must be no practicable alternative.				
	• Discharge of dredge or fill material must not cause a violation of state water quality standards, violate any applicable toxic effluent standards, jeopardize an endangered species, or injure a marine sanctuary.				

Table C.4 (continued)

Actions	Requirements	Prerequisites	Federal citation	TDEC[c] Rules, Chapter	Comments
	• No discharge shall be permitted that will cause or contribute to significant degradation of the water. • Appropriate steps to minimize adverse effects must be taken.				
Disposal of soils, treatment residuals, and other generated wastes	Attain land disposal treatment standards.	Placement of RCRA[k] hazardous waste in a landfill or waste pile	40 *CFR* 268 (Subpart D)	1200-1-11-.10 (3)	Applicable if excavated soils test as RCRA-characteristic waste
	Dispose of wastes in a RCRA Subtitle C permitted hazardous waste disposal facility.	Placement of RCRA hazardous waste that complies with the land disposal restrictions	40 *CFR* 264	1200-1-11-.07	Applicable if excavated soils test as RCRA-characteristic waste
	Dispose of wastes in a RCRA Subtitle D permitted solid waste disposal facility.	Placement of solid waste not classified as RCRA hazardous waste	40 *CFR* 258	1200-1-7-.01 *et seq.*	Applicable if excavated soils do not test as RCRA-characteristic waste but contain CERCLA[l] pollutants or contaminants
	Dispose of wastes in a RCRA-permitted mixed waste facility or in a low-level waste (LLW) storage facility according to DOE and MMES[m] Waste Management procedures	Placement of low-level radioactive waste or mixed waste	40 *CFR* 268; DOE-EPA[n] Federal Facilities Compliance Agreement for Mixed Waste; DOE Order 5820.2A, Chap. III(i)		Applicable if excavated soils contain RCRA-characteristic waste and/or LLW

Table C.4 (continued)

Actions	Requirements	Prerequisites	Federal citation	TDEC[c] Rules, Chapter	Comments
	No shipments of wastes containing LLW from a DOE facility off-site to a disposal facility	Shipments of mixed waste	DOE Moratorium on LLW shipments		TBC for off-site shipments of contaminated soil
Streambed modifications	Must comply with the substantive requirements of the TDEC Aquatic Resources Alteration Permit (ARAP) process	General permits exist for streambed modifications involving alteration of wet weather conveyances, minor road crossings, bank stabilization, sand and gravel dredging, and debris removal.		1200-4-7	Applicable for any modifications to EFPC
Surface water control	Implement good site planning and best management practices to control storm water discharges	Construction activities at sites involving disturbance of ≥5 acres total land	40 *CFR* 122	69-3-108 *et seq.*	Applicable for stormwater discharges during construction activities that impact ≥5 acres; relevant and appropriate for impacts on <5 acres
	Consultation with TDEC is required to ensure compliance with the substantive requirements of the permitting process. These include: • submit a "notice of intent" (NOI) 15 days before construction activities begin; • prepare a site erosion control plan;	Stormwater discharges associated with construction activity including clearing, grading, and excavation that result in a disturbance of ≥5 acres total land	40 *CFR* 122	1200-4-10-.05	Applicable for stormwater discharges during construction activities that impact ≥5 acres; relevant and appropriate for impacts on <5 acres

Table C.4 (continued)

Actions	Requirements	Prerequisites	Federal citation	TDEC[c] Rules, Chapter	Comments
	• describe permanent measures for stormwater control; • perform weekly erosion control inspections and maintenance and keep a log book of these activities. Mandatory construction site practices include sequencing of large construction activities to minimize impact.				
Transportation of soils	Waste must be packaged and transported according to RCRA, DOT[a], and DOE requirements.	Transportation of RCRA waste and/or radioactive waste across public highways	40 *CFR* 262; 49 *CFR* 175, 178, and 179; DOE Order 5480.3		Applicable for transportation in commerce of soils contaminated with RCRA-characteristic waste and/or LLW; DOE Order, TBC
Treatment of decontamination water	**See Table C.7 for ARARs for miscellaneous treatment units**				
Waste pile	Pile must be managed to control wind erosion.	Storage of particulate RCRA hazardous waste in a waste pile	40 *CFR* 264.251(j)	1200-1-11-.06 (12)(b)	Applicable for storage of soils contaminated with RCRA-characteristic waste prior to transportation; relevant and appropriate for storage of soils contaminated with CERCLA pollutants or contaminants

Table C.4 (continued)

Actions	Requirements	Prerequisites	Federal citation	TDEC[c] Rules, Chapter	Comments
	Design and operating requirements include liners and leachate and runon/runoff control systems.	Storage of RCRA hazardous waste in a waste pile			Applicable for storage of soils contaminated with RCRA-characteristic waste prior to transportation; relevant and appropriate for storage of soils contaminated with CERCLA pollutants or contaminants
	Operators are exempt from the above design and operating requirements if the waste pile is under a structure that provides protection from precipitation so that neither runoff nor leachate is generated provided that: • liquids or materials containing free liquids are not placed in the pile; • the pile is protected from surface water run-on by the structure or in some other manner; • the pile is designed and operated to control dispersal by wind, where necessary, by means other than wetting; and	Storage of RCRA hazardous waste in a waste pile	40 *CFR* 264.251(a)	1200-1-11-.06 (12)(b)	Applicable for storage of soils contaminated with RCRA-characteristic waste prior to transportation; relevant and appropriate for storage of soils contaminated with CERCLA pollutants or contaminants

Table C.4 (continued)

Actions	Requirements	Prerequisites	Federal citation	TDEC[c] Rules, Chapter	Comments
	• the pile will not generate leachate through decomposition or other reactions.				
	A further exemption is available if the EPA Regional Administrator finds that alternate design and operating practices, together with location characteristics, will prevent the migration of constituents into groundwater or surface water at any future time	Storage of RCRA hazardous waste in a waste pile	40 *CFR* 264.251(b)	1200-1-11-.06 (12)(b)	Applicable for storage of soils contaminated with RCRA-characteristic waste prior to transportation; relevant and appropriate for storage of soils contaminated with CERCLA pollutants or contaminants

[a]TBC = "to-be-considered" guidance.
[b]EFPC = East Fork Poplar Creek.
[c]TDEC = Tennessee Department of Environment and Conservation.
[d]DOE = U.S. Department of Energy.
[e]NESHAP = National Emission Standard for Hazardous Air Pollutants.
[f]LTTD = low-temperature thermal desorption.
[g]*CFR* = *Code of Federal Regulations.*
[h]CWA = Clean Water Act.
[i]The term "Waters of the U.S." is defined broadly in 40 *CFR* 122.2 and includes essentially any water body and wetland.
[j]NPDES = National Pollutant Discharge Elimination System.
[k]RCRA = Resource Conservation and Recovery Act.
[l]CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
[m]MMES = Martin Marietta Energy Systems, Inc.
[n]EPA = U.S. Environmental Protection Agency.
[o]DOT = U.S. Department of Transportation.

Table C.5. Chemical-, radionuclide-, and action-specific ARARs and TBC[a] guidance for institutional controls at EFPC[b]

Actions	Requirements	Prerequisites	Federal citation	TDEC[c] Rules, Chapter	Comments
Chemical-specific	**See Table C.4**				
Radionuclide-specific	**See Table C.4**				
Action-specific	**See Table C.4**				
Institutional controls	Controls include, but are not limited to: periodic monitoring, as appropriate; appropriate shielding; physical barriers to prevent access; appropriate radiological safety measures to ensure protection during activities at the site.	Interim management of residual radioactive material above guidelines left in inaccessible locations	DOE[d] Order 5400.5(IV)(6)(c)		TBC for LLW[e] left in place
	Other controls may be used for interim management such as those specified in 40 *CFR*[f] 192: • Passive controls include thick earthen covers, rock covers, massive earth and rock dikes, burial below grade, and moving piles out of locations highly subject to erosion, such as unstable river banks; • Active controls include fences, warning signs, restrictions on land use, inspection and repair of coverings, temporary dikes, and drainage courses.	Interim and long-term management of residual radioactive material above decontamination guidelines	DOE Order 5400.5(IV)(6)(c)		TBC for LLW left in place

[a]TBC = "to-be-considered" guidance.
[b]EFPC = East Fork Poplar Creek.
[c]TDEC = Tennessee Department of Environment and Conservation.
[d]DOE = U. S. Department of Energy.
[e]LLW = low level waste.
[f]*CFR* = *Code of Federal Regulations.*

Table C.6. Chemical-, radionuclide-, and action-specific ARARs and TBC[a] guidance for containment at EFPC[b]

Actions	Requirements	Prerequisites	Federal citation	TDEC[c] Rules, Chapter	Comments
Chemical-specific	**See Table C.4**				
Radionuclide-specific	**See Table C.4**				
Location-specific	**See Table C.2**				
Action-specific					
Containment (closure with waste in place)	Placement of a cap over waste (e.g., closing a landfill or closing a waste pile as a landfill) requires a cover designed and constructed to:	RCRA[d] hazardous waste left in place before closure	40 *CFR*[e] 264.310(a)	1200-1-11-.06(14)(k)	Applicable for closure of CERCLA[f] sites containing pollutants or contaminants left in place
	• provide long-term minimization of migration of liquids through the capped area;				
	• function with minimum maintenance;				
	• promote drainage and minimize erosion or abrasion of the cover;				
	• accommodate settling and subsidence so that the cover's integrity is maintained; and				
	• have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.	May not be relevant and appropriate in instances where wastes are immobile in soil	55 *FR* 8763, March 8, 1990		
Construction/ Excavation	**See Table C.4**				
Construction of roads	**See Table C.4**				

Table C.6 (continued)

Actions	Requirements	Prerequisites	Federal citation	TDEC[c] Rules, Chapter	Comments
Disposal of soils	**See Table C.4**				
Postclosure care	Restrict postclosure use of property as necessary to prevent damage to the cover.	Final closure of a RCRA landfill or waste pile with some hazardous materials or residues left in place	40 *CFR* 264.117(c)	1200-1-11-.06(7)(h)	Applicable following closure of a CERCLA site containing pollutants or contaminants left in place
	Postclosure care must: • maintain the integrity and effectiveness of the final cover, including making repairs to the cap as necessary to correct the effects of settling, subsidence, erosion, and other events; • prevent runon and runoff from erosion or other damage to the final cover.		40 *CFR* 264.310(b)	1200-1-11-.06(11)(i) 1200-1-11-.06(14)(k)	
Streambed modifications	**See Table C.4**				
Surface water control	**See Table C.4**				
Transportation of soils	**See Table C.4**				
Waste pile	**See Table C.4**				

[a]TBC = "to-be-considered" guidance.
[b]EFPC = East Fork Poplar Creek.
[c]TDEC = Tennessee Department of Environment and Conservation.
[d]RCRA = Resource Conservation and Recovery Act.
[e]*CFR* = *Code of Federal Regulations*.
[f]CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act

Table C.7. Chemical-, radionuclide-, and action-specific ARARs and TBC[a] guidance for treatment of contaminated EFPC[b] soils

Actions	Requirements	Prerequisites	Federal citation	TDEC[c] Rules, Chapter	Comments
Chemical-specific	**See Table C.4**				
Radionuclide-specific	**See Table C.4**				
Location-specific	**See Table C.2**				
Action-specific	**See Table C.4**				
Control of air emissions	Must comply with the substantive requirements of the TDEC Office of Air Pollution Control construction and operating permit process	Construction of new air contaminant source		1200-3-9-.01 *et seq.*	Applicable for emissions to air from the LTTD[d] unit or the decontamination water treatment unit
	Control emissions of hazardous and nonhazardous air pollutants	Construction of new air contaminant source		1200-3-9-.01 *et seq.*	Applicable for emissions to air from the LTTD unit or the decontamination water treatment unit
	Releases to the atmosphere must not exceed the NESHAP[e] of 10 mrem/year	Emissions of radionuclides to ambient air from DOE[f] facilities	40 *CFR*[g] 61.92		Applicable for emissions from DOE facilities, the LTTD unit, the decontamination water treatment unit or other remedial activities
Construction/ Excavation	**See Table C.4**				
Construction of roads	**See Table C.4**				
Disposal of soils	**See Table C.4**				
Streambed modifications	**See Table C.4**				
Surface water control	**See Table C.4**				
Transportation of soils	**See Table C.4**				

Table C.7 (continued)

Actions	Requirements	Prerequisites	Federal citation	TDEC[c] Rules, Chapter	Comments
Treatment in a miscellaneous unit	Design and operating standards for units in which hazardous waste is treated must ensure protection of human health and the environment.		40 *CFR* 264.601	1200-1-11-.06 (19)(b)	Applicable for soil containing RCRA[h]-characteristic waste; relevant and appropriate for treatment of CERCLA[i] waste
	Prevention of any releases that may have adverse effects on human health or the environment due to migration of waste constituents		40 *CFR* 264.601	1200-1-11-.06 (19)(b)	Applicable for soil containing RCRA-characteristic waste; relevant and appropriate for treatment of CERCLA waste
	Specific considerations must be made to prevent adverse effects in:				
	• the groundwater or subsurface environment;		40 *CFR* 264.601(a)		
	• surface water, or wetlands, or the soil surface; or		40 *CFR* 264.601(b)		
	• the air.		40 *CFR* 264.601(c)		
Waste pile	**See Table C.4**				

[a]TBC = "to-be-considered" guidance.
[b]EFPC = East Fork Poplar Creek.
[c]TDEC = Tennessee Department of Environment and Conservation.
[d]LTTD = low-temperature thermal desorption.
[e]NESHAP = National Emission Standard for Hazardous Air Pollutants.
[f]DOE = Department of Energy.
[g]*CFR* = *Code of Federal Regulations*.
[h]RCRA = Resource Conservation and Recovery Act.
[i]CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act

Table C.8. Compliance with ARARs for EFPC

Requirement	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Chemical-specific							
Compliance with TDEC 1200-4-3 ambient water quality criteria	would meet	would meet	would meet	would meet	would meet	would meet	would meet
Radionuclide-specific							
Protection of the general public from all sources of radiation. DOE Order 5400.5	would meet	would meet	would meet	would meet	would meet	would meet	would meet
Action-specific							
Capping (closure with waste in place). 40 *CFR* 264.310(a). 55 *FR* 8763, March 8, 1990	NA	would meet	NA	would meet	NA	would meet	would meet
Construction/Excavation. Land disposal restrictions (LDRs) 40 *CFR* 268 (Subpart D) [TDEC 1200-1-11-40(3)]. Control of fugitive dust (TDEC 1200-3-8-.01), local zoning requirements.	NA	would meet	would meet	would meet	would meet	would meet	would meet
Construction of roads. 33 *CFR* 323.4	NA	would meet	would meet	would meet	would meet	would meet	would meet
Disposal of soils. LDR treatment standards 40 *CFR* 268 (Subpart D), TDEC 1200-1-11-.10(3) and TDEC 1200-1-7-.01 et seq. Disposal of wastes in RCRA permitted or solid waste disposal facility 40 *CFR* 268; DOE-EPA[i] Federal Facilities Compliance Agreement for Mixed Waste; DOE Order 5820.2A, Chap. III(i).	NA	would meet	would meet	would meet	would meet	would meet	NA
Institutional controls. DOE Order 5400.5(IV)(6)(c)	NA	would meet	would meet	would meet	would meet	would meet	would meet
Postclosure care. 40 *CFR* 264.117(c), TDEC 1200-1-11-.06-7(h), 40 *CFR* 264.310(b), TDEC 1200-1-11-.06-11(i) and 1200-1-11-.06-14(k).	NA	would meet	would meet	would meet	would meet	would meet	NA
Streambed modifications	NA	would meet	would meet	would meet	would meet	would meet	would meet
Surface water control. 40 *CFR* 122, TDEC 69-3-108-et seq. and 1200-4-10-.05	NA	would meet	would meet	would meet	would meet	would meet	would meet

Table C.8 (continued)

Requirement	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Transportation of soils. 40 *CFR* 262; 49 *CFR* 175, 178, and 179; DOE Order 5480.3	NA	would meet	would meet	would meet	would meet	would meet	NA
Waste pile. 40 *CFR* 264.251(a,b,f), TDEC 1200-1-11-.06(12)(b).	NA	would meet	would meet	would meet	would meet	would meet	NA
Treatment. 40 *CFR* 264.601, TDEC 1200-1-11-.06 (19)(b)	NA	NA	NA	would meet	would meet	NA	NA
Wetlands							
Protection of wetlands Executive Order 11990; 40 *CFR* 6.302(a); 40 *CFR* 6, Appendix A; 10 *CFR* 1022	NA	would meet	would meet	would meet	would meet	would meet	would meet
Discharge of dredge or fill into wetlands. Clean Water Act §404; 40 *CFR* 230; 33 *CFR* 323	NA	would meet	would meet	would meet	would meet	would meet	would meet
Floodplains							
Protection of floodplains. Executive Order (EO) 11988; 40 *CFR* 6.302(b); 40 *CFR* 6 (Appendix A); 10 *CFR* 1022	NA	would meet	would meet	would meet	would meet	would meet	would meet
Aquatic Resources and Natural Areas							
Protection within waters of the state of Tennessee. Tennessee Water Quality Control Act of 1977 (TCA 69-3-102 (b) *et seq.*); Stream Use Classifications (TDEC[c] Rules - Chap. 1200-4-4)	would not meet	would meet	would meet	would meet	would meet	would meet	would meet
Protection of stream or river *-and-* presence of fish or wildlife resources. Fish and Wildlife Coordination Act (16 USC 661 *et seq.*) 40 *CFR* 6.302(g).	would not meet	would meet	would meet	would meet	would meet	would meet	would meet
Protection of aquatic ecosystem with dependent fish, wildlife, other aquatic life, or habitat. Clean Water Act §404. 40 *CFR* 230; 33 *CFR* 323	would not meet	would meet	would meet	would meet	would meet	would meet	would meet
Protection of a state-designated natural area. TCA 11-14-101 *et seq.*	NA	would meet	would meet	would meet	would meet	would meet	would meet

93-008PSQ/081594

Table C.8 (continued)

Requirement	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Endangered, Threatened, or Rare Species							
Protection of endangered or threatened species *-or-* critical habitat of such species as designated in 50 *CFR* 17, 50 *CFR* 226, or 50 *CFR* 227. Endangered Species Act of 1973 (16 USC 1531 *et seq.*); 50 *CFR* 402; 40 *CFR* 6.302(h); Fish and Wildlife Coordination Act (16 USC 661 *et seq.*)	would meet	would meet	would meet	would meet	would meet	would meet	would meet
Discharge of dredge or fill into an aquatic ecosystem with presence of endangered or threatened species or critical habitat (see above citation). Clean Water Act §404; 40 *CFR* 230.10(b); 33 *CFR* 323	NA	would meet	would meet	would meet	would meet	would meet	would meet
Protection of Tennessee state-listed endangered or threatened animal species as created and amended pursuant to TCA 70-8-105. Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act of 1974 (TCA 70-8-101 *et seq.*)	would meet	would meet	would meet	would meet	would meet	would meet	would meet
Protection of Tennessee state-listed species "in need of management." Tennessee Wildlife Resources Commission, Proclamation 86-29 (1991)	would meet	would meet	would meet	would meet	would meet	would meet	would meet
Archaeologic and Historic Resources							
Protection of archaeological resources on public land. Archaeological Resources Recovery Act of 1979 (16 USC 470aa-ll) 43 *CFR* 7	NA	would meet	would meet	would meet	would meet	would meet	would meet
Protection of archaeologic or historic resources. Archaeological and Historic Preservation Act (16 USC 469a-c). 40 *CFR* 6.301	NA	would meet	would meet	would meet	would meet	would meet	would meet
Protection of cemetery located on property within Tennessee. Tennessee General Cemetery Act of 1968 (TGCA 46-1-101 *et seq.*)	NA	would meet	would meet	would meet	would meet	would meet	would meet

APPENDIX D

COST

CONTENTS

TABLES . . . . . D-v
FIGURES . . . . . D-v
ACRONYMS . . . . . D-vii

D.1 GENERAL COST INFORMATION D-1
D.1.1 Purpose D-1
D.1.2 Background D-1
D.1.3 Organization of the Appendix D-1
D.1.4 Methodology D-2
D.1.5 Assumptions D-2

D.2 COST COMPONENTS D-4
D.2.1 Capital Costs D-4
D.2.2 O&M Costs D-14

D.3 LIFE CYCLE COST (PRESENT WORTH) ANALYSIS D-19

D.4 SITEWIDE ALTERNATIVE-SPECIFIC COSTS D-19
D.4.1 No Action (SWA 1) D-19
D.4.2 Excavation, Soil Cover, and Direct Disposal (SWAs 2) D-20
D.4.3 Excavation and Direct Disposal (SWA 3) D-21
D.4.4 Excavation, Soil Cover, Treatment, and Beneficial Reuse (SWA 4) . . D-21
D.4.5 Excavation, Treatment, and Beneficial Reuse (SWA 5) D-22
D.4.6 Land Acquisition, Soil Cover, and Fencing (SWA 6) D-23
D.4.7 Land Acquisition, Excavation, and Institutional Controls (SWA 7) . . D-23
D.4.8 Summary of Sitewide Alternatives Costs D-24

D.5 MANPOWER AND RESOURCE NEEDS D-25

D.6 SENSITIVITY ANALYSIS D-26
D.6.1 Sensitivity Analysis Approach D-26
D.6.2 Selection of Key Factors D-27
D.6.3 Results of Sensitivity Analysis D-28

REFERENCES D-29

TABLES

D.1 Breakdown of capital cost estimate for sitewide alternatives for EFPC FS D-33

D.2 Normalized equipment rates for excavation and backfill D-35

D.3 Rates for earth-moving construction crews D-36

D.4 Construction unit costs D-37

D.5 Summary of annual O&M costs for sitewide alternatives D-40

D.6 Summary of present worth analysis for the EFPC site D-41

D.7 Summary of local manpower resource needs, timetable, and direct capital cost estimates for sitewide alternatives D-42

D.8 Sensitivity analysis for selected sitewide alternatives D-48

FIGURES

D.1 Sitewide alternative cost estimate for EFPC site D-51

D.2 Sitewide alternative remediation time frame for the EFPC site D-52

ACRONYMS

BMAP	Biological Monitoring and Abatement Program
DOE	U.S. Department of Energy
EFPC	East Fork Poplar Creek
EPA	U.S. Environmental Protection Agency
FS	feasibility study
FTE	full-time equivalent
G&A	General Administration
GPS	General Plant Services
HDPE	high-density polyethylene
LTTD	low-temperature thermal desorption
MWTF	mixed-waste treatment facility
O&M	operation and maintenance
PAH	polyaromatic hydrocarbon
RU	remedial unit
S&M	surveillance and maintenance
SWA	sitewide alternative
TCLP	toxicity characteristic leaching procedure

APPENDIX D

COST

D.1 GENERAL COST INFORMATION

D.1.1 Purpose

The purpose of this appendix is to provide additional backup information for the cost analysis portion (Sect. 5) of the East Fork Poplar Creek (EFPC) Sewer Line Beltway feasibility study (FS).

D.1.2 Background

The cost analysis and evaluation presented in this appendix follow the guidelines of the U.S. Environmental Protection Agency (EPA) *Remedial Action Costing Procedures Manual* (EPA 1987). Cost data were obtained from *Means Heavy Construction Cost Data*, 7th annual edition (Means 1993). The cost evaluation process is documented by a calculation package that includes background information, assumptions, hand calculations, spreadsheet calculations, and a summary of the cost calculation results (SAIC 1994). This calculation document was prepared, reviewed, and approved for issue in accordance with Quality Assurance Administrative Procedure 3.5, "Calculations for Environmental Studies." Data available at the FS stage are very general; therefore, costs at the FS stage are estimated within the range of +50% to -30% of the cost estimated at the remedial design stage.

D.1.3 Organization of the Appendix

Section D.1 presents general information: the purpose of this appendix (Sect. D.1.1), background (Sect. D.1.2), the methodology employed to develop the estimates (Sect. D.1.4), and the assumptions used to develop costs (Sect. D.1.5).

The two primary components of the cost estimate are capital costs and operation and maintenance (O&M) costs. Cost components common to all alternatives are presented in Sect. D.2; capital costs are presented in Sect. D.2.1; and O&M costs are presented in Sect. D.2.2.

Because alternatives differ in the approach to remediation, it is necessary to compare them over an extended period of time. This is accomplished by performing a life cycle (present worth) analysis for each alternative (described in Sect. D.3). Capital costs and O&M costs are combined on a year-to-year basis using present worth analysis to arrive at a life cycle cost. A period of 30 years has been selected for life cycle (present worth) analysis; the actual length of the remediation would depend on numerous factors and would be determined in the Record of Decision.

Costs for the seven sitewide alternatives are presented in Sect. D.4. A short description of each alternative is followed by the capital and O&M cost components and the life cycle cost analysis.

The derivation of the waste volumes, breakdowns of unit cost per volume of waste, and local manpower and resource needs that were used in the economic impact evaluation are presented in Sect. D.5. The sensitivity analysis, conducted in accordance with EPA guidance, is presented in Sect. D.6.

D.1.4 Methodology

The cost-estimating procedure and worksheets were prepared in accordance with EPA's remedial action costing procedures manual (EPA 1987), which provides procedures and guidelines for estimating capital costs, present worth analyses, and sensitivity analyses. Lotus 1-2-3 spreadsheets were developed, instead of sophisticated cost-estimating programs, to emulate the worksheets provided in the manual because data available at the FS stage are very general. Unit cost information was entered into a single spreadsheet so that other spreadsheets could be related to this master file. Direct cost estimates were compiled for each remedial unit (RU) according to remedial action (i.e., excavation and backfill, soil cover, site development, and building services) and were summarized in tabular form. The remedial action alternatives for each RU were combined to develop sitewide cost estimates, which included direct and indirect capital costs. Next, the present worth of each sitewide alternative was analyzed; this analysis included O&M costs and thus formed the basis of the final estimated cost for each sitewide alternative. Quality Assurance Administrative Procedure 19.2 requires that computer software used in analyses be verified; each sheet generated by Lotus 1-2-3, the computer application, was checked individually to fulfill this requirement.

D.1.5 Assumptions

To estimate the cost of any remedial alternative, it is necessary to make assumptions concerning a number of factors. General and specific assumptions are presented below. Because of the preliminary nature of the alternative development, costs estimates are necessarily broad. The accepted range of accuracy is +50% to -30%. This is a very wide spread and demonstrates that the degree of alternative development is only to the level of detail necessary to compare among alternatives. Following selection of a preferred alternative in the Proposed Plan and issuance of the Record of Decision, and during the early stages of the remedial design, the cost estimate of the preferred alternative will be developed to a much greater level of accuracy by the remedial design contractor.

General assumptions are:

- Volume reduction of treated soil = 10%.
- Topsoil delivered from off site = 0.5 ft.
- Topsoil, clay, and common earth material costs are based on Means (1993), even though the borrow site is located on the Oak Ridge Reservation.
- Percent swell of excavated soil = 20%.
- Volume of backfilled soil = ex situ volume.

- Based on the EFPC remedial investigation (RI) report, the dry density of in situ soil = 85 lb/ft^3.
- In situ soil moisture content = 40%.
- Wet soil density = 110 lb/ft^3 (in situ) = 92 lb/ft^3 (ex situ).
- Excavated soil is dried to 20% moisture content before treatment/disposal; therefore, the process soil density = 85 lb/ft^3 (ex situ).
- Equipment unit costs are based on monthly rental rates.
- Equipment utilization in contaminated areas = 6 h/d for light equipment and 4 h/d for heavy equipment.
- Equipment utilization in uncontaminated areas = 8 h/d for light equipment and 6 h/d for heavy equipment.
- Equipment operator = 8 h/d per item of equipment; therefore, utilization factor = 1.33 for light equipment and 2.00 for heavy equipment.
- Dump truck capacity = 16 tons or 12 yd^3.
- Soil cover cap is high-density polyethylene (HDPE) net liner under 1 ft of borrow soil and 0.5 ft topsoil.
- Work week consists of five 8-h days (40 h/week), 52 weeks per year.
- Construction crew rates are based on hourly rate with overhead and profit.
- Equipment rates are based on monthly rental rates plus hourly fuel and maintenance costs.
- Hourly rental rates for heavy equipment for contaminated soil are based on 80 h/month; rates for light equipment, 120 h/month.
- Hourly rental rates for heavy equipment for uncontaminated soil are based on 120 h/month; rates for light equipment, 160 h/month.
- Material costs are based on bare costs plus 10% markup; equipment costs are bare costs plus 15% markup; labor costs are bare costs plus 50% overhead and profit (unless stated otherwise).
- Duration for excavation is based on a production rate of 500 tons/d, or 436 yd^3/d (ex situ) for the critical path of treatment.
- Production rate for soil cover = 200 yd^3/d.

- Certain construction activities can proceed concurrently, shortening the duration. Conversely, the duration of construction activities can be extended by weather-related delays. To accommodate this variance, the estimates cumulate (1) the preremediation construction activities for site development and building services, (2) the remediation activity of excavation or soil covering, and (3) the postremediation activity of site closure. Backfilling, treatment, and certain site development activities are assumed to be concurrent with excavation and/or soil cover activities. The equipment utilization factor accounts for equipment down-time, and lost-time for donning and doffing personal protective equipment.

- Interim institutional actions for surface water and sediments include legal restrictions (e.g., digging and fishing restrictions, periodic environmental monitoring). Costs associated with these interim actions are negligible but are assumed as an indirect cost (e.g., fees and permits). For institutional actions to limit access, it is assumed that a 6-ft-high chain-link fence topped with three strands of barbed wire would be erected between residential or agricultural properties and acquired properties on which soil covers would be placed.

D.2 COST COMPONENTS

The following section presents the cost components used to arrive at the estimated costs for the alternatives. There are two primary cost components; capital costs and O&M costs. Capital costs, presented in Sect. D.2.1, include direct and indirect costs associated with the construction-related activities of the alternative remedial action. This section also presents the general assumptions used to derive the costs. O&M costs, presented in Sect. D.2.2, cover nonconstruction activities performed to ensure the effectiveness of a remedial action and to protect human health and the environment. Alternative-specific assumptions are discussed in the sections that follow each alternative's cost development.

D.2.1 Capital Costs

Capital costs include both direct and indirect costs. A 35% contingency allowance is added to total direct and indirect costs to obtain a total capital cost. All cost are estimated in 1993 base year dollars. Based on EPA guidance (EPA 1987), the following is a breakdown of the capital cost summary:

Direct Capital Costs

1. Remediation Costs
   a. Equipment
   b. Labor
   c. Materials

2. Site Development
   a. Equipment
   b. Labor
   c. Materials

3. Building and Services
   a. Equipment
   b. Labor
   c. Materials

4. Equipment Costs
   a. Installation
   b. Purchase

5. Land and Relocation Costs

6. Disposal Costs
   a. Containerization
   b. Transportation
   c. Disposal Fee

TOTAL DIRECT COSTS

Indirect Capital Costs

1. Engineering and Design

2. Project/Construction Management

3. Independent Verification, Studies, and Assessments

4. Other Indirect Costs
   a. General Labor
   b. Sales Tax
   c. Fees/Permits
   d. Support Facilities
   e. Treatment Startup

TOTAL INDIRECT COSTS

TOTAL DIRECT AND INDIRECT COSTS
CONTINGENCY ALLOWANCE (35%)

TOTAL CAPITAL COSTS

Table D.1 summarizes capital costs in the format above for the EFPC sitewide alternatives. The subdivision of the capital costs are discussed in the following subsections.

D.2.1.1 Direct capital costs

Direct capital costs include equipment, labor, and materials needed to install or construct facilities for remedial actions. Construction costs include remedial action construction, site development, and building and services. Other direct costs include component equipment purchases, land and relocation of affected population, and disposal of waste materials. These individual direct cost components are further discussed in the following sections.

Remediation Costs

Remediation costs for the EFPC site include removing (excavating and backfilling), containing contamination (placing a soil cover), and implementing access restrictions (fencing, signs, and deed and use restrictions). Monitoring costs are included in O&M costs.

Excavation and Backfilling [sitewide alternatives (SWAs) 2, 3, 4, 5, 7]. Costs for excavation and backfilling, which would include restoring the properties to their preremedial action condition, are based on equipment and labor usage rates obtained from Means (1993) for the estimated volumes of contaminated soil. The excavation and backfilling criteria used in cost estimates for the various RUs are described below. When the alternative includes treatment (SWAs 4 and 5), dump trucks are used to haul treated backfill soil that has been acclimated with nutrients to promote the growth of vegetation.

Placing a Soil Cover (SWAs 2, 4, and 6). Soil cover costs would include placing 18 in. of clean soil over areas of contamination. The 18-in. soil cover (6 in. topsoil over 12 in. compacted clay) would be installed over a permeable HDPE net, which would act as an intrusion barrier to burrowing animals. The cover would extend ~12 ft beyond the area of contamination; the thickness would taper from 18 in. to 0 in. in this zone. To simplify the cost estimate, each capped area is assumed to be rectangular, to have a length four times its width, and to be bordered on one side of its length by EFPC.

Access Restrictions (SWAs 6 and 7). A 6-ft-high chain-link fence topped with 3 strands of barbed wire would be constructed along the border between acquired properties and both residential and agricultural properties to limit access to areas containing higher concentrations of mercury-contaminated soil. A 4-ft-wide path would be cleared to allow for the erection of the fence. Woody debris would be removed and disposed of at a construction landfill. For SWA 7, a fence would be erected around a special study area in Segment 1 to restrict access.

Excavation and containment costs are based on unit rates obtained from Means (1993) for the labor, equipment, and material required to excavate and backfill or cover the estimated volumes of contaminated soil. Table D.2 lists the normalized equipment rates; Table D.3 lists construction crew labor rates.

The contaminated soil volume estimates, from the Geographic Information System data base, are listed below:

RU	In situ (yd^3)	Ex situ (yd^3)	Surface area (yd^2)
Agricultural	0	0	0
Residential	32,800	39,400	57,900
Commercial	500	600	600
Other	12,200	14,700	19,600
DOE	8,500	10,200	9,800

The estimates assume that one crew with health and safety technicians, one foreman, and one oiler would be employed for the duration of the remedial project. Because of size limitations of the excavation sites, backhoes or gradalls are the only excavating machinery assumed to be used by the percent utilization shown below. A bobcat may be used, but cost estimates are based on the assumption that a backhoe would be used. A front-end loader would be used to load dump trucks for transport. Because production efficiency is affected by the limited surface areas and depths of contamination within the various RUs, the production efficiencies for excavation activities are assumed to be reduced by the average of these factors.

Example: The surface area of the residential RU is large; thus, no limitation, or 100% size production efficiency, can be assumed. However, the depth of contamination is shallow, and a 60% depth production efficiency is assumed. The combined efficiency is 80%.

Production efficiencies for excavation are listed below:

RU	Average depth (ft)	Production efficiency	Backhoe utilization	Gradall utilization
Agricultural	0	NA	NA	NA
Residential	1.70	80%	70%	30%
Commercial	2.67	70%	100%	0%
Other	1.87	75%	70%	30%
DOE	2.62	85%	100%	0%

NA = Not applicable.

The production rate for spreading and compacting backfill is assumed to be the same as that for excavation. Because of soil cover site size limitations, sheepsfoot rollers would be used to compact 1 ft of common earth, and backhoes would be used to spread 6 in. of topsoil.

Because of the limited surface area within the various RUs where mercury contamination exceeds 200 ppm, the production rates for soil cover activities are assumed to be reduced to the following efficiencies:

RU	Surface area (yd^2) > 200 ppm	Production efficiency
Agricultural	0	NA
Residential	57,900	80%
Commercial	600	40%
Other	19,600	75%
DOE	9,800	50%

Dump trucks are assumed to be 100% efficient for all activities and to haul backfill soil or soil cover from a borrow area at the same rate as during the excavation activity. The direct cost estimate for equipment, manpower, and material does not include decontamination activities; however, decontamination is included as an O&M cost.

All vegetation in excavation and soil cover areas would be removed before remediation begins. Trees and brush with base diameters <6 in. would be cut, chipped, and mixed with the cover or backfill soil in these areas. Trees ≥ 6 in. would be cut down as close to the ground as possible, cut to 8- to 10-ft length, and disposed of at a construction landfill; however, the branches would be chipped and mixed with the cover or backfill soil. Tree stumps and roots would be excavated and transported with the contaminated soil to either the low-temperature thermal desorption treatment or disposal facility for the excavation option. Tree stumps and roots would remain in place for the soil cover option.

Site Development Costs

Site development costs include designing, constructing, operating, maintaining, and decommissioning site property at staging areas on the EFPC site. Site development costs also include stabilizing stream banks in areas of active remediation (i.e., areas being excavated or overlain with a soil cover). The vegetative gabion walls, which would average 6 ft high and 18 in. deep, would be used to support stream banks adjacent to areas being overlain with a soil cover. Either rolled mats of grasses and wetland plants (sod) or biodegradable fiber rolls impregnated with plant seeds, in combination with willow and box elder staking, would be used to stabilize stream banks adjacent to areas being excavated and backfilled.

To minimize disturbance of the Lower EFPC watershed, equipment staging and decontamination areas would be established—4 for SWAs 2, 3, 4, and 5; 3 for SWAs 6 and 7. Segments 4 and 5 would be hydrostatically dewatered by the construction of a 2-ft by 3-ft-deep trench around the excavation site (an estimated 1000 lin ft of trench would be required per acre of contaminated surface area). It is assumed that the dewatering pumps would be attended 2 h/d for 200 d/year. Because decontamination and hydrostatic dewatering operations are assumed to be purchased services, the costs of installing and operating the decontamination facility and the operation of the dewatering pumps are categorized as O&M (see Sect. D.2.2). Remediation of the contaminated areas would proceed systematically downstream to impede recontamination by sediment transport.

Each staging area would consist of 4200 yd^2 covered with 9-in.-thick gravel, with 6 in. of topsoil removed. The effective surface cleared for remediation is assumed to be 10% greater than the contaminated area. Trees >8 in. in diameter would be cut to hauling size and removed to a construction landfill; the remaining small trees, brush, and tops of large trees would be chipped on site. The staging areas would be surrounded by 780 lin ft of temporary fencing. Access roads would be 100 ft long by 15 ft wide per acre and would consist of a 8-in.-thick layer of gravel. A 21-ft wide path would be cleared for the access roads. It is assumed that 20 miles of 4-lane roadway would need to be repaved on completion of remedial construction because of heavy truck traffic. Remediated areas, access roads, and staging areas would be restored by being hydroseeded and covered with 6 in. of topsoil; additionally, 100 5- to 6-ft trees would be planted in former woodlands. It is assumed that a concerted effort would be made to minimize the spread of contamination and that, therefore, access roads and staging areas restored with 6 in. of topsoil cover do not present an unacceptable exposure risk.

Site development assumptions for staging and decontamination areas include:

- one culvert crossing per staging area;
- 500 lin ft of precast Jersey bounce barriers, which would provide coffered areas, would be reused 20 times, at an adjusted cost of $1.15/lin ft;
- 1500 lin ft of surface controls (500 ft of ditches, 500 ft of hay bales, and 500 ft of silt fences);
- heavy equipment mobilizations;
- one temporary office trailer and one double-wide shower and toilet trailer;
- 1000 lin ft of 2-in. water line and 1000 lin ft of 8-in. waste water line; and
- 75 yd^3 of wood chips and 55 yd^3 of wood debris generated per acre of woodland.

Table D.4 lists the unit costs for construction.

Building and Services Costs

Building and services costs include designing, constructing, operating, maintaining, and decommissioning temporary structures for the low-temperature thermal desorption treatment unit and storage of treatment residuals at the K-25 Site prior to transport to an approved licensed and permitted disposal facility. Building and services costs for the Landfill VII disposal facility at the Y-12 Plant, however, are included in disposal costs. It is assumed that building and services unit costs at both locations are the same. Further building and services assumptions include:

- 3000 ft^2 of temporary office space area for 2 trailers placed on a 9-in.-deep gravel surface with 6 in. of topsoil removed,
- 1000 lin ft of 8-in. sewer line and 1000 lin ft of 2-in. water line per office trailer, and

- an allowance of $100 to install each office trailer and another $100 per trailer to install electricity.

In addition, it is assumed that the existing environmental monitoring system at the K-25 Site is adequate and no additional monitoring is required. Table D.4 lists the unit costs for building and services.

Equipment Purchase Costs

No costs are associated with the purchase of equipment. Low-temperature thermal desorption treatment unit(s), decontamination equipment, and auxiliary equipment are assumed to be provided by purchased services and are included in the O&M costs.

Land and Relocation Costs

It is assumed that acquisition costs would equal $40,000 for each acre of land; $4000 for each right-of-way to a remedial site, staging and decontamination area, or access road; and $120,000 for each house. For SWA 6, it is assumed that four homes would be acquired and demolished and the residences permanently relocated. For SWAs 2, 3, 4, 5, and 7, it is assumed that two residences would be temporarily relocated for three months. It is further assumed that each of the four permanently relocated households would receive a 10% ($12,000) allowance to pay for administrative costs (such as title surveys, real-estate commissions, moving expenses, and closing costs) and that each of two temporarily displaced households and four permanently relocated households would receive a $15,000 allowance to pay for interim living expenses. Demolition of the four purchased houses is assumed to cost $5000 each.

Disposal Costs

Disposal costs include containerization, transportation, and disposal fees or construction of a disposal facility for mercury-contaminated soil and residual waste material. Disposal costs are evaluated for two options: (1) a disposal cell at the modified Y-12 Landfill VII disposal facility for direct disposal of contaminated soil and (2) treatment/disposal of treatment residuals from the low-temperature thermal desorption unit at an approved licensed disposal facility. Landfill VII was used as a representative disposal facility for this evaluation. Landfill V or a modified Landfill VI could also meet the disposal facility criteria of a lined, leachate collection facility located at Y-12.

Modified Landfill VII Disposal Facility (SWAs 2, 3, and 7). Disposal at the Y-12 Landfill VII disposal facility is assumed to be a pile placed at grade over a single-liner system composed of 12 in. of compacted common earth over 12-in.-deep sand and gravel leachate collection system. The pile would be compacted to 95% standard proctor and sloped with a 10% grade. The final cover would be a 3-ft-thick cap composed of 24 in. of low-permeability compacted clay; a 30-mil HDPE liner; 6 in. of sand and gravel; and 6 in. of topsoil. For estimation purposes, cost for constructing large- and small-capacity facilities was calculated. The small facility, based on SWA 7, would have an ex situ capacity of 29,400 yd^3 (24,500 in situ) and would encompass 9.6 acres. The large facility would have an ex situ capacity of 64,800 yd^3 (54,000 yd^3 in situ) and would comprise 14.5 acres. Access roads, fences, lighting, decontamination pads, a leachate treatment unit, offices, and monitoring wells are included in the

site development costs. The full extent of leachate treatment requirements is uncertain at this time and will be further refined during the remedial design phase. The leachate generation rate at this size landfill is expected to be minimal. A summary of costs for modification at the Y-12 Landfill VII disposal facility follows.

	Large facility	Small facility
Total site development cost	$631,000	$557,000
Total liner construction cost	$493,000	$290,000
Total waste placement cost	$457,000	$207,000
Total closure cost	$849,000	$533,000
Total direct cost	**$2,430,000**	**$1,587,000**
Engineering, management, and support (79%)[a]	$1,920,000	$1,254,000
Independent verification, study, assessment (20%)	$486,000	$317,000
Fees and permits (10%)	$243,000	$159,000
General labor (20% of labor)	$130,000	$75,000
Sales tax (8.75% of materials)	$113,000	$75,000
Total indirect costs	**$2,892,000**	**$1,879,000**
Total direct and indirect costs	$5,322,000	$3,466,000
Contingency allowance (35%)	$1,863,000	$1,213,000
Total facility cost	**$7,185,000**	**$4,679,000**
Ex situ capacity (yd^3)	64,800	29,400
Cost per yd^3	$110.80	$159.10

[a] Includes 28% for engineering and design, 45% for project and construction management, and 6% for support facilities.

Pro-rated construction costs including indirect costs are shown in Table D.7.

Interim Storage, Treatment, and Disposal of Treatment Residuals (SWAs 4 and 5). Interim storage (disposal) costs include the containerization, transportation, temporary storage, and final treatment and disposal of residual waste materials. It is assumed that the low-temperature thermal desorption treatment residuals would be placed in interim storage for 5 years

until analysis is performed and an acceptable disposal method is finalized. Interim storage costs include the design, construction, operation, maintenance, and decommissioning of a new interim storage facility. The new interim storage facility is anticipated to consist of containers (55-gal drums) stacked on a concrete pad and covered by a synthetic fabric shell. Each drum is assumed to cost $100. Interim storage is estimated to cost $280 per drum; treatment (solidification), $455 per drum; and disposal, $315 per drum. The total cost per drum is $1050. For this evaluation, interim storage would be located at the K-25 Site.

Transportation of Wastes to the Y-12 Landfill VII Disposal Facility and K-25 Interim Storage Facility (SWAs 2, 3, 4, 5, and 7). Costs for transporting mercury-contaminated soil to the modified Y-12 Landfill VII disposal facility are included with the construction costs. Transporting residual waste from the low-temperature thermal desorption treatment facility to the K-25 interim storage facility by 20-ton cargo trucks would cost $32 per drum. It is assumed that a six-person crew (one equipment operator, one truck driver, one foreman, one health and safety technician, and two laborers) would be needed to load and unload a truck transporting drums of treatment residual material to the new K-25 interim storage facility. Waste is assumed to be transported at a rate of 2 truckloads of 32 drums each per day. This activity is assumed to proceed concurrently with treatment or excavation and backfill activities. Drums would be stored temporarily at the treatment site until two full loads (64 drums) were ready for shipment.

D.2.1.2 Indirect capital costs

Indirect capital costs include the costs of engineering, financial, supervisory, and other services necessary to carry out a remedial action. These cost are not incurred as part of actual remedial actions but are ancillary to direct or construction costs. The U.S. Department of Energy (DOE) owns the facilities in Oak Ridge. DOE has contracted with Martin Marietta Energy Systems, Inc. (Energy Systems) to integrate the operations of the plants and with MK-Ferguson Oak Ridge Company for construction activities. Energy Systems is tasked with coordinating the remedial activities for the EFPC remediation. As such, there is a requirement that Energy Systems' general and administrative (G&A) and overhead costs be included in the indirect capital cost estimate. Likewise, MK-Ferguson's costs need to be included. The combination of these multiple levels of coordination result in indirect costs being higher than similar remediation projects performed elsewhere. Titles I and II services refer to the effort necessary to prepare the engineering plans and specifications and solicitation documents. Title III services are for management during construction. Purchasing and disposing of personal protective equipment are included in general labor costs. Indirect capital costs are based on the following assumptions:

- Project management includes the project manager [1.0 full-time equivalent (FTE)], estimator (0.5 FTE), scheduler (0.2 FTE), planner (0.2 FTE), and analyst (0.1 FTE) for the duration of the project. Project management costs for the 1- to 2-year remedial project are estimated to be 3%.

- G&A and General Plant Services (GPS) markups are 52% for Energy Systems and 6.7% for others. No markups are included for A-E Titles I and II.

- A 12% markup for construction management is included.

- Percentages are rounded to the nearest 1% except for sales tax.

Indirect cost percentages are broken down as follows:

- Engineering and design (% of construction)

A-E Titles I & II	7.0%
A-E Title III	10.0%
A-E support	3.0%
G&A and GPS (6.7%)	0.9%
Subtotal	13.9%
Energy Systems Title III	4.8%
G&A and GPS (52%)	2.5%
Subtotal	7.3%
Total engineering and design:	28.2%

Engineering and design account for 28% of construction costs.

- Project and construction management

Project management	3.0%
Energy Systems project services	8.0%
Energy Systems division support	5.0%
G&A and GPS (52%)	8.3%
Total Energy Systems management:	24.3%
MK-Ferguson Indirects	5.0%
MK-Ferguson Directs	12.0%
G&A and GPS (6.7%)	1.1%
Total MK-Ferguson	18.19%
Construction management and support (12%)	2.2%
Total construction management	20.3%
Total project and construction management:	44.6%

Project and construction management constitutes ~45% of construction costs.

- Independent verification, studies, and assessments are assumed at 20% of direct capital costs.

- Other indirect costs include:

  — General labor based on a percent of labor cost

Supplies	2%
Layout of material	1%
Storage of material	1%
Cleanup of work site	4%
Security	1%
Safety equipment	1%
Personal protective equipment	10%
Total general labor:	20%

— Sales tax based on 8.75% of material cost (Note: sales tax is applied only to materials purchased by third-party vendors.)

— Fees and permits based on a percent of direct cost (Note: though CERCLA actions do not need to obtain permits or pay fees to obtain permits, these actions must comply with the substantive provisions of ARARs. Costs are included to ensure this requirement is met.)

Legal fees	5%
Licenses and permits	5%
Total fees and permits	10%

— Support facilities based on 6% of construction cost

— Treatment startup and shakedown based on a percent of direct cost for the treatment alternatives only:

Startup and shakedown	15%
Trial burn	5%
Total startup and shakedown	20%

Engineering, management, and support services account for 79% of construction costs (e.g., 28% for engineering, plus 45% for management, plus 6% for support facilities) and independent verification, studies, and assessments account for 20% of direct capital; therefore, technical and administrative services personnel are assumed to constitute 100% of the total average site construction and operation personnel needs. The duration of these services is assumed to coincide with the duration of the governing construction or operation activities, and the activities are assumed to proceed concurrently.

D.2.2 O&M Costs

O&M costs cover nonconstruction activities performed to ensure the effectiveness of a remedial action and protect human health and the environment; they include:

- confirmatory and waste acceptance sampling,
- biological and environmental monitoring,
- surveillance and maintenance,
- truck decontamination, and
- low-temperature thermal desorption treatment of contaminated soil.

Decontamination and low-temperature thermal desorption treatment activities are assumed to be provided by purchased services; therefore, they are considered as O&M costs. Five-year periodic reviews after the remedial action are completed is included in the present worth analysis over a 30-year cost period. The O&M cost components listed above are discussed in the following sections.

D.2.2.1 Confirmatory and waste acceptance sampling

For confirmatory sampling, the excavation areas would be divided into a 50-ft grid system. It is assumed that 30% of the areas sampled would require additional sampling to reach the proposed action levels. Sampling validation would be performed on 10% of the total number of samples. A minimum of 5 samples would be taken (at the center and the four corners) in areas <2500 ft^2. For estimation purposes, it is assumed that 33 confirmatory samples would be taken per acre of contaminated surface area at a cost of $500 per sample. Validation samples (3 per acre) would be verified by off-site laboratories at a cost of $2200 per sample. A total confirmatory sampling cost of $23,100 per acre of excavated area is included in O&M costs.

Waste acceptance sampling is assumed to occur at Landfill VII upon receipt of a dump truck load of mercury-contaminated soil. A composite sample is to be taken from each truckload and analyzed for moisture, density, and total mercury. The moisture and density analysis is assumed to cost $25, and the total mercury analysis is assumed to cost $400, or total analyses of $425 for each truckload. A 33% increase of this cost is included for labor. It is anticipated that ~36 dump truck loads of soil would be delivered to the Landfill VII disposal facility; therefore, the daily waste acceptance analysis cost is ~$20,500 (1.33 × $425/truckload × 36 truckloads).

D.2.2.2 Biological and environmental monitoring

Costs for biological and environmental monitoring are based on continuing the present program, if applicable, or establishing a program similar to the Biological Monitoring and Abatement Program (BMAP). The semiannual monitoring program would involve sampling groundwater, surface water, soil, sediment, and organisms at designated locations. Isotopic and metals analyses would be performed on the water, soil, and sediment samples. Biological specimens (whole body and likely depurated) collected from both aquatic and terrestrial habitats at 13 sampling stations would be analyzed for methyl mercury and total mercury. The cost estimate that follows is based on the No Action alternative (SWA 1).

The estimated number of labor hours needed for sampling would be 512 h/semester, or 1024 h/year. Total field sampling labor per year was estimated to be $55,000. The average sampling material cost was estimated to be $2000 per semester, or $4000 per year.

Mercury analyses of 3 fish, 2 terrestrial organisms, and 1 macroinvertebrate organism would be $500 per sample. Laboratory analysis for biological monitoring is estimated at $39,000/semester (6 samples/station × 13 stations × $500/sample), or $78,000 per year.

Cost estimates for laboratory analysis of water, soil, and sediment samples were based on information from vendor literature. The water laboratory analyses required may include pH, specific conductance, total organic carbons, toxicity characteristic leaching procedure (TCLP), metals, polycyclic aromatic hydrocarbons, volatile organic compounds, radionuclides, and

semivolatile organics. Laboratory analysis of environmental media is estimated to be $61,300/semester, or $123,000 per year.

The total laboratory analysis cost for biological and environmental monitoring is estimated at $201,000 per year. Total estimated annual costs for conducting the environmental monitoring program under the No Action alternative (SWA 1) are:

Sampling labor	$ 55,000
Sampling materials	$ 4,000
Laboratory analysis	$201,000
Total cost	**$260,000**

For alternatives with complete excavation of mercury-contaminated soils (SWAs 3 and 5) the biological and environmental monitoring cost is assumed to decrease to only $50,000 per year. For alternatives with a portion of mercury-contaminated soils remaining under a soil cover or controlled by institutional actions (SWAs 2, 4, and 7) the biological and environmental monitoring cost is assumed to be $60,000 per year. For the alternative with all the mercury contaminated soils contained under a soil cover (SWA 6) the biological and environmental monitoring cost is assumed to be $90,000 per year.

It is assumed that EFPC surface water would be sampled twice daily, 250 d/year during active remediation of the site; at a cost of $500 per sample, the total cost per year would be $250,000. In addition, a groundwater sample would be collected from each of 10 wells each quarter; each sample would cost $2200, totaling $88,000 per year. The estimated total annual cost for conducting the environmental monitoring program during remediation is $338,000.

D.2.2.3 Surveillance and maintenance

Surveillance and maintenance (S&M) costs include such items as mowing and inspecting and repairing soil covers, monitoring equipment, dewatering pumps, and fences. It is anticipated that postremedial surveillance and maintenance activities would be conducted twice yearly and following any major storm event. For the complete soil excavation alternatives (SWAs 3 and 5), no annual S&M for the Lower EFPC site is assumed. For the No Action alternative (SWA 1) and alternatives with a portion of mercury-contaminated soils remaining under a soil cover or controlled by institutional actions (SWAs 2, 4, and 7), the estimated annual S&M cost for the Lower EFPC site is $40,000. For the soil cover alternative (SWA 6) the estimated annual S&M cost for the Lower EFPC site is $150,000.

For SWAs 2, 3, and 7, the annual S&M cost for the modified Y-12 Landfill VII disposal facility is estimated to be $50,000. During active remediation, roadway maintenance is assumed to cost $30,000 per year and pump maintenance for hydrostatic dewatering is assumed to cost $25,000 per year. Preremedial S&M is assumed to be $75,000 per year for SWAs 2 through 7.

D.2.2.4 Transport truck decontamination

Water for decontaminating transport trucks would be treated at each temporary staging area and at either the modified Y-12 Landfill VII disposal facility or the low-temperature thermal

desorption treatment facility, as applicable, by modular treatment units. Approximately 1000 gal/d of decon water would be transported from Oak Ridge to each location. Decon water would be treated, filtered, and recycled. Approximately 200 gal/d per location is assumed to be lost through evaporation. Approximately 800 gal/d would be let down and tested before discharge. Letdown water will be sampled, analyzed, and disposed of according to ARARs. The cost estimate assumes that the letdown water is contaminated and may be discharged to the EFPC. Decontamination costs are estimated to be $150 per truck exiting the staging areas to either the disposal or low-temperature thermal desorption treatment facility. Filter cake and other treatment solids would be transported with mercury contaminated soil to either the disposal or low-temperature thermal desorption treatment facility, as applicable. The cost for transportation and treatment/disposal of filter cake is assumed negligible.

D.2.2.5 Low-temperature thermal desorption treatment (SWAs 4 and 5)

Treatment costs include the mobilization, operation, and maintenance of the low-temperature thermal desorption treatment unit(s) at the K-25 Site. Costs for the treatment unit are based on vendor price quoted for the low-temperature thermal desorption unit of $190/ton and a size reduction cost of $12/ton. Based on a soil density of 85 lb/ft^3, $218.03/yd^3 is used to estimate costs for treating mercury-contaminated soil, which include costs for monitoring air emissions. An additional $13.77/yd^3 for reducing and screening waste before it is thermally treated has been included, for a total treatment cost of $231.80/yd^3. Costs for dewatering via gravity drainage are negligible. Leachate water may be reapplied to the treated soil because it is assumed to be uncontaminated. Nutrients would also be added to the treated soil before backfill is placed; however, associated costs are assumed to be negligible.

It is assumed that two 12-hour treatment crew shifts work 7 d/week for 50 weeks/year. The duration of treatment is based on a throughput of 500 tons/d (435.7 yd^3/d) and a 2 d/week down time (20%), or 108,930 yd^3/year. The treatment operation is assumed to run concurrently with construction activities. An estimated volume reduction of 10% is assumed based on bench-scale testing conducted for the EFPC site (IT 1994). A contingency allowance of 30% of the total treatment cost is included to account for any variation in the preceding assumptions.

A sample would be collected from each truckload and analyzed for moisture and density, at a cost of $25 per sample; 36 truckloads are delivered daily, for a cost of $900/d. Posttreatment sampling would be conducted every hour at a cost of $150 per sample. TCLP sampling would be conducted at the end of each shift, or twice a day, at a cost of $1800 per sample. The total daily cost for pretreatment and posttreatment sampling is $8100.

It is estimated that 2.5 gal of treatment residuals would be generated per ton of soil. The residuals are considered to be mixed waste and would be placed in 55-gal drums; 24 drums would be generated daily. Drums would be sampled and treated at a cost of $2200 each, totaling $52,800 daily.

D.2.2.6 Sitewide alternative-specific O&M costs during active remediation

Cost criteria for confirmatory sampling, decontamination, waste acceptance sampling, and treatment residual sampling are described above. The following total costs have been identified as direct alternative-specific O&M costs for active remediation:

Sitewide alternative	Confirmatory sampling costs	Decontamination costs	Waste acceptance or treatment residual sampling cost	Total direct active remediation O&M costs
SWA 2	$276,000	$1,719,000	$1,854,000	$3,849,000
SWA 3	$419,000	$2,432,000	$3,054,000	$5,905,000
SWA 4	$276,000	$1,719,000	$4,771,000	$6,766,000
SWA 5	$419,000	$2,432,000	$7,858,000	$10,709,000
SWA 6	$0	$712,000	$0	$712,000
SWA 7	$201,000	$1,103,000	$1,385,000	$2,689,000

Costs for biological and environmental monitoring for SWAs 2 through 7 total $338,000 per year during active remediation and are based on establishing a monitoring program similar to the BMAP as described in Sect. D.2.2.2. Indirect O&M costs include surveillance and maintenance (roadway and dewatering pump maintenance) and environmental monitoring. Roadway maintenance is $30,000 per year for SWAs 2 through 7 and dewatering pump maintenance is $25,000 per year for SWAs 2,3,4,5, and 7. The annual O&M cost during active remediation is based on the following direct and indirect O&M items:

Sitewide alternative	Active remediation period (years)	Annual direct active remediation O&M [a]	Annual road maint.	Annual dewater pump maint.	Annual environ. monitoring	Total annual remediation O&M [b]
SWA 2	2	$1,925,000	$30,000	$25,000	$338,000	$2,318,000
SWA 3	2	$2,953,000	$30,000	$25,000	$338,000	$3,346,000
SWA 4	2	$3,383,000	$30,000	$25,000	$338,000	$3,776,000
SWA 5	2	$5,355,000	$30,000	$25,000	$338,000	$5,748,000
SWA 6	2	$356,000	$30,000	$0	$338,000	$724,000
SWA 7	1	$2,689,000	$30,000	$25,000	$338,000	$3,082,000

[a] Annual direct active remediation O&M costs are equal to the total direct active remediation O&M costs in the preceding table divided by the active remediation period.

[b] Treatment O&M costs are excluded from the total annual remediation O&M costs.

Table D.5 summarizes annual operation and maintenance costs (excluding treatment costs).

D.3 LIFE CYCLE COST (PRESENT WORTH) ANALYSIS

To compare remedial alternatives on an equal basis, the total cost of the alternatives for a period of 30 years was estimated (life cycle cost) and analyzed on a present worth basis. The present worth value represents the amount of money that, if invested in the initial year of construction, would be sufficient to cover all costs associated with the remedial action for the assumed 30-year period. The following assumptions were used:

- There is no annual spending cap and no escalation.
- The discount rate is 0% and the prefinance rate is 0%.
- The number of years for costing is 30.
- Capital costs are incurred at the beginning of the fiscal year, and O&M costs are incurred at the end of the fiscal year.

The present worth analysis for the EFPC site is summarized in Table D.6. All dollar figures are in $1000s.

D.4 SITEWIDE ALTERNATIVE-SPECIFIC COSTS

SWAs 1 through 7 for the EFPC FS were developed in Sect. 4 of this document and are described in detail in Sect. 5. This section presents a summary of the sitewide alternative costs.

D.4.1 No Action (SWA 1)

D.4.1.1 Description of SWA 1

SWA 1, the No Action alternative, is considered in accordance with NEPA and CERCLA and provides a baseline for comparison with other alternatives. Table 5.2 reflects the areal extent of contamination within each RU. As presented, the information reflects relatively small percentages of contamination per RU. The numbers also indicate that if the No Action alternative were implement, <3% of the EFPC OU would be affected by mercury contamination above remediation goal options.

This alternative would not provide for further remedial action at the EFPC OU. Although warning signs and fences are currently in place in some areas of the site, these controls would not be maintained. Environmental monitoring of groundwater, surface water, sediment, soil, and ambient air would be conducted periodically for all RUs except the Agricultural RU and the SLB. Biological monitoring of terrestrial and aquatic biota also would be conducted. In addition, because the contamination would remain in place, a statutory review would be required each 5 years after the initiation of this action.

D.4.1.2 Total cost of SWA 1

No capital costs are associated with SWA 1. Operation and maintenance costs include the establishment of an environmental monitoring program and a surveillance and maintenance program. These costs are described in Sects. D.2.2.2 and D.2.2.3, respectively. The annual cost of biological and environmental monitoring is estimated to be $260,000, and the annual cost of surveillance and maintenance is estimated to be $40,000, for a total operation and maintenance cost of $300,000. The operation and maintenance cost for the 5-year periodic review is estimated to be $500,000.

Summary of total cost for SWA 1 (costs are × 1000)

Direct capital	Indirect capital	Contingency	Total capital	Total O&M	30-year life cycle cost
$0	$0	$0	$0	$12,000	$12,000

D.4.2 Excavation, Soil Cover, and Direct Disposal (SWA 2)

D.4.2.1 Description of SWA 2

SWA 2 involves the removal of soil contaminated with >180 ppm of mercury on the Residential [~25,100 m^3 (32,800 yd^3)] RU and disposal at the modified Landfill VII facility (described in Sect. 5.2.6.1). For the Commercial/DOE and Other RUs, containment and institutional actions would be implemented; a 45-cm (18-in.) soil cover would be installed where soil contamination is >200 ppm. The total surface area to be contained is 0.05 ha (0.12 acre) for Commercial property; 1.64 ha (4.05 acres) for Other RU property; and 0.81 ha (2.02 acres) for DOE property. Interim institutional actions (e.g., postings, environmental monitoring, and 5-year reviews) would be implemented for the Surface Water/Sediment RU. General action descriptions are provided in Sect. 5.2.

D.4.2.2 Total cost of SWA 2

Capital costs associated with SWA 2 are $38,561,000. O&M costs include the establishment of an environmental monitoring program and an S&M program. These costs are described in Sects. D.2.2.2 and D.2.2.3, respectively. The annual remediation O&M cost is $2,318,000 over a 2-year period. The annual cost of biological and environmental monitoring is estimated to be $60,000, the annual cost of S&M for the Lower EFPC site is estimated to be $40,000, and the annual cost of S&M for the disposal cell is estimated to be $50,000, for a total annual postremediation O&M of $150,000. There is no treatment O&M cost for this alternative. An additional postremediation O&M cost for the 5-year periodic review is estimated to be $150,000.

Summary of total cost for SWA 2 (costs are × 1000)

Direct capital	Indirect capital	Contingency	Total capital	Total O&M	30-year life cycle cost
$15,363	$13,201	$9,997	$38,651	$9,586	$48,147

D.4.3 Excavation and Direct Disposal (SWA 3)

D.4.3.1 Description of SWA 3

SWA 3 involves the excavation of soil contaminated with >180 ppm of mercury on the Residential [~25,100 m^3 (32,800 yd^3)] RU; the excavation of soil contaminated with >200 ppm of mercury on the Commercial [400 m^3 (500 yd^3)] DOE [~6500 m^3 (8500 yd^3)] and Other RUs [~9400 m^3 (12,200 yd^3)]; and disposal at the modified Landfill VII. Institutional actions would be implemented for the Surface Water/Sediments RU. General action descriptions are provided in Sect. 5.2.

D.4.3.2 Total cost of SWA 3

Capital costs associated with SWA 3 are $42,342,000. O&M costs include the establishment of an environmental monitoring program and an S&M program. These costs are described in Sects. D.2.2.2 and D.2.2.3, respectively. The annual remediation O&M cost is $3,346,000 over a 2-year period. The total annual cost of biological and environmental monitoring is estimated to be $50,000, there is no annual cost of S&M of the Lower EFPC site, and the annual cost of S&M cost of the disposal cell is $50,000, for a total annual postremediation O&M cost of $100,000. There is no treatment O&M cost for this alternative. An additional postremediation O&M cost for the 5-year periodic review is estimated to be $100,000.

Summary of total cost for SWA 3 (costs are × 1000)

Direct capital	Indirect capital	Contingency	Total capital	Total O&M	30-year life cycle cost
$17,370	$13,994	$10,978	$42,342	$9,991	$52,333

D.4.4 Excavation, Soil Cover, Treatment, and Beneficial Reuse (SWA 4)

D.4.4.1 Description of SWA 4

SWA 4 would involve the excavation and treatment of soil contaminated with >180 ppm of mercury on the Residential [~25,100 m^3 (32,800 yd^3)] RU and placement of the treated soil in the excavated areas of the floodplain. Low-temperature thermal desorption would be used to treat the soil. Containment and institutional actions would include a soil cover where soil surface area contained would be 0.05 ha (0.12 acre) for Commercial property, 0.81 ha (2.02 acres) for DOE property, and 1.64 ha (4.05 acres) for Other property. Institutional actions would be implemented for the Surface Water/Sediments RU. General action descriptions are provided in Sect. 5.2.

D.4.4.2 Total cost of SWA 4

Capital costs associated with SWA 4 are $34,880,000. O&M costs include the establishment of an environmental monitoring program and an S&M program. These costs are described in Sects. D.2.2.2 and D.2.2.3, respectively. The annual remediation O&M cost is $3,776,000 over

a 2-year period. The total annual cost of biological and environmental monitoring is estimated to be $60,000, and the annual cost of S&M is estimated to be $40,000, for a total annual postremediation O&M cost of $100,000. The total O&M cost for low-temperature thermal desorption treatment is $12,816,000. An additional postremediation O&M cost for the 5-year periodic review is estimated to be $150,000.

Summary of total cost for SWA 4 (costs are × 1000)

Direct capital	Indirect capital	Contingency	Total capital	Total O&M	30-year life cycle cost
$10,988	$14,849	$9,043	$34,880	$23,918	$58,798

D.4.5 Excavation, Treatment, and Beneficial Reuse (SWA 5)

D.4.5.1 Description of SWA 5

SWA 5 involves the removal and treatment of soil contaminated with > 180 ppm of mercury on the Residential [~25,100 m^3 (32,800 yd^3)] RU and soil contaminated with >200 ppm of mercury on Commercial [~400 m^3 (500 yd^3)], DOE [~6500 m^3 (8500 yd^3)] and Other [~9400 m^3 (12,200 yd^3)] RUs and the beneficial reuse of the treated soil as backfill material for the areas of excavation within the floodplain. The low-temperature thermal desorption process would be used to treat the soil. Institutional actions would be implement for the Surface Water/Sediment RU.

D.4.5.2 Total cost of SWA 5

Capital costs associated with SWA 5 are $35,329,000. O&M costs include the establishment of an environmental monitoring program and an S&M program. These costs are described in Sects. D.2.2.2 and D.2.2.3, respectively. The annual remediation O&M cost is $5,748,000 over a 2-year period. The total annual cost of biological and environmental monitoring is estimated to be $50,000, and there is no annual cost of S&M, for a total annual postremediation O&M cost of $50,000. The total O&M cost for low-temperature thermal desorption treatment is $21,108,000. An additional postremediation O&M cost for the 5-year periodic review is estimated to be $100,000.

Summary of total cost for SWA 5 (costs are × 1000)

Direct capital	Indirect capital	Contingency	Total capital	Total O&M	30-year life cycle cost
$11,171	$14,999	$9,159	$35,329	$24,503	$69,832

D.4.6 Land Acquisition, Soil Cover, and Fencing (SWA 6)

D.4.6.1 Description of SWA 6

SWA 6 involves containment and institutional actions where soil contamination is >200 ppm of mercury on the Commercial/DOE and Other RUs. Total surface area to be contained is ~0.05 ha (0.12 acre) for Commercial RU property, ~0.81 ha (2.02 acres) for DOE-owned property, and ~1.64 ha (4.05 acres) for Other RU property (see Table 4.2). SWA 6 also involves acquisition of real estate interests in Residential RU properties with soil contamination >180 ppm of mercury and containment and institutional actions on the acquired portions(s) with soil contamination >200 ppm of mercury. To provide protectiveness for containment and institutional actions on Residential RU properties, DOE would acquire the real estate interest for areas necessary to implement the remedial action (i.e., areas containing mercury concentrations >180 ppm, areas for access roads, etc.) and access controls (i.e., fence) would be installed around the acquired areas. In the Residential RU, ~4.85 ha (11.97 acres) of soil with mercury concentrations >180 ppm would be acquired and contained with a soil cover. SWA 6 includes the fencing of additional acreage for one Residential parcel in Segment 1 which encompasses an additional 3.6 ha (8.88 acres). The additional acreage is being acquired and fenced due to the extreme difficulty in installation and maintenance of fencing over the two wetland areas (Wetland 3 and 4). Figure 4.2 presents the areas involved in containment and institutional actions.

D.4.6.2 Total cost of SWA 6

Capital costs associated with SWA 6 are $30,780,000. O&M costs include the establishment of an environmental monitoring program and an S&M program. These costs are described in Sects. D.2.2.2 and D.2.2.3, respectively. There is a 1-year delay in the start of active remediation for SWA 6 for acquisition of land, and a $75,000 preremediation O&M cost for S&M of the site during this period. The annual remediation O&M cost is $724,000 over a 2-year period. The total annual cost of biological and environmental monitoring is estimated to be $90,000, and the annual cost of S&M is estimated to be $150,000, for a total annual postremediation O&M cost of $240,000. There is no treatment O&M cost for this alternative. An additional postremediation O&M cost for the 5-year periodic review is estimated to be $400,000.

Summary of total cost for SWA 6 (costs are × 1000)

Direct capital	Indirect capital	Contingency	Total capital	Total O&M	30-year life cycle cost
$11,028	$11,772	$7,980	$30,780	$10,003	$40,783

D.4.7 Land Acquisition, Excavation, and Institutional Controls (SWA 7)

D.4.7.1 Description of SWA 7

SWA 7 involves the excavation of soil contaminated with >180 ppm of mercury from the Residential RU and disposal at the modified Landfill VII. This alternative was developed using

ecologically sensitive land use assumptions in comparison with SWAs 1 through 6. Parcel 571, (undeveloped private property) currently not in residential or agricultural use, was considered in SWAs 1 through 6 to be in the Residential RU based on potential future land use. Realty interests would be acquired for part of Parcel 571, which is adjacent to DOE property and a small portion of a commercial Parcel 58 .01 ha (0.3 acre) in Segment 1 and fenced along with the DOE parcel to prevent human access to the contaminated area. The remaining portion of Parcel 571 which is outside the area of contamination, would remain in the Residential RU. Figure 4.3 presents the areas of consideration in Segment 1 that would involve institutional actions (fencing, land use restrictions, etc). This change is based on restricting future land use to prevent residential development or agricultural use, thereby reducing the risk of exposure. SWA 7 includes the fencing of additional acreage for one Residential parcel in Segment 1 which encompasses an additional 3.6 ha (8.88 acres). The additional acreage is being acquired and fenced due to the extreme difficulty in installation and maintenance of fencing over the two wetland areas (Wetland 3 and 4).

Institutional actions, such as future use restrictions and digging permits, would be taken on the contaminated areas of Other and Commercial RU properties (>200 ppm of mercury), which are relatively small in size [~1.64 ha (4.05 acres)] and [~0.04 ha (0.09 acre)] respectively. Institutional actions would also be implement on contaminated areas of DOE property in Segments 1 and 9 on the ORR. Exposure to residual contaminants on DOE property in Segment 1 [~0.53 ha (1.30 acres)] and a small portion within the Y-12 Plant boundary [~0.07 ha (0.19 acre)] would be prevented by fencing and future use restrictions.

D.4.7.2 Total cost of SWA 7

Capital costs associated with SWA 7 are $23,072,000. O&M costs include the establishment of an environmental monitoring program and an S&M program. These costs are described in Sects. D.2.2.2 and D.2.2.3, respectively. There is a 1-year delay in the start of active remediation for SWA 7 for acquisition of land, and a $75,000 preremediation O&M cost for S&M of the site during this period. The annual remediation O&M cost is $3,082,000 over a 1-year period. The total annual cost of biological and environmental monitoring is estimated to be $60,000, the annual cost of S&M of the Lower EFPC site is estimated to be $40,000, and the annual cost of S&M of the disposal cell is estimated to be $50,000, for a total postremediation O&M cost of $150,000. There is no treatment O&M cost for this alternative. An additional postremediation O&M cost for the 5-year periodic review is estimated to be $150,000.

Summary of total cost for SWA 7 (costs are × 1000)

Direct capital	Indirect capital	Contingency	Total capital	Total O&M	30-year life cycle cost
$9,892	$7,199	$5,982	$23,073	$8,107	$31,180

D.4.8 Summary of Sitewide Alternatives Costs

To aid in the comparison of alternatives, the following table summarizes the total capital cost, the total operations and maintenance costs, and the 30-year life cycle cost for each of the Sitewide Alternatives. A graphical comparison is shown in Fig. D.1.

Summary of costs for EFPC sitewide alternatives (costs are × 1000)

Sitewide alternative	Total capital cost	Total O&M cost	30-year life cycle cost
SWA 1	$0	$12,000	$12,000
SWA 2	$38,561	$9,586	$48,147
SWA 3	$42,342	$9,991	$52,333
SWA 4	$34,880	$23,918	$58,798
SWA 5	$35,329	$34,503	$69,832
SWA 6	$30,780	$10,003	$40,783
SWA 7	$23,073	$8,107	$31,180

D.5 MANPOWER AND RESOURCE NEEDS

Table D.7 provides an estimate of the local EFPC site manpower needs and duration of remedial activity for each sitewide alternative. The time frame, as depicted in Fig. D.2, is separated into three time periods: (1) preremediation (i.e., predecessor activities such as building and services, real estate acquisition, mobilization, and site development), (2) remediation (i.e., excavation, backfill, and soil cover), and (3) closure (i.e., site restoration, landfill capping, and demobilization). The time frame is based on production rates assumed in Sect. D.1.3.

Certain construction activities can run concurrently, shortening the duration. Conversely, the duration of construction activities may be extended by weather-related delays. Therefore, for estimation purposes, the time frames for remediation, site development, and building and services activities are assumed to be cumulative. O&M activities (including treatment and some site development activities) are assumed to proceed concurrently with remediation. Technical and administrative services are assumed to be needed throughout the governing time frame of complete remediation. A 2-week loss-time is assumed to occur between each staging area setup. For 4 staging areas, this prolongs the construction time frame by 6 weeks. The critical path for remediation is based on the following assumptions:

- The total remediation time frame is the sum of the predecessor, remedial, and closure activities.
- Predecessor activities are assumed to occur during 9 months (39 weeks) for SWAs 2 through 5, 1 year and 7 weeks (59 weeks) for SWA 6, and 1 year and 3 months (65 weeks) for SWA 7.
- The time frame of remedial activity is the sum of the time frames for excavation and the placement of a soil cover.
- Concurrent activities are assumed to occur at the same time as remedial activities; therefore, the time frame for concurrent activities is the same as that for remedial activity.

- The closure activities are assumed to last for 3 months (13 weeks) for all sitewide alternatives except SWA 6, which is assumed to have 6 weeks of closure activities.

D.6 SENSITIVITY ANALYSIS

D.6.1 Sensitivity Analysis Approach

The level of alternative development in the FS is intended to provide decision makers with sufficient information to allow the selection of an alternative that is protective of human health and the environment, meets ARARs, and is cost effective. Other evaluation factors are also considered, as discussed in Sect. 6, Comparative Analysis. The degree of uncertainty in the cost estimates is a reflection of that level of development. A sensitivity analysis was performed to aid the decision makers in evaluating the cost effectiveness of the alternatives. The purpose of the sensitivity analysis is to assess the effects of varying specific assumptions in cost estimates for proposed remedial action strategies. The analysis studied key alternatives that would represent effects of cost changes on other alternatives. Key areas of concern were cost items that could, if varied slightly, substantially affect the total cost of the project. Assumptions related to the sensitivity analysis include:

- A sensitivity analysis was not performed on SWA 7 because any change to this alternative would not represent the effects of cost changes on other alternatives.

- Inflation and the cost of borrowing capital are not major factors for federal projects.

- Because the remedial action time frame is relatively short, the effect of the changes in O&M (except treatment) would not be examined.

The key sitewide alternatives studied were:

- SWA 2 - excavation, soil cover, and direct disposal (landfill);

- SWA 4 - excavation, soil cover, treatment, and beneficial reuse of treated soils (backfill); and

- SWA 6 - soil cover and institutional actions (fencing).

The key variables used were:

- raising and lowering the contaminated soil volume and contaminated surface area by 20%;

- varying the treatment cost by $\pm 50\%$; and

- examining the change in cost resulting from a $\pm 35\%$ change in the production rate.

D.6.2 Selection of Key Factors

General categories of cost factors were explored to determine appropriate factors for the sensitivity analysis. Cost factors could be eliminated from further consideration if they did not apply to the remediation technologies studies or if they did not affect the overall cost of the project. Several cost factors were candidates for consideration in the sensitivity analysis and are discussed below.

D.6.2.1 Effective life of remedial action

The effective life of remedial technologies is not applicable to the technologies studied. Excavation and soil-cover placement do not involve any equipment or materials that could wear out. Vendor-supplied rental equipment would be used for soil treatment; the vendor would replace this equipment if it failed.

D.6.2.2 Standard O&M costs

O&M costs include surveillance, maintenance, decontamination, confirmatory sampling, and environmental monitoring; these costs are reliable and represent a small portion of the overall cost of remediation. However, treatment is also categorized as an O&M item and represents a substantial portion of the overall cost. The unit cost of treatment could vary greatly from the vendor quotes obtained; therefore, a variation of $\pm 50\%$ in treatment costs was examined.

D.6.2.3 Duration of cleanup

The duration of cleanup correlates directly to the amount of material being treated and the rate at which it is being treated. This correlation is accounted for by varying the treatment rate and the volume of the contaminated soil.

D.6.2.4 Uncertainty regarding site conditions

Uncertainties regarding the extent of cleanup necessitated by site conditions were examined. The amount of contaminated soil affects the duration of the cleanup process, and uncertainty about characteristics of the soil and cleanup level could affect the treatment process rate. To account for uncertainty in soil volume, the sensitivity analysis examined a variation of $\pm 20\%$ of the contaminated soil volume. In addition, to account for uncertainties in the cleanup level and characterization of the soil being treated, a $\pm 35\%$ change in the production rate of the low-temperature thermal desorption unit was studied.

D.6.2.5 Inflation

Inflation was not considered because no escalation cost was assumed in the present worth analysis.

D.6.2.6 Cost to borrow capital

Because this is a federal project, the cost of borrowed capital was not considered.

D.6.3 Results of Sensitivity Analysis

Table D.8 summarizes the results of the sensitivity analyses for the key alternatives; a summary of the results follows.

D.6.3.1 Soil volume and surface area

Lowering the contaminated soil volume and surface area by 20% lowered the present worth cost from 5.2% to 12.1%. Raising the soil volume by 20% raised the present worth cost from 5.6 to 12.3% for each key alternative.

Changing the soil volumes and surface areas had varied effects on the present worth cost. Increasing or decreasing the soil volume and surface area by 20% changed the present worth values of SWAs 2, 4, and 6 by +9.9% and -10.0%, +12.3% and -12.1%, and +5.6% and -5.2%, respectively.

The present worth of SWA 4, which involved treatment of excavated soils, changed the most. This would indicate that a small increase in contaminated soil volume and surface area would have a greater effect on the overall cost of the treatment alternative than would changes in other cost items. The change in cost in all cases was less than the change in excavation volume, indicating that a change in the volume of contaminated soil would not significantly affect total project costs.

D.6.3.2 Treatment cost

Variations of ±50% in the treatment cost did not change the overall capital cost but did change the present worth from -10.1% to +10.1% for the alternative studied (SWA 4). None of the changes resulting from varying the treatment cost would be considered significant.

D.6.3.3 Production rate

Varying the process rate of the low-temperature thermal desorption unit by ±35% directly affected the time frame required to excavate the contaminated soil but did not affect the containment alternative. Increasing the production rate decreased the present worth costs for SWAs 2 and 4 by -0.4% and -8.0%, respectively. However, decreasing the production rate increased the present worth costs for SWAs 2 and 4 by 0.9% and 16.5%, respectively. These results indicate that decreasing the production rate has a more dramatic effect on present worth costs than increasing the production rate. In all cases, the percent changes of the overall costs are insignificant in relation to the percent changes of the production rates.

REFERENCES

EPA (U.S. Environmental Protection Agency). 1987. *Remedial Action Costing Procedures Manual.* EPA/600/8-87/049. Prepared by JRB Associates for U.S. Environmental Protection Agency, Washington, D.C.

IT (IT Corporation). 1994. *Status Report Pilot-Scale Thermal Treatment Demonstration, Lower East Fork Poplar Creek.* Prepared for Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, April 29.

Means, R.S. 1993. *Means Heavy Construction Cost Data.* 7th annual ed. R.S. Means, Inc., Kingston, Mass.

SAIC (Science Applications International Corporation). 1994. East Fork Poplar Creek Feasibility Study Cost Calculation. 1801R.940815.001.

This page intentionally left blank.

APPENDIX D

TABLES

This page intentionally left blank.

Table D.1. Breakdown of capital cost estimate for sitewide alternatives for EFPC FS

	SWA 1	SWA 2	SWA 3	SWA 4	SWA 5	SWA 6	SWA 7
	DIRECT COSTS (× $1000)						
Construction costs							
Remediation costs							
Equipment	0	770	985	770	985	424	449
Labor	0	842	1,143	842	1,143	521	519
Materials	0	406	426	152	21	407	200
Subtotal	0	2,018	2,554	1,764	2,149	1,352	1,168
Site development costs							
Equipment	0	1,443	1,414	1,443	1,414	1,488	693
Labor	0	1,303	1,224	1,303	1,224	1,422	596
Materials	0	4,973	4,753	4,973	4,753	5,325	2,335
Subtotal	0	7,719	7,391	7,719	7,391	8,234	3,625
Building and services costs							
Equipment	0	0	0	95	95	0	0
Labor	0	0	0	522	522	0	0
Materials	0	0	0	449	449	0	0
Subtotal	0	0	0	1,066	1,066	0	0
Construction cost summary							
Equipment	0	2,213	2,399	2,308	2,494	1,911	1,142
Labor	0	2,145	2,367	2,667	2,889	1,943	1,115
Materials	0	5,379	5,180	5,574	5,223	5,732	2,535
Total construction costs	0	9,737	9,945	10,548	10,606	9,586	4,793
Other direct costs							
Equipment costs							
Installation	0	0	0	0	0	0	0
Purchase	0	0	0	0	0	0	0
Subtotal	0	0	0	0	0	0	0
Land and relocation costs	0	243	240	243	240	1,442	419
Disposal costs							
Containers	0	0	0	17	28	0	0
Transportation	0	0	0	5	9	0	0
Disposal fee	0	5,384	7,185	175	289	0	4,679
Subtotal	0	5,384	7,185	197	325	0	4,679
Total other direct costs	0	5,626	7,425	440	565	1,442	5,099
TOTAL DIRECT CAPITAL COSTS	0	15,363	17,370	10,988	11,171	11,028	9,892

Table D.1 (continued)

	SWA 1	SWA 2	SWA 3	SWA 4	SWA 5	SWA 6	SWA 7
			INDIRECT COSTS (× $1000)				
Engineering and design (9% constr.)	0	2,726	2,785	2,954	2,970	2,684	1,342
Project/constr. mgmt. (90% constr.)	0	4,382	4,475	4,747	4,773	4,314	2,157
Independent verif., studies, assessments (20% total indirect)	0	3,073	3,474	2,198	2,234	2,206	1,978
Other indirect costs							
General labor (20% labor)	0	429	473	533	578	389	223
Sales tax (8.75% materials)	0	471	453	488	457	502	222
Fees/permits (10% total direct)	0	1,536	1,737	1,099	1,117	1,103	989
Support facilities (6% constr.)	0	584	597	633	636	575	288
Treatment startup (20% total direct)	0	0	0	2,198	2,234	0	0
Subtotal	0	3,020	3,260	4,950	5,022	2,568	1,722
TOTAL INDIRECT CAPITAL COSTS	0	13,201	13,994	14,849	14,999	11,772	7,199
Total direct and indirect costs	0	28,564	31,365	25,837	26,170	22,800	17,090
Contingency allowance (35% total direct and indirect costs)	0	9,997	10,978	9,043	9,159	7,980	5,982
TOTAL CAPITAL COSTS	0	38,561	42,342	34,880	35,329	30,780	23,073

Table D.2. Normalized equipment rates for excavation and backfill

Equipment	Monthly rent[a]	Hourly fuel/maint. cost	Total hourly cost[b]	Production rate: Volume (CY/hr)	Production rate: Weight (T/hr)	Unit ($/CY)
Heavy cranes and shovels						
Heavy-duty crane (100 T)	$12,600	$37.00	$194.50	NA	200	NA
Power shovel, crawler (2 CY)	$9,750	$39.85	$161.73	190	NA	$0.85
Heavy equipment						
Sheepsfoot roller (130 hp)	$5,425	$18.75	$63.96	160	NA	$0.40
Bulldozer (140 hp)	$5,550	$15.40	$84.78	45	NA	$1.88
Cherry picker (25 T)	$6,000	$18.65	$93.65	NA	1	NA
Front-end loader (130 hp)	$4,900	$16.70	$77.95	80	NA	$0.97
Light equipment						
Backhoe (80 hp)	$2,850	$11.55	$35.30	60	NA	$0.59
Compressor w/jack (160 CFM)	$783	$6.59	$13.12	3.7	5	$3.54
Bobcat (1 CY)	$2,900	$6.20	$30.37	45	NA	$0.67
Gradall (1 CY)	$9,025	$26.15	$101.36	45	NA	$2.25
Ram hoe (backhoe + hammer)	$4,250	$9.99	$63.12	1.8	NA	$35.06
Transportation equipment						
Dump truck (16 T) (20 mi RT)	$3,675	$17.85	$48.48	8	12	$6.06

[a]*Source*: Means 1993.
[b]Hourly rental rate of heavy equipment is based on an 80-h month, light equipment, 120-h month.

Key: CY = yd^3
T = ton
CFM = ft^3/min
NA = Not applicable

Table D.3. Rates for earth-moving construction crews

Personnel type	Base rate	O&P	Rate w/ O&P[a]	Production rate		
				Volume (MH/CY)	Weight (MH/T)	Area (MH/SF)
Crane operators	$24.95	52.5%	$38.05			
Heavy equipment operators	$24.10	52.5%	$36.75			
Light equipment operators	$23.10	52.6%	$35.25			
Truck drivers	$19.45	53.0%	$29.75			
Laborers	$18.55	56.9%	$29.10	0.436		
Health & safety technician	$15.50	75.0%	$27.13			
Foreman	$26.10	57.5%	$41.10			
Oiler	$20.25	52.6%	$30.90			

[a] Rate with overhead and profit (O&P) from page 299 (Division R010-070) of *Means Heavy Construction Cost Data*, 1993.

MH = Manhours
CY = yd^3
T = Ton
SF = ft^2
O&P = Overhead and profit

Table D.4. Construction unit costs

Activity	Unit	Bare costs: Material unit cost	Bare costs: Labor unit cost	Bare costs: Equipment unit cost	Bare costs: Total unit cost	Total incl. O&P	O&P percent	Hourly output	Manhour unit rate	Reference no.
Grade walls (in place)	C.Y.	$109.00	$157.00	$5.25	$271.25	$375.00	38.2%	1.270	7.087	033-130-4200
Topsoil removal (6")	C.Y.	$0.00	$0.31	$0.96	$1.27	1.53	20.5%	108.125	0.014	022-286-0020
Gravel base (9")	S.Y.	$6.05	$0.29	$0.39	$6.73	7.55	12.2%	359.375	0.014	022-308-0200
Slab in place w/o fin.	C.Y.	$56.00	$27.00	$5.00	$88.00	$110.00	25.0%	9.410	1.103	033-130-4650
Finishing	S.F.	$0.00	$0.25	$0.05	$0.30	$0.44	46.7%	90.625	0.011	033-454-0100
Pre-fab hanger w/doors	S.F.	$6.95	$1.02	$0.72	$8.69	$10.20	17.4%	173.250	0.040	131-211-0900
Moving B-25 boxes	Each	$700.00	$9.91	$14.67	$724.58	$941.95	30.0%	2.250	0.444	See calculation
Fabric cover	S.Y.	$4.26	$0.54	$0.07	$4.87	$5.60	15.0%	179.375	0.028	025-458-3640
Borrow (clay)	C.Y.	$3.70	$0.37	$0.50	$4.57	$5.20	13.8%	89.375	0.017	022-216-6065
Borrow (topsoil)	C.Y.	$12.10	$0.28	$0.34	$12.72	$14.10	10.8%	121.250	0.012	022-216-7060
Hauling (2 mi. trip)	C.Y.	$0.00	$0.74	$1.85	$2.59	$3.16	22.0%	26.250	0.038	022-266-0400
Fill (spread by dozer)	C.Y.	$0.00	$0.27	$0.83	$1.10	$1.33	20.9%	125.000	0.012	022-262-0010
Compaction (3 passes)	C.Y.	$0.00	$0.71	$0.28	$0.99	$1.42	43.4%	26.250	0.038	022-226-7020
Fine grade (slope)	S.Y.	$0.00	$0.04	$0.06	$0.10	$0.13	30.0%	1,112.500	0.002	025-122-3300
Leachate drain (6")	L.F.	$3.10	$2.85	$0.00	$5.95	$7.74	30.0%	20.000	0.100	A1.1-294-1100
1" Sodding (sloped)	M.S.F.	$184.00	$150.00	$18.40	$352.40	$455.00	29.1%	0.625	8.000	029-316-0600
Loading (20 C.Y./h)	C.Y.	$0.00	$2.26	$2.78	$5.04	$6.50	29.0%	20.000	0.100	022-238-0500
Pile grooming	C.Y.	$0.00	$1.66	$2.25	$3.91	$5.08	29.9%	25.000	0.080	See calculation
Surface control (ditch)	L.F.	$0.00	$0.06	$0.09	$0.15	$0.19	26.7%	750.000	0.003	022-702-0010
Land clearing	Acre	$0.00	$445.00	$1,550.00	$1,995.00	$2,375.00	19.0%	0.075	20.000	021-116-0340
Tree clearing (to 24")	Acre	$0.00	$1,350.00	$1,500.00	$2,850.00	$3,775.00	32.5%	0.088	68.571	021-104-0200

Table D.4 (continued)

Activity	Unit	Bare costs: Material unit cost	Bare costs: Labor unit cost	Bare costs: Equipment unit cost	Bare costs: Total unit cost	Total incl. O&P	O&P percent	Hourly output	Manhour unit rate	Reference no.
Silt fence (adv. cond.)	L.F.	$0.65	$0.31	$0.00	$0.96	$1.20	25.0%	118.750	0.017	022-704-1100
Hay bale berm (P&R)	Ton	$45.00	$150.00	$51.00	$246.00	$340.00	38.2%	0.375	8.000	022-704-1200
Hydro-seeding	M.S.F.	$22.00	$6.20	$6.75	$34.95	$41.00	17.3%	10.000	0.300	029-308-2400
Permeable HDPE net	S.Y.	$1.63	$0.18	$0.00	$1.81	$2.07	14.4%	312.500	0.010	022-704-0200
Temp. access rd. (8" deep)	S.Y.	$2.18	$1.53	$0.33	$4.04	$5.15	27.5%	76.875	0.078	015-552-0100
Monitoring well	V.L.F.	$3.41	$4.92	$2.05	$10.38	$13.65	31.5%	12.250	0.245	021-484-0050
Asphaltic conc. (2½")	S.Y.	$3.63	$1.43	$0.19	$5.25	$6.40	21.9%	82.500	0.073	025-128-0100
Equipment mobilization	Each	$0.00	$39.00	$184.00	$223.00	$263.00	17.9%	0.500	2.000	022-274-1300
Temp. office trailer	Each	$11.900	$645.00	$0.00	$12,545	$14,100.00	12.4%	0.075	26.667	015-904-0400
Electrical hook-up	Each	$0.00	$400.00	$100.00	$500.00	$500.00	0.0%	0.500	2.000	Allowance
Utility trench (6" × 18")	L.F.	$0.00	$0.31	$0.13	$0.44	$0.61	38.6%	75.000	0.013	022-258-0350
Trench backfill	L.F.	$0.00	$0.37	$0.14	$0.51	$0.73	43.1%	50.625	0.020	022-258-1350
Waste water dist. (8" P)	L.F.	$15.05	$3.78	$0.70	$19.53	$23.00	17.8%	20.000	0.175	027-166-1020
Water dist. (2" Cu'K')	L.F.	$5.20	$2.09	$0.00	$7.29	$8.90	22.1%	13.125	0.076	026-662-3020
Fencing (6', 3 strand barbed wire)	L.F.	$10.05	$2.60	$1.71	$14.36	$16.95	18.0%	31.250	0.128	028-308-0600
Pavement removal	S.Y.	$0.00	$1.23	$1.74	$2.97	$3.82	28.6%	85.000	0.059	020-554-1800
Track rem. & reinstall	L.F.	$0.00	$18.85	$4.01	$22.86	$34.00	48.7%	6.250	0.960	020-554-3700
Slab on grade demo.	C.Y.	$0.00	$54.00	$36.50	$90.50	$124.00	37.0%	3.125	2.560	020-554-5200
4" Building slab demo.	S.F.	$0.00	$1.90	$0.36	$2.26	$3.37	49.1%	50.000	0.100	020-754-0300
Metal siding demo.	S.F.	$0.00	$0.37	$0.00	$0.37	$0.58	56.8%	50.000	0.020	020-726-5020

Table D.4 (continued)

Activity	Unit	Bare costs: Material unit cost	Bare costs: Labor unit cost	Bare costs: Equipment unit cost	Bare costs: Total unit cost	Total incl. O&P	O&P percent	Hourly output	Manhour unit rate	Reference no.
Metal roofing demo.	S.F.	$0.00	$0.32	$0.15	$0.47	$0.66	40.4%	437.500	0.016	020-726-1150
Plain conc. (6") demo.	S.F.	$0.00	$4.74	$0.91	$5.65	$8.45	49.6%	20.000	0.250	020-754-2400
Steel framing demo.	L.F.	$0.00	$4.98	$2.26	$7.24	$10.25	41.6%	28.125	0.249	020-714-2400
Surveying. conv.. max.	Acre	$42.00	$1,050.00	$0.00	$1.092.00	$1,700.00	55.7%	0.075	53.333	013-306-0100
Scarify subsoil (50 HP)	M.S.F.	$0.00	$1.54	$1.43	$2.97	$3.92	32.0%	15.000	0.067	029-204-3050
Spread topsoil (6")	M S.F.	$320.00	$9.90	$34.50	$364.40	$405.00	11.1%	3.375	0.444	029-204-3850
Trees (5-6' beech)	Each	$39.00	$12.75	$10.30	$62.05	$74.00	19.3%	6.250	0.640	029-536-0200
Vegetated gabion walls	S.Y.	$60.00	$21.90	$9.98	$91.88	$111.00	20.8%	12.750	0.549	022-712-0700 doubled
Jersey bounce barriers	L.F.	$1.15	$3.29	$1.73	$6.17	$7.16	16.0%	21.250	0.330	028-404-2200 & calc.
Temporary fence (6')	L.F.	$2.02	$2.97	$0.00	$4.99	$6.90	38.3%	12.500	0.160	015-304-0200
Debris rem. & disp.	C.Y.	$0.00	$2.29	$6.80	$9.09	$11.00	21.0%	27.500	0.109	020-754-4250
Asphalt hwy. resurface	L.Y.	$101.80	$16.60	$29.80	$148.20	$165.84	11.9%	40.700	0.788	Calculation
Dewater trench (2' × 3')	C.Y.	$0.00	$2.53	$1.49	$4.02	$5.55	38.1%	16.875	0.119	021-404-0100
Creek crossing	Each	$2,500.00	$2,500.00	$2,500.00	$7,500.00	$7,500.00	0.0%	0.042	96.000	Calculation

Source: Means 1993.

Table D.5. Summary of annual O&M costs for sitewide alternatives[a]

Alternative	Active remediation period (years)	Cost (× $1000)			
		Remedial	Postremedial	Periodic	Preremedial
SWA 2	2	$2,318	$150	$150	$75
SWA 3	2	$3,346	$100	$100	$75
SWA 4	2	$3,776	$100	$150	$75
SWA 5	2	$5,748	$ 50	$100	$75
SWA 6	2	$ 724	$240	$400	$75
SWA 7	1	$3,082	$150	$150	$75

[a] Does not include cost for treatment in SWAs 4 and 5.

Table D.6. Summary of present worth analysis for the EFPC site[a]

Alternative	Capital	O&M	Years	1993 $
1	$0	$300	1-30	$12,000
		$500	5-year periodic	
2	$38,561	$2,318	1-2	$48,147
		$150	3-30	
		$150	5-year periodic	
3	$42,342	$3,346	1-2	$52,333
		$100	3-30	
		$100	5-year periodic	
4	$34,880	$10,184[b]	1-2	$58,798
		$100	3-30	
		$150	5-year periodic	
5	$35,329	$16,302[b]	1-2	$69,832
		$50	3-30	
		$100	5-year periodic	
6	$30,780	$75	1	$40,783
		$724	2-3	
		$240	4-30	
		$400	5-year periodic	
7	$23,073	$75	1	$31,180
		$3,082	2	
		$150	3-30	
		$150	5-year periodic	

[a]Costs are × $1000.
[b]Includes costs of treatment.

Table D.7. Summary of local manpower resource needs, timetable, and direct capital cost estimates for sitewide alternatives

Alt. no.	Sitewide alternative	Site activities	Estimated time frame (weeks)	Personnel manhours	Average manpower needs	Equipment cost	Labor cost	Material cost	Total direct cap. cost
2	Excavation, Soil Cover, and Direct Disposal	Building and services	0.0	0	0.0	N/A	N/A	N/A	N/A
		Real estate	13.0	6,240	12.0	$0	$242,627	$0	$242,627
		Mobilization	26.0	13,952	13.4	$490,795	$443,278	$1,691,542	$2,625,616
		Devl. Y-12 disposal facility	16.1	16,523	25.6	$700,664	$487,696	$1,281,713	$2,470,072
		Fencing	0.0	0	0.0	N/A	N/A	N/A	N/A
ADJUSTED TOTAL OF PREDECESSOR ACTIVITIES:			39.0	36,716	23.5	$1,191,459	$1,173,602	$2,973,255	$5,338,315
		Excavation	18.1	12,367	17.1	$340,048	$389,505	$0	$729,553
		Soil cover	19.4	4,453	5.7	$168,532	$146,406	$138,798	$453,736
ADJUSTED TOTAL OF REMEDIAL ACTIVITIES:			37.4	16,820	11.2	$508,579	$535,911	$138,798	$1,183,289
		Treatment crew	0.0	0	0.0	N/A	N/A	N/A	N/A
		Site preparation	37.4	20,091	13.4	$706,731	$638,309	$2,435,775	$3,780,815
		Y-12 disposal facility	18.5	28,092	38.0	$223,993	$813,262	$0	$1,037,256
		Backfill	18.1	9,873	13.7	$261,350	$305,611	$267,302	$834,263
ADJUSTED TOTAL OF CONCURRENT ACTIVITIES:			37.4	58,055	38.8	$1,192,075	$1,757,182	$2,703,077	$5,652,333
		Site closure	13.0	6,976	13.4	$245,398	$221,639	$845,771	$1,312,808
		Close Y-12 disposal facility	8.1	7,472	23.1	$100,241	$201,735	$1,574,371	$1,876,347
ADJUSTED TOTAL OF CLOSURE ACTIVITIES:			13.0	14,448	27.8	$345,639	$423,374	$2,420,142	$3,189,155
ADJUSTED TOTALS:			89.4	126,039	35.2	$3,237,751	$3,890,069	$8,235,272	$15,363,093
		Tech. and admin. svcs.	89.4	126,039	35.2	Indir.cap.	Indir. cap.	Indir. cap.	Indir. cap.
TOTAL DIRECT CAPITAL COSTS:			89.4	252,078	70.5	$3,237,751	$3,890,069	$8,235,272	$15,363,093

Table D.7 (continued)

Alt. no.	Sitewide alternative	Site activities	Estimated time frame (weeks)	Personnel manhours	Average manpower needs	Equipment cost	Labor cost	Material cost	Total direct cap. cost
3	Excavation and Direct Disposal	Building and services	0.0	0	0.0	N/A	N/A	N/A	N/A
		Real estate	13.0	2,080	4.0	$80,055	$80,055	$80,055	$240,165
		Mobilization	26.0	14,877	14.3	$534,522	$462,721	$1,797,171	$2,794,414
		Devl Y-12 disposal facility	26.0	24,000	23.1	$935,099	$650,875	$1,710,563	$3,296,537
		Fencing	0.0	0	0.0	N/A	N/A	N/A	N/A
ADJUSTED TOTAL OF PREDECESSOR ACTIVITIES:			39.0	40,957	26.3	$1,549,677	$1,193,650	$3,587,789	$6,331,116
		Excavation	29.8	20,354	17.1	$554,833	$641,127	$0	$1,195,960
		Soil cover	0.0	0	0.0	N/A	N/A	N/A	N/A
ADJUSTED TOTAL OF REMEDIAL ACTIVITIES:			29.8	20,354	17.1	$554,833	$641,127	$0	$1,195,960
		Treatment crew	0.0	0	0.0	N/A	N/A	N/A	N/A
		Site preparation	29.8	17,032	14.3	$611,951	$529,748	$2,057,501	$3,199,199
		Y-12 disposal facility	29.8	40,803	34.3	$298,939	$1,085,373	$0	$1,384,312
		Backfill	29.8	16,207	13.6	$430,326	$501,743	$426,293	$1,358,363
ADJUSTED TOTAL OF CONCURRENT ACTIVITIES:			29.8	74,042	62.2	$1,341,216	$2,116,864	$2,483,794	$5,941,874
		Site closure	13.0	7,438	14.3	$267,261	$231,360	$898,586	$1,397,207
		Close Y-12 disposal facility	13.0	10,853	20.9	$133,781	$269,234	$2,101,141	$2,504,156
ADJUSTED TOTAL OF CLOSURE ACTIVITIES:			13.0	18,292	35.2	$401,042	$500,594	$2,999,727	$3,901,363
ADJUSTED TOTALS:			81.8	153,645	47.0	$3,846,769	$4,452,235	$9,071,309	$17,370,313
		Tech. and admin. svcs.	81.8	229,301	70.1	Indir. cap.	Indir. cap.	Indir. cap.	Indir. cap.
TOTAL DIRECT CAPITAL COSTS:			81.8	382,946	117.1	$3,846,769	$4,452,235	$9,071,309	$17,370,313

Table D.7 (continued)

Alt. no.	Sitewide alternative	Site activities	Estimated time frame (weeks)	Personnel manhours	Average manpower needs	Equipment cost	Labor cost	Material cost	Total direct cap. cost
4	Excavation, Soil Cover, Treatment, and Beneficial Reuse	Building and services	41.6	15,937	9.6	$95,180	$521,875	$448,508	$1,065,564
		Real estate	13.0	520	1.0	$80,876	$80,876	$80,876	$242,627
		Mobilization	26.0	13,952	13.4	$490,795	$443,278	$1,691,542	$2,625,616
		Devl. Y-12 disposal facility	0.0	0	0.0	$0	$0	$0	$0
		Fencing	0.0	0	0.0	N/A	N/A	N/A	N/A
ADJUSTED TOTAL OF PREDECESSOR ACTIVITIES:			39.0	30,410	19.5	$666,851	$1,046,030	$2,220,926	$3,933,807
		Excavation	18.1	12,367	17.1	$340,048	$389,505	$0	$729,553
		Soil cover	19.4	4,453	5.7	$168,532	$146,406	$138,798	$453,736
ADJUSTED TOTAL OF REMEDIAL ACTIVITIES:			37.4	16,820	11.2	$508,579	$535,911	$138,798	$1,183,289
		Treatment crew	18 1	8,674	12.0	O&M cost	O&M cost	O&M cost	O&M cost
		Site preparation	37.4	20.091	13.4	$706,731	$638,309	$2,435,775	$3,780,815
		K-25 interim storage	18.1	3,614	5.0	$65,817	$65,817	$65,817	$197,450
		Backfill	18.1	18	0.0	$261,350	$305,611	$13,365	$580,326
ADJUSTED TOTAL OF CONCURRENT ACTIVITIES:			37.4	32,398	21.6	$1,033,898	$1,009,736	$2,514,956	$4,558,591
		Site closure	13.0	0	13.4	$245,398	$221,639	$845,771	$1,312,808
		Close Y-12 disposal facility	0.0	0	0.0	$0	$0	$0	$0
ADJUSTED TOTAL OF CLOSURE ACTIVITIES:			13.0	6,976	13.4	$245,398	$221,639	$845,771	$1,312,808
ADJUSTED TOTALS:			89.4	86,603	24.2	$2,454,726	$2,813,316	$5,720,452	$10,988,494
		Tech. and admin. svcs.	89.4	86,603	24.2	Indir. cap.	Indir. cap.	Indir. cap.	Indir. cap.
TOTAL DIRECT CAPITAL COSTS:			89.4	173,207	48.4	$2,454,726	$2,813,316	$5,720,452	$10,988,494

Table D.7 (continued)

Alt. no.	Sitewide alternative	Site activities	Estimated time frame (weeks)	Personnel manhours	Average manpower needs	Equipment cost	Labor cost	Material cost	Total direct cap. cost
5	Excavation, Treatment, and Beneficial Reuse	Building and services	41.6	15,937	9.6	$95,180	$521,875	$448,508	$1,065,564
		Real estate	13.0	520	1.0	$80,055	$80,055	$80,055	$240,165
		Mobilization	26.0	14,877	14.3	$534,522	$462,721	$1,797,171	$2,794,414
		Devl. Y-12 disposal facility	0.0	0	0.0	$0	$0	$0	$0
		Fencing	0.0	0	0.0	N/A	N/A	N/A	N/A
ADJUSTED TOTAL OF PREDECESSOR ACTIVITIES:			39.0	31,334	20.1	$709,758	$1,064,651	$2,325,734	$4,100,143
		Excavation	29.8	20,354	17.1	$554,833	$641,127	$0	$1,195,960
		Soil cover	0.0	0	0.0	N/A	N/A	N/A	N/A
ADJUSTED TOTAL OF REMEDIAL ACTIVITIES:			29.8	20,354	17.1	$554,833	$641,127	$0	$1,195,960
		Treatment crew	29.8	14,287	12.0	O&M cost	O&M cost	O&M cost	O&M cost
		Site preparation	29.8	17,032	14.3	$611,951	$529,748	$2,057,501	$3,199,199
		K-25 interim storage	29.8	5,953	5.0	$108,404	$108,404	$108,404	$325,212
		Backfill	29.8	16,207	13.6	$430,326	$501,743	$21,315	$953,384
ADJUSTED TOTAL OF CONCURRENT ACTIVITIES:			29.8	53,479	44.9	$1,150,681	$1,139,895	$2,187,219	$4,477,795
		Site closure	13.0	7,438	14.3	$267,261	$231,360	$898,586	$1,397,207
		Close Y-12 disposal facility	0.0	0	0.0	$0	$0	$0	$0
ADJUSTED TOTAL OF CLOSURE ACTIVITIES:			13.0	7,438	14.3	$267,261	$231,360	$898,586	$1,397,207
ADJUSTED TOTALS:			81.8	112,606	34.4	$2,682,533	$3,077,033	$5,411,539	$11,171,105
		Tech. and admin. svcs.	81.8	112,606	34.4	Indir. cap.	Indir. cap.	Indir. cap.	Indir. cap.
TOTAL DIRECT CAPITAL COSTS:			81.8	225,212	68.9	$2,682,533	$3,077,033	$5,411,539	$11,171,105

Table D.7 (continued)

Alt. no.	Sitewide alternative	Site activities	Estimated time frame (weeks)	Personnel manhours	Average manpower needs	Equipment cost	Labor cost	Material cost	Total direct cap. cost
6	Acquisition and Soil Cover	Building and services	0.0	0	0.0	N/A	N/A	N/A	N/A
		Real estate	52.0	10,400	5.0	$425,495	$425,495	$425,495	$1,276,485
		Mobilization	7.0	4,373	15.6	$148,864	$142,280	$532,893	$824,038
		Devl. Y-12 disposal facility	0.0	0	0.0	N/A	N/A	N/A	N/A
		Fencing	8.2	1,292	3.9	$20,487	$39,263	$105,384	$165,133
ADJUSTED TOTAL OF PREDECESSOR ACTIVITIES:			59.0	16,065	6.8	$594,846	$607,038	$1,063,772	$2,265,656
		Excavation	0.0	0	0.0	N/A	N/A	N/A	N/A
		Soil cover	56.9	16,385	7.2	$423,909	$520,832	$407,490	$1,352,231
ADJUSTED TOTAL OF REMEDIAL ACTIVITIES:			56.9	16,385	7.2	$423,909	$520,832	$407,490	$1,352,231
		Treatment crew	0.0	0	0.0	N/A	N/A	N/A	N/A
		Site preparation	56.9	35,574	15.6	$1,211,071	$1,157,507	$4,335,295	$6,703,872
		Y-12 disposal facility	0.0	0	0.0	N/A	N/A	N/A	N/A
		Backfill	0.0	0	0.0	N/A	N/A	N/A	N/A
ADJUSTED TOTAL OF CONCURRENT ACTIVITIES:			56.9	35,574	15.6	$1,211,071	$1,157,507	$4,335,295	$6,703,872
		Site closure	6.0	3,748	15.6	$127,598	$121,955	$456,765	$706,318
		Close Y-12 disposal facility	0.0	0	0.0	N/A	N/A	N/A	N/A
ADJUSTED TOTAL OF CLOSURE ACTIVITIES:			6.0	3,748	15.6	$127,598	$121,955	$456,765	$706,318
ADJUSTED TOTALS:			121.9	71,772	14.7	$2,357,424	$2,407,332	$6,263,321	$11,028,077
		Tech. and admin. svcs.	121.9	71,772	14.7	Indir. cap.	Indir. cap.	Indir. cap.	Indir. cap.
TOTAL DIRECT CAPITAL COSTS:			121.9	143,544	29.4	$2,357,424	$2,407,332	$6,263,321	$11,028,077

Table D.7 (continued)

Alt. no.	Sitewide alternative	Site activities	Estimated time frame (weeks)	Personnel manhours	Average manpower needs	Equipment cost	Labor cost	Material cost	Total direct cap. cost
7	Excavation, Soil Cover, and Direct Disposal	Building and services	0.0	0	0.0	N/A	N/A	N/A	N/A
		Real estate	52.0	6,240	3.0	$118,552	$118,552	$118,552	$335,655
		Mobilization	13.0	6,281	12.1	$228,148	$196,171	$768,632	$1,192,951
		Devl. Y-12 disposal facility	13.0	9,370	18.0	$797,996	$528,851	$1,155,274	$2,482,122
		Fencing	3.2	498	3.9	$7,896	$15,126	$40,543	$63,565
ADJUSTED TOTAL OF PREDECESSOR ACTIVITIES:			65.0	22,388	8.6	$1,152,592	$858,700	$2,083,001	$4,094,293
		Excavation	13.5	9,239	17.1	$254,025	$290,972	$0	$544,997
		Soil cover	0.0	0	6.5	$0	0	$0	$0
ADJUSTED TOTAL OF REMEDIAL ACTIVITIES:			13.5	9,239	17.1	$254,025	$290,972	$0	$544,997
		Treatment crew	0.0	0	0.0	N/A	N/A	N/A	N/A
		Site preparation	13.5	6,522	12.1	$236,925	$203,718	$798,201	$1,238,844
		Y-12 disposal facility	13.5	9,253	17.1	$135,585	$492,274	$0	$627,859
		Backfill	13.5	7,375	13.7	$195,236	$228,300	$199,682	$623,218
ADJUSTED TOTAL OF CONCURRENT ACTIVITIES:			13.5	23,151	42.9	$567,745	$924,292	$997,884	$2,489,921
		Site closure	13.0	6,281	12.1	$228,148	$196,171	$768,632	$1,192,951
		Close Y-12 disposal facility	6.0	2,813	11.7	$79,653	$138,971	$1,350,830	$1,569,453
ADJUSTED TOTAL OF CLOSURE ACTIVITIES:			13.0	9,094	17.5	$307,801	$335,142	$2,119,462	$2,762,405
ADJUSTED TOTALS:			91.5	63,871	17.5	$2,282,163	$2,409,106	$5,200,347	$9,891,615
		Tech. and admin. svcs.	91.5	63,871	17.5	Indir. cap.	Indir. cap.	Indir. cap.	Indir. cap.
TOTAL DIRECT CAPITAL COSTS:			91.5	127,742	34.9	$2,282,163	$2,409,106	$5,200,347	$9,891,615

Table D.8. Sensitivity analysis for selected sitewide alternatives

		Soil volume				Treatment cost				Production rate				Worst case		Best case	
SWA	Baseline cost	+20%	% Change	-20%	% Change	+50%	% Change	-50%	% Change	+35%	% Change	-35%	% Change	Cost	% Change	Cost	% Change
2	$48,147	$52,921	9.9%	$43.311	-10.0%		N/A		N/A	$47,938	-0.4%	$48,588	.09%	$53,362	10.8%	$43,102	-10.6%
4	$58,798	$66,030	12.3%	$51.656	-12.1%	$64.730	10.1%	$52,866	-10.1%	$54,121	-8.0%	$68,520	16.5%	$81,684	38.9%	$41,047	-30.2%
6	$40,783	$43,076	5.6%	$38,682	-5.2%		N/A		N/A		N/A		N/A	$43,076	5.6%	$38,682	-5.2%

APPENDIX D

FIGURES

This page intentionally left blank.

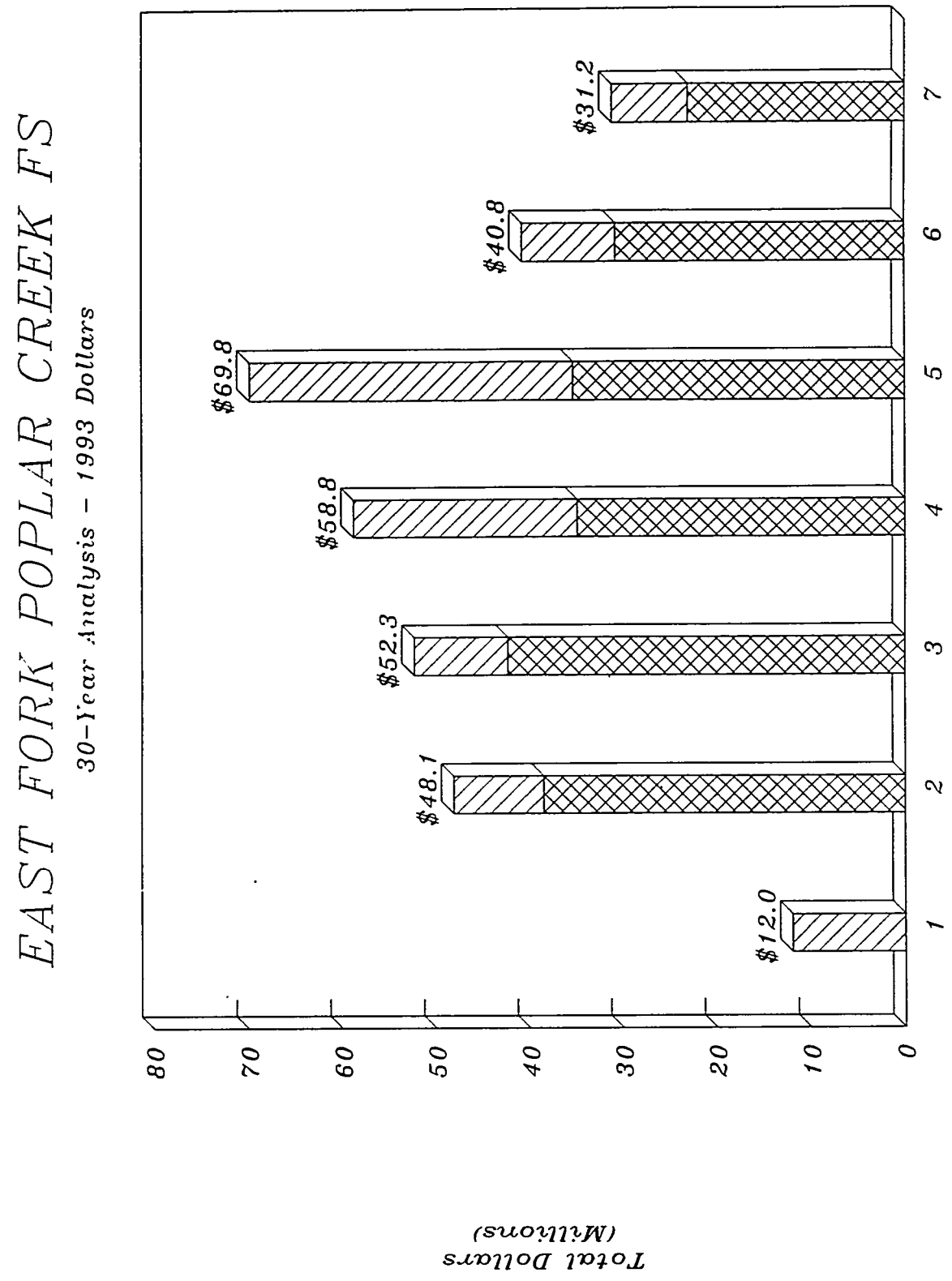


Figure D.1. SWA cost estimate for the EFPC site.

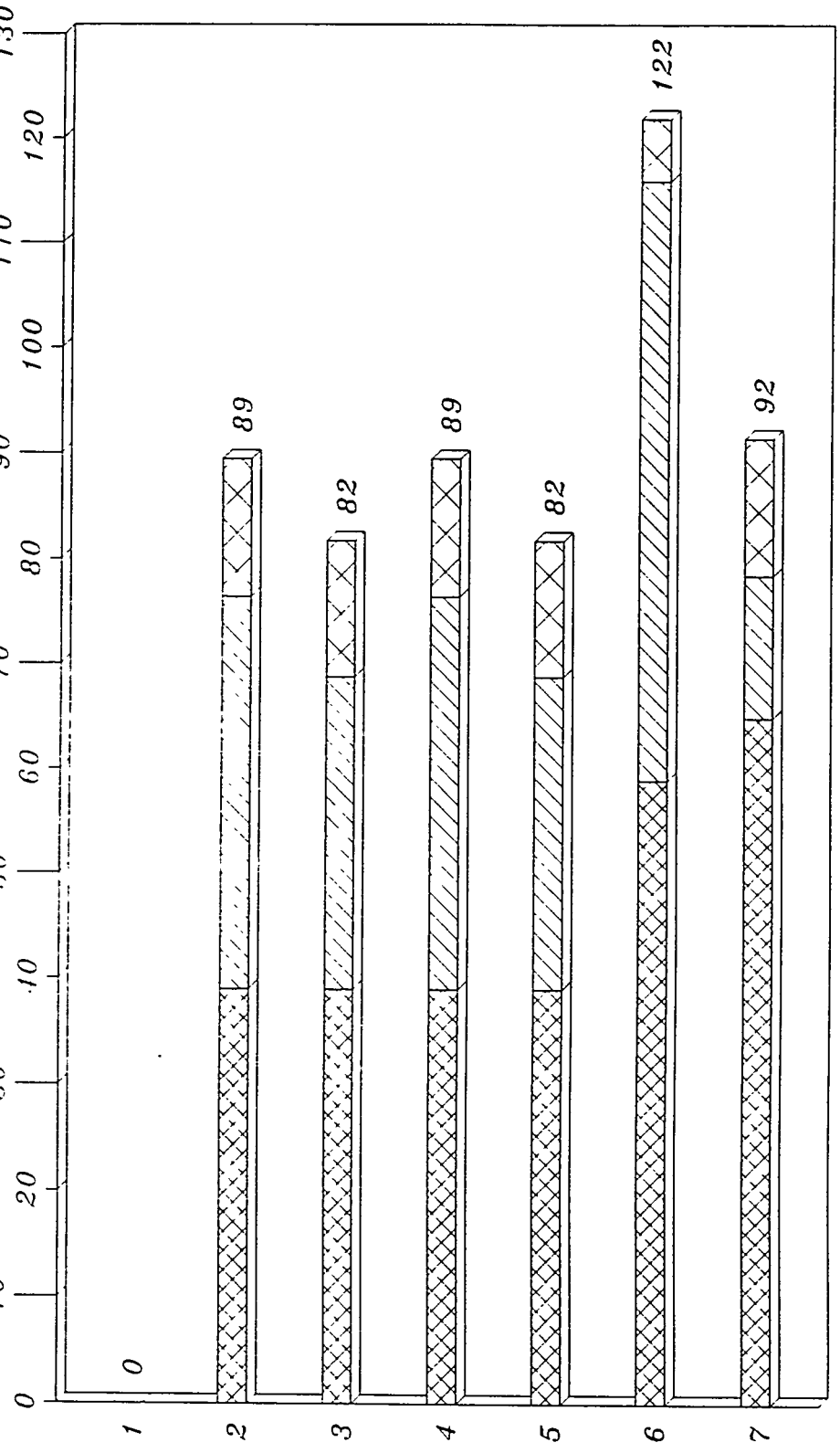


Fig. D.2. Sitewide alternative remediation time frame for the EFPC site.

APPENDIX E

METHODOLOGY FOR SOCIOECONOMICS

APPENDIX E

METHODOLOGY FOR SOCIOECONOMICS

The employment impacts methodology used to evaluate the sitewide alternatives for East Fork Poplar Creek was input-output analysis. The Regional Input-Output Modeling System (RIMS II) (U.S. Bureau of Economic Analysis 1981) of the U.S. Department of Commerce, Bureau of Economic Analysis, developed for Anderson and Roane Counties, was used. The purpose of this appendix is to document the methodology and assumptions used to calculate the impacts on employment, households, and population discussed under each alternative.

Employment impacts that result from public and private-sector projects can be estimated effectively through the use of input-output analysis. To systematically evaluate the regional responses to project changes, it is necessary to account for interindustry relationships within regions. The input-output framework is a useful tool for economic impact analysis because its multipliers depend on the interindustry relationships within regions.

Input-output analysis focuses on identifying the linkages (inputs purchased and outputs sold) among industries within an economy and, using these linkages, tracing the impacts of specific changes on detailed sectors of the economy. For example, an industry (say industry "A") purchases inputs from 10 other industries ("B to K"). Assume that two of these industries (say industries "B" and "C") purchase inputs from industry "A" as part of their production process. A change in demand for industry "A" (the "direct" effect) would then affect industries "B" and "C" (the "indirect" effect). In an input-output framework, multipliers are available for each industry included in the model, a clear advantage over the other models, which often rely on "aggregate" multipliers for the entire economy. The Bureau of Economic Analysis estimated a national input-output model; the latest model reflects the technical relationships in place in 1987.

The national model can be converted to a regional (county-level) model by "regionalizing" the coefficients, adjusting the national input-output coefficients to more accurately reflect the economic structure of the region being analyzed. In the early 1970s, the Bureau of Economic Analysis adopted a specific method for regionalizing the national model based on a short-cut method of estimating regional multipliers without requiring detailed regional surveys. This model was called the Regional Input-Output Multiplier System (RIMS) model. In the early 1980s, the method for regionalizing the national coefficients was significantly revised, allowing a more complete matrix of direct and indirect coefficients to be estimated. This new procedure uses county-level employment and earnings data from the Bureau of Economic Analysis and allows regional input-output matrices to be updated as new employment and earnings data become available. Because it relies on county-level data, a RIMS II model can be developed for any county or multiple-county region in the United States.

The regionalization process begins with the national table of direct coefficients. This table contains the input and output relationships among industries in the United States and reflects the technology used in each industry. Because not all of the industries exist in each county, the process of regionalization must account for the absence of some industries from the region. The process of identifying industries that do not exist in the study region uses the Bureau of Economic Analysis' county-level employment and earnings data. The strategy is to multiply regional location quotients and national coefficients to estimate regional technological relationships. A

household section is estimated to capture the economic interrelationships in the regional economy resulting from increases in personal income. The end result of this process is a matrix of coefficients that recognizes the structure of the regional economy and its interindustry transactions. The transactions table is manipulated to estimate the matrix of total requirements (the sum of the indirect and induced effects of a change in final local demand of $1) for output, employment, and earnings.

The Bureau of Economic Analysis tested the RIMS II estimates to determine the relative accuracy of the technique. The standard for testing compared the coefficients determined by survey-based input-output models for regions in Washington, Texas, and West Virginia. In these states, the RIMS II multipliers tended to overstate the survey-based estimates by $<10\%$. RIMS II-based impact analysis has been conducted for a number of studies, including the U.S. Department of Defense Environmental Impact Statements of military base realignments, evaluations of effects of increasing expenditures by tourists, and the results of a new factory locating in a state (U.S. Bureau of Economic Analysis 1992).

To apply input-output analysis, it is necessary to have a profile of local expenditures associated with each alternative. Total expenditures were estimated for each of the alternatives to provide a cost profile. These numbers were developed under two categories: (1) capital construction and (2) operations and maintenance expenditures. Capital construction information was broken down by labor and equipment and materials. The number of years the construction would take place was also estimated, as were the direct employment impacts associated with each alternative. Employment associated with operation and maintenance expenditures included monitoring. Each construction employee is assumed to earn $\sim$$43,000 per year. Each of the monitoring personnel was assumed to earn $\sim$$35,000 per year. Estimated expenditures for land and relocation were assumed to go to households in the region and were added to labor income.

Table E.1 shows the assumptions regarding the final demand sector for each year of the analysis for each alternative. It also reports the number of full-time equivalent (FTE) positions assumed to be filled for the remediation activities for each year. Since not every employee is assumed to work full time over the year, the FTE can reflect temporary employees, hired to work only part of the year. Final demand is separated into three categories: labor, equipment and materials, and business services. These categories correspond to columns in the input-output tables: labor costs represent payments to households; equipment and materials are assumed to be purchased from the wholesale trade industry; and business services represents the business services industry.

One of the most important issues to determine in conducting input-output analysis is the share of project expenditures actually going to firms located within the region defined by the RIMS II multipliers. For example, dollars may be spent on technical monitoring of a site, but the lab work could be conducted at the home office away from the project region. Therefore, it is necessary to make assumptions regarding the share of expenditures that will actually go to firms and individuals within the region. The input-output multipliers reflect interactions within a region and do not show impacts that could be derived by expenditures outside the region feeding back into the local economy (U.S. Bureau of Economic Analysis 1992).

One of the ways to determine how much of the expenditures will be local is to separate expenditures for direct labor from other expenditures. In this analysis it is assumed that 90% of the expenditures for wages and salaries will be spent in the local area. This share assumes a fairly high average propensity to consume; for individuals with relatively high average incomes, this value would be lower just to reflect deductions for taxes. However, this share represents a conservative assumption, reflecting an upper-bound on indirect employment effects resulting from direct employment. Each alternative also includes expenditures for materials and equipment. Since it is assumed that these purchases will be made at the wholesale level and that they reflect transactions within national markets rather than regional markets, it is assumed that 20% of the expenditures for equipment and materials will go to local firms. Other expenditures, which for the most part reflect technical business services, are assumed to be purchased from expert firms located outside the region; only 0.5% of these expenditures (with labor expenditures already accounted) are assumed to actually go to firms within the region. Most of the business services dollars reflect estimated indirect capital expenditures dealing with the administrative costs (other than labor), contingency budgets, and interest expenses.

The RIMS II earnings multipliers of the three industry categories (households, wholesale trade and business services) were used to convert the final demand vector of local expenditures into feedback effects affecting earnings in the local community. Average wage rates by two-digit Standard Industrial Classification industry were used to convert the earnings figures into indirect employment numbers. The estimated indirect employment effects by alternative are reported in Table E.2.

The next step in the estimation process is to use the employment requirements as the basis for the estimation of the maximum number of new households that could be generated from the employment increase. The maximum number of inmigrating households is estimated to be equal to the number of inmigrating job holders required (which is equal to the total employment impact) divided by 1.34, which is the average number of jobs held per household.

Population is calculated from the number of households by multiplying households times the average household size of Anderson and Roane Counties in 1990, which was 2.53 [Bureau of the Census, U.S. Department of Commerce, *1990 Census of Population and Housing, Summary Population and Housing Characteristics, Tennessee*, 1990 CPH-1-42].

REFERENCES

Drake, Ronald L. 1976. "A Short-Cut to Estimates of Regional Input-Output Multipliers," *International Regional Science Review*, Vol. 1, Fall, pp. 1-17.

Miernyk, William H. 1965. *The Elements of Input-Output Analysis*. Random House, New York.

U.S. Bureau of Economic Analysis. 1981. *Regional Input-Output Modeling System (RIMS II); Estimation, Evaluation, and Application of a Disaggregated Regional Impact Model.* U.S. Department of Commerce, Regional Economic Analysis Division, April.

U.S. Bureau of Economic Analysis. 1992. *Regional Multipliers: A User Handbook for the Regional Input-Output Modeling System (RIMS II).* U.S. Department of Commerce, Economics and Statistics Administration, Second Edition, May.

U.S. Bureau of the Census. 1990. *1990 Census of Population and Housing, Summary Population and Housing Characteristics, Tennessee*, 1990 CPH-1-42. U.S. Department of Commerce.

APPENDIX E

TABLES

This page intentionally left blank.

Table E.1. Annualized expenditures for sitewide alternatives (SWAs) for RIMS II final demand input (spending in thousands of dollars)

SWA	Description of alternative	Year	90.0% Labor[a]	20.0% Equipment/ materials	0.5% Business services	Direct employment (FTE[b]) (number)
1	No Remedial Action	1-4;6-9; 11-14;16-19; 21-24;26-29	35.0	0.0	265.0	1.0
1	No Remedial Action	5;10;15; 20;25;30	94.5	0.0	705.5	2.7
2	Partial excavation, soil cover, and on-site disposal at Y-12 Plant landfill	1-2	2,948.5	6,089.6	12,673.5	73.0
2	Partial excavation, soil cover, and on-site disposal at Y-12 Plant landfill	3-6;8-11; 13-16;18-21; 23-26;28-30	10.5	0.0	89.5	0.3
2	Partial excavation, soil cover, and on-site disposal at Y-12 Plant landfill	7;12;17;22;27	28.0	0.0	222.0	0.8
3	Complete excavation and on-site disposal at Y-12 Plant landfill	1-2	3,040.6	7,032.4	14,545.0	75.4
3	Complete excavation and on-site disposal at Y-12 Plant landfill	3-6;8-11; 13-16;18-21; 23-26;28-30	7.0	0.0	43.0	0.2
3	Complete excavation and on-site disposal at Y-12 Plant landfill	7;12;17;22;27	17.5	0.0	132.5	0.5
4	Partial excavation, soil cover, LTTD[c] treatment, and beneficial reuse of treated soils	1-2	2,604.1	4,157.1	20,984.5	65.4
4	Partial excavation, soil cover, LTTD treatment, and beneficial reuse of treated soils	3-6;8-11; 13-16;18-21; 23-26;28-30	10.5	0.0	89.5	0.3
4	Partial excavation, soil cover, LTTD treatment, and beneficial reuse of treated soils	7;12;17;22;27	28.0	0.0	222.0	0.8

Table E.1 (continued)

SWA	Description of alternative	Year	90.0% Labor[a]	20.0% Equipment/ materials	0.5% Business services	Direct employment (FTE[b]) (number)
5	Complete excavation, LTTD treatment, and beneficial reuse of treated soils	1-2	3,398.2	3,811.4	26,877.0	85.8
5	Complete excavation, LTTD treatment, and beneficial reuse of treated soils	3-6;8-11; 13-16;18-21; 23-26;28-30	7.0	0.0	43.0	0.2
5	Complete excavation, LTTD treatment, and beneficial reuse of treated soils	7;12;17;22;27	17.5	0.0	132.5	0.5
6	Acquisition of residential properties with areas >180 ppm and soil cover of areas >200 ppm	1	2,559.1	396.1	4,885.4	29.7
6	Acquisition of residential properties with areas >180 ppm and soil cover of areas >200 ppm	2-3	1,321.6	3,749.1	7,881.5	34.4
6	Acquisition of residential properties with areas >180 ppm and soil cover of areas >200 ppm	4-7;9-12; 14-17;19-22; 24-27;29-30	28.0	0.0	212.0	0.8
6	Acquisition of residential properties with areas >180 ppm and soil cover of areas >200 ppm	8;13;18;23;28	73.5	0.0	566.5	2.1
7	Excavation of residential property >180 ppm, institutional actions >200 ppm, and controlled land use	1	1,536.5	3,170.3	5,342.0	29.3
7	Excavation of residential property >180 ppm, institutional actions >200 ppm, and controlled land use	2	1,306.0	2,271.0	6,259.8	34.0

Table E.1 (continued)

SWA	Description of alternative	Year	90.0% Labor[a]	20.0% Equipment/ materials	0.5% Business services	Direct employment (FTE[b]) (number)
7	Excavation of residential property >180 ppm, institutional actions >200 ppm, and controlled land use	3-6;8-11; 13-16;18-21; 23-26;28-30	10.5	0.0	89.5	0.3
7	Excavation of residential property >180 ppm, institutional actions >200 ppm, and controlled land use	7;12;17;22;27	28.0	0.0	222.0	0.8

[a] Includes payments for land and relocation costs, which are assumed to go to households located in the region.
[b] Full-time equivalent.
[c] Low-temperature thermal desorption.

Table E.2. Summary of impacts on employment, households, and population from the Base Year for East Fork Poplar Creek sitewide alternatives (SWAs)

SWA	Description of alternative	Year	Direct employment (FTE[a])	Indirect employment (FTE)	Total employment (FTE)	House-holds	Population
1	No Remedial Action	1-4;6-9; 11-14;16-19; 21-24;36-29	1.0	0.3	1.3	1	3
1	No Remedial Action	5;10;15; 20;25;30	2.7	0.7	3.3	2	5
2	Partial excavation, soil cover, and on-site disposal at a new Y-12 Plant disposal facility	1-2	73.0	49.5	122.5	91	230
2	Partial excavation, soil cover, and on-site disposal at a new Y-12 Plant disposal facility	3-6;8-11; 13-16;18-21; 23-26;28-30	0.3	0.1	0.4	0	0
2	Partial excavation, soil cover, and on-site disposal at a new Y-12 Plant disposal facility	7;12;17;22;27	0.8	0.2	1.0	1	3
3	Complete excavation and on-site disposal at a new Y-12 Plant disposal facility	1-2	75.4	55.0	130.4	97	245
3	Complete excavation and on-site disposal at a new Y-12 Plant disposal facility	3-6;8-11; 13-16;18-21; 23-26;28-30	0.2	0.1	0.3	0	0
3	Complete excavation and on-site disposal at a new Y-12 Plant disposal facility	7;12;17;22;27	0.5	0.1	0.6	0	0
4	Partial excavation, soil cover, LTTD[b] treatment, and beneficial reuse of treated soils	1-2	65.4	40.0	105.4	79	200
4	Partial excavation, soil cover, LTTD treatment, and beneficial reuse of treated soils	3-6;8-11; 13-16;18-21; 23-26;28-30	0.3	0.1	0.4	0	0
4	Partial excavation, soil cover, LTTD treatment, and beneficial reuse of treated soils	7;12;17;22;27	0.8	0.2	1.0	1	3

Table E.2 (continued)

SWA	Description of alternative	Year	Direct employment (FTE[a])	Indirect employment (FTE)	Total employment (FTE)	House-holds	Population
5	Complete excavation, LTTD treatment, and beneficial reuse of treated soils	1-2	85.8	44.4	130.2	97	245
5	Complete excavation, LTTD treatment, and beneficial reuse of treated soils	3-6;8-11; 13-16;18-21; 23-26;28-30	0.2	0.1	0.3	0	0
5	Complete excavation, LTTD treatment, and beneficial reuse of treated soils	7;12;17;22;27	0.5	0.1	0.6	0	0
6	Acquisition of residential properties with areas >180 ppm and soil cover of areas >200 ppm	1	29.7	18.5	48.2	36	91
6	Acquisition of residential properties with areas >180 ppm and soil cover of areas >200 ppm	2-3	34.4	27.5	61.9	46	116
6	Acquisition of residential properties with areas >180 ppm and soil cover of areas >200 ppm	4-7;9-12; 14-17;19-22; 24-27;29-30	0.8	0.2	1.0	1	3
6	Acquisition of residential properties with areas >180 ppm and soil cover of areas >200 ppm	8;13;18;23;28	2.1	0.6	2.7	2	5
7	Excavation of residential property >180 ppm, soil cover >200 ppm, and controlled land use	1	29.3	25.5	54.8	41	104
7	Excavation of residential property >180 ppm, soil cover >200 ppm, and controlled land use	2	34.0	20.0	54.0	40	101

Table E.2 (continued)

SWA	Description of alternative	Year	Direct employment (FTE[a])	Indirect employment (FTE)	Total employment (FTE)	House-holds	Population
7	Excavation of residential property >180 ppm, soil cover >200 ppm, and controlled land use	3-6;8-11; 13-16;18-21; 23-26;28-30	0.3	0.1	0.4	0	0
7	Excavation of residential property >180 ppm, soil cover >200 ppm, and controlled land use	7;12;17;22;27	0.8	0.2	1.0	1	2

[a] Full-time equivalent
[b] Low-temperature thermal desorption

APPENDIX F

HUMAN HEALTH RISK ASSESSMENT

CONTENTS

TABLES . . . . . F-v
FIGURES . . . . . F-vii
ACRONYMS . . . . . F-ix

APPENDIX F. HUMAN HEALTH RISK ASSESSMENT F-1

F.1 INTRODUCTION F-1
F.1.1 Overall Protection of Human Health F-2
F.1.2 Long-Term Effectiveness and Permanence F-2
F.1.3 Short-Term Effectiveness F-2

F.2 RISK ASSESSMENT METHODS F-3
F.2.1 Long-Term Evaluation F-3
F.2.2 Short-Term Evaluation F-3
F.2.2.1 COCs and exposure point concentrations F-4
F.2.2.2 Exposure assessment F-5
F.2.2.3 Toxicity assessment F-15
F.2.2.4 Risk characterization F-16

F.3 SUMMARY OF RISK ASSESSMENT RESULTS F-19

F.4 UNCERTAINTY ANALYSIS F-20
F.4.1 Analytical Data F-21
F.4.2 Exposure Assessment F-21
F.4.2.1 Exposure scenarios F-21
F.4.2.2 Exposure models F-22
F.4.2.3 Exposure parameters F-23
F.4.3 Toxicity Information F-24
F.4.4 Risk Characterization F-24
F.4.5 Estimation of remediation goal option(s) for mercury F-24

REFERENCES F-41

ATTACHMENT F.1 . . . . . F-91

TABLES

F.1 Exposure point concentrations for mercury in soil and air used in the detailed analysis of alternatives at EFPC F-31

F.2 Exposure pathways for the human health risk assessment F-32

F.3 Exposure parameters F-33

F.4 Estimates of emission factors for remedial activities at EFPC (inhalable particulates) F-35

F.5 Estimates of emission rates for remedial activities at EFPC (inhalable particulates) F-36

F.6 Receptor characteristics for use in SCREEN2 model F-37

F.7 Mercury emission factors and rates for the low-temperature thermal desorption (LTTD) unit at the K-25 Site F-38

F.8 Sensitivity analysis: projected distances and ambient concentrations for different LTTD unit design specifications F-39

F.9 Toxicity values for mercury F-40

F.10 Qualitative uncertainty estimates F-41

F.11 Qualitative uncertainty estimates for the air pathway analysis F-42

FIGURES

F.1 EPA SCREEN2 model output for fugitive dust dispersion F-45

F.2 EPA SCREEN2 model output for mercury vapor dispersion from low-temperature thermal desorption stack F-46

F.3 Probability distribution: remediation goal option for mercury in EFPC soil F-48

ACRONYMS

APA	air pathway analysis
ARAR	applicable or relevant and appropriate requirement
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	contaminant of concern
COPC	chemical of potential concern
DOE	U.S. Department of Energy
ED	exposure duration
EFPC	East Fork Poplar Creek
EPA	U.S. Environmental Protection Agency
FS	feasibility study
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HQ	hazard quotient
IRIS	Integrated Risk Information System
LOAEL	lowest-observed-adverse-effect level
LTTD	low temperature thermal desorption
MCL	maximum contaminant level
MLE	most likely exposure
NOAEL	no-observed-adverse-effect level
NTGS	*National Technical Guidance Series*
ORNL	Oak Ridge National Laboratory
RAGS	*Risk Assessment Guidance for Superfund*
RfC	reference concentration
RfD	reference dose
RI	remedial investigation
RME	reasonable maximum exposure
RU	remedial unit
SWA	sitewide alternative
UCL	upper confidence limit

F. HUMAN HEALTH RISK ASSESSMENT

The purpose of this appendix is to present the methods and results of the human health risk assessment that was conducted to support the feasibility study (FS) at East Fork Poplar Creek (EFPC). As part of the FS process, risk assessment is used to evaluate the acceptability of proposed remedial actions and to act as a tool in developing remediation objectives (target cleanup levels). Risk assessment is used to evaluate the overall protection of human health and the short-term (i.e., during the implementation) and long-term (i.e., after the completion) effectiveness of seven remedial alternatives. This appendix provides a detailed analysis of the risks associated with implementation of different remedial alternatives.

F.1 INTRODUCTION

This appendix is organized in the following manner:

- Section F.1 - Introduction,
- Section F.2 - FS Risk Assessment Methods, and
- Section F.3 - FS Risk Assessment Results.

Human health risk assessment is one of the analytical components required by the U.S. Environmental Protection Agency (EPA) for the detailed analysis of remedial alternatives. EPA specifies that the following nine criteria be used to evaluate all remedial alternatives at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites (EPA 1988):

- Threshold Criteria
  - Overall protection of human health and the environment
  - Compliance with applicable or relevant and appropriate requirements (ARARs)

- Primary Balancing Criteria
  - Long-term effectiveness and permanence
  - Reduction of toxicity, mobility, or volume
  - Short-term effectiveness
  - Implementability
  - Cost

- Modifying Criteria
  - State acceptance
  - Community acceptance.

This risk assessment provides input for three of the nine criteria: overall protection of human health, long-term effectiveness and permanence, and short-term effectiveness.

The purpose of the detailed analysis of alternatives is to provide decision-makers with information to select an appropriate remedial alternative. As specified by EPA (1991a), certain

issues must be considered regarding human health during the detailed analysis of the alternatives. At EFPC, these include the following:

- The alternative should achieve the remediation goal options for cleanup.
- The alternative should focus on pathways involving soil contact (e.g., ingestion, dermal contact, and inhalation) that are identified as the most appropriate for remediation planning.
- The residual risks and short-term risks from one alternative to another should be compared for significant differences.
- Any specific human health effect advantage or benefit associated with a particular alternative should be identified.
- Alternatives should account for chemical exposures that an alternative may create.
- The need for engineering controls or measures during implementation of a particular alternative should be considered.
- The need for a 5-year review to assess residual contamination should be considered.

F.1.1 Overall Protection of Human Health

Overall protection of human health and the environment under each remedial alternative is evaluated to determine whether the alternative ". . . can adequately protect human health and the environment in both the short- and long-term, from unacceptable risks posed by hazardous substances, pollutants, or contaminants present at the site" (EPA 1990). This criterion ". . . draws on the assessments of other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs" (EPA 1990). Overall protectiveness is a threshold criterion. Therefore, only alternatives determined to be protective in the detailed analysis can be considered for selection as the remedy (EPA 1990).

F.1.2 Long-Term Effectiveness and Permanence

The long-term effectiveness criterion addresses the ability of an alternative to protect human health and the environment from residual waste or hazardous materials that would remain on site after the completion of remediation. The analysis under this criterion is concerned with quantifying the magnitude of residual risks including ". . . consideration of the degree of threat posed by the hazardous substances remaining at the site and the adequacy of any controls (e.g., engineering or institutional) used to manage the hazardous substances remaining at the site" (EPA 1990).

F.1.3 Short-Term Effectiveness

The short-term effectiveness criterion addresses the effects of the alternative during the construction and implementation phase. This criterion is concerned with quantifying the potential magnitude of exposure and risk to the community, workers, and the environment during remediation.

F.2 RISK ASSESSMENT METHODS

This section provides the methods used to evaluate human health risks in support of the alternative selection process. EPA guidance for this evaluation is presented in the following documents: *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988); *Risk Assessment Guidance for Superfund (RAGS), Volume I (Part C, Risk Evaluation of Remedial Alternatives)* (EPA 1991a); and *RAGS, Volume I (Part A)* (EPA 1989a).

As noted in EPA guidance for detailed analysis of alternatives (EPA 1991a), the baseline risk assessment conducted during the remedial investigation (RI) is closely linked to the risk characterization supporting the FS. The same guidance notes that risk assessment for detailed analysis of alternatives tends to reflect a lower level of effort than does the baseline risk assessment. The methods employed for risk characterization in support of the FS are generally very similar to those used in the baseline risk assessment. Furthermore, many of the FS alternatives are similar or identical from one remedial unit (RU) location to another at EFPC. The general approach is to share as many common elements as possible from the baseline risk assessment, as well as within the FS (e.g., same exposures from one location to another), to avoid needless repetition.

F.2.1 Long-Term Evaluation

The analysis of long-term human health risks involves two steps: (1) evaluating residual risk and (2) evaluating the alternative's ability to provide protection over time.

As stated in EPA guidance (EPA 1991a), "Because PRGs (referred to as remediation goal options) generally are based on chronic human health risk considerations [e.g., ARARs such as maximum contaminant levels (MCLs), or risk-based concentrations], they usually provide the standard to use to evaluate long-term health risks." Therefore, residual risk generally can be determined by indicating whether an alternative has the potential to achieve the remediation goal options; because the remediation goal options were previously established in the baseline risk assessment, the comparison involves only a discussion (i.e., no new exposure pathways or parameters were developed).

The evaluation of protectiveness over time, or permanence, is generally also a qualitative discussion. For example, if an alternative relies on institutional controls or containment methods to reduce exposure to contaminants, the issue of whether the controls or containment can be maintained over time should be addressed. It is important to remember that 5-year reviews must be conducted at all sites where wastes are managed on site above concentration levels that allow for unrestricted use and unlimited exposure. Therefore, a total system failure is unlikely to occur.

F.2.2 Short-Term Evaluation

The methods used to evaluate short-term risks in this risk assessment generally follow those used for evaluating baseline risks. These methods were covered in detail in the RI report (DOE 1994) and are presented in *RAGS*, Volume I (Part A) (EPA 1989a). They include:

- Determination of contaminants of concern (COCs) and the respective exposure point concentrations associated with each alternative,

- Determination of potential exposure pathways associated with each alternative and quantifying intake for all contaminants,

- Assessment of the toxicity of the COCs, and

- Characterization of the risks associated with each alternative.

F.2.2.1 COCs and exposure point concentrations

Numerous chemicals of potential concern (COPCs) were identified and evaluated in the baseline risk assessment. However, remediation is not required for all of these substances. For example, the concentrations of some of the metals in floodplain soils were not significantly different from levels at the reference location. Based on the results from the RI, it was decided that the soil pathway is the most appropriate basis for determining the need for site remediation and that the COC for the human health evaluation is mercury. For further detail concerning the selection of mercury as the COC, refer to Sect. 3.1.

Once COCs have been selected, environmental monitoring data must be aggregated to derive a meaningful estimate of the exposure point concentrations. Data aggregation enables the risk assessor to focus on key receptors and circumstances under which exposure is likely to occur. In the baseline risk assessment, soil data were aggregated within each of the nine segments (i.e., all samples collected within a given segment were aggregated). Further detail is presented in the baseline risk assessment. The same method of aggregation has been used in the FS. However, the FS evaluation is concerned only with those areas of contamination within a segment that have concentrations above the pertinent remediation goal option. Therefore, only those samples from each segment that were collected within the boundaries of the areas to be remediated have been included in the calculation of the exposure point concentrations for the FS risk characterization.

Furthermore, exposure point concentrations were *not* calculated separately for different land uses within a segment; only one exposure point concentration was calculated per segment. This concentration was used to calculate all risks within that segment, regardless of the land use. Land use considerations were excluded mainly because of the limited data set. In several instances, very few samples were collected within the borders of the areas designated for remediation. Aggregation according to land use within a segment would produce areas with no data points at all.

The sample data were then entered into an electronic database, and summary statistics were generated for the data set. These statistics include the number of samples analyzed; frequency of detection; the minimum, maximum, and mean concentrations of chemicals; and the reasonable maximum exposure (RME) concentration [i.e., the 95% upper confidence limit (UCL) on the arithmetic mean]. In the baseline risk assessment, both a most likely exposure (MLE) estimate *and* an RME estimate were calculated. This was done to define a range of possible exposures and quantify the uncertainty associated with the baseline risk estimates. However, EPA

Region IV requested that the RI risk characterization focus on RME risk estimates; therefore, only RME estimates are presented as the focus of the FS risk assessment.

The exposure point concentration is the 95% UCL on the arithmetic mean, which is calculated as follows:

$$UCL = \bar{x} + t_{1-\alpha,\, n-1} \bullet \left(\frac{s}{\sqrt{n}}\right), \qquad (1)$$

where

$\bar{x}$ = Mean of the data,
t = Student t-statistic (Gilbert 1987),
α = Upper-tail area,
s = Standard deviation of the data,
n = Number of samples.

However, if a data set is characterized by considerable variability and the sample size is small, the UCL may exceed the maximum observed value in the data set. In this case, EPA recommends use of the maximum observed concentration as the RME estimate (EPA 1989a). In the evaluation of EFPC, the UCL is the value derived using the above equation or the maximum observed value, whichever is smaller. Table F.1 lists the exposure point concentrations used in the risk assessment.

F.2.2.2 Exposure assessment

The purpose of the exposure assessment is to identify the receptors at potential risk from contact with contaminants, determine the exposure pathways of importance, and quantify intake, or dose, for all contaminants and pathways of concern. In this evaluation, short-term exposures of remediation workers and off-property residents *during remedial activities* are addressed.

Receptors

During remediation activities, exposures to contaminated soils would occur among remediation workers as well as residents of the community in nearby houses or farms. Two residential receptors are assumed to be exposed: children aged 3 to 12 years and adults. Remediation workers consist of adults only.

Exposure Pathways

The exposure pathways include incidental ingestion of soil, dermal contact with soil, inhalation of fugitive dust (suspended soil particulates), and inhalation of vapor originating from the low-temperature thermal desorption unit. The pathways and receptors vary according to the general action. Table F.2 presents the pathways and receptors under evaluation in the FS.

Containment. It has been assumed that no community exposures would occur for this general action. This supposition was made because little or no intrusion into contaminated soil would be expected during remedial actions. Fugitive dust emissions would therefore be minimal.

Worker exposures during remediation are assumed to occur. Although little or no soil intrusion is expected, workers would be responsible for deforesting contaminated areas and installing fences or signs where applicable. Therefore, soil ingestion, soil dermal contact, and inhalation of suspended soil particulates for workers has been evaluated. However, in comparison to other general actions (e.g., excavation, disposal), inhalation risks are expected to be less because activities such as excavation, dumping, and transportation of contaminated soils would not occur. This would result in lower exposure point concentrations. Since no models were available to predict emission rates due to deforestation and installation of fences, it was decided that exposures would be adequately represented by modeling grading activities. Estimation of exposures from fugitive dust emissions is discussed later in the section entitled "Air Emissions Modeling."

Excavation. Under this general action, residents of the community living near the areas designated for remediation would be exposed to contaminants as a result of inhaling suspended soil particulates. These particulates would be generated mainly as a result of three different activities occurring within the areas to be remediated: soil excavation, dumping soils into trucks, and transporting soils from the remediation areas to the decontamination area. Soil particulates would then be transported downwind from the remediation areas to residential areas. Soil ingestion and dermal contact exposures have not been evaluated for the community because downwind deposition of soils is likely to be insignificant given the limited duration of remedial actions at a given location.

Workers at the remediation area would be exposed to contaminated soil through ingestion, dermal contact, and inhalation of suspended soil particulates. Inhalation exposures for excavation workers have been calculated assuming three different activities: excavation, dumping soils into trucks and at the disposal or treatment facility, and transporting soils from the remediation areas to the decontamination area. The methods used to estimate exposures from fugitive dust emissions are discussed in the section entitled "Air Emissions Modeling."

Disposal. Residents of the community living near the Y-12 Plant disposal facility are assumed to be exposed to contaminants in soils as a result of inhaling suspended dust particulates originating from the disposal facility. Soil particulates suspended in air would be generated mainly as a result of three different activities occurring at the disposal facility: dumping soils, storing soils temporarily in piles (wind erosion), and grading (grooming the piles and depositing the soils in the disposal area). Soil ingestion and dermal contact exposures have not been evaluated for the community because downwind deposition of soils is likely to be insignificant.

Remediation workers at the Y-12 Plant disposal facility would be exposed to contaminated soil through ingestion, dermal contact, and inhalation of suspended soil particulates. Inhalation exposures for disposal workers have been calculated assuming the same activities as for the community: dumping soils at the disposal facility, storing soils temporarily in piles, and grading. Estimation of exposures from fugitive dust emissions is discussed in the section entitled "Air Emissions Modeling."

Treatment. Community residents living near the K-25 Site could be exposed to fugitive dust originating from soil handling activities at the site. Exposures associated with soil handling activities are assumed to be the same as those associated with disposal (i.e., including dumping, storage, and grading activities). Another potential pathway, involves community members who could be exposed to mercury vapors from the low-temperature thermal desorption unit through inhalation.

Remediation workers at the K-25 Site would be exposed to fugitive dust during soil handling activities and to mercury vapor during the operation of the low-temperature thermal desorption unit. Exposures associated with the soil handling activities are assumed to be the same as those associated with disposal. In the section entitled "Air Emissions Modeling," estimation of exposures from fugitive dust emissions and mercury vapor from the low-temperature thermal desorption unit are discussed.

Institutional Actions. These include actions such as future land use limitations, construction permit restrictions, fencing, posting signs, periodic environmental monitoring, and 5-year review. Community and worker risks are not evaluated because there is little or no potential for exposure associated with these activities.

Quantification of Intake

The parameters and equations used to quantify intake or dose through each of the above pathways are shown in Table F.3 and discussed below. Note that many of the exposure parameters are the same as those used in the baseline risk assessment for the RI (DOE 1994a).

Incidental Ingestion of Soil. During remediation activities, incidental ingestion of soil by workers could occur as a result of inadvertent hand-to-mouth contact. Remediation workers would be in direct contact with contaminated soil and dust. Exposure through this pathway is estimated using the following equation:

$$Intake = C \times \frac{IR \times CF \times FI \times EF \times ED}{BW \times AT}, \qquad (2)$$

where

C	=	Chemical concentration in soil (mg/kg),
IR	=	Ingestion rate (mg/d),
CF	=	Conversion factor for soil (10^{-6} kg/mg),
FI	=	Fraction ingested from contaminated source (unitless),
EF	=	Exposure frequency (d/week),
ED	=	Exposure duration (weeks),
BW	=	Average body weight (kg),
AT	=	Averaging time (d).

For the workers, the soil ingestion rate is assumed to be elevated, at 480 mg/d. This value is based on conservative professional judgment that soil ingestion would be elevated during soil-handling activities and on published estimates of soil ingestion rates for adults working outdoors

(EPA 1991b). It is assumed that all ingested soil originates from the contaminated site and that the total daily soil ingestion occurs at the work site (i.e., FI=1).

The exposure frequency for workers would be limited to 5 d/week but would last for the duration of remediation activities across all RUs. The duration of remedial activities has been estimated at approximately 10 weeks at an area designated for remediation. The total duration of activities for all RUs has been estimated at approximately 1.7 years for sitewide alternatives (SWAs) 2 and 4, 1.6 years for SWAs 3 and 5, 2.3 years for SWA 6, and 1.8 years for SWA 7 (professional judgment based on site-specific assumptions).

Dermal Exposure to Soil. Workers would be exposed to soils while conducting remedial activities. The equation for estimating dermal dose is as follows:

$$Dose = C \times \frac{CF \times SA \times FE \times AF \times ABS \times EF \times ED}{BW \times AT}, \qquad (3)$$

where

C	=	Chemical concentration in soil (mg/kg),
CF	=	Conversion factor (10^{-6} kg/mg),
SA	=	Total skin surface area available for contact (cm^2),
FE	=	Fraction of skin area exposed (unitless),
AF	=	Soil to skin adherence factor (mg/cm^2),
ABS	=	Absorption factor (unitless),
EF	=	Exposure frequency (d/week),
ED	=	Exposure duration (weeks),
BW	=	Average body weight (kg),
AT	=	Averaging time (d).

Values for total skin surface area available for contact based on EPA (1989b) guidelines are presented in the RI (DOE 1994) and are used here. Because dust would penetrate each worker's clothing to some extent, the exposed fraction of the skin area is assumed to be one-half of the total body surface area.

Estimates of dermal exposure to soils require information on soil adherence factors and percent absorption. Site-specific data on adherence of EFPC floodplain soil to human skin are not available. As noted in the RI, adherence factor values suggested by EPA Region IV and Region X (EPA 1992a, EPA 1991c) are 1.0 and 0.6 mg/cm^2 for high end and average exposure estimates, respectively. In this report, the more conservative (larger) adherence factor (1.0 mg/cm^2) is used in the assessment of dermal exposure to soils. Percent absorption values are chemical-specific. Because mercury is the only COC, 0.001 will be used for this parameter.

The value for exposure frequency for workers is the same as for the soil ingestion pathway, since these two pathways are assumed to occur concurrently. Exposure duration, body weight, and averaging time used for this pathway are also the same as those described for the soil ingestion pathway.

Inhalation of Particulates. Inhalation exposure to suspended particulates is assumed to occur among remediation workers and residential (community) receptors. Suspension of particulates occurs as a result of excavating, dumping, grading, storing, and transporting contaminated soils. Workers would be nearer to the sources of particulate emissions than would residents.

Exposure assumptions have been selected to conservatively reflect exposure potential. It is assumed that workers would generally be at greater risk of exposure due to proximity to the source of dust. Residential receptors also could be exposed to airborne emissions, but the concentration would be attenuated due to the greater distance from the source.

In the absence of air monitoring data, air emissions and dispersion have been modeled to estimate the concentrations of suspended material (and consequently the mercury concentration) in the air. This analysis is discussed further in the section entitled "Air Emissions Modeling."

Once the concentrations of mercury in the ambient air (C_{Air}) at the locations of workers and residents are derived, the following equation is used to estimate intake for the inhalation pathway:

$$Intake = C_{Air} \times \frac{IR \times ET \times EF \times ED}{BW \times AT}, \quad (4)$$

where

C_{Air}	=	Estimated chemical concentration in the ambient atmosphere ($\mu g/m^3$),
IR	=	Inhalation rate (m^3/h),
ET	=	Exposure time (h/d),
EF	=	Exposure frequency (d/week),
ED	=	Exposure duration (weeks),
BW	=	Average body weight (kg),
AT	=	Averaging time (d).

Inhalation rates for workers and residents are calculated based on hourly inhalation rates presented in the EPA Exposure Factors Handbook (EPA 1989b). Workers are assumed to sustain inhalation rates that correspond to moderate activities for the duration of their workday (i.e., 8 h). Residents are assumed to maintain an inhalation rate that is a combination of light (4 h) and moderate (4 h) activity for the workday.

The exposure time for both residents and workers would be limited to 8 h/d. Unlike the other exposure pathways, dust emissions are not expected to be sustained following the end of the workday, thereby limiting the exposure time for residents.

Exposure frequency also would be limited to the actual days worked for both workers and residents. Exposure frequency consequently is assumed to be 5 d/week for both sets of receptors. Exposure duration is assumed to reflect the duration of remediation activities at one area designated for remediation for residents (10 weeks). Workers are assumed to be exposed through inhalation for the duration of remediation activities across all RUs. Body weights and averaging times used for this pathway are also the same as those described for the previous pathways.

Air Emissions Modeling

Air pathway analysis (APA) is required to assess the potential for air emissions and air quality impacts during cleanup activities. APA is used in conjunction with risk assessment to measure the overall protection of human health associated with remedial activities. Risk assessment will be used to determine whether air emission control technologies or an air monitoring program is necessary.

At EFPC, digging and relocating soil will cause volatile and fugitive dust emissions, which entrained in wind, can be carried from the site. Because of the nature of the contaminants present in the floodplain, fugitive dust emissions are the primary concern. Volatile emissions related to soil handling are minimal in all cases except for vapor phase emissions from the low-temperature thermal desorption unit at the K-25 Site.

RAGS (EPA 1989a) recommends three general approaches for estimating exposure point concentrations in air for use in risk assessment: ambient air monitoring, emission measurements coupled with dispersion modeling, and emission modeling coupled with dispersion modeling. Since cleanup activities have not yet begun at EFPC and because neither measured emission rates nor air monitoring data are currently available, models have been used to estimate particulate (i.e., fugitive dust) and vapor phase emissions. In general, two kinds of models are used to estimate air concentrations: emission models that predict the rate at which chemicals may be released into the air from a source, and dispersion models that predict associated concentrations in air at potential receptor points (EPA 1989a).

For fugitive dust emissions, emission rates were calculated using published equations for various soil handling activities (e.g., excavation, grading). Next, EPA's SCREEN2 dispersion model was used to predict downwind transport of fugitive dust. Results from SCREEN2 were then used with known contaminant concentrations in soil to determine exposure point concentrations.

Fugitive mercury vapor emissions from floodplain soils have been studied independently by scientists at Oak Ridge National Laboratory (ORNL) (Kim et al. 1993). Using data from this study, concentrations of mercury vapor were estimated. These concentrations were then compared to concentrations of mercury in fugitive dust and were found to be significantly less. Therefore, risks from mercury vapor emissions from soils (other than those emerging from the low-temperature thermal desorption unit) have not been evaluated.

Vapor phase emission rates from the low-temperature thermal desorption unit are dictated by the concentration of mercury in the treated soil and the design specifications of the unit (i.e., the emission rates were be estimated assuming that the unit maintains a specific removal efficiency). EPA's dispersion model, SCREEN2, was used to carry the contaminants downwind. This time, a sensitivity analysis was performed to observe how stack height, stack diameter, and distance to receptor would affect the results of the model. The soil contaminant concentrations were then combined with the results of SCREEN2 to estimate the exposure point concentrations.

Note that the respirable portion of fugitive dust emissions are assumed to disperse in a manner indistinguishable from vapor phase emissions. The following sections explain in detail

the methods used to estimate emission rates and exposure point concentrations in air from fugitive dust and vapor phase emissions from the low-temperature thermal desorption unit.

Fugitive Dust Emissions

The following general actions are common to the SWAs: (1) containment, (2) excavation, (3) disposal, and (4) treatment. Each of these are associated with remedial activities that are expected to generate fugitive dust. The following sections detail the methods used to estimate emission rates from fugitive dust emission sources, downwind dispersion, and exposure point concentrations for use in the risk assessment.

Estimation of Emission Factors and Emission Rates. In the absence of air monitoring data, fugitive dust emission rates are used with dispersion modeling to estimate impacts of remedial activities to workers and the surrounding community. Formulas are available to estimate emission factors in EPA's Air/Superfund *National Technical Guidance Series (NTGS)*, Vol. III (EPA 1989c). These formulas use physical parameters measured during the RI (e.g., silt and moisture content in soil). In addition, control technologies (such as wetting down the soil) may be used to limit fugitive dust emissions during remedial activities. The emission factors, which are expressed in mass per unit operation, are converted to emission rates in mass per unit time, which may then be modified by the control efficiencies.

Different control technologies are available for remedial activities that are expected to occur at the removal site, the treatment site, and the disposal site. Table 13 in *NTGS*, Vol. III lists control efficiencies for different control technologies that are associated with the various activities. Control efficiencies will be built into the model and will be explained in greater detail in subsequent sections.

Particle emissions and transport are different for various particle sizes. Large particles (i.e., diameters >100 μm) are likely to settle within 5 to 10 m (16 to 33 ft) of the emission source (EPA 1989c). Moderate-size particles (i.e., 30 to 100 μm) presumably settle within 100 m (328 ft) of the source, except in cases of high atmospheric turbulence. This evaluation will focus on inhalable particulates (<10 to 15 μm) with greater probability of downwind transport, thus impacting site and community receptors. Particles >10 to 15 μm are believed to be excluded from human lungs because of natural defense mechanisms.

Contaminants, particularly metals, generally adhere more readily to the silt fraction of soil particles, which is also the fraction of the soil matter most prone to airborne dispersion during remedial activities. Metal enrichment factors from *NTGS*, Vol. III (EPA 1989c) are multiplied by the contaminant concentrations in the soil samples to provide an estimate of the metal concentrations in the emitted particulate matter. The metal enrichment factor for mercury is 3.00 (EPA 1989c).

Fugitive dust emissions from five different remedial activities will be modeled: soil excavation using a bulldozer, transportation of contaminated soils on unpaved roads, dumping into dump truck bed or onto temporary storage piles, storage (wind erosion), and grading/grooming the storage piles. Appropriate equations in NTGS will be used to estimate emission factors and emission rates for these activities. These equations and associated parameters are presented in Tables F.4 and F.5.

Combinations of the five remedial activities will be used during the different soil handling operations. For excavation activities, emission rates will be the sum of the emission rates from excavation, transportation, and dumping. For disposal and pretreatment soil handling at the K-25 Site, the emission rates will incorporate dumping, storage, and grading. For containment and institutional controls, only grading activities will be used to calculate emission rates. Dust emissions from the stack of the low-temperature thermal desorption unit will be controlled and will be negligible. The following paragraphs and Tables F.4 and F.5 outline the assumptions used in estimating individual emission rates for excavation, transportation, dumping, storage, and grading.

Excavation using a bulldozer

Contaminated floodplain soil will be excavated by front-end loaders, backhoes, and bulldozers. Fugitive dust emissions will be propagated by natural wind turbulence and by equipment traversing contaminated soil. Silt and moisture content of the floodplain soils measured during the RI have been used in this evaluation. The number of bulldozers and hours of operation are estimates reflecting best professional judgment based on site-specific assumptions. The control efficiency for excavation is 60%, based on studies in which soil was sprayed with water mixed with a surfactant during excavation activities to minimize dust emissions (EPA 1989c).

Transportation

Emissions will be estimated for soil transported on dry, gravel roads using medium-weight and heavy vehicles. The soil will be removed from the site and transported to a nearby decontamination area. The evaluation will not address transport from the decontamination area to the treatment and/or disposal facilities because the truck will be cleaned and the beds will be covered prior to exiting the decontamination area. Several assumptions and their sources are listed in Tables F.4 and F.5. During transport, the roads will be covered with gravel and kept moist, and the trucks will be covered. This will yield 95% fugitive dust control efficiency.

Dumping

Dumping includes loading dump trucks at the removal site and unloading at the staging (i.e., at the treatment facility) and disposal areas. Several assumptions related to dumping are listed in Tables F.4 and F.5, and are consistent with the RI and other sections of the FS. According to *NTGS*, Vol. III (EPA 1989c), water sprayed over the dumping area will achieve a 69% dust control efficiency.

Storage

Removed soil may be staged temporarily prior to treatment or disposal. The surface area covered by the storage pile is small because the piles will only accumulate for short periods (i.e., <24 h). Fugitive dust emissions from the storage area may be decreased by aligning the storage pile perpendicular to the prevailing wind. This will achieve a dust control efficiency of 60% (EPA 1989c).

Grading

Heavy equipment will be used to groom the storage piles at the disposal area and to replace the soil at the removal sites. The storage piles will be sprayed during the grooming process, which should achieve a 70% control efficiency of fugitive dust emissions (EPA 1989c). Fugitive dust emissions from contaminated soil at the removal area are expected to be localized during grading, which involves only surficial movement of soils, not excavation and dumping. Treated soils returned to the EFPC floodplain will not contain significant contaminant levels. Cover soils will be backfilled (dumped) on top of contaminated soils. It is expected that this activity will not result in exposure to contaminated soils. The potential for exposure to contaminants during grading is limited; thus only on-site worker exposures will be evaluated.

Trees and debris that must be removed for the containment alternative will be removed in a fashion similar to grading; that is, trees will be cut down at ground level and removed from the site using bulldozers. Therefore, it seems appropriate to use grading emission equations under the containment alternative (a 50% control efficiency also may be appropriate because the debris will be pushed over a vegetative layer). In addition, because vegetative cover is present and intrusive activity into contaminated soil is limited, exposures to downwind community receptors as a result of soil grading will not be evaluated.

Dispersion Modeling. Fugitive dust emission rates are used in conjunction with dispersion models for air pathway analysis of the remedial activities expected to occur at EFPC. Dispersion models employ emission rates and meteorological data to calculate downwind dust concentrations in air ($\mu g/m^3$). This information, in conjunction with contaminant concentrations in the removed soil, will be used to assess the impacts to workers and the community. This section outlines the assumptions used to run SCREEN2 (EPA 1992d), the dispersion model employed for this analysis.

General source and receptor characteristics are required to run SCREEN2. Figure F.1 lists input assumptions and output concentrations for the SCREEN2 model at EFPC. Because of the nature of the hot spots that must be remediated and the activities that are expected to occur, nine hypothetical area sources (i.e., one for each creek segment) were used in the evaluation. An average source height of 1 m (3 ft) with an emission rate of 1 g/s was used for a 50 × 50 m square area source (4×10^{-4} g/s · m^2). Distances to nearest community receptors for use in the model were taken from land use planning maps in conjunction with hot-spot maps. The area source algorithm in SCREEN2 cannot estimate concentrations <25 m from the center of the square source area. Because of this limitation, worker exposures and some residential exposures were modeled using the maximum concentration predicted by SCREEN2. Table F.6 lists the distances to receptors used in the model for all nine creek segments.

Estimation of Exposure Point Concentrations. After dispersion modeling and estimation of emission rates, dust concentrations in air and mercury concentrations in removed soil are used to estimate exposure point concentrations. The latter are then used in the intake equations for the inhalation pathway.

SCREEN2 outputs are dust concentrations [in units of $(\mu g/m^3)/(g/s)$] that result from fugitive dust emissions. To estimate ambient air mercury concentrations, the dust concentrations from

the dispersion models are multiplied by the emission rates and the UCL mercury concentrations in the removed soil as illustrated below.

$$\frac{(\mu g\ Hg)}{(m^3\ air)} = \left[\frac{(mg\ Hg)}{(kg\ soil)}\right]_{UCL} \times \frac{g\ soil_{Inh}}{\text{sec}} \times \frac{\dfrac{(\mu g\ soil)}{(m^3\ air)}}{\dfrac{g\ soil_{Inh}}{\text{sec}}} \times \frac{(1{,}000\ \mu g\ Hg)}{(mg\ Hg)} \times \frac{(kg\ soil)}{(10^9\ \mu g\ soil)} \quad (5)$$

The resulting exposure point concentrations used in the assessment are listed in Table F.1.

Fugitive Mercury Vapor Emissions from Soils

EPA methods for calculating emissions from volatile metals are not available. Therefore, a study conducted by ORNL (Kim et al. 1993) has been used to estimate fugitive mercury vapor emissions. According to this study, mercury vapor emissions from the EFPC floodplain range from 15 to 160 ng/m^2 · h and average 44 ng/m^2 · h. The factor that most influences the emission rate is soil temperature. The study included controlled flow chamber tests in which the soil temperature was elevated to 28°C (82.4°F), and enhanced turbulent mixing of the atmosphere was simulated. The emission rates under these controlled conditions ranged from 840 to 1470 ng/m^2 · h and averaged 1080 ng/m^2 · h. These test conditions were considered to be comparable to the worst-case soil handling conditions (in terms of soil temperature and atmospheric turbulence) that would occur during remediation activities at EFPC.

Dispersion modeling analysis was performed with the same parameters used for the fugitive dust analysis except that a mercury vapor emission rate of 1470 ng/m^2 · h (4.1×10^{-10} g/m^2 · sec) was used. This results in a maximum ambient air concentration of 4.54×10^{-3} μg/m^3. This value is greater than an order of magnitude lower than the lowest mercury concentration in air associated with excavation, disposal, and treatment. This comparison shows that the contribution of mercury vapor emissions to mercury in the air is minimal when compared to the contribution from the suspended soil particulates. Therefore, mercury vapor emissions from soils (other than those emerging from the low-temperature thermal desorption unit) have not been further evaluated.

Mercury Vapor Emissions from the Low-Temperature Thermal Desorption Unit

At a nominal operating temperature of 350°C (662°F), the low-temperature thermal desorption unit will be designed to produce mercury vapor [mercury boils at 357°C (674°F)] and recover the vapor using condenser collection devices. Other inorganic contaminants will not be captured in the low-temperature thermal desorption treatment process. Both mercury vapors and soil particulates will be released. However, fugitive dust emissions from the low-temperature thermal desorption unit are assumed to be minimal and will not be evaluated. Both worker and community exposures to mercury vapor emissions have been addressed.

Emissions from the low-temperature thermal desorption unit will be controlled by design through the use of devices such as scrubbers and vapor absorption units. The control efficiencies of these devices have been measured in bench-scale tests, which will be used to estimate mercury emission rates in mass per unit time. The emission rates will be used directly in SCREEN2 to estimate downwind dispersion and exposure point concentrations for use in risk assessment. The following sections outline the estimation of emission rates, dispersion modeling, and estimation of exposure point concentrations of mercury vapors from the low-temperature thermal desorption unit stack.

Estimation of Emission Rates. Operating characteristics determined in a bench-scale design test were used to estimate mercury vapor emission rates from the low-temperature thermal desorption unit. The emission factor, in mass per unit operation, is the product of the 99.5% removal efficiency of mercury from soil and the mercury concentration in soil. The dispersion model, SCREEN2, requires an emission rate that is the product of the emission factor, condenser control efficiency, and process rate. Emission rates are presented for each of the nine segments in Table F.7.

Dispersion Modeling and Estimation of Exposure Point Concentrations. Mercury vapor emissions are directly related to the low-temperature thermal desorption unit design and operating characteristics. In the dispersion model, several of these characteristics or parameters were varied to ascertain their sensitivity in determining emission rates. In addition, the analysis was conducted to determine specific values for each parameter that would yield risks below EPA targets. These optimal design characteristics and mercury vapor emission rates were then used to estimate downwind exposure point concentrations for use in the risk assessment.

The sensitivity analysis shows three variables that contribute most significantly to projected concentrations downwind of the unit: concentration in soil, stack dimensions, and distance to receptor. Results of the sensitivity analysis are shown in Table F.8. Mercury vapor emissions are directly proportional to the mercury concentration in the treated soil: the higher the concentration in the treated soil, the greater the emission rate, the higher the mercury concentration at the receptor, and consequently, the greater the risk estimate. Although mercury concentrations in soil may be diluted prior to treatment by mixing with uncontaminated or less contaminated soil, it is assumed that design characteristics could be modified such that emissions from the treatment unit would not necessitate dilution.

The remaining two variables, stack dimensions and distance to receptor, affect downwind dispersion. Given the proposed location of the unit, distances to receptors are constant. To determine the influence of stack dimensions on downwind dispersion, emission rates were held constant while stack dimensions were varied. In general, taller and wider exit stacks reduce downwind concentrations. With the anticipated levels of contamination and known receptor distances, it was determined that a stack height of 10 m (32.8 ft) and inside diameter of 0.75 m (2.46 ft) are required to maintain risks below the EPA target hazard index (HI) of 1.0 (Fig. F.2). Note that these dimensions for height and diameter are just one of a variety of combinations that could be chosen to meet the EPA target of 1.0 for noncarcinogens.

F.2.2.3 Toxicity assessment

The objective of this section is to evaluate the inherent toxicity of the COC (mercury) and to identify and select toxicological measures needed for this COC. In the risk characterization section, the toxicity measures are then combined with the results of the exposure assessment to estimate risks to receptors.

In assessing risks for short-term exposure, it is important to consider the duration of the exposure. As discussed in Sect. F.2.2.2, the duration for the community is assumed to be 10 weeks; for the worker, the exposure duration is assumed to be at least 1 year (or more, depending on the alternative). Because these durations are >2 weeks and <7 years, short-term toxicity values (when they exist) are used to estimate health risks (EPA 1991a).

For noncarcinogens, EPA's Environmental Criteria and Assessment Office has developed subchronic reference concentrations (RfCs) and reference doses (RfDs) for many contaminants. These RfCs and RfDs are developed based on no-observed-adverse-effect levels (NOAELs) or lowest-observed-adverse-effect levels (LOAELs) identified from subchronic (usually greater than or equal to 90 d, but less than chronic) toxicity studies. The RfC and the RfD are concentrations and daily intakes, respectively, below which no toxic effects are expected to occur. Carcinogenicity has not been discussed, as mercury has not been shown to demonstrate carcinogenic effects.

The primary source of information for these toxicity values is EPA's Integrated Risk Information System (IRIS) data base (EPA 1994a). IRIS is a computer-housed catalog of EPA risk assessment and risk management information for chemical substances. Data in the IRIS system are regularly reviewed and updated monthly. If toxicity measures are not available on IRIS, as is the case with mercury, EPA recommends use of the Health Effects Assessment Summary Tables (HEAST) (EPA 1994b) as the second current source of information. Toxicity values used in the risk evaluation are presented in Table F.9.

The toxicity profile for mercury has been included in Attachment F.1. In the toxicity profile, emphasis is placed on identifying the target effect of concern, the EPA basis for derivation of RfDs/RfCs, and uncertainty associated with the EPA toxicity values. This profile was prepared by ORNL and distributed to U.S. Department of Energy (DOE) contractors (July 13, 1993) to be used in DOE Environmental Restoration Program risk assessments. The information in this attachment has been taken verbatim from the ORNL compilation.

F.2.2.4 Risk characterization

In this section, risks are characterized for noncarcinogenic contaminants and for construction and transportation activities (physical hazards).

Noncarcinogenic Hazard Indices

The traditionally accepted practice of evaluating exposure to noncarcinogenic compounds has been to experimentally determine a NOAEL and to divide this value by a safety or uncertainty factor to establish an acceptable human dose or RfD (EPA 1989a). The RfD (or RfC for the

inhalation route) is then compared with the average daily dose experienced by the exposed population to obtain a measure of concern for adverse noncarcinogenic effects:

$$HQ = \frac{Dose}{RfD}, \qquad (6)$$

where

HQ = Hazard quotient: potential for adverse noncarcinogenic effects,
Dose = Average daily dose for subchronic or chronic exposure [mg/(kg · d)],
RfD = Acceptable intake for chronic exposure [mg/(kg · d)].

Dose and RfD are expressed in the same units and are based on common exposure periods (i.e., chronic, subchronic, or shorter-term). A hazard quotient (HQ) > 1 indicates the potential for adverse noncarcinogenic effects at the given exposure/dose level. EPA has established guidelines for evaluating exposure to mixtures of noncarcinogens (EPA 1986a, 1989a). Essentially, this involves summing the HQs (ratios of daily dose/RfD or dose/RfC) for all chemicals under evaluation. If the sum of these ratios, called the hazard index (HI), is > 1, the potential exists for adverse noncarcinogenic effects. Under these circumstances, EPA recommends summing HQ values for compounds with like or common toxicological effects and evaluating the potential for manifestation of the various adverse health effects. This approach is useful only when the HQs for individual substances are < 1 but have a combined sum > 1.

Construction Risks

Risks associated with construction activities were estimated for each alternative. Construction risks (injuries and fatalities) were estimated by multiplying the total estimated labor (in man-hours) by a unit construction risk (per man-hour). These risk factors are calculated from incidence rates provided in the Survey of Occupational Injuries and Illnesses for 1990 and 1991 conducted by the U.S. Department of Labor (1992) and are as follows:

- 6.7×10^{-5} injuries per man-hour, and
- 5.0×10^{-7} fatalities per man-hour.

The above factors include statistics from all construction categories, as none of the more specific categories were applicable to remedial work. Injury cases include both cases where workday(s) are lost and those where no workdays are lost. This may be a conservative approach because an occupational injury can be as minor as a cut.

Transportation Risks

Since most of the alternatives involve the transport of contaminated soils from the RUs to off-site facilities and/or the transport of clean borrow soil back to the RUs, the potential exists for transportation accidents involving injuries or fatalities. Note that because the trucks will be decontaminated and the contaminated soils will be covered, no exposures to hazardous materials

are expected to occur during transportation. The following equation was used to calculate risks due to waste transport:

$$Risk = RC \times DT , \quad (7)$$

where

Risk = Number of injuries or fatalities,
RC = Injury or fatality risk coefficient (risk/km),
DT = Distance traveled (km).

The risk coefficients (Cashwell et al. 1989) used in this analysis are as follows:

- 8.0×10^{-7} injuries per truck-kilometer (community),
- 5.3×10^{-8} fatalities per truck-kilometer (community),
- 2.8×10^{-8} injuries per truck-kilometer (occupational), and
- 1.5×10^{-8} fatalities per truck-kilometer (occupational).

Other assumptions included in this analysis are: (1) an average one-way trip distance of 16.1 km (10 miles) and (2) an average truck capacity of 9.3 m^3 (12 yd^3) per dump truck.

Risks Associated with a One-time Transportation Spill

Risks were evaluated for a one-time, hypothetical, transportation spill scenario. In this scenario, a dump-truck hauling contaminated soils accidentally spills its cargo. The receptors at risk of exposure are the nearby community (adults and children), truck driver, and workers who clean up the spill. Risks are calculated for a receptor who is exposed to contaminated soils for a total of 8 h for 1 d. For the sake of simplicity, the truck driver and clean-up worker are assumed to be the same receptor.

The community receptors are assumed to be exposed to contaminated soils through inhalation of fugitive dust particulates. The clean-up worker is assumed to be exposed through ingestion, dermal contact, and inhalation of dust. The soil exposure point concentration used for the ingestion and dermal contact pathways is the 95% UCL for each applicable segment.

For the inhalation pathway, the 95% UCL soil concentrations for each segment were used to model downwind concentrations. These concentrations were modeled in the same manner as for the evaluation of the sitewide alternatives. First, emission rates were calculated using the formulas for excavation and dumping from NTGS, Vol. III (EPA 1989c). The formulas and all parameters used in these formulas are shown in Tables F.4 and F.5. Next, the dispersion model, SCREEN2, was used to calculate downwind dust concentrations in air. The distance to the nearest community receptor was assumed to be 30 m (this distance corresponds to the maximum 1-h concentration at or beyond 1 m). Figure F.1 lists the input assumptions and output concentrations for the SCREEN2 model. This is a conservative assumption in that a receptor is not likely to spend all 8 h at a distance of 30 m from the spill. The exposure point concentrations in air are then calculated from the dust concentration from the dispersion model, the emission rate, and the UCL mercury concentration in the removed soil.

The exposure parameters used in the intake equations are the same as those used in the evaluation of each of the alternatives, except for the exposure duration that is assumed to be for only 8 h of 1 d. A number of assumptions have been made concerning the spill. These assumptions include:

- The soil will be wet or damp. Wetting is an important dust control measure that will be used during excavation and removal. Soil will be wet additionally as postaccident cleanup proceeds.

- Dust from cleanup of a soil spill will be no worse than that considered for excavation and removal from the floodplain.

- Spills will be contained and cleanup will occur immediately.

- All contaminated soil will be removed. Soil will not be permitted to remain at a spill site and no soil will migrate from the spill site.

Due to the lack of acute and short-term toxicity information, the toxicity value used for this evaluation is the chronic or subchronic oral RfD (the chronic and subchronic oral RfDs are the same number). Using the chronic or subchronic oral RfD is conservative as this is assumed to be a one-time event. It is important to note that the probability of such an accident occurring is very low based upon the transportation risks calculated for each of the sitewide alternatives.

Risks from this hypothetical accident evaluation are discussed in Sect. 5.3.2 for community receptors and an unprotected worker (i.e., no personal protective equipment).

F.3 SUMMARY OF RISK ASSESSMENT RESULTS

Human health risks have been used to evaluate several remedial alternatives for EFPC floodplain soils. Risk assessment results for both long-term and short-term risks are presented in Sect. 5.3 under the headings entitled "Long-term effectiveness and permanence" and "Short-term effectiveness and environmental impacts" for each sitewide alternative

Long-term residual risks have been evaluated by comparison with the remediation goal option for mercury, and this applies to the same receptors (children and adult residents) defined in the RI human health baseline risk assessment. With the exception of SWA 1 (No Action), risks to sensitive receptors (children) at EFPC are unlikely to exceed EPA human health risk targets because soil contact after remediation is likely only at concentrations below the remediation goal option for mercury.

Short-term risks during remediation have been evaluated for certain exposure scenarios that did not apply to the RI report. In this case, comparison with remediation goal options was not sufficient to evaluate the alternatives; therefore, additional risk estimates were required. Risks related to remedial activities were estimated for both on-site remediation workers and nearby members of the community. For the purpose of establishing a baseline for the additional risk estimates, neither workers nor community members were assumed to use any personal protective equipment.

With the exception of SWA 1, risks to the community (adults and children) fell below the EPA target of 1.0 for noncarcinogens. For remediation workers, all dermal contact and inhalation HIs were below the EPA target, and all ingestion HIs were above the target. The highest ingestion HIs were for workers conducting remedial activities at Segments 1 and 4. These risk estimates emphasize the need for workers to wear protective equipment and take standard health and safety precautions.

An analysis of the remediation goal options for EFPC indicates that for soil exposures, the RME remediation goal options for inorganic mercury are adequate for the protection of human health.

F.4 UNCERTAINTY ANALYSIS

This section contains an analysis of uncertainties that the reader should understand when interpreting the findings of the FS. The EFPC FS risk estimates rely on many variable parameters and assumptions that directly bear on the reported results. The analysis of uncertainty is a qualitative and quantitative description of the limitations resulting from the use of the selected parameters and assumptions. The intent is to gauge the reliability of the risk estimates in order to better determine the most appropriate remedial solutions.

EPA has specifically requested that the principal focus of the EFPC RI risk assessment should be on RME risk estimates, and for this reason they are used in the FS. RME risk estimates are supposed to evolve from a health-protective yet realistic combination of average and upper-bound parameters, and should not be entirely worst-case. Note that because of this, more realistic risks are likely to be somewhat lower than RME risks.

The term "uncertainty" as commonly used actually refers to two distinct components: uncertainty and variability. Often, variability and uncertainty are not readily distinguishable. Although this distinction can be perplexing, the important concept is that the RME risk estimates should not be considered inflexible point estimates. The risk estimates are based on numerous parameters that may not be precisely known (they are uncertain) or may be variable (a range of values could apply). Even though these parameters and risks are reported as single values, RME risk estimates may actually represent a range of values as determined by the uncertainty and variability of the input parameters.

As an illustration, if parameter "A" is believed to be 20 and it is actually 30, then it errs because it is uncertain. If RME parameter "B" is stated as 50 but sometimes could be stated as 40 or 60, then it is variable. Note that unlike parameter A, none of the parameter B values are incorrect; they are variable. In this case, the RME product of the parameters A and B would be $20 \times 50 = 1000$. The product could actually range, however, from a low of $20 \times 40 = 800$, to a high of $30 \times 60 = 1800$, depending upon the applied combination of these uncertain and variable parameters.

As noted by EPA (1992c), variability in the risk estimates usually originates from differing exposures encountered by different members of a population (e.g., contact rate, body weight, and exposure frequency), whereas uncertainty typically originates from errors in other parameters (e.g., sample data, transport model results, and toxicity values). As such, the variable parameters

are often more "behavioral" in that receptor individuality and behavior comes into play, with varied exposures truly occurring for different individuals. The uncertain parameters are usually more "physical" in that they may be based on measured or observed estimates that err from the true values they are meant to represent.

Uncertainty and variability are present in all phases in the risk assessment: in the analytical data, the exposure assessment, the toxicity information, and the risk characterization. Distinguishing between these two is currently an issue that is gaining the attention of investigators. Note, however, that uncertainty and variability are not distinguished from one another in either the RI or the FS. In the following text, the term uncertainty will be used to refer to both of these concepts. Uncertainty is inherent in the estimation of the remediation goal options. The discussion of this aspect is of particular importance for the FS. Table F.12 presents the important sources of uncertainty, the approximate magnitude, and the direction of the bias, if known.

F.4.1 Analytical Data

Uncertainty will always surround estimates of environmental concentrations. The objective is to understand, minimize, and quantify this uncertainty. In the baseline risk assessment, several issues were addressed concerning measuring exposure point concentrations: sampling program design, analytical methods, and data aggregation methods. To this end, procedures were established during sampling and analysis design to reduce uncertainty.

No new data were collected specifically to support the FS, and some of the areas designated for remediation have few data points from which to calculate exposure point concentrations. The remediation area boundaries were determined based upon the remediation goal options and professional judgment regarding the nature and extent of contamination, but they may not accurately represent exposures occurring within the floodplain.

F.4.2 Exposure Assessment

Uncertainty analysis in the exposure assessment is very important because much of the information required to estimate intake or dose is based on assumptions or professional judgment. It is used to identify the limitations of the assessment and to understand the degree to which the results are reliable.

Several sources of uncertainty have been identified in the exposure assessment (EPA 1992c):

- Scenario Uncertainty: missing or incomplete information needed to define the exposure scenario or pathway,
- Model Uncertainty: inadequate scientific theory or basis for exposure estimates or calculations, and
- Parameter Uncertainty: inadequate information to quantify an exposure variable or parameter.

F.4.2.1 Exposure scenarios

Scenario uncertainty arises when pathways were not included or were eliminated from the risk assessment. This is less applicable in the FS than in the RI because the remedial action objectives of the FS address only the soil medium, thereby limiting the pathways for evaluation to soil ingestion, dermal contact with soil, inhalation of suspended particulates, and inhalation of vapor emissions from the low-temperature thermal desorption unit.

The FS includes an evaluation of risks created as a direct result of remedial activities and includes additional exposures above and beyond those present in the RI baseline risk assessment. Methods to evaluate risk for the FS are consistent with EPA methods and guidance. Scenarios used to analyze both short-term and long-term risks for the FS are based on professional judgment and an understanding of human receptor groups likely to be present during and after remediation.

Human receptors at risk of exposure during remediation include remediation workers and community members. Exposure pathways and the potential for long-term exposure for the community as described in the FS are the same as those described in the RI baseline risk assessment. The only notable exception in the FS is that inhalation of particulates (dust) and vapors resulting from remedial actions are included, whereas in the RI dust and vapor exposures were determined to be minimal and were not considered.

The RME exposure scenarios used in the RI/FS were developed from many possible combinations of plausible exposures at EFPC. Other variations of these exposure scenarios could reasonably be used to describe similar exposures. Such variations are similar to those selected, and would likely fall somewhere between the MLE and RME estimates that are provided. As noted in the RI (DOE 1994, Sect. 5.5), including some exposure scenarios and excluding others is likely to have a minimal effect on the risk estimates. The effect is projected to alter the final risk estimates (i.e., combined risks across pathways) by less than one order of magnitude.

F.4.2.2 Exposure models

Exposures to mercury may be attributable to remedial actions, in particular, soil handling and treatment of contaminated soil. Airborne dust could contact both on and off-site receptors. Exposures to mercury vapors from the low-temperature thermal desorption treatment unit are also a concern. Since such exposures are hypothetical and exposure levels cannot be measured before remediation, dust levels and vapor concentrations were estimated using appropriate exposure models. The models are subject to limitations in their design, and this is a source of uncertainty (e.g., using model inputs for a bulldozer to represent a backhoe or grade-all, assuming square shaped area sources).

The exposure models used in the FS are published by EPA. Model input parameters were selected using either default or site-specific information based on references provided with the models. Although the model inputs have been evaluated carefully, it is essential to identify the uncertainty that surrounds key input variables and the corresponding influences on results. Table F.11 lists the key parameters and the effects on risk estimates.

The uncertainty surrounding the estimation of mercury concentrations in soil is not magnified or diminished within the air transport models. Consequently, the potential for the models themselves to underestimate or overestimate risks is relatively low.

A large number of inputs were required to estimate fugitive dust emission rates. The uncertainty and variability of physical measurements, such as silt and moisture content in floodplain soils, are described in the RI report. The effectiveness of engineering controls, which were included in the emission rate estimates, provides the greatest uncertainty. In reality, engineering controls may be unpredictable in achieving the published efficiencies, especially on turbulent days. However, if it is assumed that remedial activities will not occur during storm events, the potential for underestimating risks appears low. The remaining assumptions (e.g., numbers of bulldozers) were based on anticipated activities at the site during remediation.

Since the low-temperature thermal desorption unit has not yet been designed, the mercury vapor emission rate estimates are theoretical and, consequently, uncertain. Operational efficiencies are not available for mercury removal using an low-temperature thermal desorption unit because soil contaminated with mercury has never been treated using this technology before. The removal and condenser efficiencies used in the evaluation are based on bench-scale tests. In addition to the mercury concentrations in the untreated soil and the mercury vapor emission rate, the low-temperature thermal desorption stack dimensions influence the downwind dispersion of mercury vapor. To minimize the uncertainty contributed by the stack dimensions to the risk estimates, a sensitivity analysis was conducted to determine the optimum size of the stack. In general, taller exit stacks reduce downwind concentrations. Note that a variety of combinations of stack height and diameter could be chosen to meet the EPA target of 1.0 for noncarcinogens. The overall potential for underestimating or overestimating the risk estimates based on these parameters appears low.

SCREEN2 has been designed as a screening level dispersion model with conservative assumptions included (e.g., "worst case meteorological conditions"). The conservatism is further enhanced by the use of the maximum projected concentrations for worker exposures. When all of the noted factors and parameters are considered together, there is a moderate possibility that the risk estimates will be overestimated.

F.4.2.3 Exposure parameters

Uncertainty and variability are propagated by use of the exposure parameters in the intake equations. Intake equations are in fact simple exposure models. Uncertainty exists in the use of conceptual site models and intake equations intended to represent reality (present and future) at EFPC. Variability also may not be truly represented by the intake equations, because the exposure parameters are simple descriptions of remedial workers and the community. Discussion of the quantitative effects of uncertainty and variability of exposure parameters (other than that provided in the RI risk assessment) is provided below in the section on remediation goal options.

Many of the exposure parameters used in the risk assessment are default values recommended by EPA. These default parameters, which are generally conservative, do not necessarily reflect actual behavior and have been used in the absence of site-specific information. Although each of these parameters is commonly treated as a single point estimate, a range of values would more accurately represent these parameters. In addition, assumptions regarding

future land uses are highly speculative. In attempting to predict future exposures, assumptions must be made concerning contaminant fate and transport, future site activities, and receptor behavior. For example, in some cases, it was assumed that contaminant concentrations will be the same in the future as at present and that the contaminants themselves are immobile. The uncertainty associated with the exposure assumptions used in the risk assessment is moderate and is likely to overestimate the actual risks.

A very conservative approach is used when values for the exposure duration (ED) are placed in the intake or dose equations (equations 2, 3, and 4) for remediation workers. The duration of the entire project is used to calculate the intake or dose for each segment. In addition, the duration data include predecessor activities, remedial activities, and closure activities. The probability of overestimating the intake or dose for each segment is high.

F.4.3 Toxicity Information

Although EPA provides toxicity values that are point estimates, a significant amount of uncertainty may surround these point estimates. Identification of the sources of this uncertainty enables the risk assessor to establish the degree of confidence associated with the toxicity measures.

Uncertainty is inherent in the toxicity assessment and is primarily due to differences in study design, species, sex, routes of exposure, or dose-response relationships. A major source of uncertainty involves using toxicity values based on experimental studies that substantially differ from typical human exposure scenarios.

Mercury is of primary concern for human health assessment in the FS. Although an interim oral RFD for mercury is available in HEAST, an EPA-verified RFD is currently not available. A critical problem with the interim RfD is that the basis for its derivation is an autoimmune-type disease that has been observed in sensitive rat strains exposed to very low levels of mercury. In addition, although analyses conducted on EFPC floodplain soils indicated that mercury is present predominantly in an insoluble form (as mercuric sulfide), the interim RfD is based on the toxicities of mercuric chloride, which is highly soluble. Both of these factors contribute to the uncertainty in the risk assessment.

F.4.4 Risk Characterization

Uncertainties in any phase of the risk analysis are reflected in the risk estimates. Some uncertainty is associated with the summation of risks and HQs for multiple chemical contaminants. As stated in *RAGS* (EPA 1991a), "The assumption of dose additivity ignores possible synergisms or antagonisms among chemicals, and assumes similarity in mechanisms of action and metabolism." However, summing risks and HQs for multiple substances in this risk assessment provides a conservative estimate.

F.4.5 Estimation of Remediation Goal Options for Mercury

Long-term (residual) risks after implementation of each remedial alternative are evaluated in the EFPC FS by comparison to remediation goal options. In this way, the evaluation uses the same assumptions, exposure pathways, and scenarios as those used in the RI risk assessment.

This approach is valid for EFPC since the projected types of future land use under baseline conditions are generally the same as the projected post remedial land use.

The remediation goal options for mercury (e.g., 180 ppm in Residential/Agricultural and 200 ppm in Open/Commercial land-use areas) are estimated using the RME risk estimates for mercury. Remediation goal options are based on a target HQ, by back-calculating a remedial target concentration. These are point estimates, targeting an exposure point concentration below which adverse health effects would be below EPA-defined levels of concern.

Because the same RME parameters and assumptions apply for both the RME baseline risk estimates and remediation goal option estimates, the remediation goal option is RME by design. As stated earlier, RME risk estimates represent a range of values rather than a precise single-point estimate. It is vital to understand that this same concept applies to remediation goal options. This point is illustrated in Fig. F.3, which is the probability distribution of the remediation goal option estimate for the soil exposure pathway, based on adults. Supporting summary statistics are listed at the bottom of the page.

The cumulative distribution graph in the figure indicates the location within the distribution of the expected (mean) remediation goal option estimate by means of a labeled vertical line intersecting the distribution. The expected value is an estimate based on multiple probability density functions describing exposure parameter distributions such as ingestion rate and body weight, as originally presented in the RI report (DOE 1994). The graph shown in the figure represents the distribution for the soil pathway remediation goal option, which is built from these component exposure parameter distributions. This supports the observation that the remediation goal option inherits the uncertainty existing within the distributions of the exposure parameters.

The distribution provides an indication of more and less likely remediation goal option estimates, and places into the same perspective the single (expected) RME point estimate of the remediation goal option. In this case, the probability of achieving the target HI of 1.0 is greater as the remediation goal option concentration is reduced (more extensive cleanup). Higher clean-up levels are generally associated with somewhat lower probability that the goal of adequate health protection is achieved.

The remediation goal options for EFPC are based on single RME point estimates. Inspection of the distribution is useful because it indicates that while the expected or RME concentration is reported as a single estimate, it exists in the high end ($>98\%$) of a distribution of values, and that nearby values may have similar probabilities.

Perhaps the most important conclusion regarding remediation goal options is that the RME remediation goal options are more stringent than the expected remediation goal options. This should increase the confidence that for soil exposures, the RME remediation goal options are adequately protective of human health.

REFERENCES

Cashwell, J.W., K.S. Neuhauser, P.C. Reardon, and G.W. McNair. 1989. Transportation Impacts of the Commercial Radioactive Waste Management Program. Sandia National Laboratories, Albuquerque, New Mexico.

DOE. 1994. *East Fork Poplar Creek - Sewer Line Beltway Remedial Investigation Report.* DOE/OR/02-119&D0. Contract No. DE-AC05-90OR21851.

EPA (U.S. Environmental Protection Agency). 1986a. Guidelines for Carcinogenic Risk Assessment. Federal Register 51(185):33991-34003.

EPA. 1986b. Guidelines for the Health Risk Assessment of Chemical Mixture. Federal Register 51(185):34014-34025.

EPA. 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Office of Solid Waste and Emergency and Remedial Response. OSWER Directive 9335.3-01.

EPA. 1989a. Risk Assessment Guidance for Superfund: Human Health Evaluation Manual (Part A). Office of Solid Waste and Emergency and Remedial Response. OSWER Directive 9285.701A.

EPA. 1989b. Exposure Factors Handbook. Office of Health and Environmental Assessment. EPA/600/8-89/043.

EPA. 1989c. Air/Superfund National Technical Guidance Series, Volume III - Estimation of Air Emissions from Cleanup Activities at Superfund Sites, Interim Final. EPA-450/1-89-003.

EPA. 1990. National Oil and Hazardous Substances Pollution Contingency Plan (NCP). Federal Register 55(46):8666-8865.

EPA. 1991a. Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part C, Risk Evaluation of Remedial Alternatives). Interim. Office of Emergency and Remedial Response. OSWER Directive 9285.7-01C.

EPA. 1991b. Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors. Office of Emergency and Remedial Response, OSWER Directive 9285.6-03.

EPA. 1991c. EPA Region 10 Supplemental Risk Assessment Guidance for Superfund. August, 1991.

EPA. 1992a. New Interim Region IV Guidance. February 11, 1992. Region IV, Atlanta, Georgia.

EPA. 1992b. Dermal Exposure Assessment: Principles and Applications. Office of Health and Environmental Assessment. EPA/600/8-91/001B.

EPA. 1992c. Guidelines for Exposure Assessment. 57 FR 22888. Washington, D.C.

EPA. 1992d. SCREEN Version 2 (a software model for airborne contaminant dispersion), version dated 92245. SCREEN2 Model User's Guide, Office of Air Quality Planning and Standards, Technical Support Division, EPA-450/4-92-006, September.

EPA. 1994a. Integrated Risk Information System (IRIS). U.S. Environmental Protection Agency On-line Database of Toxicity Measures. Office of Research and Development, Environmental Criteria and Assessment Office, Cincinnati, Ohio. Electron Mail Account Information via TOXNET, National Library of Medicine, Bethesda, Maryland.

EPA. 1994b. Health Effects Assessment Summary Tables, Annual Update, Office of Research and Development. OHEA ECAO-821, March 1994.

Gilbert, R.O. 1987. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold, New York.

Hawley, J.K. 1985. "Assessment of Health Risk from Exposure to Contaminated Soil." *Risk Analysis*, Vol. 5, No. 4, pp. 289-302.

Kim, K.H., S.E. Lindberg, P.J. Hanson, T.P. Meyers, and J. Owens. 1993. Application of micrometeorological methods to measurements of mercury emissions over contaminated soils. In the Proceedings of the Ninth International Conference on Heavy Metals in the Environment, Toronto, Canada, Volume 1, pp. 328-331.

U.S. Department of Labor. 1992. Survey of Occupational Injuries and Illnesses, 1991. Bureau of Labor Statistics. Washington, D.C.

This page intentionally left blank.

APPENDIX F

TABLES

This page intentionally left blank.

Table F.1. Exposure point concentrations for mercury in soil and air used in the detailed analysis of alternatives at EFPC [a]

Segment	Number positively detected	Total number of samples analyzed	UCL concentration in soil (mg/kg)	Concentration in air at excavation site ($\mu g/m^3$) [b]	Concentration in air downwind of excavation site ($\mu g/m^3$) [c]	Concentration in air at K-25 site ($\mu g/m^3$) [d]	Concentration in air downwind of K-25 Site ($\mu g/m^3$) [e]	Concentration in air at Y-12 Site ($\mu g/m^3$) [f]	Concentration in air downwind of Y-12 Site ($\mu g/m^3$) [g]	Concentration in air during containment ($\mu g/m^3$) [h]
1	21	21	7.22E+02	4.85E-01	4.20E-01	1.17E+00	1.29E-01	9.77E-01	6.80E-02	1.40E-02
2	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3	3	3	3.21E+02	2.15E-01	2.12E-01	5.20E-01	5.73E-02	4.34E-01	3.02E-02	6.21E-03
4	21	22	4.39E+02	2.94E-01	2.55E-01	7.10E-01	7.83E-02	5.94E-01	4.13E-02	8.49E-03
5	4	4	3.52E+02	2.36E-01	2.05E-01	5.70E-01	6.29E-02	4.76E-01	3.32E-02	6.81E-03
6	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
8	8	10	2.22E+02	1.49E-01	1.29E-01	3.59E-01	3.96E-02	3.00E-01	2.09E-02	4.29E-03
9	4	4	4.98E+02	3.34E-01	2.90E-01	8.06E-01	8.89E-02	6.74E-01	4.69E-02	9.64E-03

Note: [a] – Data were aggregated for areas > 200 mg/kg mercury which will be remediated in the Commercial, Other, and DOE remedial units, and areas > 180 mg/kg mercury which will be remediated in the Agricultural and Residential remedial units. Nondetects have been included in the calculation of the average at 1/2 the detection limit. Results with "R" validation qualifiers have been excluded.

[b] – The contaminant concentration in air is the product of the UCL contaminant concentration in soil (mg contaminant/kg soil), the emission rate (g/sec) for inhalable particulates (< 15 μm) emitted from activities at the site, and airborne dust concentrations ([$\mu g/m^3$]/[g soil/sec]) from EPAs SCREEN2 dispersion model. These exposure point concentrations are for workers during excavation activities (i.e., excavation, transportation, and dumping).

[c] – The contaminant concentration in air is the product of the UCL contaminant concentration in soil (mg contaminant/kg soil), the emission rate (g/sec) for inhalable particulates (< 15 μm) emitted from activities at the site, and airborne dust concentrations ([$\mu g/m^3$]/[g soil/sec]) from EPAs SCREEN2 dispersion model. These exposure point concentrations are for residents living downwind of excavation activities (i.e., excavation, transportation, and dumping).

[d] – The contaminant concentration in air is the product of the UCL contaminant concentration in soil (mg contaminant/kg soil), the emission rate (g/sec) for inhalable particulates (< 15 μm) emitted from activities at the site and mercury vapor emissions from the LTTD stack, and airborne dust concentrations ([$\mu g/m^3$]/[g soil/sec]) from EPA's SCREEN2 dispersion model. These exposure point concentrations are for workers during treatment activities (i.e., LTTD treatment of contaminated soil).

[e] – The contaminant concentration in air is the product of the UCL contaminant concentration in soil (mg contaminant/kg soil), the emission rate (g/sec) for inhalable particulates (< 15 μm) emitted from activities at the site and mercury vapor emissions from the LTTD stack, and airborne dust concentrations ([$\mu g/m^3$]/[g soil/sec]) from EPA's SCREEN2 dispersion model. These exposure point concentrations are for downwind communities receptors during soil treatment activities (i.e., LTTD treatment of contaminated soil).

[f] – The contaminant concentration in air is the product of the UCL contaminant concentration in soil (mg contaminant/kg soil), the emission rate (g/sec) for inhalable particulates (< 15 μm) emitted from disposal activities at the Y-12 Site disposal facility, and airborne dust concentrations ([$\mu g/m^3$]/[g soil/sec]) from EPA's SCREEN2 dispersion model. The exposure point concentrations are used in the evaluation of workers during disposal activities.

[g] – The contaminant concentration in air is the product of the UCL contaminant concentration in soil (mg contaminant/kg soil), the emission rate (g/sec) for inhalable particulates (< 15 μm) emitted from disposal activities at the Y-12 Site disposal facility, and airborne dust concentrations ([$\mu g/m^3$]/[g soil/sec]) from EPA's SCREEN2 dispersion model. The exposure point concentrations are used in the evaluation of downwind residents during disposal activities.

[h] – The contaminant concentration in air is the product of the UCL contaminant concentration in soil (mg contaminant/kg soil), the emission rate (g/sec) for inhalable particulates (<15 μm) emitted from activities at the site, and airborne dust concentrations ([$\mu g/m^3$]/[g soil/sec]) from EPAs SCREEN2 dispersion model. These exposure point concentrations are for workers during containment (i.e., grading)

Table F.2. Expsoure pathways for the human health risk assessment

General actions	Receptors	Soil							Air
		Ingestion	Dermal contact	Inhalation (fugitive dust)					Inhalation (vapor)
				Exc	Trans	Dump	Stor	Grad	
Containment	Community (near the RUs)								
	Remediation workers (at RUs)	•	•					•	
Excavation	Community (near the RUs)			•	•	•			
	Remediation workers (at RUs)	•	•	•	•	•			
Disposal	Community (near the Y-12 Plant)					•	•	•	
	Remediation workers (at the Y-12 Plant)	•	•			•	•	•	
Treatment	Community (near the K-25 Site)					•	•	•	•
	Remediation Workers (at K-25 Site)	•	•			•	•	•	•

Exc - excavation
Trans - transportation
Dump - dumping
Stor - storage
Grad - grading

Table F.3. Exposure parameters

Exposure pathways and parameters	Residents		Remediation workers (adults)
	Children (3-12 years)	Adults	
Soil ingestion			
Ingestion rate (mg/d)	NA	NA	480
Fraction ingested (unitless)	NA	NA	1
Exposure frequency (d/week)	NA	NA	5
Exposure duration (weeks)	NA	NA	89[a]
Body weight (kg)	NA	NA	70
Averaging time (d) Carcinogens Noncarcinogens	NA	NA	25,550 627[b]
Dermal exposure to soil			
Skin area (cm^2)	NA	NA	23,000
Fraction exposed (unitless)	NA	NA	0.5
Adherence factor (mg/cm^2)	NA	NA	1
Dermal absorption factor	NA	NA	0.001
Exposure frequency (d/week)	NA	NA	5
Exposure duration (weeks)	NA	NA	89[a]
Body weight (kg)	NA	NA	70
Averaging time (d) Carcinogens Noncarcinogens	NA	NA	25,550 627[b]
Soil/dust inhalation			
Inhalation rate (m^3/h)	1.4	1.65	2.5
Exposure time (h/d) floodplain and Y-12 Plant K-25 Site	 8 24	 8 24	 8 8
Exposure frequency (d/week)	5	5	5
Exposure duration (weeks) floodplain Y-12 Plant and K-25 Site	 10 89[a]	 10 89[a]	 89[a] 89[a]
Body weight (kg)	26	70	70

Table F.3 (continued)

Exposure pathways and parameters	Residents		Remediation workers (adults)
	Children (3-12 years)	Adults	
Averaging time (d)			
Carcinogens	25,550	25,550	25,550
Noncarcinogens			
floodplain	70	70	627[b]
Y-12 Plant and K-25 Site	627[b]	627[b]	627[b]
Vapor inhalation			
Inhalation rate (m^3/h)	1.4	1.65	2.5
Exposure time (h/d)	24	24	8
Exposure frequency (d/week)	5	5	5
Exposure duration (weeks)	89[a]	89[a]	89[a]
Body weight (kg)	26	70	70
Averaging time (d)			
Carcinogens	25,550	25,550	25,550
Noncarcinogens	627[b]	627[b]	627[b]

[a] Corresponds to the number of weeks in 1.7 years; for SWAs other than SWAs 2 and 4, these numbers will vary according to the projected remedial duration (assumes 2 weeks of vacation).

[b] Corresponds to the number of days in 1.7 years; for SWAs other than 2 and 4, this number will vary.

NA - pathway not evaluated

Table F.4. Estimates of emission factors for remedial activities at EFPC (inhalable particulates)[a]

Excavation using a bulldozer	
$EF_{Inh\text{-}Excav} = 0.45(s)^{1.5}(M)^{-1.4}$[kg/hr]	4.14E-01
s = silt content of material [weight][b]	36.45
M = moisture content of the material [weight %][b]	50
Transportation of contaminated soils on unpaved roads	
$EF_{Inh\text{-}Trans1} = k(1.7)(s/12)(S/48)(W/2.7)^{0.7}(w/4)^{0.5}(365\text{-}p/p)$[kg/VKT]	2.19E-01
$EF_{Inh\text{-}Trans2} = k(sL/12)^{0.3}$[kg/VKT]	1.02E-01
$EF_{Inh\text{-}Trans} = EF_{Inh\text{-}Trans1} + EF_{Inh\text{-}Trans2}$ [kg/VKT]	3.21E-01
k = particle size multiplier [unitless][a]	0.35
s = silt content of material [weight %][b]	5
S = mean vehicle speed [km/hr][c]	8
W = mean vehicle (dump truck) weight [Mg][c]	24.5
w = mean number of wheels [unitless][c]	12
p = number of days/year with ≥0.254 mm (0.01 in.) of precipitation [unitless][a]	127
sL = road surface silt loading [g/m²][a]	0.2
VKT = vehicle kilometers traveled [km][b]	
Dumping	
$EF_{Inh\text{-}Dump} = k(0.0016)(U/2.2)^{1.3}(M/2)^{-1.4}$[kg/Mg of soil dumped]	5.50E-06
k = particle size multiplier [unitless][a]	0.35
U = mean wind speed [m/s][b]	2.01
M = moisture content of the material [weight %][b]	50
Storage	
$EF_{Inh\text{-}Store} = 1.8U$ [kg/ha/hr]	3.62E+00
U = mean wind speed [m/s][b]	2.01
Grading	
$EF_{Inh\text{-}Grade} = 0.0056(S)^2$[kg/VKT]	1.40E-01
S = mean speed of grader vehicle [km/hr][c]	5

[a] *Air/Superfund National Technical Guidance Series, Volume III — Estimation of Air Emissions from Cleanup Activities at Superfund Sites* (Interim Final), January 1989, EPA 450/1-89-003 (EPA 1989a).

[b] Geophysical and meteorological data taken from the RI report.

[c] Anticipated activities at the site during remediation.

[d] Oak Ridge Climate Data Base average rainfall 1951 to 1992; NOAA-ATDD (Atmospheric Turbulence Diffusion Division).

Table F.5. Estimates of emission rates for remedial activities at EFPC (inhalable particulates)[a]

Excavation using a bulldozer	
$ER_{Inh\text{-}Excav}$ = [kg/hr]	2.49E-01
Spray of active excavation area, water [percent][a]	60
Number of bulldozers[c]	1.5
Hours/day bulldozing[c]	4
Transportation of contaminated soils on unpaved roads	
$ER_{Inh\text{-}Trans}$ [kg/hr]	5.78E-02
Dust suppressant, unpaved road [percent][a]	95
Distance to decontamination area [km/trip][c]	0.8
Trips/day to decontamination area[c]	36
Dumping	
$ER_{Inh\text{-}Dump}$ [kg/hr]	4.57E-05
Spray of dumping area, front end loader to truck: area spray water [percent][a]	69
Volume of soil excavated by bulldozer per day [yd^3/day][c]	216
Conversion factor: m^3/yd^3	0.76
Bulk density of soil [g/cm^3 = Mg/m^3][b]	1.3
Mass of soil dumped at staging area [Mg/day][c]	214.69
Storage	
$ER_{Inh\text{-}Store}$ [kg/hr]	3.62E-01
Orientation of storage pile length perpendicular to prevailing wind [percent][a]	60
Surface area covered by storage pile [hectare][c]	0.25
Grading	
$ER_{Inh\text{-}Grade}$ [kg/hr]	5.25E-03
Dust suppressant, waste pile [percent][a]	70
Duration of the grading [hr/day][c]	8
Vehicle kilometers traveled [km/day][c]	1
$ER_{Inh\text{-}EXCAV}$ = $ER_{Inh\text{-}Excav+Trans+Dump}$ [kg/hr]	3.06E-01
$ER_{Inh\text{-}DIS}$ = $ER_{Inh\text{-}Dump+Store+Grade}$[kg/hr]	3.67E-01
$ER_{Inh\text{-}IA}$ = $ER_{Inh\text{-}Grade}$ [kg/hr]	5.25E-03

[a] *Air/Superfund National Technical Guidance Series, Volume III — Estimation of Air Emissions from Cleanup Activities at Superfund Sites* (Interim Final), January 1989, EPA 450/1-89/003 (EPA 1989a).

[b] Geophysical and meteorological data taken from the RI report; silt content is lower for transportation than for excavation because transport will occur on gravel roads; moisture content is a median value for data taken from the RI report.

[c] Anticipated activities at the site during remediation.

Table F.6. Receptor characteristics for use in SCREEN2 model

Segment	Distance from RU to nearest residential receptor (m)[a]	Land use areas within segment (current)
1	100	Open Residential
3	50	Residential
4	100	Residential
5	100	Open Residential
8	100	Residential
9	100	Residential DOE

[a] Distance to worker is assumed to be 30 m.

Table F.7. Mercury emission factors and rates for the LTTD unit at the K-25 Site

	Maximum	Segment 1	Segment 2	Segment 3	Segment 4	Segment 5	Segment 6	Segment 7	Segment 8	Segment 9
Mercury concentration (mg Hg/kg treated soil)	1.59E+03	7.220E+02	0.000E+00	3.210E+02	4.386E+02	3.520E+02	0.000E+00	0.000E+00	2.216E+02	4.979E+02
Emission factor (mg Hg/kg treated soil)	1.58E+03	7.18E+02	0.00E+00	3.19E+02	4.36E+02	3.50E+02	0.00E+00	0.00E+00	2.20E+02	4.95E+02
Mercury vapor emissions from the LTTD stack[a] (mg Hg/hour)	2.99E+03	1.36E+03	0.00E+00	6.04E+02	8.25E+02	6.62E+02	0.00E+00	0.00E+00	4.17E+02	9.36E+02
Mercury vapor emissions from the LTTD stack[a] (g Hg/sec)	8.31E-04	3.77E-04	0.00E+00	1.68E-04	2.29E-04	1.84E-04	0.00E+00	0.00E+00	1.16E-04	2.60E-04

[a] The process rate is 4.54E+05 kg soil/day. The LTTD removal efficiency from soil is 99.5%, and the condenser control efficiency is 99.99%.

Table F.8. Sensitivity analysis: projected distances and ambient concentrations for different LTTD unit design specifications

Segment	Emission Rate	Stack Height = 6.1 m, Diameter = 0.08m		Stack Height = 9.1 m, Diameter = 0.08 m		Stack Height = 6.1 m, Diameter = 0.1 m		Stack Height = 9.1 m, Diameter = 0.1 m		Stack Height = 10.7 m, Diameter = 0.2 m		Stack Height = 10 m, Diameter = 1.0 m	
		Max Conc.	Dist. to Max	Max Conc.	Dist. to Max	Max Conc.	Dist. to Max	Max Conc.	Dist. to Max	Max Conc.	Dist. to Max	Max Conc.	Dist. to Max
										This column is used in the calculation			
Maximum	8.31E-04	6.31E+00	15	1.17E+00	41	5.13E+00	17	1.00E+00	41	4.23E-01	158	1.15E-01	195
Segment 1	3.77E-04	2.86E+00	15	5.30E-01	41	2.33E+00	17	4.56E-01	41	1.92E-01	158	5.21E-02	195
Segment 2	0.00E+00	0.00E+00	15	0.00E+00	41	0.00E+00	17	0.00E+00	41	0.00E+00	158	0.00E+00	195
Segment 3	1.68E-04	1.27E+00	15	2.36E-01	41	1.04E+00	17	2.03E-01	41	8.55E-02	158	2.32E-02	195
Segment 4	2.29E-04	1.74E+00	15	3.22E-01	41	1.42E+00	17	2.77E-01	41	1.17E-01	158	3.16E-02	195
Segment 5	1.84E-04	1.40E+00	15	2.59E-01	41	1.14E+00	17	2.22E-01	41	9.37E-02	158	2.54E-02	195
Segment 6	0.00E+00	0.00E+00	15	0.00E+00	41	0.00E+00	17	0.00E+00	41	0.00E+00	158	0.00E+00	195
Segment 7	0.00E+00	0.00E+00	15	0.00E+00	41	0.00E+00	17	0.00E+00	41	0.00E+00	158	0.00E+00	195
Segment 8	1.16E-04	8.79E-01	15	1.63E-01	41	7.15E-01	17	1.40E-01	41	5.90E-02	158	1.60E-02	195
Segment 9	2.60E-04	1.97E+00	15	3.66E-01	41	1.61E+00	17	3.14E-01	41	1.33E-01	158	3.59E-02	195

SCREEN Input Assumptions
Stack gas velocity = 1 m/sec
Stack gas temperature = 323 K
Ambient temperature = 293 K
Receptor height = 2 m
Rural option
Simple terrain
Building height = 4 m
Minimum horizontal building dimension = 10 m
Maximum horizontal building dimension = 15m
Full meteorology
Terrain height above stack base = 0 m

Table F.9. Toxicity values for mercury

COC	Oral subchronic RfD (mg/(kg•day))	Inhalation subchronic RfC (mg/m^3)	Oral slope factor $(mg/(kg•day))^{-1}$	Inhalation slope factor $(mg/(kg•day))^{-1}$
Mercury	3.00E-04	3.00E-04*	NA	NA

NA - not available
* - this inhalation RfC has been converted to an inhalation RfD by multiplying by 20 m^3/day and dividing by 70 kg
Source: EPA 1994b

Table F.10. Qualitative uncertainty estimates

Assumptions	Effect on risk estimates		
	Potential for overestimating risk	Potential for underestimating risk	Potential for overestimating or underestimating risk
Environmental sampling/analysis			
Sufficient number of samples obtained within RUs			M
Precision and accuracy of chemical analysis		L	
Data aggregation and statistical analysis			M
Exposure assumptions			
Likelihood of exposure scenarios occurring	L		
Contact, uptake, and absorption rates are representative of exposed populations	L to M		
Assumption that chemicals do not transform or degrade over time	L		
COC selection			
Mercury is the only COC		L	
Toxicity assessment			
Use of EPA interim RfD for mercury	L		
Dermal exposure risks are estimated using oral RfDs			M
Risk characterization			
Likelihood that receptors under evaluation are actually at risk	M		
Bioavailability of mercury in soil			
All mercury is present as mercuric chloride	H		
All mercury is released from the soil matrix	H		
Mercuric sulfide has the same solubility as mercuric chloride	H		

L = Low
M = Medium
H = High

93-008P/080694

Table F.11. Qualitative uncertainty estimates for the air pathway analysis

Assumptions	Effect on risk estimates		
	Potential for overestimating risk	Potential for underestimating risk	Potential for overestimating or underestimating risk
Mercury concentration in soil			L
Emission rates			
Fugitive dust	L		
Mercury vapor			L
SCREEN2 model			
Fugitive dust		M	
Mercury Vapor		M	

L = Low
M = Medium

APPENDIX F

FIGURES

This page intentionally left blank.

02/02/94
18:05:54

```
*** SCREEN2 MODEL RUN ***
*** VERSION DATED 92245 ***
Screening level dispersion model for fugitive dust emissions from Y-12 disposal
SIMPLE TERRAIN INPUTS:
   SOURCE TYPE                =          AREA
   EMISSION RATE (G/(S-M**2)) =      .400000E-03
   SOURCE HEIGHT (M)          =        1.0000
   LENGTH OF SIDE (M)         =       50.0000
   RECEPTOR HEIGHT (M)        =        2.0000
   URBAN/RURAL OPTION         =         RURAL

BUOY. FLUX =     .000 M**4/S**3;  MOM. FLUX =     .000 M**4/S**2.

*** FULL METEOROLOGY ***
**********************************
*** SCREEN AUTOMATED DISTANCES ***
**********************************

*** TERRAIN HEIGHT OF    0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***
  DIST      CONC              U10M   USTK  MIX HT   PLUME   SIGMA   SIGMA
   (M)   (UG/M**3)   STAB   (M/S)  (M/S)    (M)   HT (M)  Y (M)   Z (M)  DWASH
-------  ----------  ----  -------  -----  ------  ------  ------  ------  -----
     1.   .0000        0      .0     .0       .0     .00     .00     .00
   100.   3837.        6     1.0    1.0  10000.0    1.00    2.99    2.73   NO
   200.   2821.        6     1.0    1.0  10000.0    1.00    6.72    4.44   NO
   300.   2207.        6     1.0    1.0  10000.0    1.00   10.26    5.94   NO
   400.   1767.        6     1.0    1.0  10000.0    1.00   13.68    7.35   NO
   500.   1422.        6     1.0    1.0  10000.0    1.00   17.03    8.68   NO
   600.   1156.        6     1.0    1.0  10000.0    1.00   20.32    9.96   NO
   700.   955.1        6     1.0    1.0  10000.0    1.00   23.55   11.16   NO
   800.   807.8        6     1.0    1.0  10000.0    1.00   26.74   12.20   NO
   900.   691.6        6     1.0    1.0  10000.0    1.00   29.89   13.20   NO
  1000.   599.6        6     1.0    1.0  10000.0    1.00   33.01   14.14   NO

MAXIMUM 1-HR CONCENTRATION AT OR BEYOND     1. M:
    30.   4424.        6     1.0    1.0  10000.0    1.00     .14    1.38   NO

 DWASH=   MEANS NO CALC MADE (CONC = 0.0)
 DWASH=NO MEANS NO BUILDING DOWNWASH USED
 DWASH=HS MEANS HUBER-SNYDER DOWNWASH USED
 DWASH=SS MEANS SCHULMAN-SCIRE DOWNWASH USED
 DWASH=NA MEANS DOWNWASH NOT APPLICABLE, X<3*LB

**********************************
*** SCREEN DISCRETE DISTANCES ***
**********************************
*** TERRAIN HEIGHT OF    0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***
  DIST      CONC              U10M   USTK  MIX HT   PLUME   SIGMA   SIGMA
   (M)   (UG/M**3)   STAB   (M/S)  (M/S)    (M)   HT (M)  Y (M)   Z (M)  DWASH
-------  ----------  ----  -------  -----  ------  ------  ------  ------  -----
  2000.   224.0        6     1.0    1.0  10000.0    1.00   62.86   21.76   NO

 DWASH=   MEANS NO CALC MADE (CONC = 0.0)
 DWASH=NO MEANS NO BUILDING DOWNWASH USED
 DWASH=HS MEANS HUBER-SNYDER DOWNWASH USED
 DWASH=SS MEANS SCHULMAN-SCIRE DOWNWASH USED
 DWASH=NA MEANS DOWNWASH NOT APPLICABLE, X<3*LB

    ****************************************
    *** SUMMARY OF SCREEN MODEL RESULTS ***
    ****************************************

 CALCULATION        MAX CONC    DIST TO   TERRAIN
  PROCEDURE        (UG/M**3)    MAX (M)    HT (M)
--------------    -----------   -------   -------
SIMPLE TERRAIN      4424.          30.        0.
**************************************************
** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **
**************************************************
```

Fig. F.1. EPA SCREEN2 model output for fugitive dust dispersion.

93-008P/021194

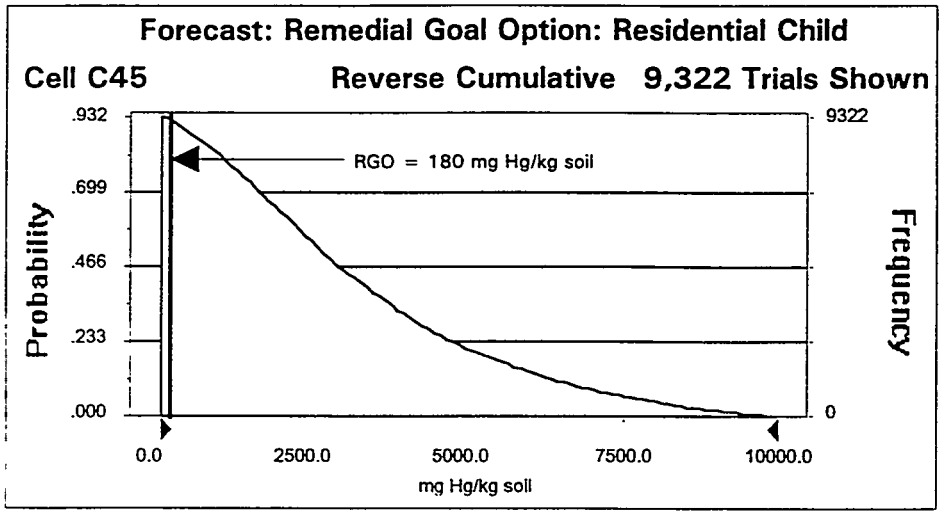
```
                                                                02/07/94
                                                                08:17:55
  *** SCREEN2 MODEL RUN ***
  *** VERSION DATED 92245 ***
 LTTD Building (H=4m, L=15m, W=10m)
 SIMPLE TERRAIN INPUTS:
    SOURCE TYPE              =        POINT
    EMISSION RATE (G/S)      =      1.00000
    STACK HEIGHT (M)         =      10.0000
    STK INSIDE DIAM (M)      =        .7500
    STK EXIT VELOCITY (M/S)=        10.0000
    STK GAS EXIT TEMP (K)    =     323.0000
    AMBIENT AIR TEMP (K)     =     293.0000
    RECEPTOR HEIGHT (M)      =       2.0000
    URBAN/RURAL OPTION       =        RURAL
    BUILDING HEIGHT (M)      =       4.0000
    MIN HORIZ BLDG DIM (M) =        10.0000
    MAX HORIZ BLDG DIM (M) =        15.0000

 BUOY. FLUX =    1.281 M**4/S**3;  MOM. FLUX =   12.756 M**4/S**2.

 *** FULL METEOROLOGY ***
 ************************************
 *** SCREEN AUTOMATED DISTANCES ***
 ************************************

 *** TERRAIN HEIGHT OF    0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

   DIST      CONC                 U10M   USTK  MIX HT   PLUME   SIGMA   SIGMA
    (M)   (UG/M**3)   STAB      (M/S)  (M/S)    (M)    HT (M)  Y (M)   Z (M)  DWASH
 -------  ----------  ----  ---------  -----  ------  ------  ------  ------  -----
      1.      .0000     1        1.0    1.0   320.0   35.79    1.73    1.69    NO
    100.     122.6      2        3.5    3.5  1120.0   17.37   19.38   10.81    NO
    200.     138.0      3        2.5    2.5   800.0   20.32   23.80   14.34    NO
    300.     126.1      3        1.5    1.5   480.0   27.20   34.64   20.91    NO
    400.     119.0      4        2.0    2.0   640.0   22.90   29.68   15.71    NO
    500.     110.9      4        2.0    2.0   640.0   22.90   36.33   18.66    NO
    600.     104.1      4        1.5    1.5   480.0   27.20   43.00   21.77    NO
    700.     94.72      4        1.5    1.5   480.0   27.20   49.43   24.53    NO
    800.     89.26      4        1.0    1.0   320.0   35.79   56.06   27.78    NO
    900.     84.04      4        1.0    1.0   320.0   35.79   62.32   30.37    NO
   1000.     78.16      4        1.0    1.0   320.0   35.79   68.52   32.93    NO

 MAXIMUM 1-HR CONCENTRATION AT OR BEYOND     1. M:
    195.     138.1      3        2.5    2.5   800.0   20.32   23.37   14.08    NO

  DWASH=   MEANS NO CALC MADE (CONC = 0.0)
  DWASH=NO MEANS NO BUILDING DOWNWASH USED
  DWASH=HS MEANS HUBER-SNYDER DOWNWASH USED
  DWASH=SS MEANS SCHULMAN-SCIRE DOWNWASH USED
  DWASH=NA MEANS DOWNWASH NOT APPLICABLE, X<3*LB

 ************************************
 *** SCREEN DISCRETE DISTANCES ***
 ************************************

 *** TERRAIN HEIGHT OF    0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

   DIST      CONC                 U10M   USTK  MIX HT   PLUME   SIGMA   SIGMA
    (M)   (UG/M**3)   STAB      (M/S)  (M/S)    (M)    HT (M)  Y (M)   Z (M)  DWASH
 -------  ----------  ----  ---------  -----  ------  ------  ------  ------  -----
   1061.     74.46      4        1.0    1.0   320.0   35.79   72.28   34.15    NO

  DWASH=   MEANS NO CALC MADE (CONC = 0.0)
  DWASH=NO MEANS NO BUILDING DOWNWASH USED
  DWASH=HS MEANS HUBER-SNYDER DOWNWASH USED
  DWASH=SS MEANS SCHULMAN-SCIRE DOWNWASH USED
  DWASH=NA MEANS DOWNWASH NOT APPLICABLE, X<3*LB
```

Fig. F.2. EPA SCREEN2 model output for mercury vapor dispersion from low-temperature thermal desorption stack.

```
**********************************************
*  SUMMARY OF TERRAIN HEIGHTS ENTERED FOR    *
*     SIMPLE ELEVATED TERRAIN PROCEDURE      *
**********************************************

     TERRAIN        DISTANCE RANGE (M)
      HT (M)      MINIMUM      MAXIMUM
     -------      --------     --------
          0.           1.         1000.
          0.        1061.           --

*** CAVITY CALCULATION - 1 ***      *** CAVITY CALCULATION - 2 ***
 CONC (UG/M**3)      =    .0000       CONC (UG/M**3)      =    .0000
 CRIT WS @10M (M/S) =   99.99        CRIT WS @10M (M/S) =   99.99
 CRIT WS @ HS (M/S) =   99.99        CRIT WS @ HS (M/S) =   99.99
 DILUTION WS (M/S)  =   99.99        DILUTION WS (M/S)  =   99.99
 CAVITY HT (M)       =    4.25       CAVITY HT (M)       =    4.05
 CAVITY LENGTH (M)  =   13.55        CAVITY LENGTH (M)  =   10.77
 ALONGWIND DIM (M)  =   10.00        ALONGWIND DIM (M)  =   15.00

CAVITY CONC NOT CALCULATED FOR CRIT WS > 20.0 M/S.  CONC SET = 0.0

     ****************************************
     *** SUMMARY OF SCREEN MODEL RESULTS ***
     ****************************************

 CALCULATION       MAX CONC     DIST TO    TERRAIN
  PROCEDURE       (UG/M**3)    MAX (M)     HT (M)
--------------    ----------   -------    -------
SIMPLE TERRAIN      138.1         195.         0.

**************************************************
** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **
**************************************************
```

Fig. F.2. (continued)

Statistics:	Value
Trials	10000
Mean	4128.1
Median (approx.)	3083.9
Mode (approx.)	1559.2
Standard Deviation	3837.1
Variance	14723666.2
Skewness	2.67
Kurtosis	15.41
Coeff. of Variability	0.93
Range Minimum	52.9
Range Maximum	43091.5
Range Width	43038.7
Mean Std. Error	38.37



Percentiles:

Percentile	mg Hg/kg soil (approx.)
100% 99.88% = 58 mg Hg/kg soil	52.9
90% 98.70% = 180 mg Hg/kg soil	790.7
80%	1384.3
70%	1934.9
60%	2470.5
50%	3083.9
40%	3811.4
30%	4726.8
20%	6091.9
10%	8544.0
0%	43091.5

Fig. F.3. Probability distribution: remediation goal option for mercury in EFPC soil.

ATTACHMENT F.1

TOXICITY SUMMARY FOR MERCURY

This page intentionally left blank.

TOXICITY SUMMARY FOR MERCURY

November, 1991

Prepared by:

Robert A. Young, Ph.D., D.A.B.T.
Chemical Hazard Evaluation and Communication Group
Biomedical and Environmental Information Analysis Section
Health and Safety Research Division
Oak Ridge National Laboratory*
Oak Ridge, Tennessee

Prepared for:

OAK RIDGE RESERVATION ENVIRONMENTAL RESTORATION PROGRAM

*Managed by Martin-Marietta Energy Systems, Inc. for the U.S. Department of Energy under Contract No. DE-AC05-84OR21400

93-008P/021494

This page intentionally left blank.

1. INTRODUCTION

Mercury (Hg) is a naturally occurring element that may exist in elemental, inorganic, or organic forms, and in various oxidation states. Mercury is used in a wide variety of products and processes, including pressure sensitive devices (thermometers, barometers), electrical apparatus (wiring, switches, batteries), paints, pharmaceuticals, and in the production of various chemicals (ATSDR, 1989). The oxidation state and chemical form of mercury are important in determining its toxicity, with mercurous salts (monovalent mercury) being less toxic than mercuric salts (divalent mercury). Organic mercurials such as methyl mercury are highly toxic. In the environment, mercury may undergo transformations among the various oxidation states and chemical forms. Both environmental and occupational exposure are relevant to mercury and its compounds, although environmental exposure is unimportant for mercury vapor. Mercury intake from occupational exposure is of greater significance than that from environmental exposure. Environmental exposure to mercury may involve dietary intake (especially from fish) and possibly from dental amalgams, the latter source being controversial (ATSDR, 1989; Langworth et al., 1991).

2. METABOLISM AND DISTRIBUTION

2.1 ABSORPTION

Generally, organic mercurials are absorbed much more rapidly than are inorganic forms. However, approximately 80% of mercury vapor is absorbed following inhalation exposure. Data on the inhalation absorption of organic mercury are limited and inconclusive. Metallic mercury and mercurous salts (e.g. Hg_2Cl_2) are poorly absorbed (<0.10%) following oral exposure (Friberg and Nordberg, 1973). Absorption of mercuric chloride by adult mice was reported to be only 1-2% (Clarkson, 1971) but 1-week old mice absorbed 38% of the orally administered compound. Gastrointestinal absorption of inorganic salts of mercury from food is <15% for mice and about 7% for humans (Goyer, 1991). Organic mercury compounds (methyl- and phenylmercury) have been shown to readily absorbed (>80%) by humans and animals following oral exposure (ATSDR, 1989; Goyer, 1991).

2.2 DISTRIBUTION

Being lipid soluble, mercury vapor readily enters the red blood cells and the CNS following inhalation exposure. The kidneys will exhibit the greatest concentration of mercury following exposure to inorganic mercury salts. Organic mercury is readily distributed throughout the body but tends to concentrate in the brain and kidneys (ATSDR, 1989; Goyer, 1991). Mercury is known to bind to microsomal and mitochondrial enzymes resulting in cell injury and death. Mercury in renal cells localizes in lysosomes (Madsen and Christensen, 1971). Petersson et al. (1991) administered ^{203}Hg-labeled methyl mercury intraperitoneally to rabbits twice weekly for nine weeks. After one week of treatment, the highest concentration of ^{203}Hg was detected in the fur with substantially lower levels being found in the kidney, liver, brain, muscle, and blood. Inorganic mercury levels in the liver of the rabbits increased with time after cessation of

treatment. A report by Dutczak et al. (1991) providing data for guinea pigs, hamsters and a macaque monkey indicate that extensive absorption of methyl mercury occurs in the gall bladder. Subsequent biliary-hepatic cycling of the compound may contribute to the long biologic half-life of methyl mercury. Yoshida et al. (1991) reported that substantial concentrations of metallothionein-associated mercury were found in the kidneys and livers of neonate guinea pigs exposed to mercury vapor for 120 minutes on the day of birth. Metallothionein synthesis increased in the liver but not in the kidneys. Animal data indicate that all forms of mercury cross the placenta, and that mercury levels may be 2-fold greater than in maternal levels with fetal red blood cells containing mercury levels 30% higher than maternal red blood cells (Goyer, 1991).

2.3 METABOLISM

Mercury is not destroyed by metabolism but rather converted to different forms and oxidation states. The metabolism of mercury and mercury compounds appears to be similar for animals and humans (ATSDR, 1989), and involves an oxidation-reduction cycle. Inhaled mercury vapor is rapidly oxidized to the divalent form in red blood cells (Halbach and Clarkson, 1978). Oxidation of elemental mercury also occurs in the lungs of humans and animals (Magos et al., 1973; Hursh et al., 1980), and there is some evidence for hepatic-mediated oxidation (Magos et al., 1978). Animal studies have provided some data suggesting that the divalent inorganic mercury cation may be further reduced to elemental mercury (Clarkson and Rothstein, 1964; Dunn et al., 1981). Organic mercury compounds are also converted to divalent mercury by cleavage of the carbon-mercury bond (Goyer, 1991) with subsequent metabolism occurring via the oxidation reduction cycle. Aryl mercury compounds (e.g. phenylmercury) undergo this conversion more readily than do the short-chain (methyl) mercury compounds. No evidence of demethylation of methyl mercury by the brain of rabbits was noted following parenteral administration of the compound (Petersson et al., 1991).

2.4 EXCRETION

The urine and feces are the primary routes for the excretion of inorganic mercury by humans (ATSDR, 1989). Following brief exposure of humans to inorganic mercury, urinary excretion accounts for 13% of the total body burden, whereas this value increases to 58% for long-term exposure. For inorganic mercury, the urinary levels do not parallel blood levels (ATSDR, 1989). Henderson et al. (1974) identified three forms of mercury in the urine of occupationally-exposed individuals: elemental mercury, a reducible mercuric-cysteine complex, and a large complex in which the mercury can only be released following organic destruction. The data available for elemental mercury and mercury vapor indicate half-times for these forms to be 35 to 90 days (Goyer, 1991). The biologic half-time for inorganic mercury salts is about 40 days.

Fecal elimination is an important excretory route following exposure to organic mercury compounds (Norseth and Clarkson, 1970). However, Petersson et al. (1991) using ^{203}Hg-labeled methyl mercury administered intraperitoneally to rabbits twice weekly for nine weeks, showed that 12 weeks after cessation of treatment 54% of administered dose had been excreted in the urine and only 5% had been excreted in the feces.

The elimination of organic mercury compounds generally follows first-order kinetics with whole body clearance times and blood clearance times being longer than for inorganic mercury. The biologic half-time for methyl mercury is about 70 days. There is some evidence that females tend to excrete organic mercury faster than males (Aberg et al., 1969; Miettinen, 1973). Additional excretory routes include saliva, bile, and sweat (ATSDR, 1989).

3. NONCARCINOGENIC HEALTH EFFECTS

3.1 ORAL EXPOSURES

3.1.1 Acute Toxicity

3.1.1.1 Human

Generally, any form of mercury in high acute doses may cause tissue damage resulting from the ability of mercury to denature proteins, thereby disrupting cellular processes (WHO, 1976). However, oral exposure to mercury metal is usually without serious effects. A dose of 200 g caused no adverse health effects in a 2-year old child and unspecified large amounts were without effect in adults (Goldwater, 1972).

Ingestion of inorganic salts of mercury such as mercury bichloride (corrosive sublimate) may cause gastrointestinal disorders including pain, vomiting, diarrhea and hemorrhage, and renal failure resulting in death. Additional effects of acute mercury poisoning include shock and cardiovascular collapse (WHO, 1976). Acute lethal doses in humans range from 1 to 4 g (10-42 mg Hg/kg for a 70 kg adult) for inorganic mercuric salts (ATSDR, 1989).

A hypersensitivity reaction to mercurous compounds such as mercurous chloride (calomel) is characterized by vasodilation, hyperkeratosis, and hypersecretion of the sweat glands. Children exhibiting this condition, also known as acrodynia or pink disease, may also develop fever, a pink-colored rash, swelling of the spleen and lymph nodes, and hyperkeratosis and swelling of the fingers (Matheson et al., 1980; Goyer, 1991).

The effects of acute exposure to organic mercury compounds are not well documented. However, exposure to organomercurials are known to contribute to the body burden of mercury and have resulted in serious developmental and neurological effects as reported in the following sections.

3.1.1.2 Animal

The acute toxicity of inorganic mercury in animals is similar to that observed in humans (ATSDR, 1989). Neurological effects and death have been reported for various animal species receiving inorganic mercury orally (ATSDR, 1989). The LD_{50} values in animals for elemental mercury range from 10 to 40 mg/kg (WHO, 1976).

3.1.2 Subchronic Toxicity

3.1.2.1 Human

The effects of subchronic exposure to mercury and mercury compounds are likely to be similar to those of chronic exposure if the exposure level and body burden of mercury is increased (see Section 3.1.3.1.). Renal toxicity and neurological effects would be the most typical effects associated with subchronic exposure.

In Iraq, over 6000 individuals were hospitalized and 459 individuals died as a result of consuming bread prepared with flour made from wheat and barley treated with a methylmercurial fungicide (Bakir et al., 1973). Methyl mercury concentration in the wheat flour ranged from 4.8-14.6 μg/g (mean=9.1 μg/g). The clinical symptoms included paresthesia, visual disorders, dysarthria, and deafness. The most severe cases resulted in coma and death due to CNS failure. Based on data obtained during this incident, a dose-response relationship between blood mercury levels (< 10 μg/dL to 500 μg/dL), and frequency and severity of symptoms showed that mild symptoms occurred at the lower blood mercury levels and that deaths occurred at levels >300μg/dL.

3.1.2.2 Animal

Oral exposure to inorganic mercury has produced neurological, immunological and systemic effects in rodents exposed for periods of 1-11 weeks. The no-observed-adverse-effect level (NOAEL) for these studies was 0.42 mg/kg/day, and the lowest-observed-adverse effect level (LOAEL) was 0.8 mg/kg/day (ATSDR, 1989).

In a 110-day exposure of mice to mercuric chloride (1 or 3 mg/kg/day) only decreased body weight gain was noted (Ganser and Kirschner, 1985).

Behavioral and pathological effects were reported for cats receiving methyl mercury at doses of 0.01 mg/kg/day for 11 months or 0.45 mg/kg/day for 83 days, and for rats receiving the compound at 0.6-2.4 mg/kg/day for 8 weeks or 1 mg/kg/day for 11 weeks (USAF, 1990). Systemic, neurological and developmental effects resulting from subchronic, oral exposure to organic mercury have been reported for various species of rodents (ATSDR, 1989). Necrosis and degeneration of brain tissue were reported for rabbits exposed to metallic mercury vapor (0.86 mg/m^3) for 12 weeks (Ashe et al., 1953).

3.1.3 Chronic Toxicity

3.1.3.1 Human

Chronic oral exposure to mercury or mercury compounds may affect the CNS, gastrointestinal tract and the kidneys; the renal effect, in part, involving an immunologically mediated response (ATSDR, 1989). Davis et al. (1974) reported dementia, colitis, and renal failure in two women chronically (6 and 25 years) ingesting a mercurous chloride-containing laxative. Generally, little information is available regarding the toxicity of inorganic mercury following chronic oral exposure.

Exposure to organic mercury causes CNS effects, especially in the fetus and neonate. Although any exposure to organic mercury compounds will contribute to the body burden of mercury, exposure during pregnancy or the postnatal period has the most significant consequences as discussed in Section 3.1.4.

3.1.3.2 Animals

Chronic oral exposure (2 years) of rats to inorganic mercury produces glomerulonephritis (Fitzhugh et al., 1950).

Neurological as well as other systemic toxic effects have resulted following chronic oral exposure of animals to organic mercury compounds (ATSDR, 1989). Neurotoxic effects indicative of CNS involvement have been reported for mice and rats orally administered organic mercury compounds (usually methyl mercury) for several weeks to over a year (ATSDR, 1989). Glomerulonephrotic changes were observed in rats fed phenylmercuric acetate for two years (Fitzhugh et al., 1950). Monkeys orally exposed to methyl mercury for 1000 days at doses adjusted to maintain a blood mercury level of 100-400 μg/mL, exhibited reduced sensitivity to visual stimulation, somesthetic impairment, and incoordination (Evans et al., 1977). Rice and Gilbert (1982) noted impaired spatial vision in monkeys given methyl mercury at 0.05 mg/kg/day from birth until 3-4 years of age.

3.1.4 Developmental and Reproductive Toxicity

3.1.4.1 Human

No information was available regarding developmental/reproductive toxicity of inorganic mercury in humans following oral exposure.

The developmental toxicity of organic mercury is best exemplified by the epidemic poisonings by methyl mercury in Iraq and Minamata and Niigata, Japan. Although no evidence of teratogenicity was observed, Amin-Zaki et al. (1974) found other severe developmental effects (impaired motor and mental function, hearing loss and blindness) in infants of mothers exposed via contaminated grain during the Iraqi epidemic. The most severely affected infants had mercury blood levels ranging from 319 to 422 μg Hg/dL. It is also important to note that a 45% mortality rate was reported for pregnant women with signs of mercury poisoning versus a 7% mortality rate for the general population. In Minamata and Niigata, Japan, methyl mercury poisoning resulted from the ingestion of fish that had accumulated methyl mercury and other mercury compounds resulting from contaminated surface waters (WHO, 1976). Harada (1978) reported that at about 6 months of age 13 of the 220 infants prenatally exposed to methyl mercury during the Minamata Bay incident showed signs of mercury poisoning characterized by instability of the neck, convulsions, and severe neurological and mental impairment. Choi et al. (1978) reported abnormal cytoarchitecture of the brain in infants prenatally exposed to methyl mercury. No other significant anatomical defects have been reported.

3.1.4.2 Animal

Only limited information was available regarding the developmental toxicity of inorganic mercury. Gale (1974) reported an increase in fetal resorptions in hamsters receiving a single oral

dose of mercuric chloride (31.4 mg Hg/kg). This study also identified a dose of 15.7 mg Hg/kg as a NOAEL for hamsters based on the absence of developmental toxicity.

A 100% incidence of neonatal deaths and failure of dams to deliver was reported for rats receiving dietary methylmercuric chloride equivalent to 5 mg Hg/kg/day (Khera and Tabacova, 1973). The investigators reported no maternal toxicity.

Ultrastructural changes in the nervous system of mice exposed in utero to methylmercuric hydroxide (up to 10 mg Hg/kg/day) were reported by Hughes and Annau (1976). A dose of 3 mg Hg/kg/day produced significant behavioral changes in the mice. Ultrastructural changes in the nervous system have also been reported for rats prenatally exposed to methylmercuric chloride (4 mg Hg/kg/day) (Chang et al., 1977).

Exposure of rats to methyl mercury in the drinking water (0.25-0.50 mg Hg/kg/day) from 1 month prior to mating to the end of gestation resulted in ultrastructural changes in the livers of the fetuses (Fowler and Woods, 1977).

In their study using monkeys exposed from birth to 3 or 4 years of age (Section 3.1.3.1.), Rice and Gilbert (1982) noted that the young, developing monkeys were especially vulnerable to the toxic effects of methyl mercury on visual function as demonstrated by the low dose at which these effects occurred.

Pregnant monkeys (Macaca fascicularis) given methyl mercury in apple juice (50 or 90 μg methyl mercury/kg/day resulting in blood mercury levels of 1.0 ± 0.13 ppm or 2.0 ± 0.33 ppm, respectively) exhibited a decrease in pregnancy rate and increased abortion rate for mercury blood levels above 1 ppm (Mottet et al., 1985).

3.1.5 Reference Dose

3.1.5.1 Subchronic

Inorganic mercury:

ORAL RfD_o:	3E-4 mg/kg/day (U.S. EPA, 1991b)
UNCERTAINTY FACTOR:	1000
NOAEL:	Not available
LOAEL:	0.317 mg Hg/kg/day
PRINCIPAL STUDY:	Bernaudin et al., 1981

Methyl mercury:

ORAL RfD_o:	3E-4 mg/kg/day (U.S. EPA, 1991b)
UNCERTAINTY FACTOR:	10
MODIFYING FACTOR:	1
NOAEL:	None
LOAEL:	200 ng Hg/mL blood equivalent to 0.003 mg Hg/kg/day
CONFIDENCE:	

Study:	Medium
Data base:	Medium
RfD:	Medium
PRINCIPAL STUDY:	Clarkson et al., 1976; Nordberg and Strangert, 1976; WHO, 1976
COMMENTS:	The RfD is based on an exposure that would produce a blood level of 200 ng Hg/mL, which is the blood concentration associated with early mercury-induced health effects in humans.

3.1.5.2 Chronic

Inorganic mercury:

ORAL RfD_c:	3E-4 mg/kg/day (U.S. EPA, 1991a)
UNCERTAINTY FACTOR:	1000
MODIFYING FACTOR:	None
NOAEL:	Not available
LOAEL:	0.317 mg Hg/kg/day
CONFIDENCE:	Not available (see comments)
VERIFICATION DATE:	See comments
PRINCIPAL STUDY:	Bernaudin et al., 1981
COMMENTS:	RfD is not yet verified but the review panel is in concordance with the data (U.S. EPA, 1991).

Methyl mercury:

ORAL RfD_c:	3E-4 mg/kg/day (U.S. EPA, 1991a)
UNCERTAINTY FACTOR:	10
MODIFYING FACTOR:	1
NOAEL:	None
LOAEL:	200 ng Hg/mL blood equivalent to 0.003 mg Hg/kg/day
CONFIDENCE:	
Study:	Medium
Data base:	Medium
RfD:	Medium
VERIFICATION DATE:	12/02/85 (U.S. EPA, 1991)
PRINCIPAL STUDY:	Clarkson et al., 1976; Nordberg and Strangert, 1976, WHO, 1976

COMMENTS: RfD is based on an exposure that would produce a blood level of 200 ng Hg/mL, which is the blood concentration associated with early mercury-induced health effects in humans.

3.2 INHALATION EXPOSURES

3.2.1 Acute Toxicity

3.2.1.1 Human

Inhalation of mercury vapor may result in corrosive bronchitis, interstitial pneumonitis, and death (Goyer, 1991). Systemic effects following inhalation exposure may include shock, renal disorders, and CNS effects characterized by lethargy and neurobehavioral effects (insomnia, loss of memory, excitability, etc.). Occupational exposure to metallic mercury vapor at concentrations of 1.1 to 44 mg/m^3 for 4 to 8 hours produced chest pains, dyspnea, cough, hemoptysis, impairment of pulmonary function, and interstitial pneumonitis (ATSDR, 1989). Acute effects of inorganic mercury poisoning may be accompanied by a metallic taste, sore gums, and excessive salivation.

A case report cited an incident wherein four adults were acutely exposed to mercury vapor resulting from the smelting of dental amalgams (Taueg et al., 1991). Initial signs of toxicity included nausea, diarrhea, dyspnea, and chest pains. Despite chelation therapy, all four patients died 11 to 24 days after initial exposure. Mercury concentrations in the house were as high as 912 $\mu g/m^3$ at or within 11 to 188 days after the exposure, and postmortem blood mercury levels ranged from 58 to 369 $\mu g/L$.

Historically, the triad of increased excitability, tremors, and gingivitis has been recognized as characteristic for mercury poisoning (Goyer, 1991).

3.2.1.2 Animal

Death resulting from severe pulmonary edema has been reported for mice, guinea pigs, and rats following inhalation exposure to mercury vapor (Christensen et al., 1937). Similarly, inhalation exposure of rabbits to mercury vapor at a concentration of 1 to 1.1 mg/m^3 for 1 to 30 hours resulted in death (Ashe et al., 1953). This same study also showed that 30-hour exposure of rabbits to mercury vapor at a concentration of 28.8 mg/m^3 caused extensive necrosis of the lungs.

Data are lacking regarding the effects of inhalation exposure of animals to organic mercury compounds (ATSDR, 1989).

3.2.2 Subchronic Toxicity

3.2.2.1 Human

Subchronic inhalation exposure to mercury vapor will result in effects similar to those for acute exposure, and will vary depending on exposure severity and duration. Sax and Lewis

(1989) reported a lowest toxic exposure level of 0.15 mg/m^3 for human females exposed to mercury vapor for 46 days. Sexton et al. (1976) reported tremors (especially in activities requiring fine control), insomnia, and nervousness resulting from 7 to 25 weeks of exposure to mercury vapor.

Langolf et al. (1978) noted that short-term exposure to high levels of mercury appears to induce greater neurological effects than does long-term exposure to lower mercury levels.

Exposure of humans to diethylmercury at vapor concentrations of 1 to 1.1 mg/m^3 for 4 to 5 months resulted in death, the cause of which was not determined (Hill, 1943). Data are lacking regarding inhalation exposure to methyl mercury.

3.2.2.2 Animal

The effects of subchronic inhalation exposure to mercury or mercury compounds is dependent on the exposure concentration and the specific form of mercury. Low levels of exposure will generally affect the kidney and CNS while high-level exposure will target the respiratory, cardiovascular, and gastrointestinal systems as described in Section 3.1. Exposure of rabbits to mercury vapor (0.86-6.0 mg/m^3) for 2 to 12 weeks resulted in marked degeneration and necrosis of the heart (Ashe et al., 1953). Subchronic inhalation exposure of rats and rabbits to mercury has also produced neurobehavioral changes (ATSDR, 1989). Evidence for a systemic autoimmune response was reported by Bernaudin et al. (1981) for rats inhaling vapors of mercuric chloride or methyl mercuric chloride 4 hours/day for 60 days. The kidney, lungs, and spleen were identified as target organs.

3.2.3 Chronic Toxicity

3.2.3.1 Human

Chronic exposure to low levels of mercury vapor may induce immunologic glomerular disease (Goyer, 1991). A number of studies have been conducted with individuals occupationally exposed to inorganic mercury compounds (mercuric oxides, mercurial chlorides, mercuric nitrate) and are reviewed in USAF (1990). Briefly, neuropsychological symptoms (insomnia, fatigue, headaches, etc.) and renal effects that correlated with blood mercury levels were reported for those exposed $\geq$ 2 years. The emotional and psychological disturbances often referred to as the "Mad Hatter Syndrome" has been attributed to inhalation of the dust or vapors of mercuric nitrate used in the making of felt hats (Clarkson, 1989).

Chronic exposure to mercury vapor results in CNS effects including fatigue and tremors, and gingivitis (Goyer, 1991). As exposure increases, the frequency and magnitude of muscle tremors increase and are accompanied by personality and behavioral changes (memory loss, excitability, depression, and hallucinations).

Chronic exposure to low levels of mercury may affect the peripheral nervous system resulting in polyneuropathies (reduced sensory and motor nerve function), and neuropsychological effects (visual alterations, sensory loss, stress) (ATSDR, 1989), these effects correlating with tissue levels of 20-40 μg/g. Fawer et al. (1983) reported an increase in the frequency of intention tremors of workers exposed to mercury vapor (time-weighted-average [TWA] of 0.026 mg/m^3)

over an average of 26 years. Neuropsychological effects were also reported by Smith et al (1970) for occupational exposure to mercury levels of >0.1 mg/m^3. Mercury concentrations below this value did not appear to cause observable effects.

Inhalation exposure to alkyl mercury compounds may occur during the manufacture or use of alkylmercury fungicides. The effects reported for these compounds include paresthesia of the extremities, mouth and lips, constriction of the visual field, deafness, motor incoordination and compromised reflex function. In severe cases, loss of speech and mental deterioration may occur (McComish et al., 1988).

3.2.3.2 Animal

Chronic inhalation exposure (72-83 weeks) of rats, rabbits and dogs to metallic mercury vapor (0.01 mg/m^3) did not produce histological evidence of renal toxicity (Ashe et al., 1953). Additional information on the chronic inhalation toxicity of inorganic mercury in animals was not available.

Information regarding the toxicity of organic mercury following chronic exposure of animals was not available.

3.2.4 Developmental and Reproductive Toxicity

3.2.4.1 Humans

There is evidence that chronic exposure of women to metallic mercury vapor may increase the frequency of menstrual disturbances and spontaneous abortions (Derobert and Tara, 1950; ATSDR, 1989). Mishonova et al. (1980) reported an increased frequency of pregnancy complications for women occupationally exposed to metallic mercury vapor.

No data were available regarding the developmental/reproductive toxicity potential of inhaled organic mercury compounds.

3.2.4.2 Animal

Steffek et al. (1987) showed that exposure of pregnant rats to metallic mercury vapor at concentrations of 0.5 mg/m^3 on gestational days 10-15 caused an increase in resorptions and congenital defects in the offspring.

Prolongation of the estrus cycle of rats exposed to metallic mercury vapor at concentrations of 2.6 mg/m^3, 6 hours/day for 21 days was reported by Baranski and Szmczyk (1973). This same study also showed that gestational exposure of rats to metallic mercury vapor (2.5 mg/m^3) resulted in a decrease in the number of living fetuses and increased pup mortality.

3.2.5 Reference Concentration

3.2.5.1 Subchronic

Inorganic mercury:

INHALATION RfC_s:	0.0003 mg Hg/m^3 (U.S. EPA, 1991b)
UNCERTAINTY FACTOR:	30
MODIFYING FACTOR:	None
NOAEL:	None
LOAEL:	0.03 mg Hg/m^3
PRINCIPAL STUDY:	Fawer et al., 1983

Methyl mercury:

Not available.

3.2.5.2. Chronic

Inorganic mercury:

INHALATION RfC:	0.0003 mg Hg/m^3 (U.S. EPA, 1991b)
UNCERTAINTY FACTOR:	30
MODIFYING FACTOR:	None
NOAEL:	None
LOAEL:	0.03 mg Hg/m^3
CONFIDENCE:	Not available
VERIFICATION DATE:	Not verified (U.S. EPA, 1991b)
PRINCIPAL STUDY:	Fawer et al. (1983)
COMMENTS:	RfC is not yet verified but the review panel is in concordance with the data.

Methyl mercury:

Not available.

3.3 OTHER ROUTES OF EXPOSURE

3.3.1 Acute Toxicity

Dermal contact with organic or inorganic mercury compounds may cause dermatitis especially in hypersensitive individuals (USAF, 1990). Renal effects have been reported

following dermal exposure to organic mercurials, and neurological effects have been reported for dermal exposure to inorganic mercury (ATSDR, 1989).

No data are available for other routes of exposure.

3.3.2 Subchronic Toxicity

No information was available regarding the subchronic toxicity of mercury by other routes of exposure.

3.3.3 Chronic Toxicity

No information was available regarding the chronic toxicity of mercury by other routes of exposure.

3.3.4 Developmental Toxicity

No information was available regarding developmental toxicity of mercury by other routes of exposure.

3.4 TARGET ORGANS/CRITICAL EFFECTS

3.4.1 Oral Exposures

3.4.1.1 Primary target(s)

1. CNS and Kidney: Both the CNS and kidneys are affected by inorganic mercury. The toxic effects may occur with acute, subchronic, or chronic exposure depending on the exposure level and the resulting body burden of mercury. Animal data suggests that the renal effects may be immunologically mediated. The CNS, especially during prenatal and postnatal development, is the primary target organ for methyl mercury.

3.4.1.2 Other target(s)

1. Cardiovascular system: acute exposure to mercury has caused cardiovascular collapse and some effects associated with acrodynia involve cardiovascular responses.

2. Immune system: As noted in section 3.4.1.1., animal data suggests that the nephrotoxic effects of mercury may, in part, be the result of mercury-induced immunological effects.

3. Skin: Skin rashes and hyperkeratosis are involved in acrodynia, a response to mercurous chloride (calomel).

3.4.2 Inhalation Exposures

3.4.2.1 Primary target(s)

1. CNS and Peripheral Nervous System: The critical target organs for inhalation exposure to elemental mercury vapor are the CNS and the peripheral nervous system.

2. Kidney: Inorganic mercury salts will primarily affect the kidneys.

Definitive data were unavailable regarding the target organ for inhalation exposure to organic mercury compounds but, as for oral exposure, it is likely that the CNS would be the primary target organ.

3.4.2.2 Other target(s)

1. Respiratory System: Exposure to high concentrations of metallic mercury vapor may cause irritation of the respiratory system.

2. Cardiovascular System: Exposure to high concentrations of metallic mercury vapor may also affect the cardiovascular system.

3. Gastrointestinal Tract: Exposure to high concentrations of metallic mercury vapor may also affect the gastrointestinal systems, probably as a result of swallowing mercury that has been removed from the airways by the mucociliary escalator.

4. CARCINOGENICITY

4.1 ORAL EXPOSURE

4.1.1 Human

Definitive data regarding the potential carcinogenicity of mercury and mercury compounds in humans was unavailable.

4.1.2 Animal

Definitive data regarding the potential carcinogenicity of mercury and mercury compounds in animals was unavailable.

4.2 INHALATION EXPOSURE

4.2.1 Human

Definitive data regarding the potential carcinogenicity of mercury and mercury compounds in humans was unavailable. An equivocal study by Janicki et al. (1987) reported an association between exposure to mercury-containing fungicides and leukemia.

4.2.2 Animal

Definitive data regarding the potential carcinogenicity of mercury and mercury compounds in humans was unavailable.

4.3 OTHER ROUTES OF EXPOSURE

No information was available regarding the potential carcinogenicity of mercury or mercury compounds by other routes of exposure.

4.4 EPA WEIGHT-OF-EVIDENCE

Inorganic mercury:

Classification D - Not classifiable as to human carcinogenicity
Basis - No human data available. Animal and supporting data are inadequate.
(U.S. EPA, 1991a)

Methyl mercury:

Methyl mercury has not been evaluated by the U.S. EPA for evidence of human carcinogenic potential.

4.5 CARCINOGENICITY SLOPE FACTOR

None have been calculated

5. REFERENCES

Aberg, B., R. Ekman, U. Falk, et al. 1969. Metabolism of methylmercury (^{203}Hg) compounds in man: Excretion and distribution. Arch. Environ. Health 19:478-484. (Cited in ATSDR, 1989)

Amin-Zaki, L., S. Elhassani, M.A. Majeed, T.W. Clarkson, R.A. Doherty and M. Greenwood. 1974. Intra-uterine methylmercury poisoning. Pediatrics 54:587-595. (Cited in USAF, 1990)

ATSDR (Agency for Toxic Substances and Disease Registry). 1989. Toxicological Profile for Mercury. ATSDR/U.S. Public Health Service.

Ashe, W., E. Largent, F. Dutra, et al. 1953. Behavior of mercury in the animal organism following inhalation. Arch. Ind. Hyg. Occup. Med. 17: 19-43. (Cited in ATSDR, 1989)

Bakir, F., S.F. Kamluji, L. Amin-Zaki, et al. 1973. Methylmercury poisoning in Iraq. Science 181: 230-241.

Baranski, B. and I. Szmczyk. 1973. Effects of mercury vapor upon reproductive functions of female white rats. Med. Pr 24: 248. (Cited in ATSDR, 1989)

Bernaudin, J.F., E. Druet, P. Druet and R. Masse. 1981. Inhalation or ingestion of organic or inorganic mercurials produces auto-immune disease in rats. Clin. Immun. Immunopath. 20: 129-135.

Chang, L.W., K.R. Reuhl and G.W. Lee. 1977. Degenerative changes in the developing nervous system as a result of in utero exposure to methylmercury. Environ. Res. 14: 414-425.

Choi, C.M., L.W. Lapham, L. Amin-Zake, et al. 1978. Abnormal neuronal migration, deranged cerebral cortical organization and diffuse white matter astrocytosis of human fetal brain: a major effect of methylmercury poisoning in utero. J. Neuropathol. Exp. Neurol. 37: 719-732 (Cited in ATSDR, 1989).

Christensen, H. M. Krohg and M. Nielsen. 1937. Acute mercury poisoning in a respiration chamber. Nature 139: 1026-1670. (Cited in ATSDR, 1989)

Clarkson, T.W. 1971. Epidemiological and experimental aspects of lead and mercury contamination. Food Cosemt. Toxicol. 9: 229-243. (Cited in ATSDR, 1989)

Clarkson, T.W. 1989. Mercury. J. Am. Coll. Toxicol. 8: 1291-1295.

Clarkson, T.W. and A. Rothstein. 1964. The excretion of volatile mercury by rats injected with mercuric salts. Health Phys. 10: 1115-1121. (Cited in ATSDR, 1989)

Davis, L.E., J.R. Wands, S.A. Weiss, et al. 1974. Central nervous intoxication from mercurous chloride laxatives - quantitative, histochemical and ultrastructure studies. Arch. Neurol. 30: 428-431. (Cited in ATSDR, 1989)

Derobert, L. and S. Tara. 1950. Mercury intoxication in pregnant women. Ann. Med. Leg. 30: 222-225. (Cited in ATSDR, 1989)

Dunn, J.D., T.W. Calrkson and L. Magos. 1981. Ethanol reveals novel mercury detoxification step in tissues. Science 213: 1123-1125. (Cited in ATSDR, 1989)

Dutczak, W., T.W. Clarkson and N. Ballatori. 1991. Biliary-hepatic recycling of a xenobiotic: gallbladder absorption of methyl mercury. Amer. J. Physiol. 260: G873-G880.

Evans, H.L., R. Garman and B. Weiss. 1977. Methylmercury: Exposure duration and regional distribution as determinants of neurotoxicity in nonhuman primates. Toxicol. Appl. Pharmacol. 41: 15-33. (Cited in ATSDR, 1989)

Fawer, R.F., Y. De Ribaupierre, M.P. Guillemin, M. Berode and M. Lob. 1983. Measurement of hand tremor induced by industrial exposure to metallic mercury. Br. J. Indust. Med. 40: 204-208.

Fitzhugh, O.G., A.A. Nelson, E.P. Laug, et al. 1950. Chronic oral toxicities of mercuri-phenyl and mercuric salts. Arch. Ind. Hyg. Occup. Med. 2: 433-442. (Cited in ATSDR, 1989)

Friberg, L. and F. Nordberg. 1973. Inorganic mercury - a toxicological and epidemiological appraisal. In: Miller, M.W. and T.W. Clarkson, eds. Mercury, mercurials and mercaptans. Charles C. Thomas Co., Springfield, Il. pp. 5-22.

Fowler, B. and J.S. Woods. 1977. The transplacental toxicity of methylmercury to fetal rat liver mitochondria. Lab. Invest. 36: 122-130. (Cited in ATSDR, 1989)

Gale, T.F. 1974. Embryopathic effects of different routes of administration of mercuric acetate on the hamster. Environ. Res. 8: 207-213. (Cited in ATSDR, 1989)

Ganser, A.L. and D.A. Kirschner. 1985. The interaction of mercurials with myelin: Comparison of in vitro and in vivo effects. Neurotoxicology 6: 63-78. (Cited in ATSDR, 1989)

Goldwater, L.J. 1972. Mercury: A history of quicksilver. York Press, Baltimore, MD. (Cited in USAF, 1990)

Goyer. R. 1991. Toxic effects of metals. In: Amdur, M.O., J.D. Doull and C.D. Klassen, Eds. Casarett and Doull's Toxicology. 4th ed. Pergamon Press, New York. pp.623-680.

Halbach, S. and T.W. Clarkson. 1978. Enzymatic oxidation of mercury vapor by erythrocytes. Biochem. Biophys. Acta 523: 522-531. (Cited in ATSDR, 1989)

Harada, M. 1978. Congenital Minamata disease: Intrauterine methylmercury poisoning. Teratology 18: 285-288.

Henderson, R., H.P. Shotwell and L.A. Kraus. 1974. Analyses for total, ionic and elemental mercury in urine as a basis for biological standard. Ann. Ind. Hyg. Assoc. J. 38: 576. (Cited in ATSDR, 1989)

Hill, W. 1943. A report on two deaths from exposure to the fumes of a di-ethyl mercury. Can. J. Pub. Health 34: 158-160. (Cited in ATSDR, 1989)

Hughes, J.A. and Z. Annau. 1976. Postnatal behavioral effects in mice after prenatal exposure to methylmercury. Pharmacol. Biochem. Behav. 4: 385-391. (Cited in ATSDR, 1989)

Hursh, J.D, M.R. Greenwood, T.W. Clarkson, et al. 1980. The effect of ethanol on the fate of mercury vapor inhaled by man. J. Pharmacol. Exp. Ther. 214: 520-527. (Cited in ATSDR, 1989)

Janicki, K.; J. Dobrowolski and K. Drasnicki. 1987. Correlation between contamination of the rural environment with mercury and occurrence of leukemia in men and cattle. Chemosphere 16: 253-257. (Cited in ATSDR, 1989)

Khera, K.S. and S.A. Tabacova. 1973. Effects of methylmercuric chloride on the progeny of mice and rats treated before or during gestation. Food Cosmet. Toxicol. 11: 245-254. (Cited in ATSDR, 1989)

Langolf, G.D., D.B. Chaffin, R. Henderson, et al. 1978. Evaluation of workers exposed to elemental mercury using quantitative tests. Am. Ind. Hyg. Assoc. J. 39: 976-984. (Cited in ATSDR, 1989)

Langworth, S., C.G. Elinder, C.J. Göthe, and O. Vesterberg. 1991. Biological monitoring of environmental and occupational exposure to mercury. Int. Arch. Occup. Environ. Health 63: 161-167.

McComish, M.F., and J.H. Ong. 1988. Trace metals. In: Environmental Inorganic Chemistry. Properties, Processes, and Estimation Methods. Bodek, I. et al. Eds., Pergamon Press, New York, pp. 7.10-1 - 7.10-17.

Madsen, K.M. and E.F. Christensen. 1978. Effects of mercury on lysosomal protein digestion in the kidney proximal tubule. Lab. Invest. 38: 165-171. (Cited in Goyer, 1991)

Magos, L., T.W. Clarkson and M.R. Greenwood. 1973. The depression of pulmonary retention of mercury vapor by ethanol; identification of the site of action. Toxicol. Appl. Pharmacol. 26: 1-4. (Cited in ATSDR, 1989)

Magos, L., S. Halbach and T.W. Clarkson. 1978. Role of catalase in the oxidation of mercury vapor. Biochem. Pharmacol. 27: 1373-1377. (Cited in ATSDR, 1989)

Matheson, D.S., T.W. Clarkson and E. Gelfand. 1980. Mercury toxicity (acrodynia) induced by long-term injection of gamma globulin. J. Pediatr. 97: 153-155. (Cited in Goyer, 1991)

Miettinen, J.K. 1973. Absorption and elimination of dietary (Hg^{++}) and methylmercury in man. In: Miller, M.W. and T.W. Clarkson, Eds. Mercury. Mercurials, and Mercaptans. Springfield, IL. pp 233-243. (Cited in ATSDR, 1989)

Mishonova, V.N., P.A. Stepanova and V.V. Zarudin. 1980. Characteristics of the course of pregnancy and births in women with occupational contact with small concentrations of metallic mercury vapors in industrial facilities. Gig. Truda. i Prof. Zabol. 24: 21-23. (Cited in ATSDR, 1989)

Mottet, N.K., C.-M. Shaw and T.M. Bubacher. 1985. Health risks from increases in methylmercury exposure. Environ. Health Perspect. 63: 133-140.

Petersson, K., L. Dock, K. Söderling and M. Vahter. 1991. Distribution of mercury in rabbits subchronically exposed to low levels of radiolabeled methyl mercury. Pharmacol. Toxicol. 68: 464-468.

Rice, D.C. and S.G. Gilbert. 1982. Early chronic low-level methylmercury poisoning in monkeys impairs spatial vision. Science 216: 759-761. (Cited in ATSDR, 1989).

Norseth, T. and T.W. Clarkson. 1970. Studies on the biotransformation of ^{203}Hg-labeled methylmercury chloride. Arch. Environ. Health 21: 717-727. (Cited in ATSDR, 1989)

Sax, N.I. and R.J. Lewis, Sr., Eds. 1989. Dangerous Properties of Industrial Materials. 7th. ed. Van Nostrand Reinhold, New York.

Sexton, D., K. Powell, J. Liddle, et al. 1976. A nonoccupational outbreak of inorganic mercury vapor poisoning. Arch. Environ. Health 33: 186-191. (Cited in ATSDR, 1989)

Smith, R.G., A.J. Vorwald, L.S. Patil and T.F. Mooney. 1970. Effects of exposure to mercury in the manufacture of chlorine. Am. Ind. Hyg. Assoc. J. 31: 687-700.

Steffek, A.J., R. Clayton, C. Seiw and A.C. Verrusio. 1987. Effects of elemental mercury vapor on pregnant Sprague-Dawley rats. Teratology 35: 59A.

Taueg, C., D.J. Sanfilippo, B. Rowens, J. Szejda and J.L. Hesse. 1991. J. Amer. Med. Assoc. 266: 196-197.

USAF. 1990. Mercury. In: Installation Restoration Toxicology Guide. Vol. 5. Harry G. Armstrong Aerospace Medical Research Laboratory, Wright Patterson AFB, OH.

U.S. EPA. 1991a. Mercury. Integrated Risk Information System (IRIS). Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, Cincinnati, OH.

U.S. EPA. 1991b. Health Effects Summary Tables, FY-1991 Annual. Office of Research and Development, Office of Emergency and Remedial Response, Washington, D.C. OERR 9200.6-303(91-1).

WHO (World Health Organization). 1976. Environmental health criteria. 1. Mercury. United Nations Environment Programme and World Health Organization, Geneva, 131 pp.

Yoshida, M., H. Satoh, S. Kojima and Y. Yamamura. 1991. Metallothionein concentrations and organ retention of mercury in the liver and kidney of the neonatal guinea pig after exposure to mercury. Tohoku J. Exp. Med. 164: 13-22.

APPENDIX G

ECOLOGICAL RISK ASSESSMENT

CONTENTS

TABLES . . . . . G-v
FIGURES . . . . . G-v
ACRONYMS . . . . . G-vii

G.1 METHOD FOR BALANCING ECOTOXICOLOGICAL RISK AND ECOREMEDIAL RISK IN CONTAMINATED HABITATS OF LOWER EAST FORK POPLAR CREEK G-1

G.2 CALCULATION OF THE SEDIMENT REMEDIATION GOAL OPTIONS USING RESULTS FROM THE EFPC FOOD WEB STUDY G-6

G.3 METHOD FOR EVALUATING RELATIVE HABITAT VALUES G-11

REFERENCES G-13

TABLES

G.1 Habitat types occurring on the ORR G-17

G.2 Reptiles and amphibians occurring in the various habitats on the ORR G-18

G.3 Total number of birds counted by sample plot method at Sites 2 through 6 on EFPC and Mill Branch G-21

G.4 Total number of birds counted by belt transect method at Site 1 at EFPC G-24

G.5 Bird species occurring in various habitat types on the EFPC floodplain G-25

G.6 Riparian or water/land interfaces: SWAs 2 through 6 by segment, RU, and habitat type G-31

G.7 Riparian or water/land interfaces: SWA 7 by segment, RU, and habitat type G-41

G.8 Terrestrial habitat areas: SWAs 2 through 6 by segment, RU, and habitat type G-52

G.9 Terrestrial habitat areas: SWA 7 by segment, RU, and habitat type G-65

FIGURES

G.1 Riparian habitat and wetlands with contamination levels in 100-year floodplain for SWAs 2 through 6 . . . . . G-81

G.2 Riparian habitat and wetlands with contamination levels in 100-year floodplain for SWA 7 . . . . . G-93

G.3 Contaminated forest areas along East Fork Poplar Creek for SWAs 2 through 6 . . . . . G-105

G.4 Contaminated forest areas along East Fork Poplar Creek for SWA 7 . . . . . G-117

ACRONYMS

DOE	U.S. Department of Energy
EFK	East Fork kilometer
EFPC	East Fork Poplar Creek
FS	feasibility study
GIS	Geological Information System
HSI	habitat suitability index
HU	habitat units
LOEL	lowest observed effect level
NOEL	no observed effect level
ORNL	Oak Ridge National Laboratory
OU	operable unit
REL	reproductive effects level
RGO	remediation goal option
RI	remedial investigation
SWA	sitewide alternative

APPENDIX G

ECOLOGICAL RISK ASSESSMENT

G.1 METHOD FOR BALANCING ECOTOXICOLOGICAL RISK AND ECOREMEDIAL RISK IN CONTAMINATED HABITATS OF LOWER EAST FORK POPLAR CREEK

There is a need to balance various types of risk for the Lower East Fork Poplar Creek (EFPC) project. CERCLA requires that human health and environmental risks be given equal consideration in the selection of remedial alternatives. Sometimes it is necessary not only to balance human and environmental risks, but to balance different types of environmental risk. A method for balancing human and environmental (hereafter termed ecological) risks has been proposed (Suter et al. 1995). No easily available and pertinent method for balancing different ecological risks is known, so the following method was developed to help evaluate the relative impacts of the alteration of forests and other habitats that would result from remediation (short-term risk) and the presence of concentrations of toxic mercury in the soil (long-term risk).

The new method focuses on balancing ecotoxicological risk and ecoremedial risk. Ecotoxicological risk means the probability of toxicological harm to plant and animal populations and habitats arising from mercury in the soil and other media. Ecoremedial risk refers to direct mortality to plants, animals, and habitats that would result from such remedial activities as soil capping, excavation, and soil treatments followed by repopulation of the "clean" area after recovery. If one of these two types of risk dominates the other, it may be easy to recognize whether remediation should or should not be recommended. For example, a highly polluted habitat where nothing can survive means ecotoxicological risk outweighs ecoremedial risk; and, therefore, the need for remediation is straightforward and reasonable. Most situations in EFPC are less obvious; therefore, the feasibility study (FS) process requires a method to systematically determine how to best evaluate the particular locations.

Important technical variables are associated with this balancing or tradeoff of risks: the size of the contaminated area or habitat, the time to recover once a habitat is disturbed, and the degree of toxicity of soil contaminants. The method requires sound and proven technical variables such as these, which serve to focus the issues by systematically defining the problem. For example, when it is learned that only ~7.3 ha (18 acres) [~3% of the 255 ha (630 acres)] exceed the proposed ecological soil remediation goal option of 200 mg/kg of mercury, one can stop worrying about destoying the entire floodplain ecosystem to excavate the mercury present at concentrations considerably higher than the remediation goal option. We can use measurements and modeled values to conduct the tradeoff analysis of ecotoxicological and ecoremedial risk. We selected the above-mentioned three variables for doing this, and each is defined below.

Size of the Contaminated Area. The size of the contaminated area means the areal extent of a habitat in which the soil exceeds the remediation goal option of 200 mg/kg of mercury. The larger the size of the contaminated area, the greater the acreage of possible alteration of habitats where organisms live. The smaller the size of the contaminated area, the smaller the acreage of possible alteration of habitats. From the ecotoxicological viewpoint, the relationship is similar: the larger the area of contamination, the worse the extent of ecological effects, and conversely. A gradient of sizes, ranging from small habitats to large ones, would provide a way of recognizing the range of possible areas and where a given EFPC habitat fits in the range.

Years of Time to Recover. Time to recover means the number of years for ecological succession to occur and for the habitat to be restored to near its current state. The slower the recovery time of the remediated area or habitat, the longer the negative impact to plants and animals that once lived there. The faster the recovery time of the remediated area, the shorter the negative impact to plants and animals whose home was altered. The incremental gradient of ecological succession or orderly changing of habitats through time, is one way to organize time from the ecoremedial perspective (Odum 1983).

Degree of Toxicity. Degree of toxicity means the ecotoxicological effects possible as a function of contaminant concentration between 200 and 1800 mg/kg (the observed range above the remediation goal option) in the soil. The higher the concentration of the contaminant, the greater the magnitude of the ecological effect. The lower the concentration of the contaminant, the lower the magnitude of the ecological effect. From the ecotoxicological viewpoint, time means how long the organisms are exposed to the mercury. Mercury is expected to persist for a long time, possibly millennia, unless the form of mercury becomes less toxic or exposure is reduced by some natural phenomenon, such as siltation, or by some remedial alternative. From the remedial risk viewpoint, the contaminant's degree of concentration above the remediation goal option has little effect because once remediation is triggered, the remedial risk is the same whatever the contaminant level is as long as it is above the remediation goal option. A dose-response relationship in which the range of lowest observed effects through lethality is related to soil mercury concentrations is one way to provide a gradient to help classify and trade off these two types of risk.

These three variables can be organized into a logical decision model leading to remediation or no remediation that balances ecotoxicological and ecoremedial risks. This method needs three types of measurements: habitat area, time to recovery after remedial disturbance, and degree of mercury toxicity. The sizes of habitats above certain contaminant concentration levels can be measured on the ground by transits, on maps with rulers, or by electronic means on Geographic Information System (GIS). EFPC measurements were obtained using all three methods, with emphasis on the latter. Time to recover depends on the current habitat type and using known recovery times for each habitat type; this information comes from standard ecology texts and personal observation from land owners and ecologists. The degree of toxicity may be evaluated from the ecotoxicological literature or from field-observed effects. Field-observed effects are difficult to document, so we must rely on dose-response relationships from laboratory studies, which are extrapolated to the field setting. These laboratory studies for mercury are published in a variety of compendia and scientific articles in the world literature (Eisler 1987, NIOSH 1983).

Three sizes of animal home ranges define the three categories of habitat size. Home range means the area used by an animal for its food, cover, and reproduction. Home ranges vary in size depending on the size and role of the organism (Austing and Terres 1964, Burt and Grossenheider 1976, Johnsquard 1988, Peterson and Peterson 1980). For example, small rodents have small home ranges [0.2 to 0.5 ha (0.5 to 1.2 acres)]; top predators have large home ranges [20 to 30+ ha (48 to 72+ acres)]; and other organisms have many sizes in between. Remediation goal options for top predators depend on the fraction of their feeding range that is in the contaminated area (DOE 1994b). To protect this trophic level, contaminated areas must be small enough to provide sufficient prey from the uncontaminated portion of the feeding range. This limit was set at 5 ha (12 acres), which is 20% of a total home range (Suter et al. 1995).

We defined small habitat size as <0.5 ha (<1.2 acres); intermediate as 0.5 to 5 ha (1.2 to 12 acres); and large as >5 ha (>12 acres).

There are three rates or speeds of recovery: fast (represented by old field), slow recovery (represented by mature forests), and intermediate (represented by young forest and riparian habitat). Grass and herbaceous-dominated habitats represent an early stage in ecological succession. If this early stage were disturbed, natural processes would restore a similar mix of grasses and herbaceous plants in 1 to 5 years. Bushes, small trees, and a few larger trees dominate habitats of intermediate ages. Recovery from their disturbance would require 5 to 30 years. Mature forests and some wetlands represent the result of 30 to 70+ years of ecological succession. If destroyed, habitat of this age would require 30 to 70+ years to recover. In general, the smaller the vegetation, the younger the habitat, and the shorter the recovery period; the larger the vegetation, the older the habitat, and the longer the recovery period. Ecotoxicological risk from mercury is not expected to change over time. These three rates of recovery are used in the method to classify areas on the EFPC floodplain for this one of the three technical variables.

There are three ecotoxicity conditions for the soil ingestion pathway: less than the remediation goal option, which is usually derived from the lowest observed effect level (LOEL); greater than the reproductive effects level (REL); and between the LOEL and REL. We define the REL as the concentration in soil that would result in an exposure through the food chain equal to the exposure determined in laboratory studies to cause a 50% decrease in reproduction. The dose-response relationship ranges from small dose and no effect below the no observed effect level (NOEL), meaning there is no measurable effect, to large dose and mortality above the REL. These two relationships provide the lower and upper boundaries; every dose-response relationship between the NOEL and the REL is defined as intermediate. These cutoff points are used in the method to classify toxicity.

Once data are organized, we use them to answer three key questions: (1) what is the size of the affected area? (2) what is the habitat type and the recovery time of that habitat? and (3) what are the soil concentration of mercury and the expected toxicological responses associated with that concentration (i.e., soil exposure). There are 27 different combinations of answers to these 3 questions. Every patch of habitat in EFPC can be listed by answering the above three questions.

There are eight guidelines to facilitate the evaluation of the relative impacts of ecotoxicological and ecoremedial risks. Each contaminated habitat can be evaluated according to these guidelines and classified as to whether ecotoxicological risk or ecoremedial risk predominates. However, site-specific factors must also be taken into account when the final balancing is done. For example, critical habitats for threatened and endangered species are protected by law. Remediation goal options and RELs can be derived separately for threatened and endangered species and used in the evaluation of relative risks. The results of such evaluations could take precedence over evaluations for other biota.

1. If the maximum concentration in a single contiguous habitat is below the remediation goal option, no action is required, because there is no ecotoxicological risk. Areas where concentrations are above the remediation goal option should be delineated and evaluated separately.

2. If the mean contaminant concentration in a contiguous area of old field or grassland is above a concentration (REL) that would cause a 50% decrease in reproduction, ecotoxicological risk predominates, no matter what size the area, because of the severity of the ecotoxicological response.

3. If the maximum concentration in a contiguous area of old field or grassland 0.5 ha (1.2 acres) or greater is above the remediation goal option, ecotoxicological risk predominates because of the rapid recovery time of those habitats.

4. If the contiguous contaminated area is $\leq$0.5 ha (1.2 acres), ecoremedial risk predominates, because ecotoxicological risk is limited to approximately the home range of one intermediate predator and can have little effect on populations. This guideline is subordinate to guideline 2.

5. If the contiguous contaminated area of young forest or riparian habitat is $>$5 ha (1.2 acres), ecotoxicological risk predominates because the contaminated area is $>$20% of the range of a top predator.

6. If the mean contaminant concentration in a contiguous area of any habitat $>$0.5 ha (1.2 acres) is above the REL, ecotoxicological risk predominates because the contaminants have a severe impact on more than the home range of more than one mid-level predator.

7. If the mean contaminant concentration in a contiguous area of mature forest or wooded wetland is above the REL, ecoremedial risk predominates because the habitat destroyed by remediation would take more than 30 years to replace.

8. If the contiguous contaminated area of young forest or riparian habitat is $>$0.5 ha (1.2 acres) but $\leq$5 ha (1.2 acres), other factors such as cost or proximity of other remedial activities should be taken into consideration.

The application of these guidelines is illustrated in Table 1 and in the following examples.

When a contaminated habitat is $<$0.5 ha (1.2 acres) in size, takes $<$5 years to recover, and has small toxicological risk, ecoremedial risk predominates. This is the case with 16.5% of the floodplain area contaminated above 200 mg/kg. The EFPC floodplain contains many small old fields on which only a few individual organisms live who have no-expected to low-expected body burdens of mercury.

When a contaminated habitat is $>$5 ha (1.2 acres) in size, takes 30 to 70+ years to recover, and has intermediate ecotoxicological risk, there is a need to remediate from the ecotoxicological viewpoint. However, the permanence of the extensive forest habitat is considered more important than the ongoing risk from mercury and, therefore, ecoremedial risk predominates.

Intermediate situations in terms of size, years to recover, and toxicity can also be classified by the method. Numerous intermediate conditions exist, and each can be classified as to the predominant risk. For example, in intermediate-sized habitats, of which there are few in the floodplain, ecotoxicological risk predominates if they are rapid recoverers (e.g., old fields that exhibit soil concentrations above the REL). Ecoremedial risk predominates when they are slow

Table 1. Type of risk predominating in contaminated habitats

Contaminant concentration[a]	Old field or grassland with area (recovery 1 to 5 years) ≤0.5 ha		0.5 to 5 ha		>5 ha	
< RGO	No Action	(1)[b]	No Action	(1)	No Action	(1)
RGO to REL	Ecoremedial	(4)	Ecotoxicological	(3)	Ecotoxicological	(3)
> REL	Ecotoxicological	(2)	Ecotoxicological	(2)	Ecotoxicological	(2)
Contaminant concentration	**Young forest or riparian zone with area (recovery 5 to 30 years)** ≤0.5 ha		0.5 to 5 ha		>5 ha	
< RGO	No Action	(1)	No Action	(1)	No Action	(1)
RGO to REL	Ecoremedial	(4)	BALANCE[c]	(8)	Ecotoxicological	(5)
> REL	Ecoremedial	(4)	Ecotoxicological	(6)	Ecotoxicological	(5)
Contaminant concentration	**Mature forest or wooded wetland with area (recovery >30 years)** ≤0.5 ha		0.5 to 5 ha		>5 ha	
< RGO	No Action	(1)	No Action	(1)	No Action	(1)
RGO to REL	Ecoremedial	(4)	Ecoremedial	(7)	Ecoremedial	(7)
> REL	Ecoremedial	(4)	Ecotoxicological	(6)	Ecotoxicological	(5)

[a] Maximum concentration compared to RGO, mean concentration compared to REL.
[b] Number in parentheses refers to the first evaluation guideline to apply.
[c] Requires further consideration of location-specific factors, as described in the text.

recoverers (e.g., mature forests that exhibit soil concentrations between the remediation goal option and the REL). Some cells in the intermediate part of the matrix require additional considerations: geographical proximity to other remedial sites and size of the patches of habitat and their effect on populations. All of these combinations are shown on Table 1.

In summary, a method that classifies ecotoxicological risk and ecoremedial risk was developed. The method uses three technical variables that are used in combination to systematically evaluate which form of risk is greater. The technical variables are: (1) size of the contaminated area or habitat; (2) type of habitat and time in years to recover to the present state once disturbed (i.e., remediated); and (3) degree of ecotoxicity associated with food chain exposure from soil concentration of mercury. Each variable has three categories ranging from small to large, slow to fast, and low to high. In the 27 combinations of the 3 × 3 × 3 matrix, each area above the soil remediation goal option is classified according to its dominate type of risk, whether it be ecotoxicological risk or ecoremedial risk. Large, slow recovery, and highly

toxic areas differ from small, fast recovery, and low toxicity areas. Most of the contaminated areas in the EFPC floodplain fit the condition in which ecoremedial risk exceeds ecotoxicological risk.

G.2 CALCULATION OF THE SEDIMENT REMEDIATION GOAL OPTIONS USING RESULTS FROM THE EFPC FOOD WEB STUDY

The purpose of this summary is to describe the process by which sediment remediation goal options were calculated using the results of the food web study in the EFPC Remedial Investigation (RI) addendum (DOE 1994b). The food web study was performed by scientists at the Oak Ridge National Laboratory (ORNL) Environmental Sciences Division to support the EFPC RI, and was described in the RI addendum (DOE 1994b). The food web study generated site-specific data on concentrations of total and methyl mercury in surface water, periphyton, stoneroller minnows (stonerollers), and striped shiner minnows. A bioconcentration factor for methyl mercury in fathead minnows (*Pimephales promelas*) was obtained from the literature (Olson 1975). Site-specific K_d values for methyl mercury in EFPC sediment were available in the RI report (DOE 1994a), as was the empirical relationship between total and methyl mercury concentrations in the sediments. A benchmark methyl mercury concentration of 50 ng/g in fish (which is the limit for protection of piscivorous birds) was obtained in the literature (Eisler 1987). All of these data are summarized in Table 2. These data were used to calculate remediation goal options by using several of the same equations that were also used to calculate ecological sediment remediation goal options in the RI addendum (see Sect. 3.2.3.2, DOE 1994b).

The food web relationship that was assumed for the calculation of the remediation goal options are presented in Figs. 2.43 and 2.44 of the main text of this FS. The food web depicts site-specific data using stonerollers from East Fork kilometer (EFK) 24.4. Calculation of the remediation goal options entailed a five-step process, using the site-specific and literature data.

The five steps are as follows:

1. Calculate the methyl mercury body burden in fish that is attributable to uptake from water using literature bioconcentration factor for methyl mercury and site-specific concentration of methyl mercury in water.

2. Calculate the percentage of methyl mercury in whole body that is attributable to uptake from water by dividing the concentration calculated in step 1 by total methyl mercury body burden.

3. Calculate concentration of methyl mercury in water that does not result in fish body burden of methyl mercury exceeding the benchmark for protection of piscivorous birds using site-specific water concentrations and body burdens, as well as the benchmark concentration.

4. Calculate the concentration of methyl mercury in sediment that would yield the water concentration in step 3, using site-specific K_d.

Table 2. EFPC food web results

Site	Methyl mercury concentration	Bioconcentration factor	Bioaccumulation factor	Protective sediment concentration total Hg (mg/kg) (RGO)
		Water		
EFK 24.4	0.1035 ng/L	NA	NA	NA
EFK 18.0	0.195 ng/L	NA	NA	NA
		Periphyton		
EFK 24.4	3.56 ng/g	3.4×10^{4a}	NA	NA
EFK 18.0	2.78 ng/g	1.4×10^{4a}	NA	NA
		Stoneroller		
EFK 24.4	49.43 ng/g	8.17×10^{4a}	11.5	325
EFK 18.0	90.90 ng/g	8.17×10^{4a}	27.5	331
		Striped shiner		
EFK 24.4	232.0 ng/g	8.17×10^{4a}	62.6	68

[a] Olson 1975.
Site-specific K_d = 885,000 L/kg (DOE 1994a)
NA = Not applicable.
RGO = Remediation goal option.

5. Calculate the total mercury concentration in sediment that corresponds to the methyl mercury concentration calculated in step 4, using site-specific data on relationship between total and methyl mercury in sediments.

Application of the above five steps in determining the remediation goal options using the 50 ng methyl mercury/g benchmark in stonerollers and striped shiners is presented below.

Methodology for calculating mercury sediment remediation goal option using 50 ng/g methyl mercury benchmark in stonerollers

- Stoneroller benchmark: 50 ng/g
- Mean $[\text{methyl mercury}]_{\text{water}}$: **EFK 24.4** 0.1035 ng/L; **EFK 18.0** 0.195 ng/L

- Mean [methyl mercury]$_{stoneroller}$: **EFK 24.4** 49.43 ng/g; **EFK 18.0** 90.90 ng/g

Step 1: If the bioconcentration factor for stoneroller is 81,700, then using site-specific water concentration, calculate the methyl mercury body burden attributable to uptake from water. .

EFK 24.4

$$81700 = \frac{X \text{ ng/g}}{0.1035 \times 10^{-3} \text{ ng/mL}}$$

$X = 8.4$ ng/g

EFK 18.0

$$81700 = \frac{X \text{ ng/g}}{0.195 \times 10^{-3} \text{ ng/mL}}$$

$X = 15.93$ ng/g

Step 2: Calculate the percentage of methyl mercury body burden that is attributable to uptake from water.

EFK 24.4

$$\frac{8.4 \text{ ng/g from water}}{49.4 \text{ ng/g total methyl mercury}} \times 100 = 17.0\ \%$$

EFK 18.0

$$\frac{15.93 \text{ ng/g from water}}{90.90 \text{ ng/g total methyl mercury}} \times 100 = 17.5\ \%$$

Step 3: Calculate the acceptable concentration of methyl mercury in water that is protective of stonerollers.

EFK 24.4

$(0.1035 \times 10^{-3}$ ng/mL) / 49.4 ng/g stoneroller = $(X_1 \times 10^{-3}$ ng/mL) / 50 ng/g

$X_1 = 0.105$ ng methyl mercury/L at EFK 24.4

EFK 18.0

$(0.195 \times 10^{-3}$ ng/mL) / 90.90 ng/g stoneroller = $(X_2 \times 10^{-3}$ ng/mL) / 50 ng/g

$X_2 = 0.107$ ng methyl mercury/L at EFK 18.0

Step 4: Calculate concentration of methyl mercury in sediment from the concentration of methyl mercury in water.

Based on U.S. Department of Energy (DOE) 1994a where K_d = 885000 L/kg

EFK 24.4

$$\frac{Y_1 \text{ ng methyl mercury/kg}}{K_d} = 0.105 \text{ ng/L}$$

Y_1 = 92.92 μg methyl mercury/kg in sediment

EFK 18.0

$$\frac{Y_2 \text{ ng methyl mercury/kg}}{K_d} = 0.107 \text{ ng/L}$$

Y_2 = 94.69 μg methyl mercury/kg in sediment

Step 5: Calculate the total mercury concentration in the sediment.

Based on DOE 1994a, site-specific relationship of total mercury and methyl mercury is:
Total mercury = methyl mercury × 3500

EFK 24.4

$[\text{Total mercury}]_{\text{sediment}}$ = (92.92 μg methyl mercury/kg) × 3500
$[\text{Total mercury}]_{\text{sediment}}$ = 325 mg/kg

EFK 18.0

$[\text{Total mercury}]_{\text{sediment}}$ = (94.69 μg methyl mercury/kg) × 3500
$[\text{Total mercury}]_{\text{sediment}}$ = 331 mg/kg

Methodology for calculating mercury sediment remediation goal option using 50 ng/g methyl mercury benchmark in striped shiners

- Mean $[\text{methyl mercury}]_{\text{water}}$: 0.1035 ng/L
- Mean $[\text{methyl mercury}]_{\text{shiner}}$: 232.0 ng/g
- Striped shiner benchmark: 50 ng/g

Step 1: If the bioconcentration factor for shiners is 81,700, then using site-specific water concentration, calculate the methyl mercury body burden attributable to uptake from water.

$$81700 = \frac{X \text{ ng/g}}{0.1035 * (10^{-3} \text{ ng/mL})}$$

$X = 8.4$ ng/g

Step 2: Calculate the percentage of methyl mercury body burden that is attributable to uptake from water.

$$\frac{8.4 \text{ ng/g from water}}{232.0 \text{ ng total methyl mercury/g}} * (100) = 3.62\%$$

Step 3: Calculate the acceptable concentration of methyl mercury in water that is protective of shiners.

$(0.1035 * 10^{-3}$ ng/mL)/ 232 ng/g shiners = $(X * 10^{-3}$ng/mL)/ 50 ng/g

$X = 0.022$ ng methyl mercury/L

Step 4: Calculate concentration of methyl mercury in sediment from the concentration of methyl mercury in water.

Based on DOE 1994a where $K_d = 885000$ L/kg

$$\frac{Y \text{ ng methyl mercury/kg}}{K_d} = 0.022 \text{ ng/L}$$

$Y = 19.47$ μg methyl mercury/kg

Step 5: Calculate the total mercury concentration in the sediment.

Based on DOE 1994a, site-specific relationship of total mercury and methyl mercury in sediment is:

Total mercury = methyl mercury * 3500

$[\text{Total mercury}]_{\text{sediment}} = (19.47 \ \mu\text{g methyl mercury/kg}) * 3500$

$[\text{Total mercury}]_{\text{sediment}} = 68.15$ mg/kg

UNCERTAINTIES

This section is not intended to provide a quantitative discussion of uncertainties associated with the above remediation goal options. However, several sources of uncertainty that could influence the outcome of the remediation goal option calculations are qualitatively discussed below.

- The literature value bioconcentration factor for methyl mercury in fish (Olson 1975) may not be accurate for the two fish species in this study, so the methyl mercury concentrations in the fish that was attributable to uptake from water may be over or underestimated.

- The water concentrations of methyl mercury reported in the food web study were single point in time grab samples, and may not accurately reflect the range of exposure concentrations that occur to the fish over their lifespan.

- Some fraction of the body burden of methyl mercury assumed to be attributable to uptake from food (i.e., the total minus the fraction attributable to uptake from water) might actually have been associated with unassimilated methyl mercury bound to food or sediment in the gut.

- The K_d that was used from the RI report (DOE 1994a) might not have been accurate for the sediment types that were present at EFK 24.4 and EFK 18.0, thereby overestimating or underestimating methyl mercury concentrations in the sediment.

- Likewise, the empirical relationship between total and methyl mercury in sediment reported in the RI report (DOE 1994a) might not have been accurate for the sediments in the food web study, and thus over or underestimated total mercury concentrations.

These uncertainties emphasize the importance of additional evaluation of risks from instream sediments once the source of mercury to EFPC surface water and floodplain soil has been remediated.

G.3 METHOD FOR EVALUATING RELATIVE HABITAT VALUES

One method for comparing the relative values of different areas of habitat uses the area of habitat available multiplied by a factor termed the "habitat suitability index" (HSI). Multiplying the area (acres) of habitat by the HSI yields the value termed habitat units (HU). The HU is then used to compare the relative values of different areas of habitat. Usually, the HSI is derived for selected indicator species using a peer-reviewed and accepted mathematical model that yields an HSI based on habitat-determined life requisites for that species. These requisites or conditions that are contained within a habitat are more readily measured than performing a survey or census of the actual population of an indicator species. For example, the model for deriving the HSI for the black-capped chickadee is based on the number of dead trees 10 to 25 cm (4 to 10 in.) in diameter per acre of habitat. This was determined to be a life requisite factor for black-capped chickadees based on their use of tree cavities for nesting. The number of dead trees in an area is a basic life requisite for that area to support a reproducing population of black-capped chickadees.

Surveys of small mammal populations were performed within the EFPC floodplain for use in examining potential contaminant effects on population levels. The results of the small mammal studies were expressed as relative abundance indices among the sampling locations. These indices have been used as an HSI value in computing HU values for the habitat susceptible to conversion or destruction during remediation within each segment of the operable unit (OU). The table below shows each sampling site and the segment of which it is representative, the relative abundance index for small mammal populations at each site, and a calculated HSI.

Site	Segment(s)	Relative abundance index	HSI[a]
1	1	5.25	4.73
2	1	1.88	1.69
3	3,4,5	1.91	1.72
4	8	3.44	3.10
5	9	4.19	3.77
6	9	0.37	0.33
Mill Branch	Reference	1.11	1.00

[a] HSI values based on setting reference value (Mill Branch) equal to 1.00.

The following table shows, by OU segment, the acres of habitat subject to destruction or conversion during remediation under sitewide alternatives (SWAs) 2 through 6, the HSI value for habitat within that segment, and the habitat units (HUs) resulting from multiplying the acres of habitat times the HSI. Where two sampling sites were located within a single OU segment, the HSI values are given as a range.

Segment	Acres of habitat ×	HSI =	HUs
1	4.9	1.69-4.73	8.28-23.18
3	0.7	1.72	1.20
4	5.7	1.72	9.80
5	1.0	1.72	1.72
8	0.7	3.10	2.17
9	0.8	0.33-3.77	0.26-3.02

Because of the narrow range of all HSI values, the area of habitat plays a larger role in determining the number of HUs than does the HSI value (i.e., the larger areas of habitat are of more value to wildlife than smaller areas).

REFERENCES

Austing, R.A. and J. K. Terres. 1964. *The World of the Red-Tailed Hawk*. J.B. Lippincott Company, Philadelphia.

Burt, W.H. and R.P. Grossenheider. 1976. *A Field Guide to the Mammals, North America North of Mexico*, 3rd ed., Houghton Mifflin Company, Boston.

Eisler, R. 1987. *Mercury Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*. Biological Report 85(1.10), U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Laurel, MD. April.

Johnsquard, P.A. 1988. *North American Owls*. Smithsonian Institution Press, Washington, D.C.

NIOSH (National Institute for Occupational Safety and Health). 1983. *Registry of Toxic Effects Chemical Substances*. U.S. Department of Health, Education, and Welfare.

Odum, E.P. 1983. *Basic Ecology*. Saunders College Publishing. Philadelphia, PA. pp. 613.

Peterson, R.T. and V.M. Peterson. 1980. *A Field Guide to the Birds*. Houghton Mifflin Company, Boston.

Suter, G.W. II, B.W. Cornaby, C.T. Hadden, R.N. Hull, M. Stack, and F.A. Zafran. 1995. *An Approach for Balancing Health and Ecological Risks at Hazardous Waste Sites*. Risk Analysis (in press).

This page intentionally left blank.

APPENDIX G

TABLES

This page intentionally left blank.

Table G.1. Habitat types occurring on the ORR

Habitat type	Description
Type 1	Includes open water, streams, and swampy areas.
Type 2	Old fields including highly disturbed areas such as roadsides, regularly mowed areas, and shrub and tree invaded fields.
Type 3	Loblolly pine (*Pinus taeda*) plantations and pine stands. These are hardwood forest types.
Type 4	The wettest forest type mainly occurring in floodplain areas.
Type 5	Occurs usually on north-facing slopes, lower slopes, coves, and other areas that are fairly moist.
Type 6	Occurs in relatively dry areas: upper slopes, ridges, south-facing slopes, rocky and thin-soiled areas.

Source: Johnson 1964, as presented in Kitchings and Mann 1976.

Table G.2. Reptiles and amphibians occurring in the various habitats on the ORR

Name	Genus	Species	Variety	Habitat type[a]					
				Type 1	Type 2	Type 3	Type 4	Type 5	Type 6
Northern cricket frog	*Acris*	*crepitans*	*crepitans*	X	X				
American Toad	*Bufo*	*americanus*	*americanus*		X		X	X	X
Fowler's Toad	*Bufo*	*woodhousei*	*fowleri*		X		X	X	X
Eastern narrow-mouthed toad	*Gastrophryne*	*carolinensis*	*carolinensis*		X		X	X	X
Spring peeper	*Hyla*	*crucifer*	*crucifer*	X	X				
Gray tree frog	*Hyla*	*versicolor*	*versicolor*					X	
Upland chorus frog	*Pseudacris*	*triseriata*		X	X				
Bullfrog	*Rana*	*catesbeiana*		X					
Bronze frog	*Rana*	*clamitans*		X					
Pickerel frog	*Rana*	*palustris*					X	X	X
Leopard frog	*Rana*	*pipiens*					X	X	X
Wood frog	*Rana*	*sylvatica*		X					
Eastern spadefoot	*Scaphiopus*	*holbrooki*	*holbrooki*	X	X				
Spotted salamander	*Ambystoma*	*maculatum*		X	X				
Hellbender	*Cryptobranchus*	*alleganiensis*		X					
Dusky salamander	*Desmognathus*	*fuscus*		X	X				
Red spotted newt	*Diemictylus*	*viridescens*	*viridescens*	X			X	X	X
Southern two-lined salamander	*Eurycea*	*bislineata*		X					
Three-lined salamander	*Eurycea*	*longicauda*		X	X		X	X	
Cave salamander	*Eurycea*	*lucifuga*		X	X				
Spring salamander	*Gyrinophilus*	*porphyriticus*		X			X	X	

Table G.2 (continued)

Name	Genus	Species	Variety	Habitat type[a]					
				Type 1	Type 2	Type 3	Type 4	Type 5	Type 6
Mudpuppy	*Necturus*	*maculosus*		X					
Red-backed salamander	*Plethodon*	*cinereus*		X			X	X	
Slimy salamander	*Plethodon*	*glutinosus*	*glutinosus*	X					
Northern red salamander	*Pseudotriton*	*ruber*	*ruber*	X	X				
Snapping turtle	*Chelydra*	*serpentina*	*serpentina*	X					
Eastern painted turtle	*Chrysemys*	*picta*		X					
Map turtle	*Graptemys*	*geographica*		X	X				
Ouachita map turtle	*Graptemys*	*pseudogeographi*	*ouachitensis*	X	X				
Slider	*Pseudemys*	*concinna*	*hieroglyphica*	X	X				
Yellow-bellied turtle	*Pseudemys*	*scripta*		X	X				
Striped-neck musk turtle	*Sternothaerus*	*minor*	*peltifer*	X	X				
Stinkpot	*Sternothaerus*	*odoratus*		X	X				
Eastern box turtle	*Terrapene*	*carolina*	*carolina*		X		X	X	X
Eastern spiny softshell turtle	*Trionyx*	*spinifer*	*spinifer*	X					
Northern copperhead	*Agkistrodon*	*contortrix*	*mokeson*			X	X	X	X
Green anole	*Anolis*	*carolinensis*			X				
Eastern worm snake	*Carphophis*	*amoenus*	*amoenus*		X		X	X	X
Scarlet snake	*Cemophora*	*coccinea*				X	X	X	X
Six-line racerunner	*Cnemidophorus*	*sexlineatus*			X	X	X	X	X
Northern black racer	*Coluber*	*constrictor*			X	X	X	X	X
Timber rattlesnake	*Crotalus*	*horridus*					X	X	X

Table G.2 (continued)

Name	Genus	Species	Variety	Habitat type[a]					
				Type 1	Type 2	Type 3	Type 4	Type 5	Type 6
Northern ringneck snake	*Diadophis*	*punctatus*	*edwardsi*				X	X	X
Corn snake	*Elaphe*	*guttata*	*guttata*		X	X			
Black rat snake	*Elaphe*	*obsoleta*			X	X	X	X	X
Five-lined skink	*Eumeces*	*fasciatus*			X	X	X	X	X
Broadhead skink	*Eumeces*	*laticeps*					X	X	X
Eastern hognose snake	*Heterodon*	*platyrhinos*			X	X			
Mole snake	*Lampropeltis*	*calligaster*	*rhombomaculata*		X	X			
Eastern milk snake	*Lampropeltis*	*doliata*	*triangulum*			X	X	X	X
Black king snake	*Lampropeltis*	*getulus*	*niger*		X	X			
Ground skink	*Lygosoma*	*laterale*			X	X	X	X	X
Queen snake	*Natrix*	*septemvittata*	*septemvittata*	X	X				
Northern water snake	*Natrix*	*sipedon*		X	X				
Rough green snake	*Opheodrys*	*aestivus*			X				
Slinder glass lizard	*Ophisaurus*	*attenuatus*			X				X
Fence lizard	*Sceloporus*	*undulatus*	*hyacinthinus*		X	X	X	X	X
Northern brown snake	*Storeria*	*dekayi*			X	X	X	X	X
Northern red-bellied snake	*Storeria*	*occipitomaculata*	*occipitomaculata*				X	X	X
Southeastern crowned snake	*Tantilla*	*coronata*		X	X		X	X	X
Eastern garter snake	*Thamnophis*	*sirtalis*	*sirtalis*	X	X		X	X	X

[a] See Table 2.4 for description of habitat types.

Source: Johnson 1964, as presented in Kitchings and Mann 1976.

Table G.3. Total number of birds counted by sample plot method at Sites 2 through 6 on EFPC and Mill Branch

Species	Sampling location						Total
	Site 2	Site 3	Site 4	Site 5	Site 6	Mill Branch	
Wood Duck *(Aix sponsa)*	0	0	0	0	1	0	1
Red-shouldered Hawk *(Buteo lineatus)*	1	0	0	0	0	0	1
Broad-winged Hawk *(Buteo platypterus)*	0	0	0	0	0	1	1
Killdeer *(Charadrius vociferus)*	1	0	0	0	0	0	1
Mourning Dove *(Zenaida macroura)*	0	0	0	0	0	2	2
Yellow-billed Cuckoo *(Coccyzus americanus)*	0	1	0	1	1	1	4
Chimney Swift *(Chaetura pelagica)*	0	0	1	1	0	0	2
Belted Kingfisher *(Ceryle alcyon)*	0	0	0	0	3	1	4
Red-bellied Woodpecker *(Melanerpes carolinus)*	9	0	7	0	3	7	26
Yellow-bellied Sapsucker *(Sphyrapicus varius)*	1	0	0	0	0	0	1
Downy Woodpecker *(Picoides pubescens)*	7	0	7	5	5	6	30
Hairy Woodpecker *(Picoides villosus)*	0	0	2	0	1	2	5
Northern Flicker *(Colaptes auratus)*	4	1	2	0	0	3	10
Pileated Woodpecker *(Drocopus pileatus)*	0	1	1	0	0	1	3
Eastern Wood Pewee *(Contopus virens)*	0	0	1	1	0	0	2
Eastern Phoebe *(Sayornis pheoebe)*	0	2	0	0	0	0	2
Blue Jay *(Cyanocitta cristata)*	16	23	6	6	4	5	60
American Crow *(Corvus branchyrhynchos)*	2	8	3	0	3	5	21
Carolina Chickadee *(Parus Carolinesis)*	15	20	26	8	5	10	84
Tufted Titmouse *(Parus bicolor)*	9	0	12	7	2	1	31
White-breasted Nuthatch *(Sitta carolinensis)*	0	0	2	0	0	1	3

Table G.3 (continued)

Species	Sampling location						Total
	Site 2	Site 3	Site 4	Site 5	Site 6	Mill Branch	
Carolina Wren *(Thryothorus ludovicianus)*	20	20	23	13	26	5	107
Ruby-crowned Kinglet *(Regulus calendula)*	0	0	0	0	1	0	1
American Robin *(Turdus migratorius)*	4	5	3	0	0	0	12
Northern Mockingbird *(Mimus polyglottos)*	0	0	1	0	0	0	1
Brown Thrasher *(Toxostoma rufum)*	0	0	0	1	4	0	5
European Starling *(Sturnus vulgaris)*	0	0	1	0	0	0	1
Tennessee Warbler *(Vermivora peregrina)*	0	1	0	0	0	0	1
Chestnut-sided Warbler *(Dendroica pensylvanica)*	1	0	0	0	0	0	1
Magnolia Warbler *(Dendroica magnolia)*	1	4	0	0	0	2	7
Yellow-rumped Warbler *(Dendroica coronata)*	0	0	0	1	2	0	3
Yellow-throated Warbler *(Dendroica dominica)*	0	1	0	0	0	0	1
Pine Warbler *(Dendroica pinus)*	2	0	0	6	0	1	9
Palm Warbler *(Dendroica palmarum)*	0	1	0	0	0	0	1
Bay-breasted Warbler *(Dendroica castanea)*	0	1	2	0	0	8	11
Black and White Warbler *(Mniotilta varia)*	0	0	1	0	0	1	2
American Redstart *(Setophaga ruticilla)*	0	1	0	0	0	0	1
Ovenbird *(Seirus acurocapillus)*	0	2	1	0	0	0	3
Common Yellowthroat *(Geothlypis trichas)*	0	2	0	0	0	0	2
Hooded Warbler *(Wilsonia citrina)*	0	0	0	0	1	0	1
Canada Warbler *(Wilsonia canadensis)*	0	0	0	1	0	0	1
Northern Cardinal *(Cardinalis cardinalis)*	9	7	25	4	13	0	58

Table G.3 (continued)

Species	Sampling location						Total
	Site 2	Site 3	Site 4	Site 5	Site 6	Mill Branch	
Rose-breasted Grosbeak *(Pheucticus ludovicianus)*	3	6	0	2	2	4	17
Rufus-sided Towhee *(Pipilo erythrophthalmus)*	0	0	5	0	1	0	6
Red-winged Blackbird *(Agelaius phoeniceus)*	0	6	0	0	0	0	6
TOTAL	105	113	132	57	78	67	552

Table G.4. Total number of birds counted by belt transect method at Site 1 at EFPC

Species	Total
Belted kingfisher	1
Downy woodpecker	5
Hairy woodpecker	1
Eastern phoebe	1
Blue jay	1
Carolina chickadee	9
Tufted titmouse	6
Carolina wren	9
Northern cardinal	5
Rose-breasted grosbeak	1
TOTAL	39

Table G.5. Bird species occurring in various habitat types on the EFPC floodplain[a,b]

Name	Scientific name	Status[c]	Habitat type			
			Aquatic	Forest	Fields	Built-up
Great blue heron	*Ardea herodias*	WR	X			
Cattle egret	*Bubulcus ibis*	T	X			
Green-backed heron	*Butorides striatus*	P	X			
Wood duck	*Aix sponsa*	P	X			
Black vulture	*Coragyps atratus*	P			X	X
Turkey vulture	*Cathartes aura*	P			X	X
Cooper's hawk	*Accipiter cooperii*	P		X		
Broad-winged hawk	*Buteo platypterus*	SR		X	X	
Red-tailed hawk	*Buteo jamaicensis*	P		X	X	
American kestrel	*Falco sparverius*	P			X	
Wild turkey	*Meleagris gallopavo*	P		X		
Northern bobwhite	*Colinus virginianus*	P			X	X
Killdeer	*Charadrius vociferus*	P			X	X
Spotted sandpiper	*Actitis macularia*	T	X			
Common snipe	*Gallinago gallinago*	WR			X	
American woodcock	*Scolopax minor*	P		X	X	
Rock dove	*Columba livia*	P				X
Mourning dove	*Zenaida macroura*	P			X	X
Yellow-billed cuckoo	*Coccyzus americanus*	SR		X		
Barn owl	*Tyto alba*	P		X		X

Table G.5 (continued)

Name	Scientific name	Status[c]	Habitat type			
			Aquatic	Forest	Fields	Built-up
Eastern screech owl	*Otus asio*	P		X		X
Great horned owl	*Bubo virginianus*	P		X		
Barred owl	*Strix varia*	P		X		
Common nighthawk	*Chordeiles minor*	SR				X
Chuck-will's-widow	*Caprimulgus carolinensis*	SR		X		
Whippoorwill	*Caprimulgus vociferus*	SR		X	X	
Chimney swift	*Chaetura pelagica*	SR				X
Ruby-throated hummingbird	*Archilochus colubris*	SR		X	X	X
Belted kingfisher	*Ceryle alcyon*	P	X			
Red-bellied woodpecker	*Melanerpes carolinus*	P		X		
Yellow-bellied sapsucker	*Sphyrapicus varius*	WR		X		
Downy woodpecker	*Picoides pubescens*	P		X		
Hairy woodpecker	*Picoides villosus*	P		X		
Northern flicker	*Colaptes auratus*	P		X		
Pileated woodpecker	*Dryocopus pileatus*	P		X		
Eastern wood-pewee	*Contopus virens*	SR		X		
Acadian flycatcher	*Empidonax virescens*	SR		X		
Least flycatcher	*Empidonax traillii*	T		X		
Eastern phoebe	*Sayornis phoebe*	SR		X		
Great crested flycatcher	*Myiarchus crinitus*	SR		X		

Table G.5 (continued)

Name	Scientific name	Status[c]	Habitat type			
			Aquatic	Forest	Fields	Built-up
Eastern kingbird	*Tyrannus tyrannus*	SR		X		
Horned lark	*Eremophila alpestris*	WR			X	
Barn swallow	*Hirundo rustica*	SR				X
Blue jay	*Cyanocitta cristata*	P		X		X
American crow	*Corvus brachyrhynchos*	P			X	X
Carolina chickadee	*Parus carolinensis*	P		X		X
Tufted titmouse	*Parus bicolor*	P		X		X
Red-breasted nuthatch	*Sitta canadensis*	WR		X		
White-breasted nuthatch	*Sitta caronlinensis*	P		X		
Brown creeper	*Certhia americana*	WR		X		
Carolina wren	*Thryothorus ludovicianus*	P		X		
Golden-crowned kinglet	*Regulus satrapa*	WR		X		
Ruby-crowned kinglet	*Regulus calendula*	WR		X		
Blue-gray gnatcatcher	*Polioptila caerulea*	SR		X		
Eastern bluebird	*Sialis sialis*	P		X		X
Gray-cheeked thrush	*Catharus minimus*	T		X		
Swainson's thrush	*Catharus ustulatus*	T		X		
Hermit thrush	*Catharus guttatus*	WR		X		
Wood thrush	*Hylocichla mustelina*	SR		X		
American robin	*Turdus migratorius*	P		X		X

Table G.5 (continued)

Name	Scientific name	Status[c]	Habitat type			
			Aquatic	Forest	Fields	Built-up
Gray catbird	*Dumetella carolinensis*	SR		X		
Northern mockingbird	*Mimus polyglottos*	P		X		X
Brown thrasher	*Toxostoma rufum*	SR		X		
Cedar waxwing	*Bombycilla cedrorum*	WR		X		
Loggerhead shrike	*Lanius ludovicianus*	WR		X	X	
European starling	*Sturnus vulgaris*	P		X	X	X
White-eyed vireo	*Vireo griseus*	SR		X		
Yellow-throated vireo	*Vireo flavifrons*	SR		X		
Red-eyed vireo	*Vireo olivaceus*	SR		X		
Blue-winged warbler	*Vermivora pinus*	T		X		
Golden-winged warbler	*Vermivora chrysoptera*	T		X		
Tennessee warbler	*Vermivora peregrina*	T		X		
Orange-crowned warbler	*Vermivora celata*	T		X		
Northern parula	*Parula americana*	SR		X		
Yellow warbler	*Dendroica petechia*	SR		X	X	X
Chestnut-sided warbler	*Dendroica pensylvanica*	T		X		
Magnolia warbler	*Dendroica magnolia*	T		X		
Cape may warbler	*Dendroica tigrina*	T		X		
Yellow-rumped warbler	*Dendroica coronata*	WR		X		
Black-throated green warbler	*Dendroica virens*	T		X		

Table G.5 (continued)

Name	Scientific name	Status[c]	Habitat type			
			Aquatic	Forest	Fields	Built-up
Blackburnian warbler	*Dendroica fusca*	T		X		
Yellow-throated warbler	*Dendroica dominica*	T		X		
Pine warbler	*Dendroica pinus*	T		X		
Prairie warbler	*Dendroica discolor*	SR		X	X	
Palm warbler	*Dendroica palmarum*	T		X	X	
Bay-breasted warbler	*Dendroica castanea*	T		X		
Cerulean warbler	*Dendroica cerulea*	T	X	X		
Black-and-white warbler	*Mniotilta varia*	SR		X		
Worm-eating warbler	*Helmitheros vermivorus*	SR		X		
Swainson's warbler	*Limnothlypis swainsonii*	T		X		
Ovenbird	*Seiurus aurocapillus*	T		X		
Kentucky warbler	*Oporornis formosus*	SR		X		
Connecticut warbler	*Oporornis agilis*	T		X		
Mourning warbler	*Oporornis philadelphia*	T		X		
Common yellowthroat	*Geothlypis trichas*	SR		X	X	
Hooded warbler	*Wilsonia citrina*	SR		X		
Yellow-breasted chat	*Icteria virens*	SR		X	X	
Summer tanager	*Piranga rubra*	T		X		
Scarlet tanager	*Piranga olivacea*	SR		X		
Northern cardinal	*Cardinalis cardinalis*	P		X	X	X

Table G.5 (continued)

Name	Scientific name	Status[c]	Habitat type			
			Aquatic	Forest	Fields	Built-up
Rose-breasted grosbeak	*Pheucticus ludovicianus*	T		X		
Blue grosbeak	*Guiraca caerulea*	T			X	X
Indigo bunting	*Passerina cyanea*	SR		X	X	X
Rufous-sided towhee	*Pipilo erythrophthalmus*	P		X	X	X
Field sparrow	*Spizella pusilla*	P			X	
Song sparrow	*Melospiza melodia*	P			X	X
White-throated sparrow	*Zonotrichia albicollis*	WR			X	
Dark-eyed junco	*Junco hyemalis*	WR		X	X	
Red-winged blackbird	*Agelaius phoeniceus*	P	X		X	X
Eastern meadowlark	*Sturnella magna*	P			X	X
Common grackle	*Quiscalus quiscula*	P		X	X	X
Brown-headed cowbird	*Molothrus ater*	P		X	X	X
Orchard oriole	*Icterus spurius*	SR		X	X	
Purple finch	*Carpodacus purpureus*	WR		X	X	X
American goldfinch	*Carduelis tristis*	P			X	X
Evening grosbeak	*Coccothraustes vespertinus*	T		X	X	X
House sparrow	*Passer domesticus*	P			X	X

[a] Based on Howell and Monroe 1971, and Alsop 1971. This list has been edited to contain only those species that could be expected to occur on a regular basis on the EFPC floodplain.

[b] Scientific names are based on the A.O.U. Checklist of North American Birds, sixth edition, 1983 as amended in the Thirty-Fifth Supplement (**The Auk**, July 1985), the Thirty-Sixth Supplement (**The Auk**, July 1986), and the Thirty-Seventh Supplement (**The Auk**, July 1989).

[c] P - Permanent Resident
WR - Winter Resident
SR - Summer Resident
T - Transient (occurring in only the spring and fall)

Table G.6. Riparian or water/land interfaces: SWAs 2 through 6 by segment, RU, and habitat type

Seg	Residential Bottomland hardwood		Residential Old field		Commercial Bottomland hardwood		DOE Bottomland hardwood		Other Bottomland hardwood		Other Old field		Total	
	converted	current	converted	current	converted	current	converted	current	converted	current	converted	current	converted	current
yd 1	577	1,931			3	17	466	1,316	8	737			1,054	4,808
2														
3	278	1,227			68	992							346	3,010
4	598	1,016	174	174					461	913	95	246	1,328	2,425
5	167	772							240	765			407	1,537
6														
7														
8	207	2,342											207	2,411
9	100	5,350					154	18,257					254	25,788
Total	1,927	15,622[a]	174	248[a]	71	1,271[a]	620	19,572[a]	709	8,315[a]	95	246[a]	3,596	58,287[a]
m 1	527	1,766			3	16	426	1,203	7	674			963	4,396
2														
3	254	1,122			62	907							316	2,752
4	547	929	159	159					422	835	87	225	1,215	2,217
5	153	706							219	700			372	1,405
6														
7														
8	189	2,141											189	2,205
9	91	4,892					141	16,694					232	23,581
Total	1,761	14,285[a]	159	227[a]	65	1,162[a]	567	17,897[a]	648	7,603[a]	87	225	3,287	53,298[a]

[a] The total current number is the total length for all segments within EFPC floodplain for the specified RU and habitat.

Table G.6 (continued)

SEGMENT 1		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
COM	BOTTOMLAND	15.8	52.0	3.1	10.1	12.8	41.9
	COMMERCIAL	327.7	1075.0	0.0	0.0	327.7	1075.0
	ALL	343.5	1127.0	3.1	10.1	340.5	1116.9
DOE	BOTTOMLAND	1203.0	3947.0	426.3	1398.6	776.7	2548.4
	ALL	1203.0	3947.0	426.3	1398.6	776.7	2548.4
OTHER	BOTTOMLAND	673.9	2211.0	7.4	24.2	666.5	2186.8
	COMMERCIAL	1.5	5.0	0.0	0.0	1.5	5.0
	FILL	150.6	494.0	0.0	0.0	150.6	494.0
	GRASS	92.0	302.0	0.0	0.0	92.0	302.0
	ALL	918.0	3012.0	7.4	24.2	910.6	2987.8
RES	BOTTOMLAND	1766.0	5794.0	527.3	1730.0	1238.7	4064.0
	FILL	6.4	21.0	0.0	0.0	6.4	21.0
	ALL	1772.4	5815.0	527.3	1730.0	1245.1	4085.0
UNDEF	BOTTOMLAND	136.2	447.0	0.0	0.0	136.2	447.0
	FILL	18.9	62.0	0.0	0.0	18.9	62.0
	GRASS	4.6	15.0	0.0	0.0	4.6	15.0
	ALL	159.7	524.0	0.0	0.0	159.7	524.0
ALL	BOTTOMLAND	3794.9	12451.0	964.1	3162.9	2831.0	9288.1
	COMMERCIAL	329.2	1080.0	0.0	0.0	329.2	1080.0
	FILL	175.9	577.0	0.0	0.0	175.9	577.0
	GRASS	96.6	317.0	0.0	0.0	96.6	317.0
	ALL	4396.6	14425.0	964.1	3162.9	3432.7	11262.1

Notes: >180 ppm in Agricultural and Residential RUs
>200 ppm in Other, DOE and Commercial RUs
Created by program fslinsum.pgm on 21Jul94 by J Chason

Table G.6 (continued)

SEGMENT 2		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
COM	BOTTOMLAND	239.3	785.0	0.0	0.0	239.3	785.0
	COMMERCIAL	1204.3	3951.0	0.0	0.0	1204.3	3951.0
	GRASS	15.8	52.0	0.0	0.0	15.8	52.0
	ALL	1459.4	4788.0	0.0	0.0	1459.4	4788.0
OTHER	BOTTOMLAND	713.5	2341.0	0.0	0.0	713.5	2341.0
	GRASS	277.7	911.0	0.0	0.0	277.7	911.0
	ALL	991.2	3252.0	0.0	0.0	991.2	3252.0
RES	BOTTOMLAND	923.5	3030.0	0.0	0.0	923.5	3030.0
	COMMERCIAL	28.0	92.0	0.0	0.0	28.0	92.0
	GRASS	812.6	2666.0	0.0	0.0	812.6	2666.0
	ALL	1764.1	5788.0	0.0	0.0	1764.1	5788.0
UNDEF	BOTTOMLAND	58.2	191.0	0.0	0.0	58.2	191.0
	COMMERCIAL	55.8	183.0	0.0	0.0	55.8	183.0
	GRASS	23.8	78.0	0.0	0.0	23.8	78.0
	ALL	137.8	452.0	0.0	0.0	137.8	452.0
ALL	BOTTOMLAND	1934.5	6347.0	0.0	0.0	1934.5	6347.0
	COMMERCIAL	1288.1	4226.0	0.0	0.0	1288.1	4226.0
	GRASS	1129.9	3707.0	0.0	0.0	1129.9	3707.0
	ALL	4352.5	14280.0	0.0	0.0	4352.5	14280.0

Table G.6 (continued)

SEGMENT 3		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
COM	BOTTOMLAND	907.4	2977.0	62.2	204.2	845.2	2772.9
	COMMERCIAL	40.2	132.0	0.0	0.0	40.2	132.0
	GRASS	75.6	248.0	0.0	0.0	75.6	248.0
	OLD FIELD	139.6	458.0	0.0	0.0	139.6	458.0
	ALL	1162.8	3815.0	62.2	204.2	1100.6	3610.9
OTHER	BOTTOMLAND	109.4	359.0	0.0	0.0	109.4	359.0
	ALL	109.4	359.0	0.0	0.0	109.4	359.0
RES	BOTTOMLAND	1121.7	3680.0	254.5	834.9	867.2	2845.2
	OLD FIELD	44.5	146.0	0.0	0.0	44.5	146.0
	ALL	1166.2	3826.0	254.5	834.9	911.7	2991.2
AGRI	BOTTOMLAND	120.7	396.0	0.0	0.0	120.7	396.0
	ALL	120.7	396.0	0.0	0.0	120.7	396.0
UNDEF	BOTTOMLAND	180.7	593.0	0.0	0.0	180.7	593.0
	GRASS	12.8	42.0	0.0	0.0	12.8	42.0
	ALL	193.5	635.0	0.0	0.0	193.5	635.0
ALL	BOTTOMLAND	2439.9	8005.0	316.7	1039.1	2123.2	6966.1
	COMMERCIAL	40.2	132.0	0.0	0.0	40.2	132.0
	GRASS	88.4	290.0	0.0	0.0	88.4	290.0
	OLD FIELD	184.1	604.0	0.0	0.0	184.1	604.0
	ALL	2752.6	9031.0	316.7	1039.1	2435.9	7992.1

Table G.6 (continued)

SEGMENT 4		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
OTHER	BOTTOMLAND	835.2	2740.0	421.6	1383.0	413.6	1357.0
	GRASS	57.6	189.0	0.0	0.0	57.6	189.0
	OLD FIELD	224.9	738.0	86.6	284.2	138.3	453.8
	ALL	1117.7	3667.0	508.2	1667.2	609.5	1999.8
RES	BOTTOMLAND	929.3	3049.0	546.6	1793.3	382.7	1255.7
	OLD FIELD	159.0	521.6	159.0	521.6	0.0	0.0
	ALL	1088.3	3570.6	705.6	2314.9	382.7	1255.7
UNDEF	BOTTOMLAND	11.0	36.0	0.0	0.0	11.0	36.0
	ALL	11.0	36.0	0.0	0.0	11.0	36.0
ALL	BOTTOMLAND	1775.5	5825.0	968.2	3176.3	807.3	2648.7
	GRASS	57.6	189.0	0.0	0.0	57.6	189.0
	OLD FIELD	383.9	1259.6	245.6	805.8	138.3	453.8
	ALL	2217.0	7273.6	1213.8	3982.1	1003.2	3291.5

Table G.6 (continued)

SEGMENT 5		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
OTHER	BOTTOMLAND	699.8	2296.0	219.6	720.5	480.2	1575.5
	ALL	699.8	2296.0	219.6	720.5	480.2	1575.5
RES	BOTTOMLAND	705.9	2316.0	152.4	500.1	553.5	1816.0
	ALL	705.9	2316.0	152.4	500.1	553.5	1816.0
ALL	BOTTOMLAND	1405.7	4612.0	372.0	1220.6	1033.7	3391.5
	ALL	1405.7	4612.0	372.0	1220.6	1033.7	3391.5

SEGMENT 6		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
OTHER	BOTTOMLAND	20.1	66.0	0.0	0.0	20.1	66.0
	ALL	20.1	66.0	0.0	0.0	20.1	66.0
RES	BOTTOMLAND	1791.3	5877.0	0.0	0.0	1791.3	5877.0
	OLD FIELD	22.9	75.0	0.0	0.0	22.9	75.0
	PASTURE	73.5	241.0	0.0	0.0	73.5	241.0
	ALL	1887.7	6193.0	0.0	0.0	1887.7	6193.0
AGRI	BOTTOMLAND	8.8	29.0	0.0	0.0	8.8	29.0
	PASTURE	14.6	48.0	0.0	0.0	14.6	48.0
	UPLAND	14.6	48.0	0.0	0.0	14.6	48.0
	ALL	38.0	125.0	0.0	0.0	38.0	125.0
UNDEF	BOTTOMLAND	71.6	235.0	0.0	0.0	71.6	235.0
	PASTURE	1.2	4.0	0.0	0.0	1.2	4.0
	ALL	72.8	239.0	0.0	0.0	72.8	239.0
ALL	BOTTOMLAND	1891.8	6207.0	0.0	0.0	1891.8	6207.0
	OLD FIELD	22.9	75.0	0.0	0.0	22.9	75.0
	PASTURE	89.3	293.0	0.0	0.0	89.3	293.0
	UPLAND	14.6	48.0	0.0	0.0	14.6	48.0
	ALL	2018.6	6623.0	0.0	0.0	2018.6	6623.0

Table G.6 (continued)

SEGMENT 7		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
OTHER	BOTTOMLAND	4551.3	14932.0	0.0	0.0	4551.3	14932.0
	ALL	4551.3	14932.0	0.0	0.0	4551.3	14932.0
RES	BOTTOMLAND	13.4	44.0	0.0	0.0	13.4	44.0
	ALL	13.4	44.0	0.0	0.0	13.4	44.0
AGRI	BOTTOMLAND	3952.3	12967.0	0.0	0.0	3952.3	12967.0
	OLD FIELD	229.5	753.0	0.0	0.0	229.5	753.0
	PASTURE	1527.4	5011.0	0.0	0.0	1527.4	5011.0
	ALL	5709.2	18731.0	0.0	0.0	5709.2	18731.0
UNDEF	BOTTOMLAND	90.5	297.0	0.0	0.0	90.5	297.0
	UPLAND	4.3	14.0	0.0	0.0	4.3	14.0
	ALL	94.8	311.0	0.0	0.0	94.8	311.0
ALL	BOTTOMLAND	8607.5	28240.0	0.0	0.0	8607.5	28240.0
	OLD FIELD	229.5	753.0	0.0	0.0	229.5	753.0
	PASTURE	1527.4	5011.0	0.0	0.0	1527.4	5011.0
	UPLAND	4.3	14.0	0.0	0.0	4.3	14.0
	ALL	10368.7	34018.0	0.0	0.0	10368.7	34018.0

Table G.6 (continued)

SEGMENT 8		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
RES	BOTTOMLAND	2141.2	7025.0	188.9	619.8	1952.3	6405.2
	ALL	2141.2	7025.0	188.9	619.8	1952.3	6405.2
UNDEF	BOTTOMLAND	63.4	208.0	0.0	0.0	63.4	208.0
	ALL	63.4	208.0	0.0	0.0	63.4	208.0
ALL	BOTTOMLAND	2204.6	7233.0	188.9	619.8	2015.7	6613.2
	ALL	2204.6	7233.0	188.9	619.8	2015.7	6613.2

SEGMENT 9		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
DOE	BOTTOMLAND	16693.9	54770.0	141.0	462.6	16552.9	54307.4
	HARDWOOD	603.8	1981.0	0.0	0.0	603.8	1981.0
	TRANSPORTA-TION	1.5	5.0	0.0	0.0	1.5	5.0
	UPLAND	967.1	3173.0	0.0	0.0	967.1	3173.0
	ALL	18266.3	59929.0	141.0	462.6	18125.3	59466.4
RES	BOTTOMLAND	4892.3	16051.0	91.8	301.2	4800.5	15749.8
	PASTURE	57.0	187.0	0.0	0.0	57.0	187.0
	RIGHT OF WAY	56.4	185.0	0.0	0.0	56.4	185.0
	TRANSPORTA-TION	2.7	9.0	0.0	0.0	2.7	9.0
	ALL	5008.4	16432.0	91.8	301.2	4916.6	16130.8
UNDEF	BOTTOMLAND	175.3	575.0	0.0	0.0	175.3	575.0
	HARDWOOD	73.8	242.0	0.0	0.0	73.8	242.0
	TRANSPORTA-TION	8.2	27.0	0.0	0.0	8.2	27.0
	UPLAND	48.5	159.0	0.0	0.0	48.5	159.0
	ALL	305.8	1003.0	0.0	0.0	305.8	1003.0
ALL	BOTTOMLAND	21761.5	71396.0	232.8	763.8	21528.7	70632.2

Table G.6 (continued)

SEGMENT 9 (CONTINUED)		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
ALL	HARDWOOD	677.6	2223.0	0.0	0.0	677.6	2223.0
	PASTURE	57.0	187.0	0.0	0.0	57.0	187.0
	RIGHT OF WAY	56.4	185.0	0.0	0.0	56.4	185.0
	TRANSPORTA-TION	12.4	41.0	0.0	0.0	12.4	41.0
	UPLAND	1015.6	3332.0	0.0	0.0	1015.6	3332.0
	ALL	23580.5	77364.0	232.8	763.8	23347.7	76600.2

ALL		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
COM	BOTTOMLAND	1162.5	3814.0	65.3	214.3	1097.3	3599.8
	COMMERCIAL	1572.2	5158.0	0.0	0.0	1572.2	5158.0
	GRASS	91.4	300.0	0.0	0.0	91.4	300.0
	OLD FIELD	139.6	458.0	0.0	0.0	139.6	458.0
	ALL	2965.7	9730.0	65.3	214.3	2900.5	9515.8
DOE	BOTTOMLAND	17896.9	58717.0	567.3	1861.2	17329.6	56855.8
	HARDWOOD	603.8	1981.0	0.0	0.0	603.8	1981.0
	TRANSPORTA-TION	1.5	5.0	0.0	0.0	1.5	5.0
	UPLAND	967.1	3173.0	0.0	0.0	967.1	3173.0
	ALL	19469.3	63876.0	567.3	1861.2	18902.0	62014.8
OTHER	BOTTOMLAND	7603.2	24945.0	648.6	2127.7	6954.6	22817.3
	COMMERCIAL	1.5	5.0	0.0	0.0	1.5	5.0
	FILL	150.6	494.0	0.0	0.0	150.6	494.0
	GRASS	427.3	1402.0	0.0	0.0	427.3	1402.0
	OLD FIELD	224.9	738.0	86.6	284.2	138.3	453.8
	ALL	8407.5	27584.0	735.2	2411.9	7672.3	25172.1
RES	BOTTOMLAND	14284.6	46866.0	1761.5	5779.3	12523.1	41086.9

Table G.6 (continued)

ALL (CONTINUED)		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
RES	COMMERCIAL	28.0	92.0	0.0	0.0	28.0	92.0
	FILL	6.4	21.0	0.0	0.0	6.4	21.0
	GRASS	812.6	2666.0	0.0	0.0	812.6	2666.0
	OLD FIELD	226.4	742.6	159.0	521.6	67.4	221.0
	PASTURE	130.5	428.0	0.0	0.0	130.5	428.0
	RIGHT OF WAY	56.4	185.0	0.0	0.0	56.4	185.0
	TRANSPORTATION	2.7	9.0	0.0	0.0	2.7	9.0
	ALL	15547.6	51009.6	1920.5	6300.9	13627.1	44708.9
AGRI	BOTTOMLAND	4081.8	13392.0	0.0	0.0	4081.8	13392.0
	OLD FIELD	229.5	753.0	0.0	0.0	229.5	753.0
	PASTURE	1542.0	5059.0	0.0	0.0	1542.0	5059.0
	UPLAND	14.6	48.0	0.0	0.0	14.6	48.0
	ALL	5867.9	19252.0	0.0	0.0	5867.9	19252.0
UNDEF	BOTTOMLAND	786.9	2582.0	0.0	0.0	786.9	2582.0
	COMMERCIAL	55.8	183.0	0.0	0.0	55.8	183.0
	FILL	18.9	62.0	0.0	0.0	18.9	62.0
	GRASS	41.2	135.0	0.0	0.0	41.2	135.0
	HARDWOOD	73.8	242.0	0.0	0.0	73.8	242.0
	PASTURE	1.2	4.0	0.0	0.0	1.2	4.0
	TRANSPORTATION	8.2	27.0	0.0	0.0	8.2	27.0
	UPLAND	52.8	173.0	0.0	0.0	52.8	173.0
	ALL	1038.8	3408.0	0.0	0.0	1038.8	3408.0
ALL	BOTTOMLAND	45815.9	150316.0	5042.4	9982.5	42773.4	140333.8
	COMMERCIAL	1657.5	5438.0	0.0	0.0	1657.5	5438.0
	FILL	175.9	577.0	0.0	0.0	175.9	577.0
	GRASS	1372.5	4503.0	0.0	0.0	1372.5	4503.0
	HARDWOOD	677.6	2223.0	0.0	0.0	677.6	2223.0
	OLD FIELD	820.4	2691.6	245.6	805.8	574.9	1885.8
	PASTURE	1673.7	5491.0	0.0	0.0	1673.7	5491.0
	RIGHT OF WAY	56.4	185.0	0.0	0.0	56.4	185.0
	TRANSPORTATION	12.4	41.0	0.0	0.0	12.4	41.0
	UPLAND	1034.5	3394.0	0.0	0.0	1034.5	3394.0
	ALL	53296.8	174859.6	3288.3	10788.3	50008.7	164071.6

Table G.7. Riparian or water/land interfaces: SWA 7 by segment, RU, and habitat type

Segment	Residential Bottomland hardwood				Residential Old field				Total			
	converted		current		converted		current		converted		current	
	m	yd	m	yd	m	yd	m	yd	m	yd	m	yd
1	31	34	632	691					31	34	4,428	4,843
2												
3	254	278	1,120	1,225					254	278	2,753	3,011
4	547	598	671	734	159	174	159	174	706	772	2,231	2,440
5	153	167	712	779					153	167	1,417	1,550
6												
7												
8	189	207	2,161	2,363					189	207	2,225	2,433
9	91	100	4,937	5,399					91	100	23,755	25,979
Total	1,265	1,384	12,746[a]	13,939[a]	159	174	227[a]	248[a]	1,424	1,558	53,691[a]	58,717[a]

[a] The total current number is the total length for all segments within EFPC floodplain for the specified RU and habitat.

Table G.7 (continued)

SEGMENT 1		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
COM	BOTTOMLAND	16.1	52.9	0.0	0.0	16.1	52.9
	COMMERCIAL	329.7	1081.6	0.0	0.0	329.7	1081.6
	ALL	345.8	1134.5	0.0	0.0	345.8	1134.5
DOE	BOTTOMLAND	1207.3	3960.9	0.0	0.0	1207.3	3960.9
	ALL	1207.3	3960.9	0.0	0.0	1207.3	3960.9
OTHER	BOTTOMLAND	1780.7	5842.2	0.0	0.0	1780.7	5842.2
	COMMERCIAL	1.5	5.1	0.0	0.0	1.5	5.1
	FILL	158.7	520.8	0.0	0.0	158.7	520.8
	GRASS	92.2	302.5	0.0	0.0	92.2	302.5
	ALL	2033.1	6670.6	0.0	0.0	2033.1	6670.6
RES	BOTTOMLAND	631.8	2072.7	31.0	101.7	600.8	1971.0
	ALL	631.8	2072.7	31.0	101.7	600.8	1971.0
UNDEF	BOTTOMLAND	187.3	614.6	0.0	0.0	187.3	614.6
	FILL	18.9	62.0	0.0	0.0	18.9	62.0
	GRASS	4.6	15.1	0.0	0.0	4.6	15.1
	ALL	210.8	691.7	0.0	0.0	210.8	691.7
ALL	BOTTOMLAND	3823.2	12543.3	31.0	101.7	3792.2	12441.6
	COMMERCIAL	331.2	1086.7	0.0	0.0	331.2	1086.7
	FILL	177.6	582.8	0.0	0.0	177.6	582.8
	GRASS	96.8	317.6	0.0	0.0	96.8	317.6
	ALL	4428.8	14530.4	31.0	101.7	4397.8	14428.7

Notes: > 180 ppm in Agricultural and Residential RUs
> 200 ppm in RUs except in Segment 1
No habitat conversion in Commercial and DOE RUs
Created on 21JUL94 from program a7linsum.pgm by J Chason

Table G.7 (continued)

SEGMENT 2		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
COM	BOTTOMLAND	241.0	790.7	0.0	0.0	241.0	790.7
	COMMERCIAL	1210.4	3971.3	0.0	0.0	1210.4	3971.3
	GRASS	16.3	53.3	0.0	0.0	16.3	53.3
	ALL	1467.7	4815.3	0.0	0.0	1467.7	4815.3
OTHER	BOTTOMLAND	950.9	3119.7	0.0	0.0	950.9	3119.7
	COMMERCIAL	27.5	90.4	0.0	0.0	27.5	90.4
	GRASS	708.4	2324.0	0.0	0.0	708.4	2324.0
	ALL	1686.8	5534.1	0.0	0.0	1686.8	5534.1
RES	BOTTOMLAND	694.5	2278.5	0.0	0.0	694.5	2278.5
	COMMERCIAL	1.6	5.1	0.0	0.0	1.6	5.1
	GRASS	387.8	1272.3	0.0	0.0	387.8	1272.3
	ALL	1083.9	3555.9	0.0	0.0	1083.9	3555.9
UNDEF	BOTTOMLAND	58.9	193.3	0.0	0.0	58.9	193.3
	COMMERCIAL	56.4	185.1	0.0	0.0	56.4	185.1
	GRASS	23.9	78.6	0.0	0.0	23.9	78.6
	ALL	139.2	457.0	0.0	0.0	139.2	457.0
ALL	BOTTOMLAND	1945.3	6382.2	0.0	0.0	1945.3	6382.2
	COMMERCIAL	1295.9	4251.9	0.0	0.0	1295.9	4251.9
	GRASS	1136.4	3728.2	0.0	0.0	1136.4	3728.2
	ALL	4377.6	14362.3	0.0	0.0	4377.6	14362.3

Table G.7 (continued)

SEGMENT 3		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
COM	BOTTOMLAND	915.9	3004.8	0.0	0.0	915.9	3004.8
	COMMERCIAL	41.1	135.0	0.0	0.0	41.1	135.0
	GRASS	76.0	249.2	0.0	0.0	76.0	249.2
	OLD FIELD	141.5	464.3	0.0	0.0	141.5	464.3
	ALL	1174.5	3853.3	0.0	0.0	1174.5	3853.3
OTHER	BOTTOMLAND	110.1	361.2	0.0	0.0	110.1	361.2
	ALL	110.1	361.2	0.0	0.0	110.1	361.2
RES	BOTTOMLAND	1120.2	3675.1	254.5	834.9	865.7	2840.2
	OLD FIELD	45.3	148.6	0.0	0.0	45.3	148.6
	ALL	1165.5	3823.7	254.5	834.9	911.0	2988.8
AGRI	BOTTOMLAND	122.1	400.5	0.0	0.0	122.1	400.5
	ALL	122.1	400.5	0.0	0.0	122.1	400.5
UNDEF	BOTTOMLAND	168.2	552.0	0.0	0.0	168.2	552.0
	GRASS	13.0	42.6	0.0	0.0	13.0	42.6
	ALL	181.2	594.6	0.0	0.0	181.2	594.6
ALL	BOTTOMLAND	2436.5	7993.6	254.5	834.9	2182.0	7158.7
	COMMERCIAL	41.1	135.0	0.0	0.0	41.1	135.0
	GRASS	89.0	291.8	0.0	0.0	89.0	291.8
	OLD FIELD	186.8	612.9	0.0	0.0	186.8	612.9
	ALL	2753.4	9033.3	254.5	834.9	2498.9	8198.4

Table G.7 (continued)

SEGMENT 4		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
OTHER	BOTTOMLAND	1104.1	3622.5	0.0	0.0	1104.1	3622.5
	GRASS	57.9	189.8	0.0	0.0	57.9	189.8
	OLD FIELD	227.8	747.2	0.0	0.0	227.8	747.2
	ALL	1389.8	4559.5	0.0	0.0	1389.8	4559.5
RES	BOTTOMLAND	671.4	2202.7	546.6	1793.3	124.8	409.4
	OLD FIELD	159.0	521.6	159.0	521.6	0.0	0.0
	ALL	830.4	2724.3	705.6	2314.9	124.8	409.4
UNDEF	BOTTOMLAND	11.1	36.5	0.0	0.0	11.1	36.5
	ALL	11.1	36.5	0.0	0.0	11.1	36.5
ALL	BOTTOMLAND	1786.6	5861.7	546.6	1793.3	1240.0	4068.4
	GRASS	57.9	189.8	0.0	0.0	57.9	189.8
	OLD FIELD	386.8	1268.8	159.0	521.6	227.8	747.2
	ALL	2231.3	7320.3	705.6	2314.9	1525.7	5005.4

Table G.7 (continued)

SEGMENT 5		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
OTHER	BOTTOMLAND	704.7	2312.1	0.0	0.0	704.7	2312.1
	ALL	704.7	2312.1	0.0	0.0	704.7	2312.1
RES	BOTTOMLAND	712.1	2336.3	152.2	499.5	559.9	1836.8
	ALL	712.1	2336.3	152.2	499.5	559.9	1836.8
ALL	BOTTOMLAND	1416.8	4648.4	152.2	499.5	1264.6	4148.9
	ALL	1416.8	4648.4	152.2	499.5	1264.6	4148.9

SEGMENT 6		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
OTHER	BOTTOMLAND	20.4	67.0	0.0	0.0	20.4	67.0
	ALL	20.4	67.0	0.0	0.0	20.4	67.0
RES	BOTTOMLAND	1805.2	5922.5	0.0	0.0	1805.2	5922.5
	OLD FIELD	23.8	78.2	0.0	0.0	23.8	78.2
	PASTURE	74.6	244.8	0.0	0.0	74.6	244.8
	ALL	1903.6	6245.5	0.0	0.0	1903.6	6245.5
AGRI	BOTTOMLAND	9.2	30.1	0.0	0.0	9.2	30.1
	PASTURE	15.0	49.4	0.0	0.0	15.0	49.4
	UPLAND	14.8	48.4	0.0	0.0	14.8	48.4
	ALL	39.0	127.9	0.0	0.0	39.0	127.9
UNDEF	BOTTOMLAND	72.1	236.6	0.0	0.0	72.1	236.6
	PASTURE	1.3	4.4	0.0	0.0	1.3	4.4
	ALL	73.4	241.0	0.0	0.0	73.4	241.0
ALL	BOTTOMLAND	1906.9	6256.2	0.0	0.0	1906.9	6256.2
	OLD FIELD	23.8	78.2	0.0	0.0	23.8	78.2
	PASTURE	90.9	298.6	0.0	0.0	90.9	298.6
	UPLAND	14.8	48.4	0.0	0.0	14.8	48.4
	ALL	2036.4	6681.4	0.0	0.0	2036.4	6681.4

Table G.7 (continued)

SEGMENT 7		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
OTHER	BOTTOMLAND	4582.1	15033.2	0.0	0.0	4582.1	15033.2
	ALL	4582.1	15033.2	0.0	0.0	4582.1	15033.2
RES	BOTTOMLAND	13.7	44.9	0.0	0.0	13.7	44.9
	ALL	13.7	44.9	0.0	0.0	13.7	44.9
AGRI	BOTTOMLAND	3990.0	13090.6	0.0	0.0	3990.0	13090.6
	OLD FIELD	232.0	761.0	0.0	0.0	232.0	761.0
	PASTURE	1540.0	5052.6	0.0	0.0	1540.0	5052.6
	ALL	5762.0	18904.2	0.0	0.0	5762.0	18904.2
UNDEF	BOTTOMLAND	104.0	341.3	0.0	0.0	104.0	341.3
	UPLAND	4.3	14.2	0.0	0.0	4.3	14.2
	ALL	108.3	355.5	0.0	0.0	108.3	355.5
ALL	BOTTOMLAND	8689.8	28510.0	0.0	0.0	8689.8	28510.0
	OLD FIELD	232.0	761.0	0.0	0.0	232.0	761.0
	PASTURE	1540.0	5052.6	0.0	0.0	1540.0	5052.6
	UPLAND	4.3	14.2	0.0	0.0	4.3	14.2
	ALL	10466.1	34337.8	0.0	0.0	10466.1	34337.8

Table G.7 (continued)

SEGMENT 8		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
RES	BOTTOMLAND	2161.1	7090.2	188.9	619.8	1972.2	6470.4
	ALL	2161.1	7090.2	188.9	619.8	1972.2	6470.4
UNDEF	BOTTOMLAND	63.8	209.2	0.0	0.0	63.8	209.2
	ALL	63.8	209.2	0.0	0.0	63.8	209.2
ALL	BOTTOMLAND	2224.9	7299.4	188.9	619.8	2036.0	6679.6
	ALL	2224.9	7299.4	188.9	619.8	2036.0	6679.6

SEGMENT 9		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
DOE	BOTTOMLAND	16807.1	55141.3	0.0	0.0	16807.1	55141.3
	HARDWOOD	610.0	2001.5	0.0	0.0	610.0	2001.5
	TRANSPORTATION	2.0	6.5	0.0	0.0	2.0	6.5
	UPLAND	975.8	3201.5	0.0	0.0	975.8	3201.5
	ALL	18394.9	60350.8	0.0	0.0	18394.9	60350.8
RES	BOTTOMLAND	4936.3	16195.4	91.8	301.3	4844.5	15894.1
	PASTURE	58.0	190.3	0.0	0.0	58.0	190.3
	RIGHT OF WAY	56.7	186.0	0.0	0.0	56.7	186.0
	TRANSPORTATION	2.9	9.4	0.0	0.0	2.9	9.4
	ALL	5053.9	16581.1	91.8	301.3	4962.1	16279.8
UNDEF	BOTTOMLAND	175.6	576.0	0.0	0.0	175.6	576.0
	HARDWOOD	73.9	242.5	0.0	0.0	73.9	242.5
	TRANSPORTATION	8.3	27.3	0.0	0.0	8.3	27.3
	UPLAND	48.8	160.0	0.0	0.0	48.8	160.0
	ALL	306.6	1005.8	0.0	0.0	306.6	1005.8
ALL	BOTTOMLAND	21919.0	71912.7	91.8	301.3	21827.2	71611.4

Table G.7 (continued)

SEGMENT 9 (CONTINUED)		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
ALL	HARDWOOD	683.9	2244.0	0.0	0.0	683.9	2244.0
	PASTURE	58.0	190.3	0.0	0.0	58.0	190.3
	RIGHT OF WAY	56.7	186.0	0.0	0.0	56.7	186.0
	TRANSPORTATION	13.2	43.2	0.0	0.0	13.2	43.2
	UPLAND	1024.6	3361.5	0.0	0.0	1024.6	3361.5
	ALL	23755.4	77937.7	91.8	301.3	23663.6	77636.4

ALL		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
COM	BOTTOMLAND	1173.0	3848.4	0.0	0.0	1173.0	3848.4
	COMMERCIAL	1581.2	5187.9	0.0	0.0	1581.2	5187.9
	GRASS	92.3	302.5	0.0	0.0	92.3	302.5
	OLD FIELD	141.5	464.3	0.0	0.0	141.5	464.3
	ALL	2988.0	9803.1	0.0	0.0	2988.0	9803.1
DOE	BOTTOMLAND	18014.4	59102.2	0.0	0.0	18014.4	59102.2
	HARDWOOD	610.0	2001.5	0.0	0.0	610.0	2001.5
	TRANSPORTATION	2.0	6.5	0.0	0.0	2.0	6.5
	UPLAND	975.8	3201.5	0.0	0.0	975.8	3201.5
	ALL	19602.2	64311.7	0.0	0.0	19602.2	64311.7
OTHER	BOTTOMLAND	9253.0	30357.9	0.0	0.0	9253.0	30357.9
	COMMERCIAL	29.0	95.5	0.0	0.0	29.0	95.5
	FILL	158.7	520.8	0.0	0.0	158.7	520.8
	GRASS	858.5	2816.3	0.0	0.0	858.5	2816.3
	OLD FIELD	227.8	747.2	0.0	0.0	227.8	747.2
	ALL	10527.0	34537.7	0.0	0.0	10527.0	34537.7

Table G.7 (continued)

ALL (CONTINUED)		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
RES	BOTTOMLAND	12746.3	41818.3	1265.0	4150.5	11481.3	37667.8
	COMMERCIAL	1.6	5.1	0.0	0.0	1.6	5.1
	GRASS	387.8	1272.3	0.0	0.0	387.8	1272.3
	OLD FIELD	228.1	748.4	159.0	521.6	69.1	226.8
	PASTURE	132.6	435.1	0.0	0.0	132.6	435.1
	RIGHT OF WAY	56.7	186.0	0.0	0.0	56.7	186.0
	TRANSPORTA-TION	2.9	9.4	0.0	0.0	2.9	9.4
	ALL	13556.0	44474.6	1424.0	4672.1	12132.0	39802.5
AGRI	BOTTOMLAND	4121.3	13521.2	0.0	0.0	4121.3	13521.2
	OLD FIELD	232.0	761.0	0.0	0.0	232.0	761.0
	PASTURE	1555.0	5102.0	0.0	0.0	1555.0	5102.0
	UPLAND	14.8	48.4	0.0	0.0	14.8	48.4
	ALL	5923.1	19432.6	0.0	0.0	5923.1	19432.6
UNDEF	BOTTOMLAND	841.0	2759.5	0.0	0.0	841.0	2759.5
	COMMERCIAL	56.4	185.1	0.0	0.0	56.4	185.1
	FILL	18.9	62.0	0.0	0.0	18.9	62.0
	GRASS	41.5	136.3	0.0	0.0	41.5	136.3
	HARDWOOD	73.9	242.5	0.0	0.0	73.9	242.5
	PASTURE	1.3	4.4	0.0	0.0	1.3	4.4
	TRANSPORTA-TION	8.3	27.3	0.0	0.0	8.3	27.3
	UPLAND	53.1	174.2	0.0	0.0	53.1	174.2
	ALL	1094.4	3591.3	0.0	0.0	1094.4	3591.3
ALL	BOTTOMLAND	46149.0	151407.5	1265.0	4150.5	44884.0	147257.0
	COMMERCIAL	1668.2	5473.6	0.0	0.0	1668.2	5473.6
	FILL	177.6	582.8	0.0	0.0	177.6	582.8

Table G.7 (continued)

ALL (CONTINUED)		CURRENT		CONVERTED		REMAINING	
		M	FT	M	FT	M	FT
ALL	GRASS	1380.1	4527.4	0.0	0.0	1380.1	4527.4
	HARDWOOD	683.9	2244.0	0.0	0.0	683.9	2244.0
	OLD FIELD	829.4	2720.9	159.0	521.6	670.4	2199.3
	PASTURE	1688.9	5541.5	0.0	0.0	1688.9	5541.5
	RIGHT OF WAY	56.7	186.0	0.0	0.0	56.7	186.0
	TRANSPORTA-TION	13.2	43.2	0.0	0.0	13.2	43.2
	UPLAND	1043.7	3424.1	0.0	0.0	1043.7	3424.1
	ALL	53690.7	176151.0	1424.0	4672.1	52266.7	171478.9

Table G.8. Terrestrial habitat areas: SWAs 2 through 6 by segment, RU, and habitat type

Seg	Residential Bottomland hardwood		Residential Old field		Residential Grass		Commercial Bottomland hardwood		DOE Bottomland hardwood		Other Bottomland hardwood		Other Old field		Total	
	converted	current	converted	current	converted	current	converted	current	converted	current	converted	current	converted	current	converted	current
acres																
1	3.4	19.2					<0.1	3.2	1.5	4.0					4.9	39.1
2																
3	0.6	7.0					0.1	1.6							0.7	30.3
4	3.8	10.1	2.5	2.5							1.9	10.0	1.4	5.7	9.6	33.8
5	0.6	5.8									0.4	3.4	0.3	9.0	1.3	19.6
6																
7																
8	0.7	15.1			0.1	9.0									0.8	26.4
9	0.3	42.6							0.5	93.3					0.8	297.1
Total	9.4	114.1[a]	2.5	18.9[a]	0.1	21.6[a]	0.1	5.8[a]	2.0	137.4[a]	2.3	57.3[a]	1.7	20.8[a]	18.1	633.0[a]
ha																
1	1.4	7.8					<0.1	1.3	0.6	1.6					2.0	15.9
2																
3	0.2	2.8					0.1	0.6							0.3	12.2
4	1.6	4.1	1.0	1.0							0.8	4.0	0.6	2.3	4.0	13.6
5	0.2	2.3									0.2	1.4	0.1	3.6	0.5	8.0
6																
7																
8	0.3	6.1			0.1	3.6									0.4	10.7
9	0.1	17.2							0.2	37.8					0.3	120.0
Total	3.8	46.2[a]	1.0	7.5[a]	0.1	8.9[a]	0.1	2.3[a]	0.8	55.6[a]	1.0	23.2[a]	0.7	8.4[a]	7.5	256.1[a]

[a] The total current number is the total area for all segments within EFPC floodplain for the specified RU and habitat.

Table G.8 (continued)

SEGMENT 1		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
COM	BOT	1.3	3.2	0.0	0.0	1.3	3.2
	COM	4.4	10.8	0.0	0.0	4.4	10.8
	GRASS	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	5.7	14.0	0.0	0.0	5.7	14.0
DOE	BOT	1.6	4.0	0.5	1.2	1.1	2.8
	ALL	1.6	4.0	0.5	1.2	1.1	2.8
OPEN	BOT	0.4	0.9	0.0	0.0	0.4	0.9
	COM	0.0	0.1	0.0	0.0	0.0	0.1
	FILL	0.2	0.4	0.0	0.0	0.2	0.4
	GRASS	0.1	0.2	0.0	0.0	0.1	0.2
	ALL	0.7	1.6	0.0	0.0	0.7	1.6
RES	BOT	7.8	19.2	1.3	3.2	6.5	16.0
	FILL	0.1	0.2	0.0	0.0	0.1	0.2
	ALL	7.9	19.4	1.3	3.2	6.6	16.2
UNDEF	BOT	0.0	0.1	0.0	0.0	0.0	0.1
	FILL	0.0	0.0	0.0	0.0	0.0	0.0
	GRASS	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	0.0	0.1	0.0	0.0	0.0	0.1
ALL	BOT	11.1	27.4	1.8	4.4	9.3	23.0
	COM	4.4	10.9	0.0	0.0	4.4	10.9
	FILL	0.3	0.6	0.0	0.0	0.3	0.6
	GRASS	0.1	0.2	0.0	0.0	0.1	0.2
	ALL	15.9	39.1	1.8	4.4	14.1	34.7

Notes: > 180 ppm in Agricultural and Residential RUs
> 200 ppm in Commercial, DOE and Other RUs
Created by fshabsum.pgm on 21JUL94 by J Chason

Table G.8 (continued)

SEGMENT 2		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
COM	BOT	0.4	1.0	0.0	0.0	0.4	1.0
	COM	0.7	1.7	0.0	0.0	0.7	1.7
	GRASS	0.6	1.5	0.0	0.0	0.6	1.5
	ALL	1.7	4.2	0.0	0.0	1.7	4.2
OPEN	BOT	1.5	3.8	0.0	0.0	1.5	3.8
	COM	1.7	4.2	0.0	0.0	1.7	4.2
	GRASS	1.2	3.1	0.0	0.0	1.2	3.1
	ALL	4.4	11.1	0.0	0.0	4.4	11.1
RES	BOT	2.2	5.4	0.0	0.0	2.2	5.4
	COM	0.1	0.2	0.0	0.0	0.1	0.2
	FILL	0.4	1.1	0.0	0.0	0.4	1.1
	GRASS	2.7	6.6	0.0	0.0	2.7	6.6
	OF	1.2	2.9	0.0	0.0	1.2	2.9
	ALL	6.6	16.2	0.0	0.0	6.6	16.2
UNDEF	BOT	0.1	0.2	0.0	0.0	0.1	0.2
	COM	0.1	0.3	0.0	0.0	0.1	0.3
	GRASS	0.2	0.4	0.0	0.0	0.2	0.4
	OF	0.1	0.2	0.0	0.0	0.1	0.2
	ALL	0.5	1.1	0.0	0.0	0.5	1.1
ALL	BOT	4.2	10.4	0.0	0.0	4.2	10.4
	COM	2.6	6.4	0.0	0.0	2.6	6.4
	FILL	0.4	1.1	0.0	0.0	0.4	1.1
	GRASS	4.7	11.6	0.0	0.0	4.7	11.6
	OF	1.3	3.1	0.0	0.0	1.3	3.1
	ALL	13.2	32.6	0.0	0.0	13.2	32.6

Table G.8 (continued)

SEGMENT 3		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
COM	BOT	0.6	1.6	0.0	0.1	0.6	1.5
	COM	0.9	2.3	0.0	0.0	0.9	2.3
	GRASS	0.7	1.8	0.0	0.0	0.7	1.8
	OF	0.6	1.4	0.0	0.0	0.6	1.4
	PAST	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	2.8	7.1	0.0	0.1	2.8	7.0
OPEN	BOT	0.1	0.2	0.0	0.0	0.1	0.2
	ALL	0.1	0.2	0.0	0.0	0.1	0.2
RES	BOT	2.8	7.0	0.2	0.5	2.6	6.4
	COM	1.4	3.4	0.0	0.0	1.4	3.4
	GRASS	0.5	1.2	0.0	0.0	0.5	1.2
	OF	1.2	3.1	0.0	0.0	1.2	3.1
	ALL	5.9	14.7	0.2	0.5	5.7	14.1
AGRI	BOT	0.4	0.9	0.0	0.0	0.4	0.9
	GRASS	0.1	0.2	0.0	0.0	0.1	0.2
	ALL	0.5	1.1	0.0	0.0	0.5	1.1
UNDEF	BOT	0.0	0.1	0.0	0.0	0.0	0.1
	COM	0.1	0.3	0.0	0.0	0.1	0.3
	GRASS	2.8	6.8	0.0	0.0	2.8	6.8
	OF	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	2.9	7.2	0.0	0.0	2.9	7.2
ALL	BOT	3.9	9.8	0.2	0.6	3.7	9.1
	COM	2.4	6.0	0.0	0.0	2.4	6.0
	GRASS	4.1	10.0	0.0	0.0	4.1	10.0
	OF	1.8	4.5	0.0	0.0	1.8	4.5
	PAST	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	12.2	30.3	0.2	0.6	12.0	29.6

Table G.8 (continued)

SEGMENT 4		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
COM	BOT	0.0	0.0	0.0	0.0	0.0	0.0
	COM	0.0	0.1	0.0	0.0	0.0	0.1
	ALL	0.0	0.1	0.0	0.0	0.0	0.1
OPEN	BOT	4.1	10.0	0.8	1.9	3.3	8.2
	GRASS	2.1	5.3	0.0	0.0	2.1	5.3
	OF	2.3	5.7	0.6	1.5	1.7	4.2
	ALL	8.5	21.0	1.4	3.4	7.1	17.7
RES	BOT	4.1	10.1	1.5	3.7	2.6	6.5
	OF	1.0	2.5	1.0	2.5	0.0	0.0
	ALL	5.1	12.6	2.5	6.2	2.6	6.5
UNDEF	BOT	0.0	0.1	0.0	0.0	0.0	0.1
	ALL	0.0	0.1	0.0	0.0	0.0	0.1
ALL	BOT	8.2	20.2	2.3	5.6	5.9	14.8
	COM	0.0	0.1	0.0	0.0	0.0	0.1
	GRASS	2.1	5.3	0.0	0.0	2.1	5.3
	OF	3.3	8.2	1.6	4.0	1.7	4.2
	ALL	13.6	33.8	3.9	9.6	9.7	24.4

Table G.8 (continued)

SEGMENT 5		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
COM	COM	0.0	0.0	0.0	0.0	0.0	0.0
	OF	0.1	0.3	0.0	0.0	0.1	0.3
	ALL	0.1	0.3	0.0	0.0	0.1	0.3
OPEN	BOT	1.4	3.4	0.2	0.4	1.2	2.9
	COM	0.0	0.1	0.0	0.0	0.0	0.1
	GRASS	0.3	0.6	0.0	0.0	0.3	0.6
	OF	3.7	9.0	0.1	0.2	3.6	8.8
	ALL	5.4	13.1	0.3	0.6	5.1	12.4
RES	BOT	2.4	5.8	0.2	0.5	2.1	5.3
	GRASS	0.0	0.1	0.0	0.0	0.0	0.1
	OF	0.1	0.3	0.0	0.0	0.1	0.3
	ALL	2.5	6.2	0.2	0.5	2.2	5.7
UNDEF	BOT	0.0	0.0	0.0	0.0	0.0	0.0
	COM	0.0	0.0	0.0	0.0	0.0	0.0
	GRASS	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	0.0	0.0	0.0	0.0	0.0	0.0
ALL	BOT	3.8	9.2	0.4	0.9	3.3	8.2
	COM	0.0	0.1	0.0	0.0	0.0	0.1
	GRASS	0.3	0.7	0.0	0.0	0.3	0.7
	OF	3.9	9.6	0.1	0.2	3.8	9.4
	ALL	8.0	19.6	0.5	1.1	7.4	18.4

Table G.8 (continued)

SEGMENT 6		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
OPEN	BOT	0.5	1.2	0.0	0.0	0.5	1.2
	GRASS	0.0	0.0	0.0	0.0	0.0	0.0
	OF	0.2	0.5	0.0	0.0	0.2	0.5
	ALL	0.7	1.7	0.0	0.0	0.7	1.7
RES	BOT	3.5	8.7	0.0	0.0	3.5	8.7
	GRASS	0.4	0.9	0.0	0.0	0.4	0.9
	OF	1.3	3.3	0.0	0.0	1.3	3.3
	PAST	4.1	10.1	0.0	0.0	4.1	10.1
	UF	0.1	0.2	0.0	0.0	0.1	0.2
	ALL	9.4	23.2	0.0	0.0	9.4	23.2
AGRI	BOT	0.0	0.0	0.0	0.0	0.0	0.0
	PAST	0.1	0.3	0.0	0.0	0.1	0.3
	UF	0.0	0.1	0.0	0.0	0.0	0.1
	ALL	0.1	0.4	0.0	0.0	0.1	0.4
UNDEF	BOT	0.3	0.7	0.0	0.0	0.3	0.7
	GRASS	0.0	0.0	0.0	0.0	0.0	0.0
	OF	0.1	0.1	0.0	0.0	0.1	0.1
	PAST	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	0.4	0.8	0.0	0.0	0.4	0.8
ALL	BOT	4.3	10.6	0.0	0.0	4.3	10.6
	GRASS	0.4	0.9	0.0	0.0	0.4	0.9
	OF	1.6	3.9	0.0	0.0	1.6	3.9
	PAST	4.2	10.4	0.0	0.0	4.2	10.4
	UF	0.1	0.3	0.0	0.0	0.1	0.3
	ALL	10.6	26.1	0.0	0.0	10.6	26.1

Table G.8 (continued)

SEGMENT 7		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
COM	FILL	0.0	0.1	0.0	0.0	0.0	0.1
	ALL	0.0	0.1	0.0	0.0	0.0	0.1
OPEN	BOT	15.3	37.8	0.0	0.0	15.3	37.8
	GRASS	0.4	1.0	0.0	0.0	0.4	1.0
	OF	2.3	5.6	0.0	0.0	2.3	5.6
	PINE	1.6	4.1	0.0	0.0	1.6	4.1
	UF	3.7	9.1	0.0	0.0	3.7	9.1
	ALL	23.3	57.6	0.0	0.0	23.3	57.6
RES	BOT	0.1	0.2	0.0	0.0	0.1	0.2
	GRASS	0.2	0.4	0.0	0.0	0.2	0.4
	LAWN	0.1	0.1	0.0	0.0	0.1	0.1
	OF	0.0	0.1	0.0	0.0	0.0	0.1
	ALL	0.4	0.8	0.0	0.0	0.4	0.8
AGRI	BOT	9.1	22.6	0.0	0.0	9.1	22.6
	COM	0.0	0.0	0.0	0.0	0.0	0.0
	FILL	0.3	0.7	0.0	0.0	0.3	0.7
	GRASS	0.0	0.0	0.0	0.0	0.0	0.0
	OF	2.5	6.1	0.0	0.0	2.5	6.1
	PAST	15.6	38.4	0.0	0.0	15.6	38.4
	UF	0.6	1.5	0.0	0.0	0.6	1.5
	ALL	28.1	69.3	0.0	0.0	28.1	69.3
UNDEF	BOT	0.1	0.2	0.0	0.0	0.1	0.2
	FILL	0.0	0.0	0.0	0.0	0.0	0.0
	OF	0.0	0.0	0.0	0.0	0.0	0.0
	UF	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	0.1	0.2	0.0	0.0	0.1	0.2
ALL	BOT	24.6	60.8	0.0	0.0	24.6	60.8
	COM	0.0	0.0	0.0	0.0	0.0	0.0

Table G.8 (continued)

SEGMENT 7 (CONTINUED)		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
ALL	FILL	0.3	0.8	0.0	0.0	0.3	0.8
	GRASS	0.6	1.4	0.0	0.0	0.6	1.4
	LAWN	0.1	0.1	0.0	0.0	0.1	0.1
	OF	4.8	11.8	0.0	0.0	4.8	11.8
	PAST	15.6	38.4	0.0	0.0	15.6	38.4
	PINE	1.6	4.1	0.0	0.0	1.6	4.1
	UF	4.3	10.6	0.0	0.0	4.3	10.6
	ALL	51.9	128.0	0.0	0.0	51.9	128.0

SEGMENT 8		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
RES	BOT	6.1	15.1	0.3	0.7	5.8	14.3
	COM	0.1	0.4	0.0	0.0	0.1	0.4
	GRASS	3.7	9.0	0.1	0.2	3.6	8.9
	LAWN	0.3	0.8	0.0	0.0	0.3	0.8
	OF	0.4	0.9	0.0	0.0	0.4	0.9
	PAST	0.1	0.2	0.0	0.0	0.1	0.2
	UF	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	10.7	26.4	0.4	0.9	10.3	25.5
UNDEF	BOT	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	0.0	0.0	0.0	0.0	0.0	0.0
ALL	BOT	6.1	15.1	0.3	0.7	5.8	14.3
	COM	0.1	0.4	0.0	0.0	0.1	0.4
	GRASS	3.7	9.0	0.1	0.2	3.6	8.9
	LAWN	0.3	0.8	0.0	0.0	0.3	0.8
	OF	0.4	0.9	0.0	0.0	0.4	0.9
	PAST	0.1	0.2	0.0	0.0	0.1	0.2

Table G.8 (continued)

SEGMENT 8 (CONTINUED)		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
ALL	UF	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	10.7	26.4	0.4	0.9	10.3	25.5

SEGMENT 9		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
DOE	BOT	54.0	133.4	0.2	0.5	53.8	132.9
	HARD	3.2	8.0	0.0	0.0	3.2	8.0
	OF	4.6	11.4	0.0	0.0	4.6	11.4
	PINE	6.4	15.8	0.0	0.0	6.4	15.8
	TRANS	0.2	0.5	0.0	0.0	0.2	0.5
	UF	22.3	55.1	0.0	0.0	22.3	55.1
	ALL	90.7	224.2	0.2	0.5	90.5	223.7
RES	BOT	17.2	42.6	0.1	0.3	17.1	42.3
	GRASS	1.4	3.4	0.0	0.0	1.4	3.4
	LAWN	1.4	3.5	0.0	0.0	1.4	3.5
	OF	2.3	5.8	0.0	0.0	2.3	5.8
	PAST	5.2	12.9	0.0	0.0	5.2	12.9
	R-O-W	0.4	1.0	0.0	0.0	0.4	1.0
	TRANS	0.0	0.0	0.0	0.0	0.0	0.0
	UF	0.8	1.9	0.0	0.0	0.8	1.9
	ALL	28.7	71.1	0.1	0.3	28.6	70.8
UNDEF	BOT	0.3	0.8	0.0	0.0	0.3	0.8
	HARD	0.0	0.1	0.0	0.0	0.0	0.1
	TRANS	0.3	0.8	0.0	0.0	0.3	0.8
	UF	0.0	0.1	0.0	0.0	0.0	0.1
	ALL	0.6	1.8	0.0	0.0	0.6	1.8
ALL	BOT	71.5	176.8	0.3	0.8	71.2	176.0

Table G.8 (continued)

SEGMENT 9 (CONTINUED)		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
ALL	GRASS	1.4	3.4	0.0	0.0	1.4	3.4
	HARD	3.2	8.1	0.0	0.0	3.2	8.1
	LAWN	1.4	3.5	0.0	0.0	1.4	3.5
	OF	6.9	17.2	0.0	0.0	6.9	17.2
	PAST	5.2	12.9	0.0	0.0	5.2	12.9
	PINE	6.4	15.8	0.0	0.0	6.4	15.8
	R-O-W	0.4	1.0	0.0	0.0	0.4	1.0
	TRANS	0.5	1.3	0.0	0.0	0.5	1.3
	UF	23.1	57.1	0.0	0.0	23.1	57.1
	ALL	120.0	297.1	0.3	0.8	119.7	296.3

ALL		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
COM	BOT	2.3	5.8	0.0	0.1	2.3	5.7
	COM	6.0	14.9	0.0	0.0	6.0	14.9
	FILL	0.0	0.1	0.0	0.0	0.0	0.1
	GRASS	1.3	3.3	0.0	0.0	1.3	3.3
	OF	0.7	1.7	0.0	0.0	0.7	1.7
	PAST	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	10.3	25.8	0.0	0.1	10.3	25.7
DOE	BOT	55.6	137.4	0.7	1.7	54.9	135.7
	HARD	3.2	8.0	0.0	0.0	3.2	8.0
	OF	4.6	11.4	0.0	0.0	4.6	11.4
	PINE	6.4	15.8	0.0	0.0	6.4	15.8
	TRANS	0.2	0.5	0.0	0.0	0.2	0.5
	UF	22.3	55.1	0.0	0.0	22.3	55.1
	ALL	92.3	228.2	0.7	1.7	91.6	226.5

Table G.8 (continued)

ALL (CONTINUED)		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
OPEN	BOT	23.3	57.3	1.0	2.3	22.3	55.0
	COM	1.7	4.4	0.0	0.0	1.7	4.4
	FILL	0.2	0.4	0.0	0.0	0.2	0.4
	GRASS	4.1	10.2	0.0	0.0	4.1	10.2
	OF	8.5	20.8	0.7	1.7	7.8	19.1
	PINE	1.6	4.1	0.0	0.0	1.6	4.1
	UF	3.7	9.1	0.0	0.0	3.7	9.1
	ALL	43.1	106.3	1.7	4.0	41.4	102.3
RES	BOT	46.2	114.1	3.6	8.9	42.5	105.1
	COM	1.6	4.0	0.0	0.0	1.6	4.0
	FILL	0.5	1.3	0.0	0.0	0.5	1.3
	GRASS	8.9	21.6	0.1	0.2	8.8	21.5
	LAWN	1.8	4.4	0.0	0.0	1.8	4.4
	OF	7.5	18.9	1.0	2.5	6.5	16.4
	PAST	9.4	23.2	0.0	0.0	9.4	23.2
	R-O-W	0.4	1.0	0.0	0.0	0.4	1.0
	TRANS	0.0	0.0	0.0	0.0	0.0	0.0
	UF	0.9	2.1	0.0	0.0	0.9	2.1
	ALL	77.2	190.6	4.7	11.6	72.4	179.0
AGRI	BOT	9.5	23.5	0.0	0.0	9.5	23.5
	COM	0.0	0.0	0.0	0.0	0.0	0.0
	FILL	0.3	0.7	0.0	0.0	0.3	0.7
	GRASS	0.1	0.2	0.0	0.0	0.1	0.2
	OF	2.5	6.1	0.0	0.0	2.5	6.1
	PAST	15.7	38.7	0.0	0.0	15.7	38.7
	UF	0.6	1.6	0.0	0.0	0.6	1.6
	ALL	28.7	70.8	0.0	0.0	28.7	70.8

Table G.8 (continued)

ALL (CONTINUED)		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
UNDEF	BOT	0.8	2.2	0.0	0.0	0.8	2.2
	COM	0.2	0.6	0.0	0.0	0.2	0.6
	FILL	0.0	0.0	0.0	0.0	0.0	0.0
	GRASS	3.0	7.2	0.0	0.0	3.0	7.2
	HARD	0.0	0.1	0.0	0.0	0.0	0.1
	OF	0.2	0.3	0.0	0.0	0.2	0.3
	PAST	0.0	0.0	0.0	0.0	0.0	0.0
	TRANS	0.3	0.8	0.0	0.0	0.3	0.8
	UF	0.0	0.1	0.0	0.0	0.0	0.1
	ALL	4.5	11.3	0.0	0.0	4.5	11.3
ALL	BOT	137.7	340.3	5.3	13.0	132.3	327.2
	COM	9.5	23.9	0.0	0.0	9.5	23.9
	FILL	1.0	2.5	0.0	0.0	1.0	2.5
	GRASS	17.4	42.5	0.1	0.2	17.3	42.4
	HARD	3.2	8.1	0.0	0.0	3.2	8.1
	LAWN	1.8	4.4	0.0	0.0	1.8	4.4
	OF	24.0	59.2	1.7	4.2	22.3	55.0
	PAST	25.1	61.9	0.0	0.0	25.1	61.9
	PINE	8.0	19.9	0.0	0.0	8.0	19.9
	R-O-W	0.4	1.0	0.0	0.0	0.4	1.0
	TRANS	0.5	1.3	0.0	0.0	0.5	1.3
	UF	27.5	68.0	0.0	0.0	27.5	68.0
	ALL	256.1	633.0	7.1	17.4	248.9	615.6

Table G.9. Terrestrial habitat areas: SWA 7 by segment, RU, and habitat type

Segment	Residential Bottomland hardwood				Residential Old field				Residential Grass				Total			
	converted		current		converted		current		converted		current		converted		current	
	ha	acres	ha	acres	ha	acres	ha	acres	ha	acres	ha	acres	ha	acres	ha	acres
1	0.1	0.1	2.7[a]										0.1	0.1	15.9	39.1
2																
3	0.2	0.6	2.8										0.2	0.6	12.2	30.3
4	1.6	3.8	3.8	10.1	1.0	2.5	1.0	2.5					2.6	6.3	13.6	33.8
5	0.2	0.6	2.3	5.8									0.2	0.6	8.0	19.6
6																
7																
8	0.3	0.7	6.1	15.1					0.1	0.1	3.6	9.0	0.4	0.8	10.7	26.4
9	0.1	0.3	17.2	42.6									0.1	0.3	120.0	297.1
Total	2.5	6.1	41.2[b]	101.8[b]	1.0	2.5	7.7[b]	18.9[b]	0.1		7.5[b]	18.6[b]	3.6	8.7	256.1[b]	633.0[b]

[a] Area less than SWAs 2 through 6 due to land use restriction.
[b] The total current number is the total area for all segments within EFPC floodplain for the specified RU and habitat.

1 ha = 2.47 acres
1 acre = 0.405 ha

Table G.9 (continued)

SEGMENT 1		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
COM	BOT	1.3	3.2	0.0	0.0	1.3	3.2
	COM	4.4	10.8	0.0	0.0	4.4	10.8
	GRASS	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	5.7	14.0	0.0	0.0	5.7	14.0
DOE	BOT	1.6	3.9	0.0	0.0	1.6	3.9
	ALL	1.6	3.9	0.0	0.0	1.6	3.9
OPEN	BOT	5.4	13.4	0.0	0.0	5.4	13.4
	COM	0.0	0.1	0.0	0.0	0.0	0.1
	FILL	0.3	0.6	0.0	0.0	0.3	0.6
	GRASS	0.1	0.2	0.0	0.0	0.1	0.2
	ALL	5.8	14.3	0.0	0.0	5.8	14.3
RES	BOT	2.7	6.7	0.0	0.1	2.7	6.6
	ALL	2.7	6.7	0.0	0.1	2.7	6.6
UNDEF	BOT	0.1	0.2	0.0	0.0	0.1	0.2
	FILL	0.0	0.0	0.0	0.0	0.0	0.0
	GRASS	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	0.1	0.2	0.0	0.0	0.1	0.2
ALL	BOT	11.1	27.4	0.0	0.1	11.1	27.3
	COM	4.4	10.9	0.0	0.0	4.4	10.9
	FILL	0.3	0.6	0.0	0.0	0.3	0.6
	GRASS	0.1	0.2	0.0	0.0	0.1	0.2
	ALL	15.9	39.1	0.0	0.1	15.9	39.0

Notes: > 180 ppm in Agricultural and Residential RUs
> 200 in Other RUs
Created by program a7habsum.pgm on 21JUL94 by J Chason

Table G.9 (continued)

SEGMENT 2		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
COM	BOT	0.4	1.0	0.0	0.0	0.4	1.0
	COM	0.7	1.7	0.0	0.0	0.7	1.7
	GRASS	0.6	1.5	0.0	0.0	0.6	1.5
	ALL	1.7	4.2	0.0	0.0	1.7	4.2
OPEN	BOT	1.5	3.8	0.0	0.0	1.5	3.8
	COM	1.7	4.2	0.0	0.0	1.7	4.2
	GRASS	1.2	3.1	0.0	0.0	1.2	3.1
	ALL	4.4	11.1	0.0	0.0	4.4	11.1
RES	BOT	2.2	5.4	0.0	0.0	2.2	5.4
	COM	0.1	0.2	0.0	0.0	0.1	0.2
	FILL	0.4	1.1	0.0	0.0	0.4	1.1
	GRASS	2.7	6.6	0.0	0.0	2.7	6.6
	OF	1.2	2.9	0.0	0.0	1.2	2.9
	ALL	6.6	16.2	0.0	0.0	6.6	16.2
UNDEF	BOT	0.1	0.2	0.0	0.0	0.1	0.2
	COM	0.1	0.3	0.0	0.0	0.1	0.3
	GRASS	0.2	0.4	0.0	0.0	0.2	0.4
	OF	0.1	0.2	0.0	0.0	0.1	0.2
	ALL	0.5	1.1	0.0	0.0	0.5	1.1
ALL	BOT	4.2	10.4	0.0	0.0	4.2	10.4
	COM	2.6	6.4	0.0	0.0	2.6	6.4
	FILL	0.4	1.1	0.0	0.0	0.4	1.1
	GRASS	4.7	11.6	0.0	0.0	4.7	11.6
	OF	1.3	3.1	0.0	0.0	1.3	3.1
	ALL	13.2	32.6	0.0	0.0	13.2	32.6

Table G.9 (continued)

SEGMENT 3		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
COM	BOT	0.6	1.6	0.0	0.0	0.6	1.6
	COM	0.9	2.3	0.0	0.0	0.9	2.3
	GRASS	0.7	1.8	0.0	0.0	0.7	1.8
	OF	0.6	1.4	0.0	0.0	0.6	1.4
	PAST	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	2.8	7.1	0.0	0.0	2.8	7.1
OPEN	BOT	0.1	0.2	0.0	0.0	0.1	0.2
	ALL	0.1	0.2	0.0	0.0	0.1	0.2
RES	BOT	2.8	7.0	0.2	0.5	2.6	6.4
	COM	1.4	3.4	0.0	0.0	1.4	3.4
	GRASS	0.5	1.2	0.0	0.0	0.5	1.2
	OF	1.2	3.1	0.0	0.0	1.2	3.1
	ALL	5.9	14.7	0.2	0.5	5.7	14.1
AGRI	BOT	0.4	0.9	0.0	0.0	0.4	0.9
	GRASS	0.1	0.2	0.0	0.0	0.1	0.2
	ALL	0.5	1.1	0.0	0.0	0.5	1.1
UNDEF	BOT	0.0	0.1	0.0	0.0	0.0	0.1
	COM	0.1	0.3	0.0	0.0	0.1	0.3
	GRASS	2.8	6.8	0.0	0.0	2.8	6.8
	OF	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	2.9	7.2	0.0	0.0	2.9	7.2
ALL	BOT	3.9	9.8	0.2	0.5	3.7	9.2
	COM	2.4	6.0	0.0	0.0	2.4	6.0
	GRASS	4.1	10.0	0.0	0.0	4.1	10.0
	OF	1.8	4.5	0.0	0.0	1.8	4.5
	PAST	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	12.2	30.3	0.2	0.5	12.0	29.7

Table G.9 (continued)

SEGMENT 4		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
COM	BOT	0.0	0.0	0.0	0.0	0.0	0.0
	COM	0.0	0.1	0.0	0.0	0.0	0.1
	ALL	0.0	0.1	0.0	0.0	0.0	0.1
OPEN	BOT	4.1	10.0	0.0	0.0	4.1	10.0
	GRASS	2.1	5.3	0.0	0.0	2.1	5.3
	OF	2.3	5.7	0.0	0.0	2.3	5.7
	ALL	8.5	21.0	0.0	0.0	8.5	21.0
RES	BOT	4.1	10.1	1.5	3.7	2.6	6.4
	OF	1.0	2.5	1.0	2.5	0.0	0.0
	ALL	5.1	12.6	2.5	6.2	2.6	6.4
UNDEF	BOT	0.0	0.1	0.0	0.0	0.0	0.1
	ALL	0.0	0.1	0.0	0.0	0.0	0.1
ALL	BOT	8.2	20.2	1.5	3.7	6.7	16.6
	COM	0.0	0.1	0.0	0.0	0.0	0.1
	GRASS	2.1	5.3	0.0	0.0	2.1	5.3
	OF	3.3	8.2	1.0	2.5	2.3	5.7
	ALL	13.6	33.8	2.5	6.2	11.1	27.7

Table G.9 (continued)

SEGMENT 5		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
COM	COM	0.0	0.0	0.0	0.0	0.0	0.0
	OF	0.1	0.3	0.0	0.0	0.1	0.3
	ALL	0.1	0.3	0.0	0.0	0.1	0.3
OPEN	BOT	1.4	3.4	0.0	0.0	1.4	3.4
	COM	0.0	0.1	0.0	0.0	0.0	0.1
	GRASS	0.3	0.6	0.0	0.0	0.3	0.6
	OF	3.7	9.0	0.0	0.0	3.7	9.0
	ALL	5.4	13.1	0.0	0.0	5.4	13.1
RES	BOT	2.4	5.8	0.2	0.5	2.1	5.3
	GRASS	0.0	0.1	0.0	0.0	0.0	0.1
	OF	0.1	0.3	0.0	0.0	0.1	0.3
	ALL	2.5	6.2	0.2	0.5	2.2	5.7
UNDEF	BOT	0.0	0.0	0.0	0.0	0.0	0.0
	COM	0.0	0.0	0.0	0.0	0.0	0.0
	GRASS	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	0.0	0.0	0.0	0.0	0.0	0.0
ALL	BOT	3.8	9.2	0.2	0.5	3.5	8.7
	COM	0.0	0.1	0.0	0.0	0.0	0.1
	GRASS	0.3	0.7	0.0	0.0	0.3	0.7
	OF	3.9	9.6	0.0	0.0	3.9	9.6
	ALL	8.0	19.6	0.2	0.5	7.7	19.1

Table G.9 (continued)

SEGMENT 6		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
OPEN	BOT	0.5	1.2	0.0	0.0	0.5	1.2
	GRASS	0.0	0.0	0.0	0.0	0.0	0.0
	OF	0.2	0.5	0.0	0.0	0.2	0.5
	ALL	0.7	1.7	0.0	0.0	0.7	1.7
RES	BOT	3.5	8.7	0.0	0.0	3.5	8.7
	GRASS	0.4	0.9	0.0	0.0	0.4	0.9
	OF	1.3	3.3	0.0	0.0	1.3	3.3
	PAST	4.1	10.1	0.0	0.0	4.1	10.1
	UF	0.1	0.2	0.0	0.0	0.1	0.2
	ALL	9.4	23.2	0.0	0.0	9.4	23.2
AGRI	BOT	0.0	0.0	0.0	0.0	0.0	0.0
	PAST	0.1	0.3	0.0	0.0	0.1	0.3
	UF	0.0	0.1	0.0	0.0	0.0	0.1
	ALL	0.1	0.4	0.0	0.0	0.1	0.4
UNDEF	BOT	0.3	0.7	0.0	0.0	0.3	0.7
	GRASS	0.0	0.0	0.0	0.0	0.0	0.0
	OF	0.1	0.1	0.0	0.0	0.1	0.1
	PAST	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	0.4	0.8	0.0	0.0	0.4	0.8
ALL	BOT	4.3	10.6	0.0	0.0	4.3	10.6
	GRASS	0.4	0.9	0.0	0.0	0.4	0.9
	OF	1.6	3.9	0.0	0.0	1.6	3.9
	PAST	4.2	10.4	0.0	0.0	4.2	10.4
	UF	0.1	0.3	0.0	0.0	0.1	0.3
	ALL	10.6	26.1	0.0	0.0	10.6	26.1

Table G.9 (continued)

SEGMENT 7		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
COM	FILL	0.0	0.1	0.0	0.0	0.0	0.1
	ALL	0.0	0.1	0.0	0.0	0.0	0.1
OPEN	BOT	15.3	37.7	0.0	0.0	15.3	37.7
	GRASS	0.4	1.0	0.0	0.0	0.4	1.0
	OF	2.3	5.6	0.0	0.0	2.3	5.6
	PINE	1.6	4.1	0.0	0.0	1.6	4.1
	UF	3.7	9.1	0.0	0.0	3.7	9.1
	ALL	23.3	57.5	0.0	0.0	23.3	57.5
RES	BOT	0.1	0.2	0.0	0.0	0.1	0.2
	GRASS	0.2	0.4	0.0	0.0	0.2	0.4
	LAWN	0.1	0.1	0.0	0.0	0.1	0.1
	OF	0.0	0.1	0.0	0.0	0.0	0.1
	ALL	0.4	0.8	0.0	0.0	0.4	0.8
AGRI	BOT	9.2	22.7	0.0	0.0	9.2	22.7
	COM	0.0	0.0	0.0	0.0	0.0	0.0
	FILL	0.3	0.7	0.0	0.0	0.3	0.7
	GRASS	0.0	0.0	0.0	0.0	0.0	0.0
	OF	2.5	6.1	0.0	0.0	2.5	6.1
	PAST	15.5	38.4	0.0	0.0	15.5	38.4
	UF	0.6	1.5	0.0	0.0	0.6	1.5
	ALL	28.1	69.4	0.0	0.0	28.1	69.4
UNDEF	BOT	0.1	0.2	0.0	0.0	0.1	0.2
	FILL	0.0	0.0	0.0	0.0	0.0	0.0
	OF	0.0	0.0	0.0	0.0	0.0	0.0
	UF	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	0.1	0.2	0.0	0.0	0.1	0.2
ALL	BOT	24.7	60.8	0.0	0.0	24.7	60.8
	COM	0.0	0.0	0.0	0.0	0.0	0.0

Table G.9 (continued)

SEGMENT 7 (CONTINUED)		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
ALL	FILL	0.3	0.8	0.0	0.0	0.3	0.8
	GRASS	0.6	1.4	0.0	0.0	0.6	1.4
	LAWN	0.1	0.1	0.0	0.0	0.1	0.1
	OF	4.8	11.8	0.0	0.0	4.8	11.8
	PAST	15.5	38.4	0.0	0.0	15.5	38.4
	PINE	1.6	4.1	0.0	0.0	1.6	4.1
	UF	4.3	10.6	0.0	0.0	4.3	10.6
	ALL	51.9	128.0	0.0	0.0	51.9	128.0

SEGMENT 8		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
RES	BOT	6.1	15.1	0.3	0.7	5.8	14.3
	COM	0.1	0.4	0.0	0.0	0.1	0.4
	GRASS	3.7	9.0	0.1	0.2	3.6	8.9
	LAWN	0.3	0.8	0.0	0.0	0.3	0.8
	OF	0.4	0.9	0.0	0.0	0.4	0.9
	PAST	0.1	0.2	0.0	0.0	0.1	0.2
	UF	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	10.7	26.4	0.4	0.9	10.3	25.5
UNDEF	BOT	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	0.0	0.0	0.0	0.0	0.0	0.0
ALL	BOT	6.1	15.1	0.3	0.7	5.8	14.3
	COM	0.1	0.4	0.0	0.0	0.1	0.4
	GRASS	3.7	9.0	0.1	0.2	3.6	8.9
	LAWN	0.3	0.8	0.0	0.0	0.3	0.8
	OF	0.4	0.9	0.0	0.0	0.4	0.9
	PAST	0.1	0.2	0.0	0.0	0.1	0.2

Table G.9 (continued)

SEGMENT 8 (CONTINUED)		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
ALL	UF	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	10.7	26.4	0.4	0.9	10.3	25.5

SEGMENT 9		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
DOE	BOT	54.0	133.5	0.0	0.0	54.0	133.5
	HARD	3.2	8.0	0.0	0.0	3.2	8.0
	OF	4.6	11.4	0.0	0.0	4.6	11.4
	PINE	6.4	15.8	0.0	0.0	6.4	15.8
	TRANS	0.2	0.5	0.0	0.0	0.2	0.5
	UF	22.3	55.1	0.0	0.0	22.3	55.1
	ALL	90.7	224.3	0.0	0.0	90.7	224.3
RES	BOT	17.2	42.6	0.1	0.3	17.1	42.3
	GRASS	1.4	3.4	0.0	0.0	1.4	3.4
	LAWN	1.4	3.5	0.0	0.0	1.4	3.5
	OF	2.3	5.8	0.0	0.0	2.3	5.8
	PAST	5.2	12.9	0.0	0.0	5.2	12.9
	R-O-W	0.4	1.0	0.0	0.0	0.4	1.0
	TRANS	0.0	0.0	0.0	0.0	0.0	0.0
	UF	0.8	1.9	0.0	0.0	0.8	1.9
	ALL	28.7	71.1	0.1	0.3	28.6	70.8
UNDEF	BOT	0.3	0.8	0.0	0.0	0.3	0.8
	HARD	0.0	0.1	0.0	0.0	0.0	0.1
	TRANS	0.3	0.8	0.0	0.0	0.3	0.8
	UF	0.0	0.1	0.0	0.0	0.0	0.1
	ALL	0.6	1.8	0.0	0.0	0.6	1.8
ALL	BOT	71.5	176.9	0.1	0.3	71.4	176.6

Table G.9 (continued)

SEGMENT 9 (CONTINUED)		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
ALL	GRASS	1.4	3.4	0.0	0.0	1.4	3.4
	HARD	3.2	8.1	0.0	0.0	3.2	8.1
	LAWN	1.4	3.5	0.0	0.0	1.4	3.5
	OF	6.9	17.2	0.0	0.0	6.9	17.2
	PAST	5.2	12.9	0.0	0.0	5.2	12.9
	PINE	6.4	15.8	0.0	0.0	6.4	15.8
	R-O-W	0.4	1.0	0.0	0.0	0.4	1.0
	TRANS	0.5	1.3	0.0	0.0	0.5	1.3
	UF	23.1	57.1	0.0	0.0	23.1	57.1
	ALL	120.0	297.2	0.1	0.3	119.9	296.9

ALL		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
COM	BOT	2.3	5.8	0.0	0.0	2.3	5.8
	COM	6.0	14.9	0.0	0.0	6.0	14.9
	FILL	0.0	0.1	0.0	0.0	0.0	0.1
	GRASS	1.3	3.3	0.0	0.0	1.3	3.3
	OF	0.7	1.7	0.0	0.0	0.7	1.7
	PAST	0.0	0.0	0.0	0.0	0.0	0.0
	ALL	10.3	25.8	0.0	0.0	10.3	25.8
DOE	BOT	55.6	137.4	0.0	0.0	55.6	137.4
	HARD	3.2	8.0	0.0	0.0	3.2	8.0
	OF	4.6	11.4	0.0	0.0	4.6	11.4
	PINE	6.4	15.8	0.0	0.0	6.4	15.8
	TRANS	0.2	0.5	0.0	0.0	0.2	0.5
	UF	22.3	55.1	0.0	0.0	22.3	55.1
	ALL	92.3	228.2	0.0	0.0	92.3	228.2

Table G.9 (continued)

ALL (CONTINUED)		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
OPEN	BOT	28.3	69.7	0.0	0.0	28.3	69.7
	COM	1.7	4.4	0.0	0.0	1.7	4.4
	FILL	0.3	0.6	0.0	0.0	0.3	0.6
	GRASS	4.1	10.2	0.0	0.0	4.1	10.2
	OF	8.5	20.8	0.0	0.0	8.5	20.8
	PINE	1.6	4.1	0.0	0.0	1.6	4.1
	UF	3.7	9.1	0.0	0.0	3.7	9.1
	ALL	48.2	118.9	0.0	0.0	48.2	118.9
RES	BOT	41.1	101.6	2.3	5.8	38.8	95.8
	COM	1.6	4.0	0.0	0.0	1.6	4.0
	FILL	0.4	1.1	0.0	0.0	0.4	1.1
	GRASS	8.9	21.6	0.1	0.2	8.8	21.4
	LAWN	1.8	4.4	0.0	0.0	1.8	4.4
	OF	7.5	18.9	1.0	2.5	6.5	16.4
	PAST	9.4	23.2	0.0	0.0	9.4	23.2
	R-O-W	0.4	1.0	0.0	0.0	0.4	1.0
	TRANS	0.0	0.0	0.0	0.0	0.0	0.0
	UF	0.9	2.1	0.0	0.0	0.9	2.1
	ALL	72.0	177.9	3.4	8.5	68.6	169.4
AGRI	BOT	9.6	23.6	0.0	0.0	9.6	23.6
	COM	0.0	0.0	0.0	0.0	0.0	0.0
	FILL	0.3	0.7	0.0	0.0	0.3	0.7
	GRASS	0.1	0.2	0.0	0.0	0.1	0.2
	OF	2.5	6.1	0.0	0.0	2.5	6.1
	PAST	15.6	38.7	0.0	0.0	15.6	38.7
	UF	0.6	1.6	0.0	0.0	0.6	1.6
	ALL	28.7	70.9	0.0	0.0	28.7	70.9

Table G.9 (continued)

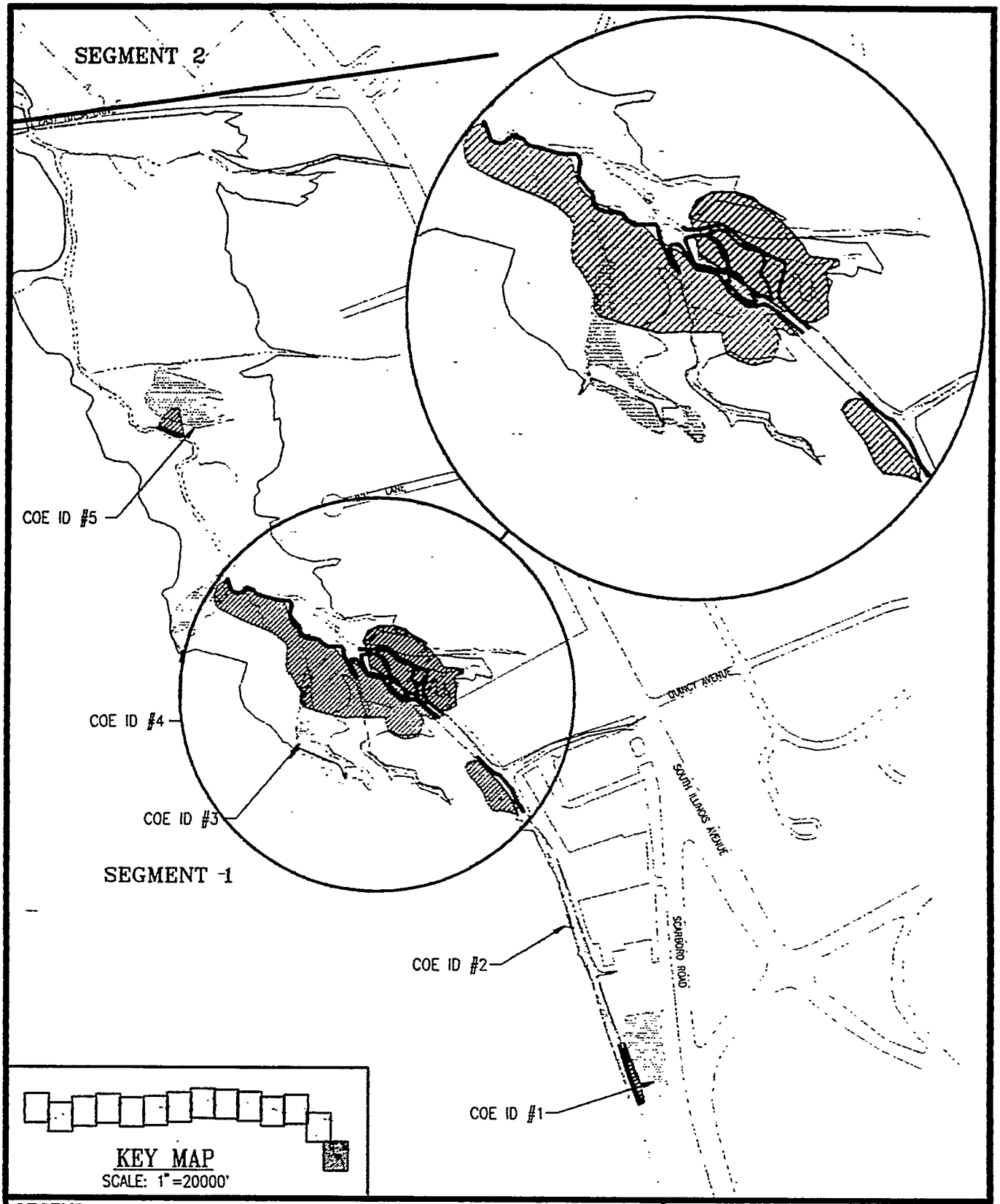
ALL (CONTINUED)		CURRENT		CONVERTED		REMAINING	
		HA	AC	HA	AC	HA	AC
UNDEF	BOT	0.9	2.4	0.0	0.0	0.9	2.4
	COM	0.2	0.6	0.0	0.0	0.2	0.6
	FILL	0.0	0.0	0.0	0.0	0.0	0.0
	GRASS	3.0	7.2	0.0	0.0	3.0	7.2
	HARD	0.0	0.1	0.0	0.0	0.0	0.1
	OF	0.2	0.3	0.0	0.0	0.2	0.3
	PAST	0.0	0.0	0.0	0.0	0.0	0.0
	TRANS	0.3	0.8	0.0	0.0	0.3	0.8
	UF	0.0	0.1	0.0	0.0	0.0	0.1
	ALL	4.6	11.4	0.0	0.0	4.6	11.4
ALL	BOT	137.8	340.4	2.3	5.8	135.5	334.5
	COM	9.5	23.9	0.0	0.0	9.5	23.9
	FILL	1.0	2.5	0.0	0.0	1.0	2.5
	GRASS	17.4	42.5	0.1	0.2	17.3	42.3
	HARD	3.2	8.1	0.0	0.0	3.2	8.1
	LAWN	1.8	4.4	0.0	0.0	1.8	4.4
	OF	24.0	59.2	1.0	2.5	23.0	56.7
	PAST	25.0	61.9	0.0	0.0	25.0	61.9
	PINE	8.0	19.9	0.0	0.0	8.0	19.9
	R-O-W	0.4	1.0	0.0	0.0	0.4	1.0
	TRANS	0.5	1.3	0.0	0.0	0.5	1.3
	UF	27.5	68.0	0.0	0.0	27.5	68.0
	ALL	256.1	633.1	3.4	8.5	252.7	624.6

This page intentionally left blank.

APPENDIX G

FIGURES

This page intentionally left blank.

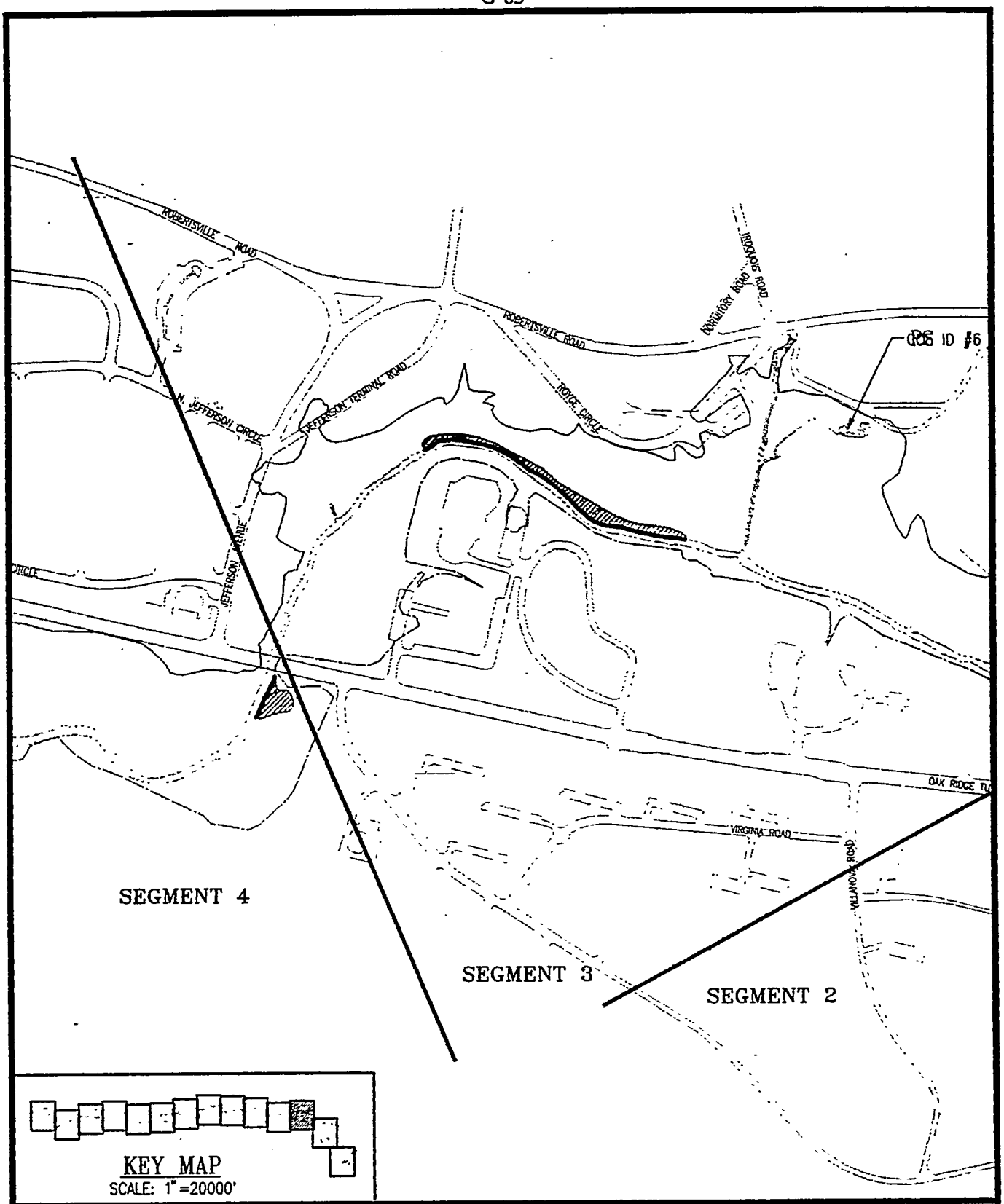


EAST FORK POPLAR CREEK OAK RIDGE, TENNESSEE

Fig. G.1 (a). Riparian habitat and wetlands with contamination levels in the 100-year floodplain (SWAs 2 through 6).

SHT. 1 OF 6	94015\DWGS\73SWET5.DWG	V1
DRAWING #	CAD FILE #	VIEW

This page intentionally left blank.



KEY MAP
SCALE: 1"=20000'

LEGEND:

- PRIMARY ROADS
- SECONDARY ROADS
- CREEK & TRIBUTARIES
- 100 YEAR FLOODPLAIN
- REMEDIAL INVESTIGATION SEGMENT
- SEGMENT 1 SEGMENT
- WETLANDS
- Hg CONTAMINATION >180 PPM
- Hg CONTAMINATION >200 PPM

RESIDENTIAL MERCURY (Hg) CONTAMINATION (DEPTH 0-32")
> 180 PPM

COMMERCIAL-DOE-OTHER MERCURY (Hg) CONTAMINATION (DEPTH 0-32")
> 200 PPM

34°13'± O.R. ADMIN. GRID TRUE NORTH

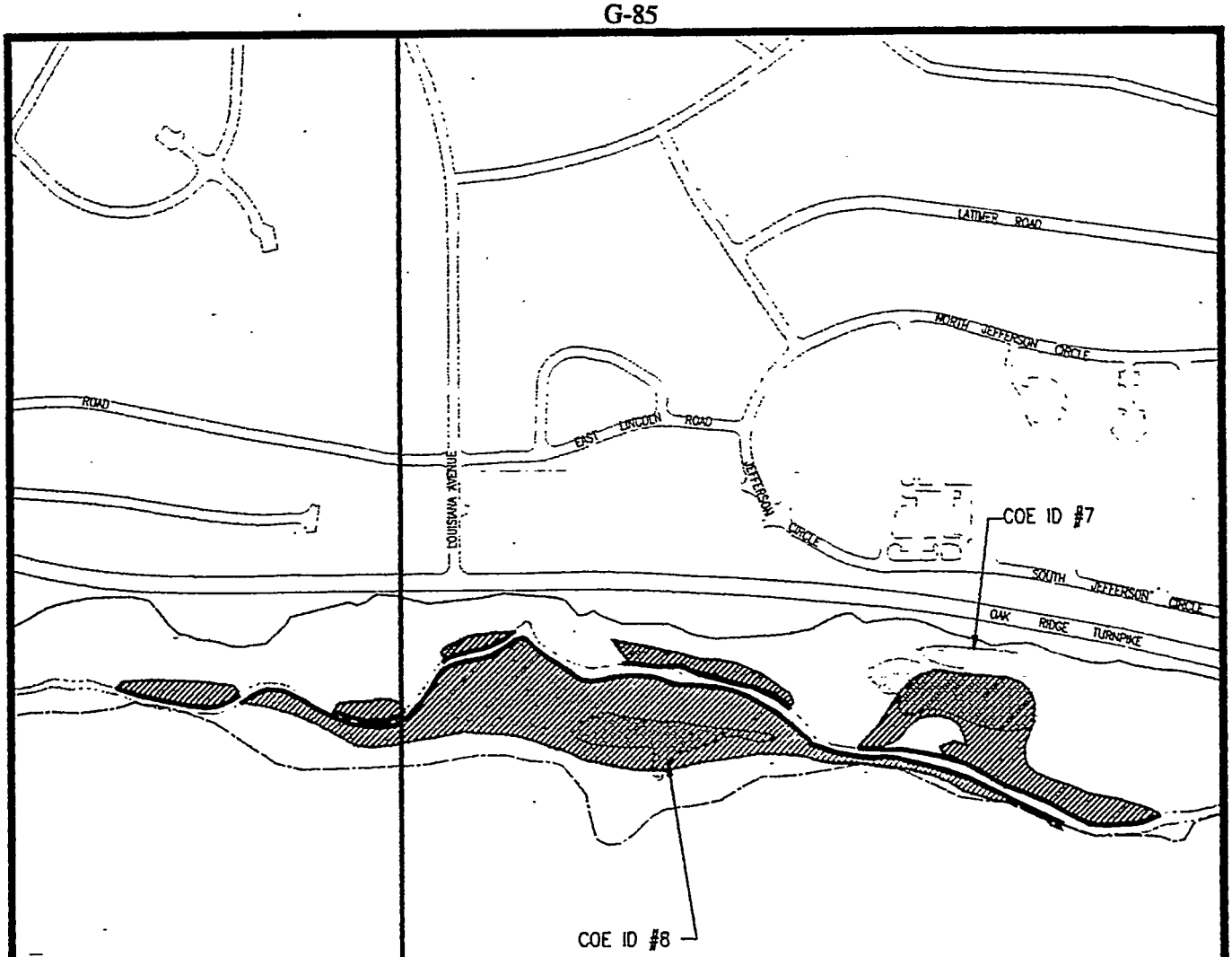
0 250 500
SCALE: 1" = 500'

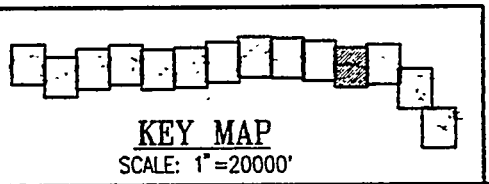
EAST FORK POPLAR CREEK OAK RIDGE, TENNESSEE

Fig. G.1 (b). Riparian habitat and wetlands with contamination levels in the 100-year floodplain (SWAs 2 through 6).

SHT. 2 OF 6	94015\DWGS\735WETS.DWG	V3
DRAWING #	CAD FILE #	VIEW

This page intentionally left blank.





LEGEND:

- PRIMARY ROADS
- SECONDARY ROADS
- CREEK & TRIBUTARIES
- 100 YEAR FLOODPLAIN
- REMEDIAL INVESTIGATION SEGMENT 1 SEGMENT
- WETLANDS
- Hg CONTAMINATION >180 PPM
- Hg CONTAMINATION >200 PPM

RESIDENTIAL MERCURY (Hg) CONTAMINATION (DEPTH 0–32")
> 180 PPM

COMMERCIAL–DOE–OTHER MERCURY (Hg) CONTAMINATION (DEPTH 0–32")
> 200 PPM

34°13'± O.R. ADMIN. GRID TRUE NORTH

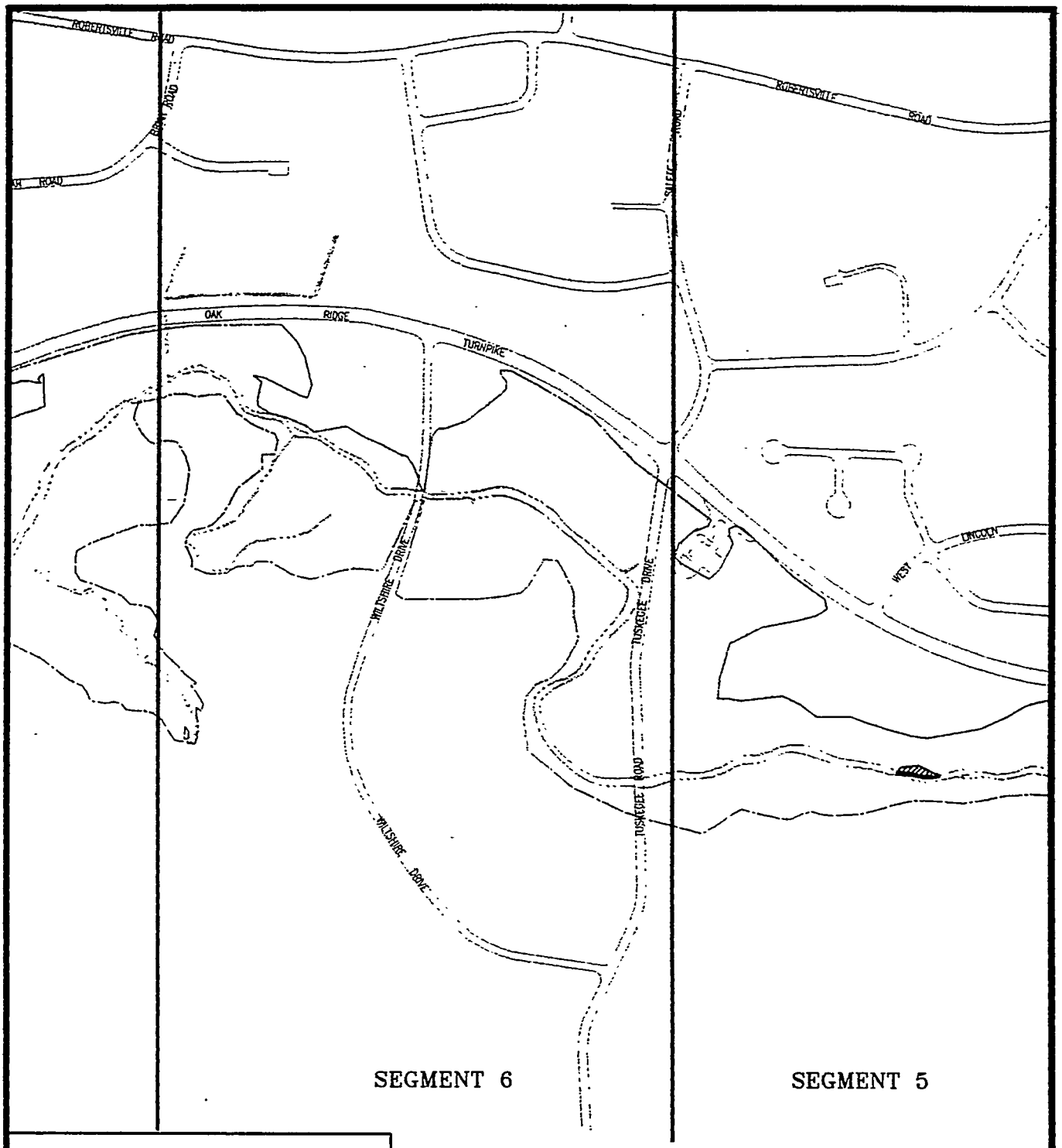
0 250 500
SCALE: 1" = 500'

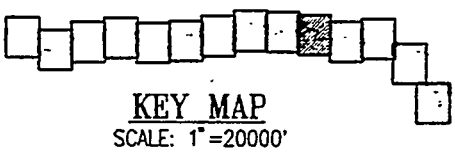
EAST FORK POPLAR CREEK OAK RIDGE, TENNESSEE

Fig. G.1 (c). Riparian habitat and wetlands with contamination levels in the 100-year floodplain (SWAs 2 through 6).

SHT. 3 OF 6 DRAWING | 94015\DWGS\73SWETS.DWG CAD FILE | V4 VIEW

This page intentionally left blank.





KEY MAP
SCALE: 1"=20000'

LEGEND:

- PRIMARY ROADS
- SECONDARY ROADS
- CREEK & TRIBUTARIES
- 100 YEAR FLOODPLAIN
- REMEDIAL INVESTIGATION SEGMENT 1 SEGMENT
- WETLANDS
- Hg CONTAMINATION >180 PPM
- Hg CONTAMINATION >200 PPM

RESIDENTIAL MERCURY (Hg) CONTAMINATION (DEPTH 0-32")
> 180 PPM

COMMERCIAL-DOE-OTHER MERCURY (Hg) CONTAMINATION (DEPTH 0-32")
> 200 PPM

34°13'± O.R. ADMIN. GRID TRUE NORTH

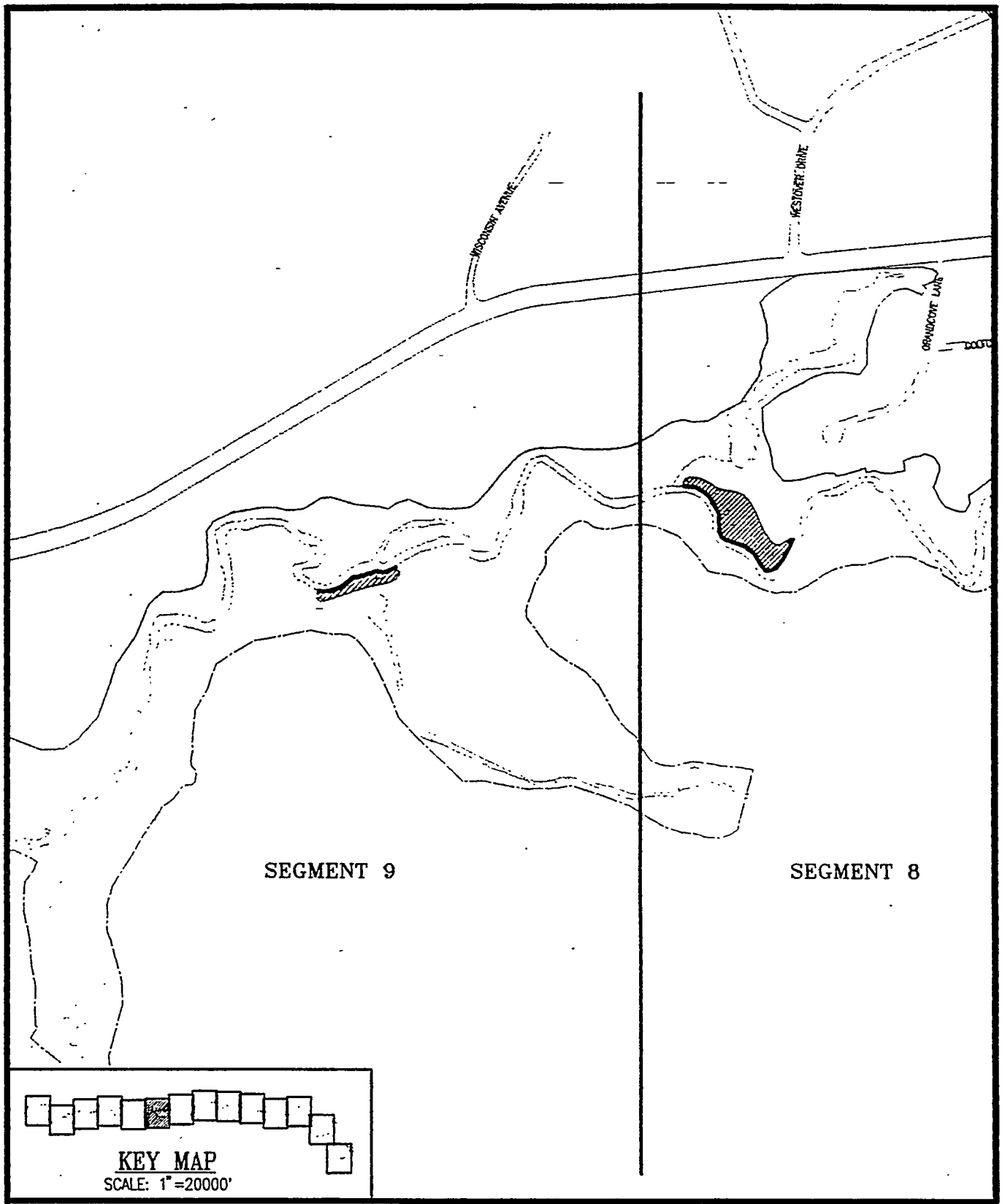
0 250 500
SCALE: 1" = 500'

EAST FORK POPLAR CREEK OAK RIDGE, TENNESSEE

Fig. G.1 (d). Riparian habitat and wetlands with contamination levels in the 100-year floodplain (SWAs 2 through 6).

SHT 4 OF 6	94015\DWGS\735WET5.DWG	V5
DRAWING #	CAD FILE #	VIEW

This page intentionally left blank.



KEY MAP
SCALE: 1"=20000'

LEGEND:

- PRIMARY ROADS
- SECONDARY ROADS
- CREEK & TRIBUTARIES
- 100 YEAR FLOODPLAIN
- REMEDIAL INVESTIGATION SEGMENT 1 SEGMENT
- WETLANDS
- ...Hg CONTAMINATION >180 PPM
- ...Hg CONTAMINATION >200 PPM

RESIDENTIAL MERCURY (Hg) CONTAMINATION (DEPTH 0-32")
.....> 180 PPM

COMMERCIAL-DOE-OTHER MERCURY (Hg) CONTAMINATION (DEPTH 0-32")
.....> 200 PPM

34°13'± O.R. ADMIN. GRID TRUE NORTH

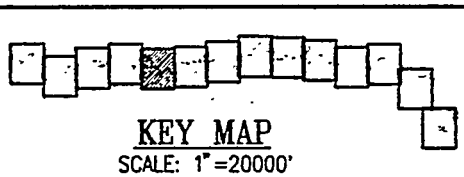
0 250 500
SCALE: 1" = 500'

EAST FORK POPLAR CREEK OAK RIDGE, TENNESSEE

Fig. G.1 (e). Riparian habitat and wetlands with contamination levels in the 100-year floodplain (SWAs 2 through 6).

SHT. 5 OF 6	94015\DWGS\735WETS.DWG	V9
DRAWING #	CAD FILE #	VIEW

This page intentionally left blank.



LEGEND:

- PRIMARY ROADS
- SECONDARY ROADS
- CREEK & TRIBUTARIES
- 100 YEAR FLOODPLAIN
- REMEDIAL INVESTIGATION SEGMENT 1 SEGMENT
- WETLANDS
- Hg CONTAMINATION >180 PPM
- Hg CONTAMINATION >200 PPM

RESIDENTIAL MERCURY (Hg) CONTAMINATION (DEPTH 0-32") > 180 PPM

COMMERCIAL-DOE-OTHER MERCURY (Hg) CONTAMINATION (DEPTH 0-32") > 200 PPM

34°13'± O.R. ADMIN. GRID TRUE NORTH

0 250 500

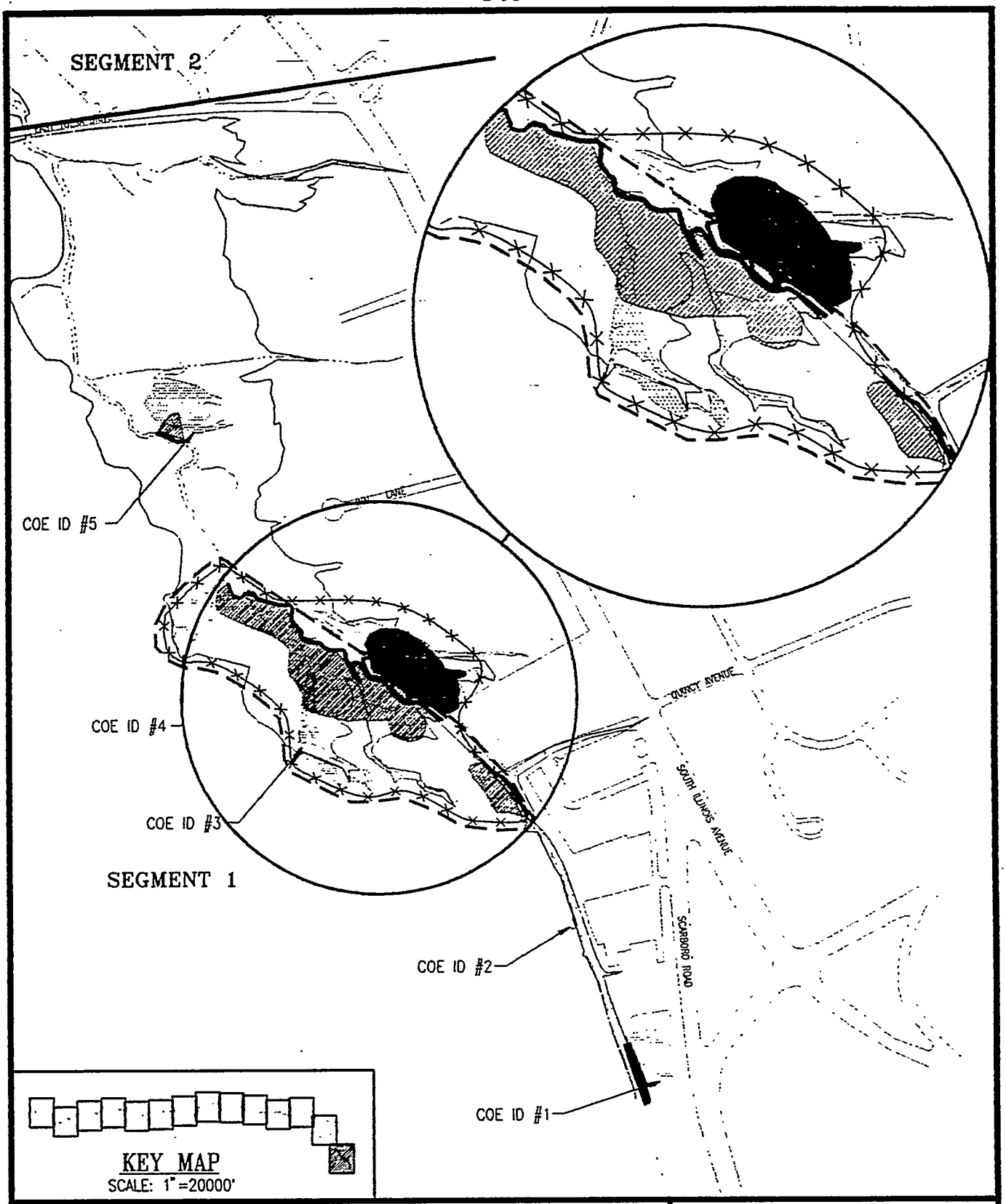
SCALE: 1" = 500'

EAST FORK POPLAR CREEK OAK RIDGE, TENNESSEE

Fig. G.1 (f). Riparian habitat and wetlands with contamination levels in the 100-year floodplain (SWAs 2 through 6).

SHT. 6 OF 6	94015\DWGS\7.3SHEETS.DWG	V10
DRAWING #	CAD FILE #	VIEW

This page intentionally left blank.

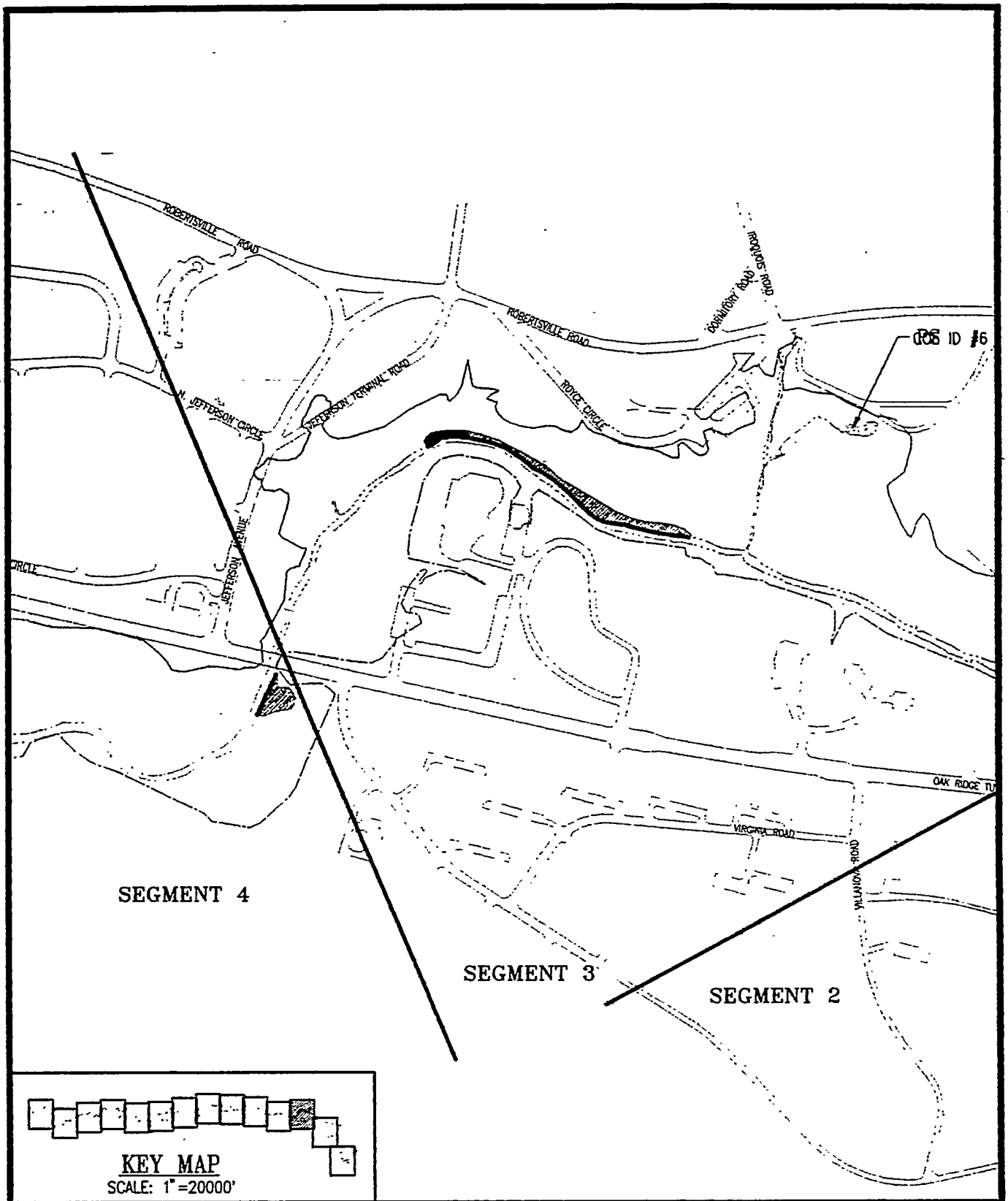


EAST FORK POPLAR CREEK OAK RIDGE, TENNESSEE

Fig. G.2 (a). Riparian habitat and wetlands with contamination levels in the 100-year floodplain (SWA 7).

SHT. 1 OF 6	94015\DWGS\735WET7.DWG	V1
DRAWING #	CAD FILE #	VIEW

This page intentionally left blank.

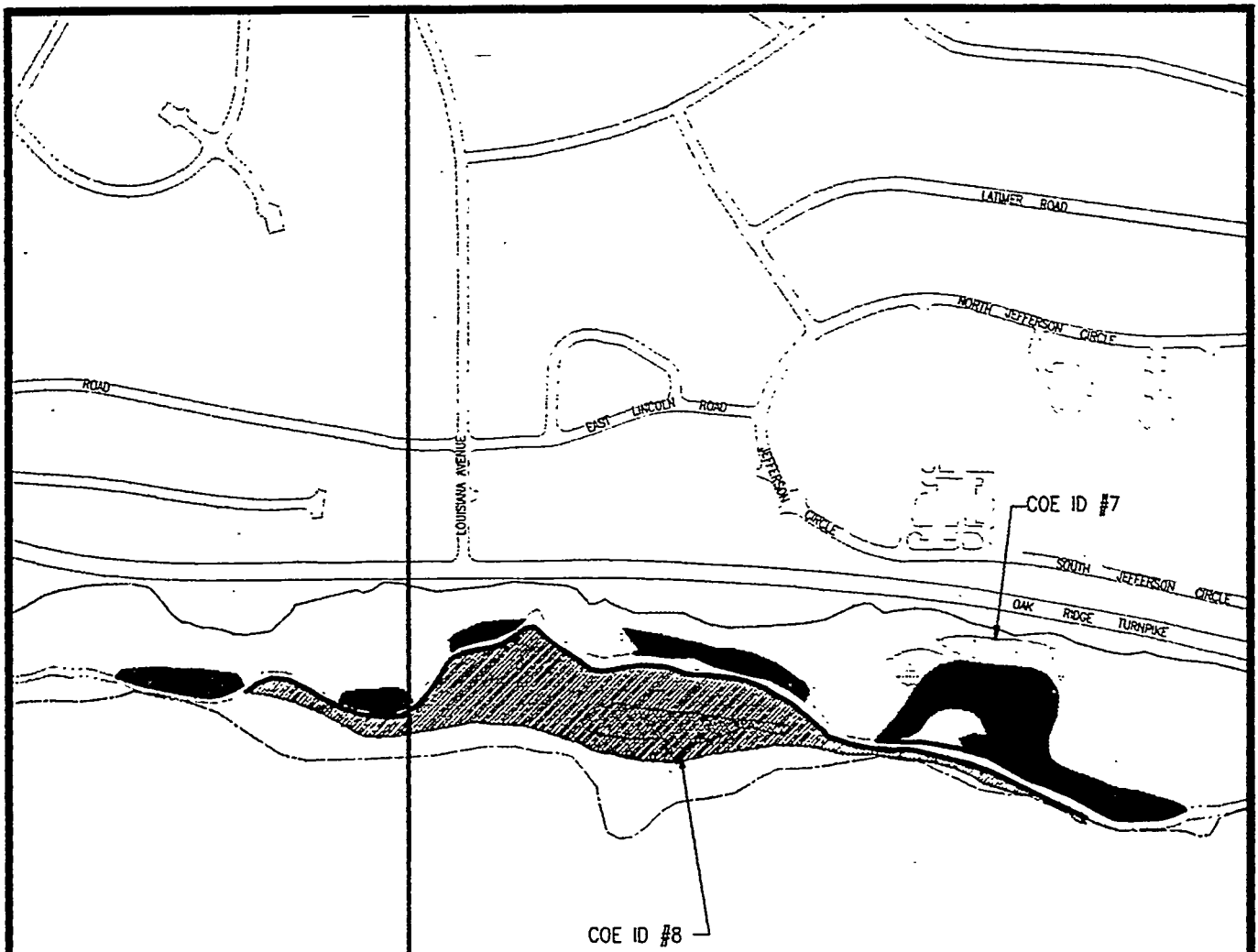


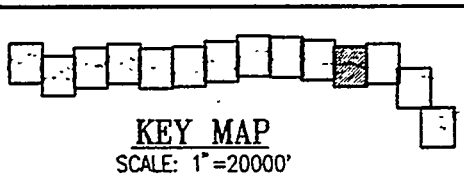
EAST FORK POPLAR CREEK OAK RIDGE, TENNESSEE

Fig. G.2 (b). Riparian habitat and wetlands with contamination levels in the 100-year floodplain (SWA 7).

SHT. 2 OF 6	94015\DWGS\735WET7.DWG	V2
DRAWING #	CAD FILE #	VIEW

This page intentionally left blank.



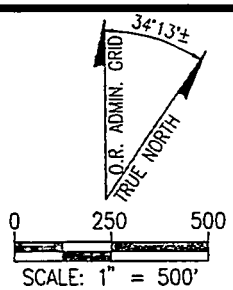


LEGEND:

- PRIMARY ROADS
- SECONDARY ROADS
- CREEK & TRIBUTARIES
- 100 YEAR FLOODPLAIN
- REMEDIAL INVESTIGATION SEGMENT 1 ..... SEGMENT
- WETLANDS
- Hg CONTAMINATION >180 PPM
- Hg CONTAMINATION >180 PPM

RESIDENTIAL MERCURY (Hg) CONTAMINATION (DEPTH 0-32")
..... > 180 PPM

COMMERCIAL-DOE-OTHER CONTAMINATION (DEPTH 0-32")
..... > 180 PPM

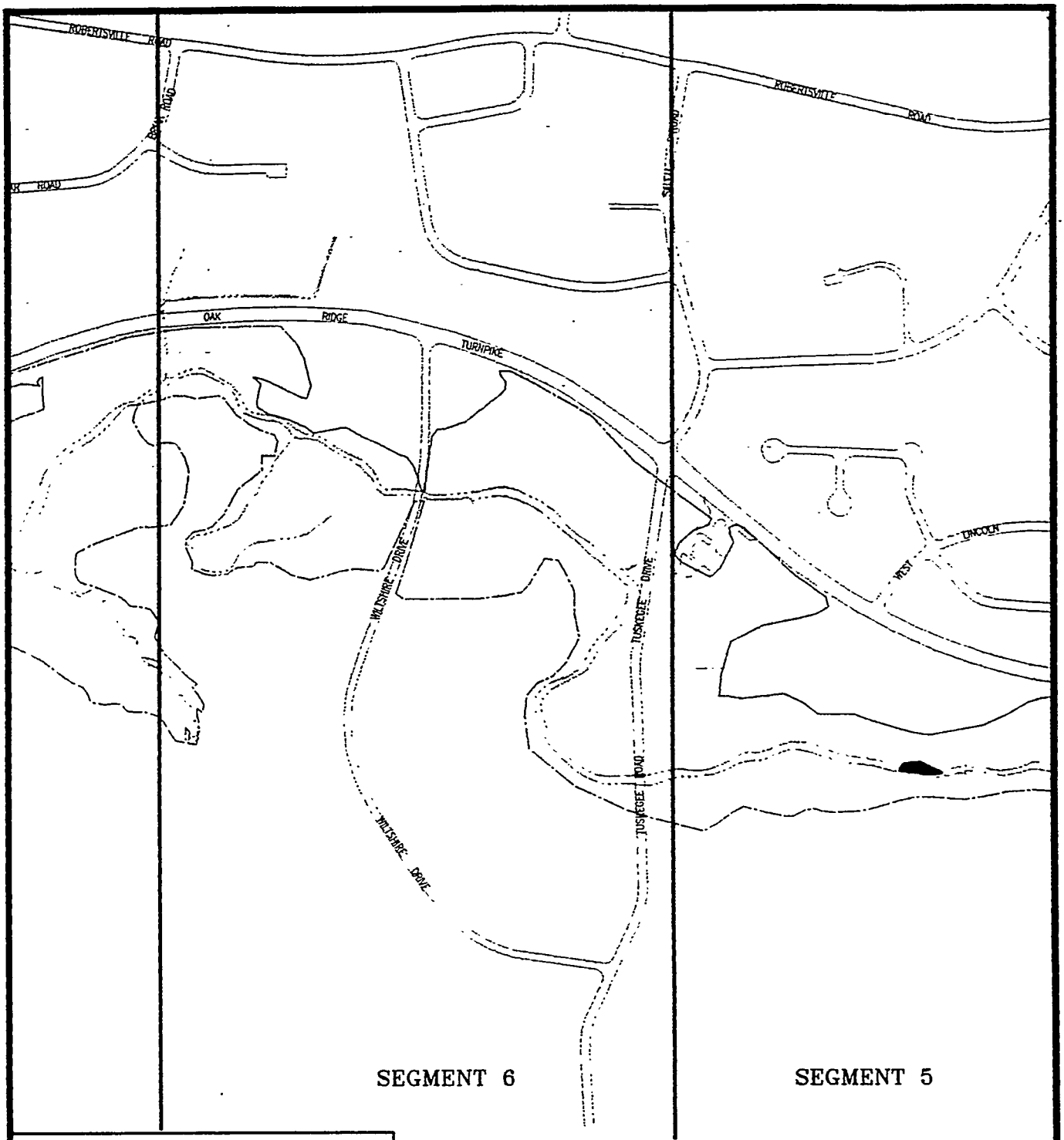


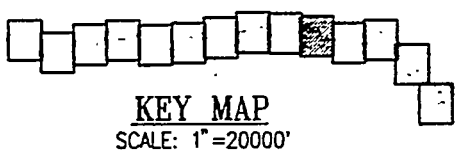
EAST FORK POPLAR CREEK OAK RIDGE, TENNESSEE

Fig. G.2 (c). Riparian habitat and wetlands with contamination levels in the 100-year floodplain (SWA 7).

SHT. 3 OF 6	94015\DWGS\73SWET7.DWG	V4
DRAWING #	CAD FILE #	VIEW

This page intentionally left blank.





KEY MAP
SCALE: 1"=20000'

LEGEND:

- PRIMARY ROADS
- SECONDARY ROADS
- CREEK & TRIBUTARIES
- 100 YEAR FLOODPLAIN
- REMEDIAL INVESTIGATION SEGMENT 1 SEGMENT
- WETLANDS
- Hg CONTAMINATION >180 PPM
- Hg CONTAMINATION >180 PPM

RESIDENTIAL MERCURY (Hg) CONTAMINATION (DEPTH 0-32")
> 180 PPM

COMMERCIAL-DOE-OTHER CONTAMINATION (DEPTH 0-32")
> 180 PPM

34°13'± O.R. ADMIN. GRID TRUE NORTH

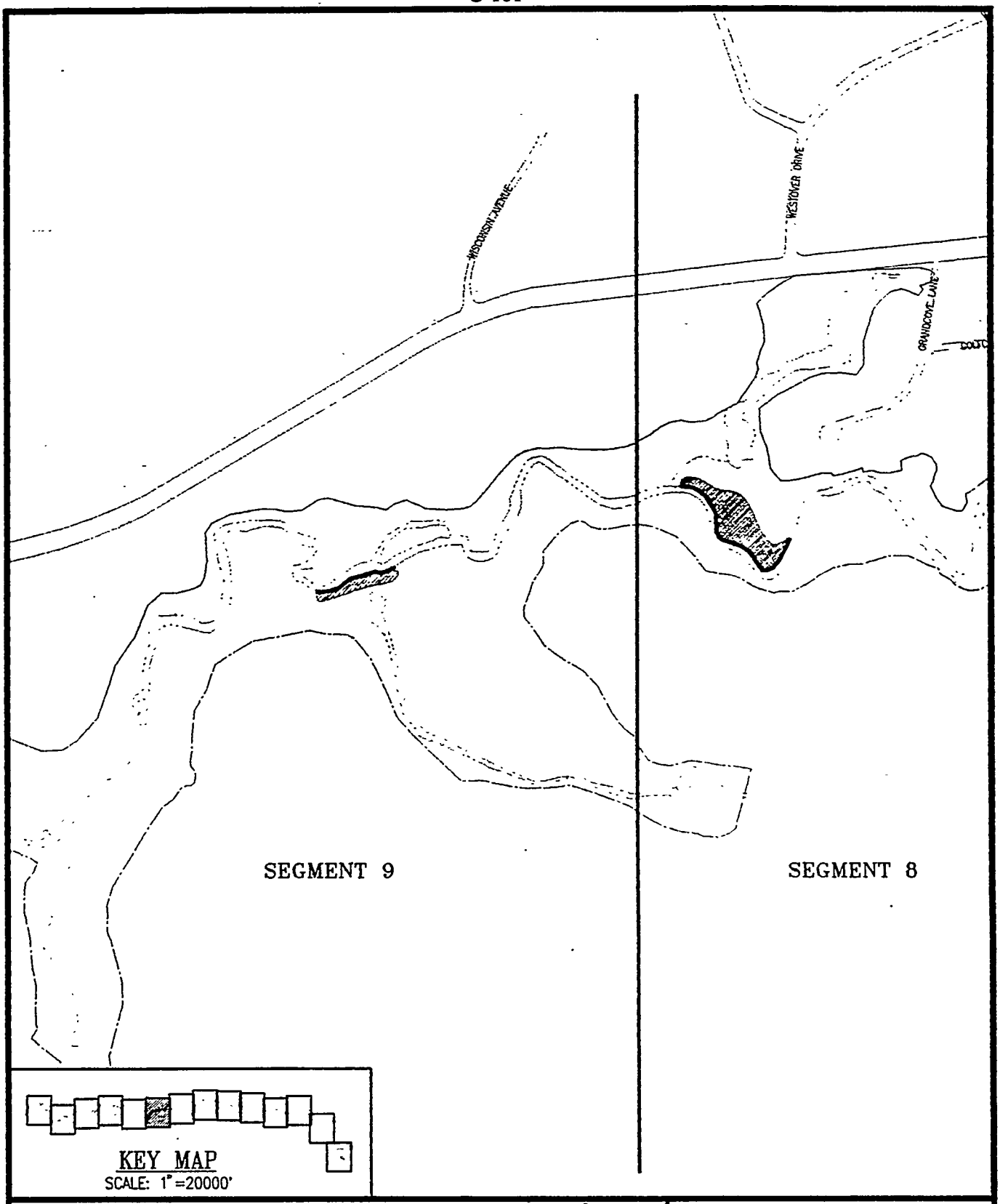
0 250 500
SCALE: 1" = 500'

EAST FORK POPLAR CREEK OAK RIDGE, TENNESSEE

Fig. G.2 (d). Riparian habitat and wetlands with contamination levels in the 100-year floodplain (SWA 7).

SHT. 4 OF 6 DRAWING # | 94015\DWGS\735WET7.DWG CAD FILE # | V5 VIEW

This page intentionally left blank.



KEY MAP
SCALE: 1"=20000'

LEGEND:

- PRIMARY ROADS
- SECONDARY ROADS
- CREEK & TRIBUTARIES
- 100 YEAR FLOODPLAIN
- REMEDIAL INVESTIGATION SEGMENT 1 SEGMENT
- WETLANDS
- Hg CONTAMINATION >180 PPM
- Hg CONTAMINATION >180 PPM

RESIDENTIAL MERCURY (Hg) CONTAMINATION (DEPTH 0-32")
> 180 PPM

COMMERCIAL-DOE-OTHER CONTAMINATION (DEPTH 0-32")
> 180 PPM

34°13'± O.R. ADMIN. GRID TRUE NORTH

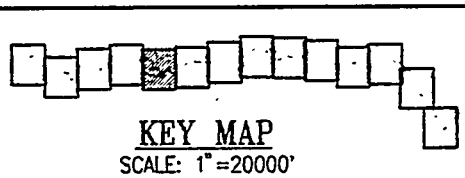
0 250 500
SCALE: 1" = 500'

EAST FORK POPLAR CREEK OAK RIDGE, TENNESSEE

Fig. G.2 (e). Riparian habitat and wetlands with contamination levels in the 100-year floodplain (SWA 7).

SHT. 5 OF 6 DRAWING # | 94015\DWGS\735WET7.DWG CAD FILE # | V9 VIEW

This page intentionally left blank.

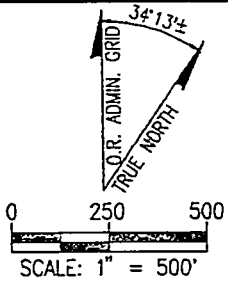


LEGEND:

- PRIMARY ROADS
- SECONDARY ROADS
- CREEK & TRIBUTARIES
- 100 YEAR FLOODPLAIN
- REMEDIAL INVESTIGATION SEGMENT
- SEGMENT 1 SEGMENT
- WETLANDS
- ...Hg CONTAMINATION >180 PPM
- ...Hg CONTAMINATION >180 PPM

RESIDENTIAL MERCURY (Hg) CONTAMINATION (DEPTH 0-3Z")
> 180 PPM

COMMERCIAL-DOE-OTHER CONTAMINATION (DEPTH 0-3Z")
> 180 PPM

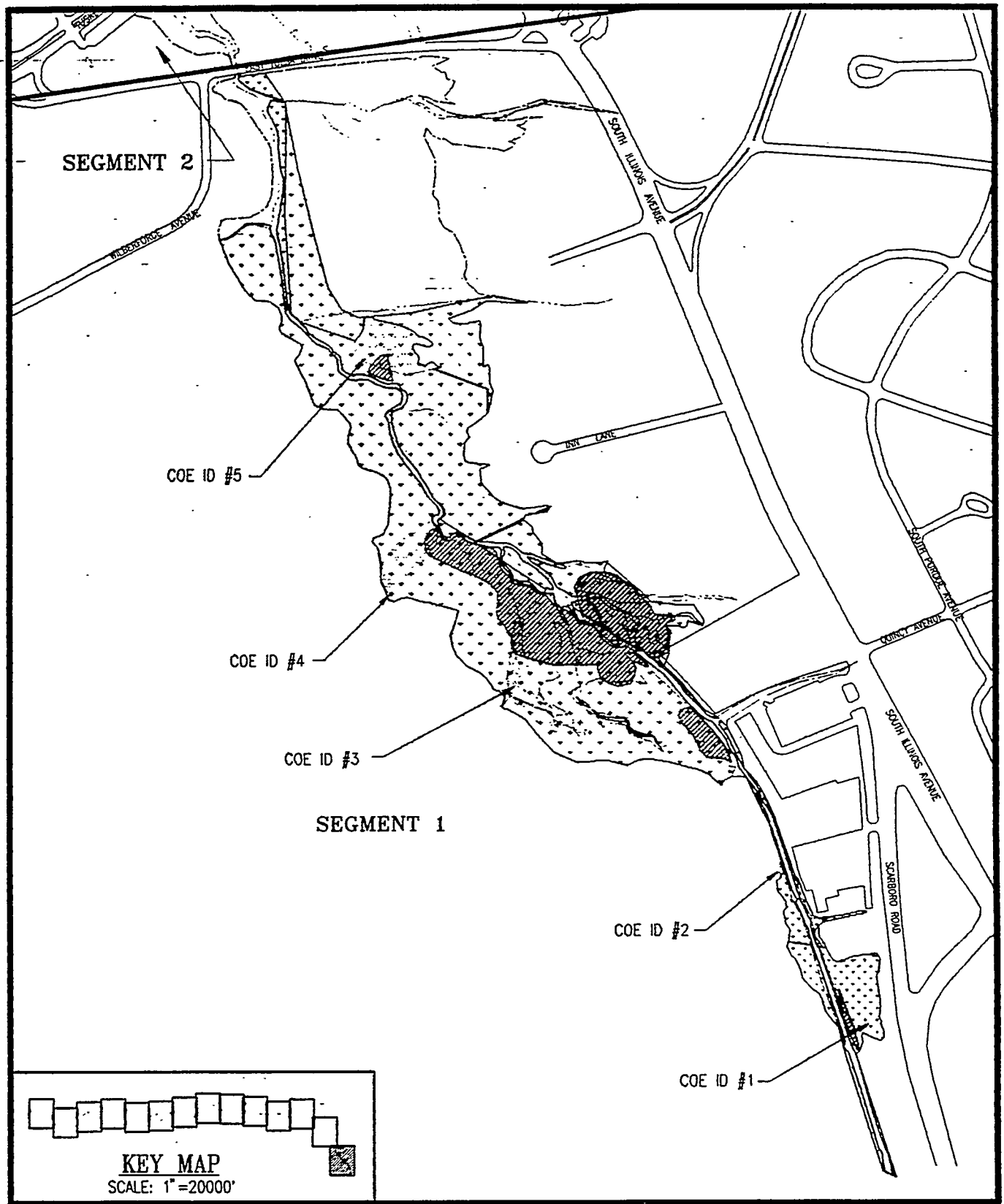


EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE

Fig. G.2 (f). Riparian habitat and wetlands with contamination levels in the 100-year floodplain (SWA 7).

SHT. 6 OF 6	94015\DWGS\735WET7.DWG	V10
DRAWING #	CAD FILE #	VIEW

This page intentionally left blank.



LEGEND:

- PRIMARY ROADS
- SECONDARY ROADS
- CREEK & TRIBUTARIES
- 100 YEAR FLOODPLAIN
- REMEDIAL INVESTIGATION SEGMENT 1 SEGMENT
- WETLANDS
- BOTTOMLAND HARDWOOD FOREST AREA

RESIDENTIAL MERCURY (Hg) CONTAMINATION (DEPTH 0-32")
- > 180 PPM

COMMERCIAL-DOE-OTHER MERCURY (Hg) CONTAMINATION (DEPTH 0-32")
- > 200 PPM

34°13'± O.R. ADMIN. GRID TRUE NORTH

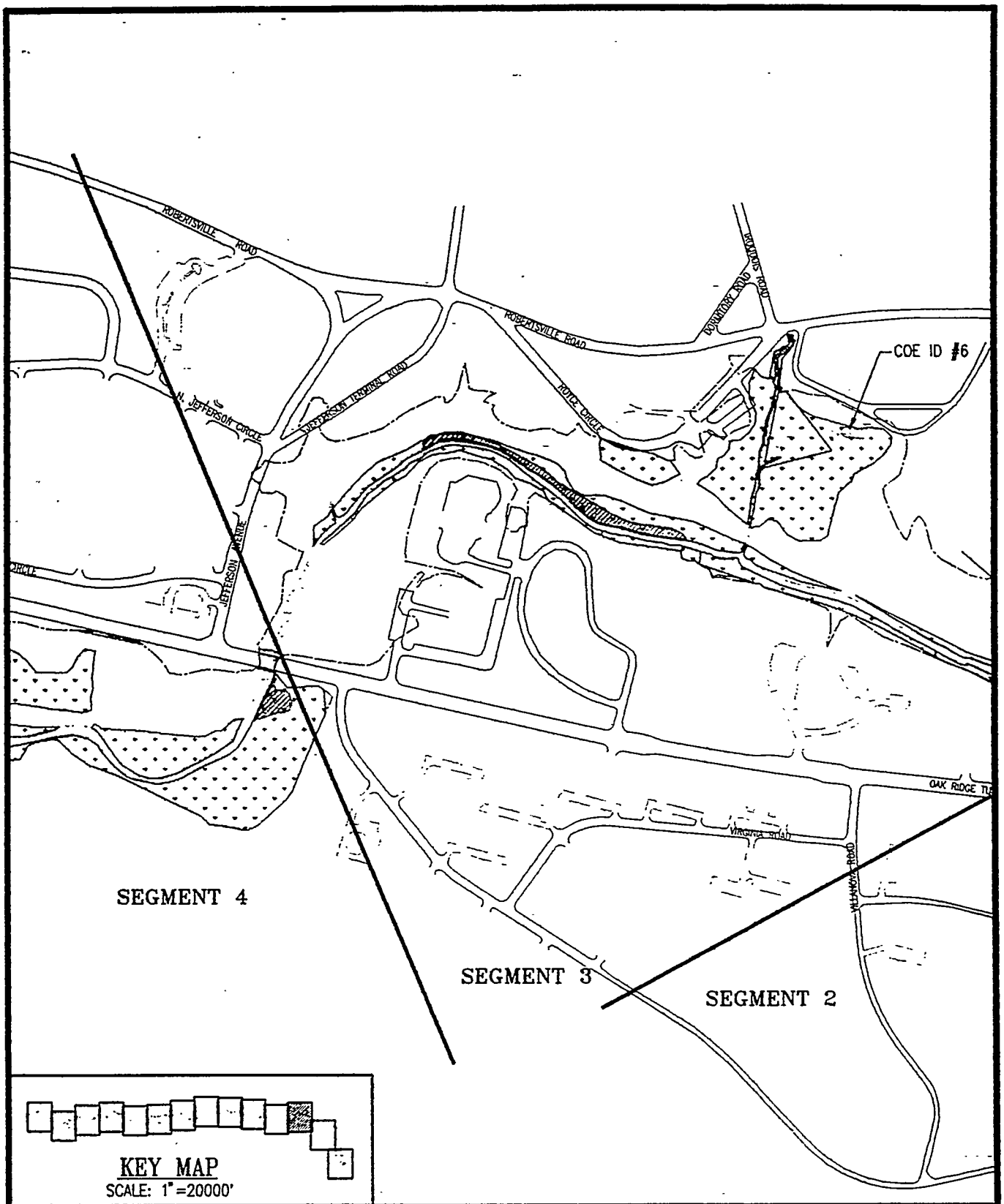
0 250 500
SCALE: 1" = 500'

EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE

Fig. G.3 (a). Contaminated forest areas along East Fork Poplar Creek (SWAs 2 through 6).

SHT. 1 OF 6	94015\DWGS\735FOR.DWG	V1
DRAWING #	CAD FILE #	VIEW

This page intentionally left blank.



KEY MAP
SCALE: 1"=20000'

LEGEND:

- PRIMARY ROADS
- SECONDARY ROADS
- CREEK & TRIBUTARIES
- 100 YEAR FLOODPLAIN
- REMEDIAL INVESTIGATION SEGMENT 1 SEGMENT
- WETLANDS
- BOTTOMLAND HARDWOOD FOREST AREA

RESIDENTIAL MERCURY (Hg) CONTAMINATION (DEPTH 0-32")
- > 180 PPM

COMMERCIAL-DOE-OTHER MERCURY (Hg) CONTAMINATION (DEPTH 0-32")
- > 200 PPM

34°13'± O.R. ADMIN. GRID TRUE NORTH

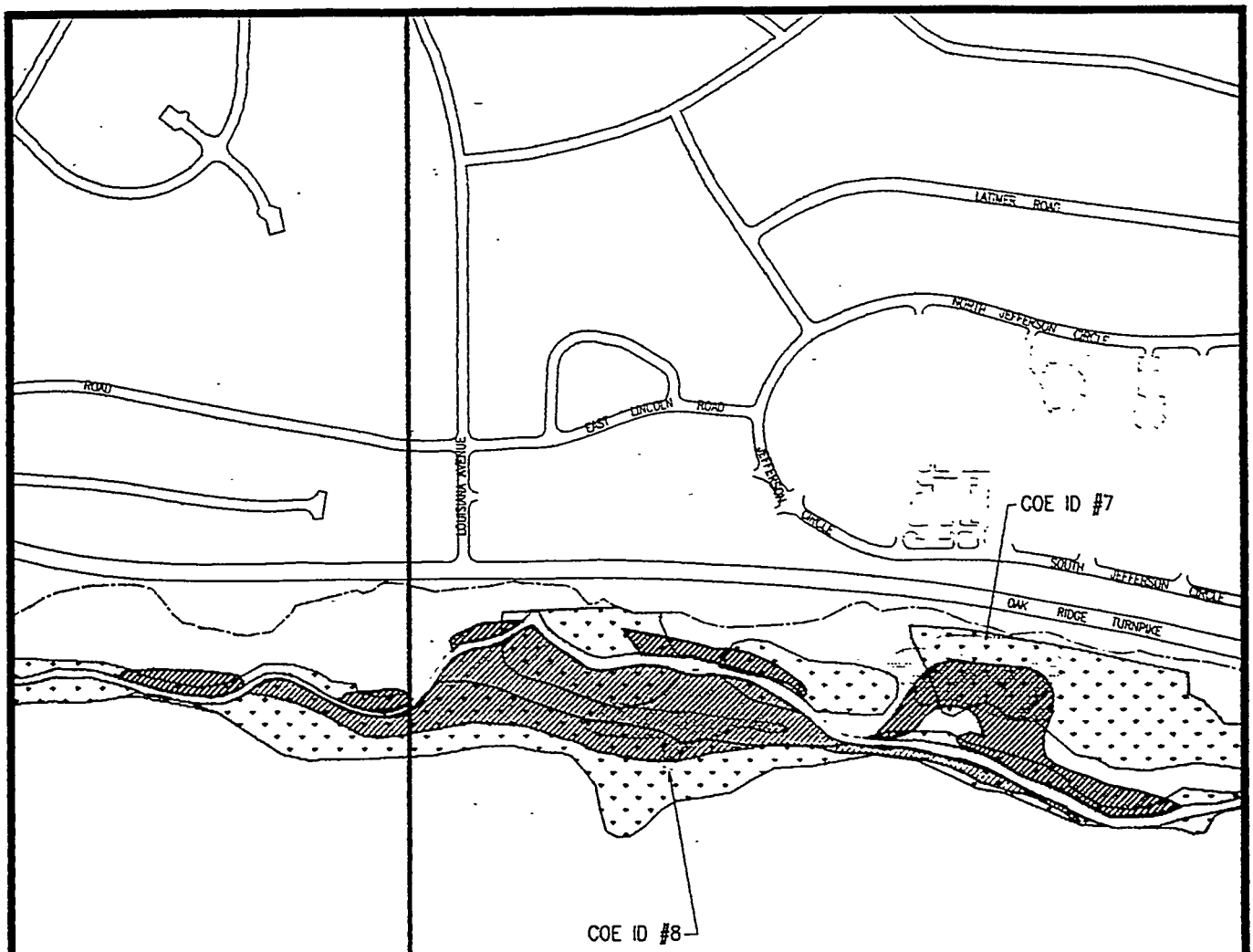
0 250 500
SCALE: 1" = 500'

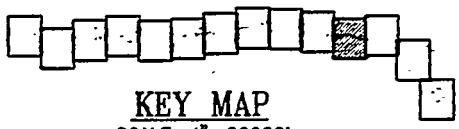
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE

Fig. G.3 (b). Contaminated forest areas along East Fork Poplar Creek (SWAs 2 through 6).

SHT. 2 OF 6 DRAWING # | 94015\DWGS\735FOR.DWG CAD FILE # | V3 VIEW

This page intentionally left blank.





KEY MAP
SCALE: 1"=20000'

LEGEND:

- PRIMARY ROADS
- SECONDARY ROADS
- CREEK & TRIBUTARIES
- 100 YEAR FLOODPLAIN
- REMEDIAL INVESTIGATION SEGMENT 1 SEGMENT
- WETLANDS
- BOTTOMLAND HARDWOOD FOREST AREA

RESIDENTIAL MERCURY (Hg) CONTAMINATION (DEPTH 0-32")
- > 180 PPM

COMMERCIAL-DOE-OTHER MERCURY (Hg) CONTAMINATION (DEPTH 0-32")
- > 200 PPM

34°13'± O.R. ADMIN. GRID TRUE NORTH

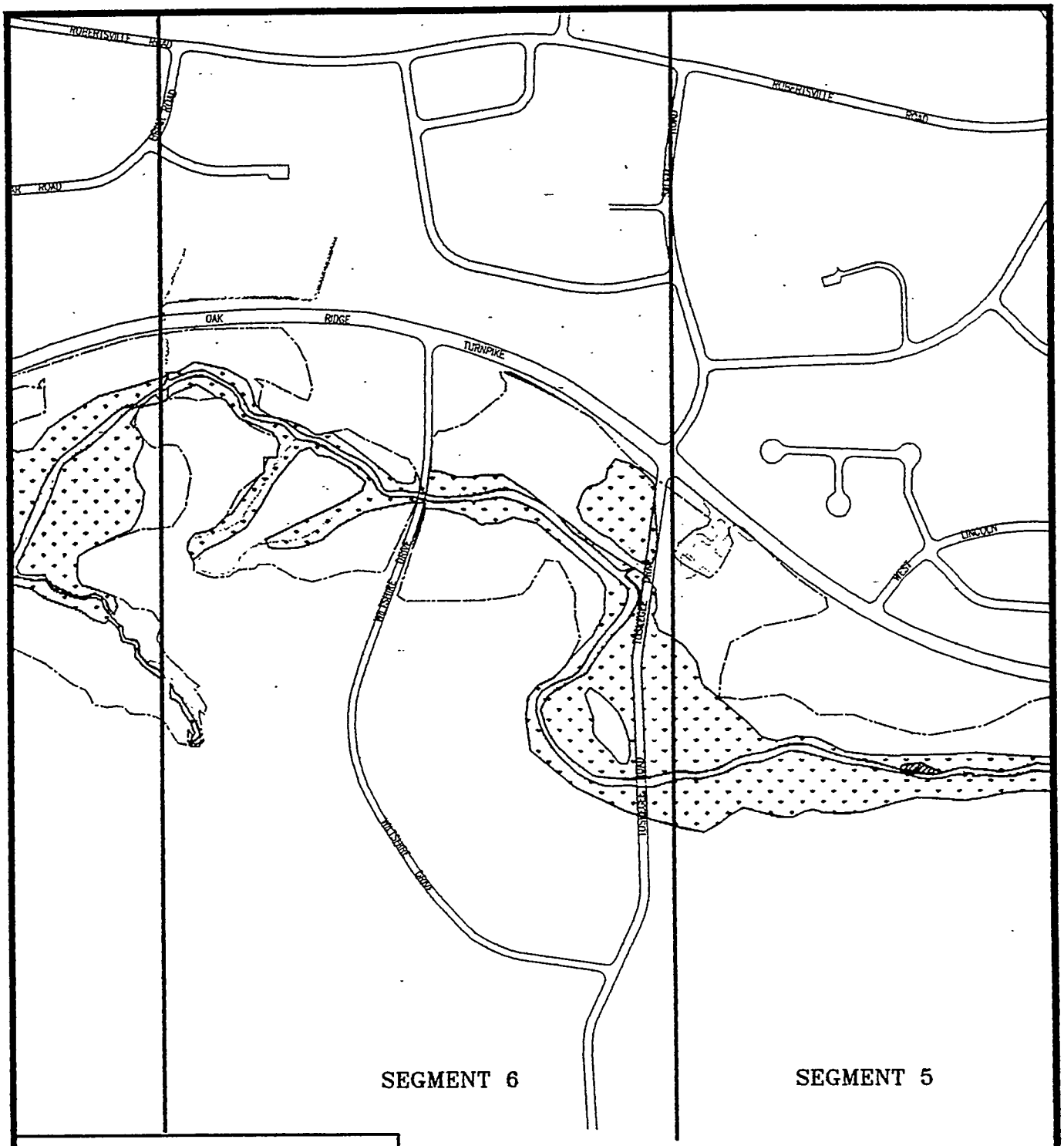
0 250 500
SCALE: 1" = 500'

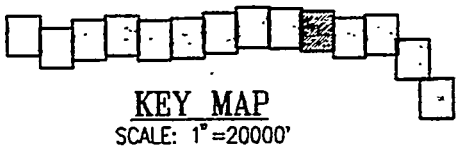
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE

Fig. G.3 (c). Contaminated forest areas along East Fork Poplar Creek (SWAs 2 through 6).

SHT 3 OF 6	94015\DWGS\735FOR.DWG	V4
DRAWING #	CAD FILE	VIEW

This page intentionally left blank.





KEY MAP
SCALE: 1"=20000'

LEGEND:
- PRIMARY ROADS
- SECONDARY ROADS
- CREEK & TRIBUTARIES
- 100 YEAR FLOODPLAIN
- REMEDIAL INVESTIGATION SEGMENT 1 SEGMENT
- WETLANDS
- BOTTOMLAND HARDWOOD FOREST AREA

RESIDENTIAL MERCURY (Hg) CONTAMINATION (DEPTH 0-32")
- > 180 PPM

COMMERCIAL-DOE-OTHER MERCURY (Hg) CONTAMINATION (DEPTH 0-32")
- > 200 PPM

34°13'± O.R. ADMIN. GRID / TRUE NORTH

0 250 500
SCALE: 1" = 500'

EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE

Fig. G.3 (d). Contaminated forest areas along East Fork Poplar Creek (SWAs 2 through 6).

SHT. 4 OF 6 DRAWING # | 94015\DWGS\735FOR.DWG CAD FILE # | V5 VIEW

This page intentionally left blank.

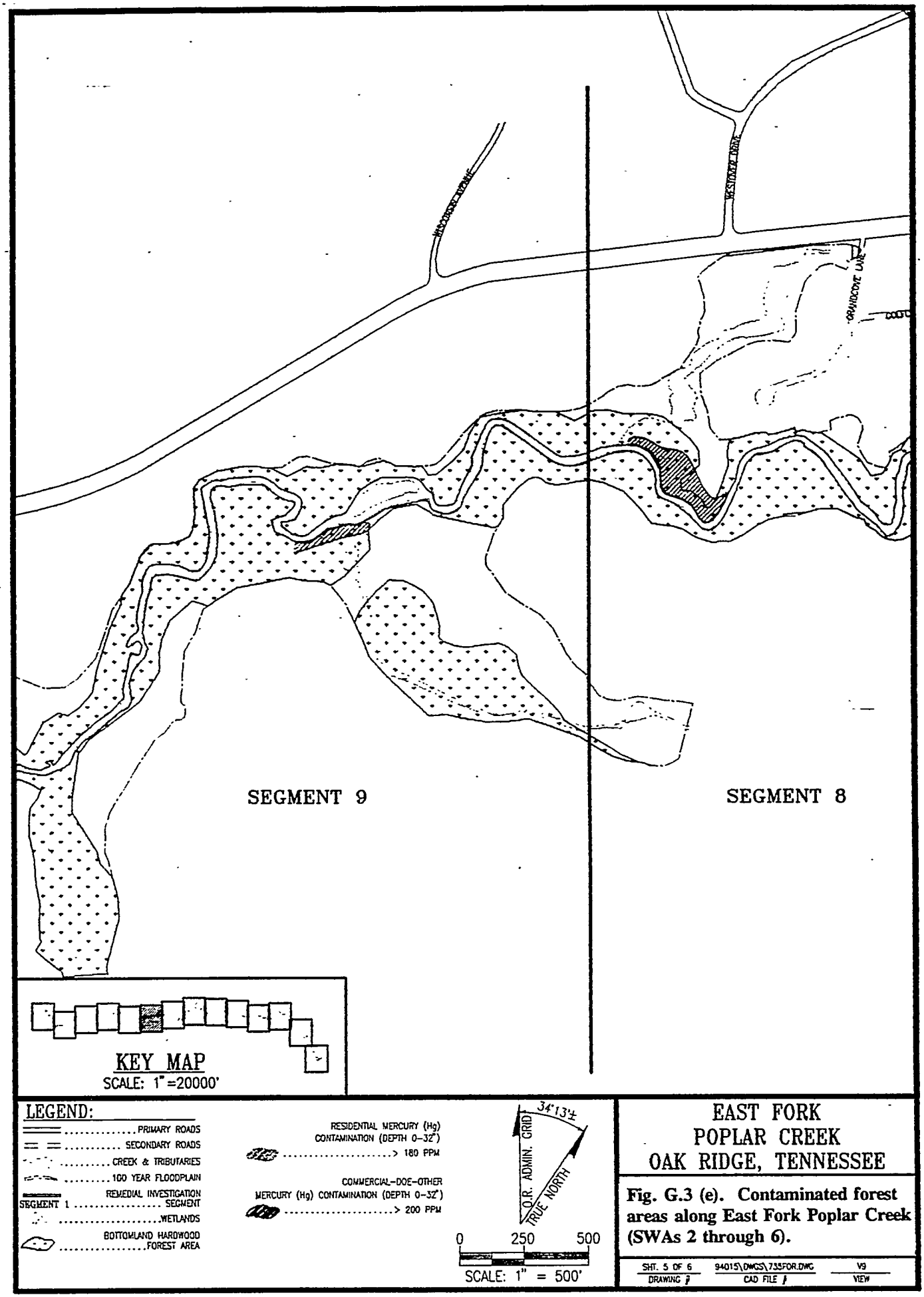
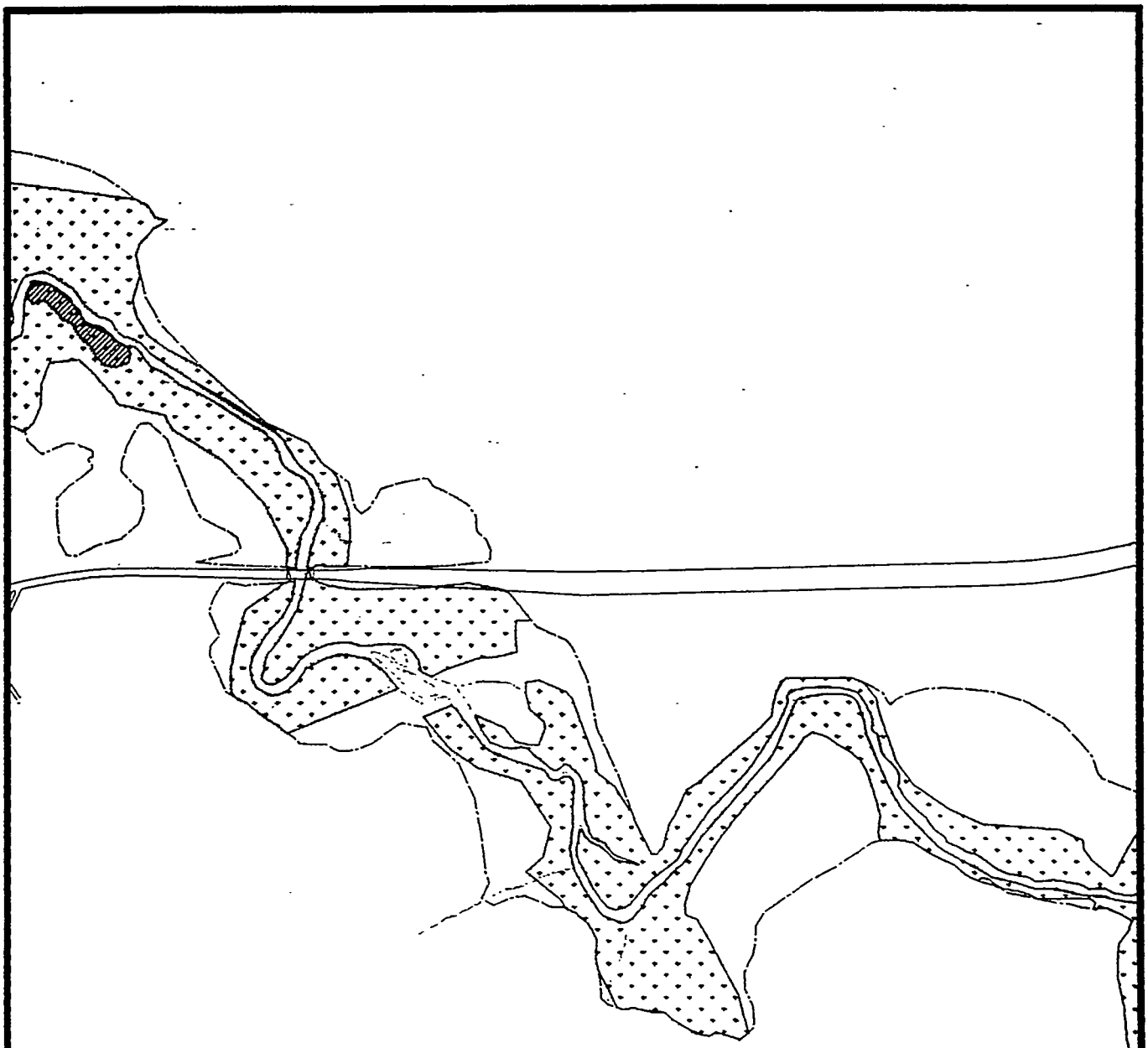
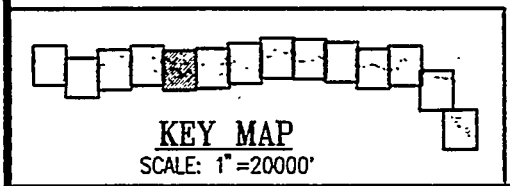


Fig. G.3 (e). Contaminated forest areas along East Fork Poplar Creek (SWAs 2 through 6).

This page intentionally left blank.



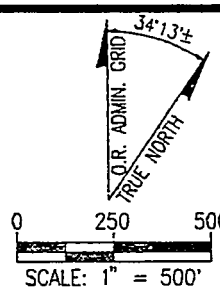


LEGEND:

- PRIMARY ROADS
- SECONDARY ROADS
- CREEK & TRIBUTARIES
- 100 YEAR FLOODPLAIN
- REMEDIAL INVESTIGATION SEGMENT 1 SEGMENT
- WETLANDS
- BOTTOMLAND HARDWOOD FOREST AREA

RESIDENTIAL MERCURY (Hg) CONTAMINATION (DEPTH 0-3Z')
- > 180 PPM

COMMERCIAL-DOE-OTHER MERCURY (Hg) CONTAMINATION (DEPTH 0-3Z')
- > 200 PPM



EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE

Fig. G.3 (f). Contaminated forest areas along East Fork Poplar Creek (SWAs 2 through 6).

SHT. 6 OF 6	94015\DWGS\735FOR.DWG	V10
DRAWING #	CAD FILE #	VIEW

This page intentionally left blank.

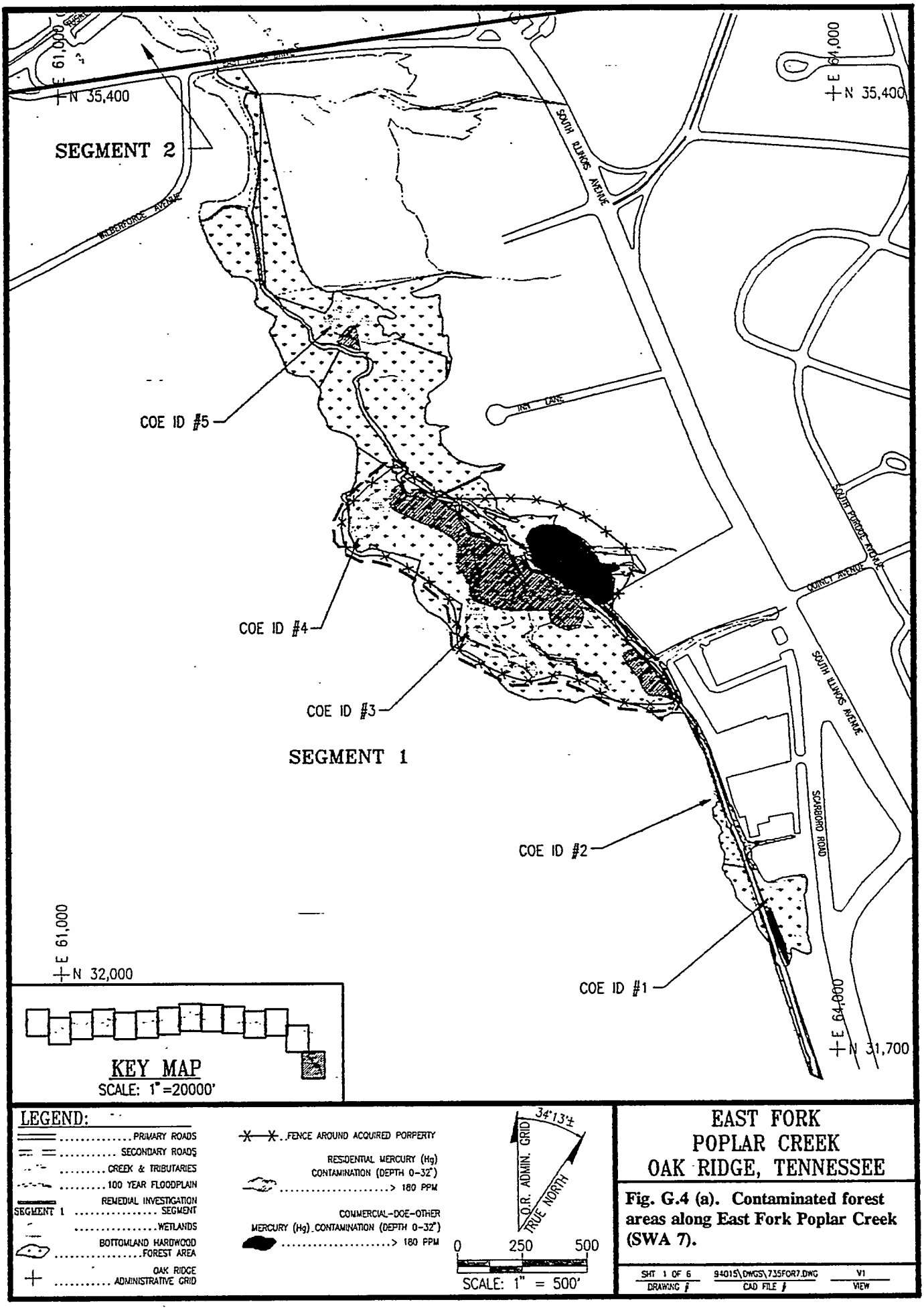


Fig. G.4 (a). Contaminated forest areas along East Fork Poplar Creek (SWA 7).

This page intentionally left blank.

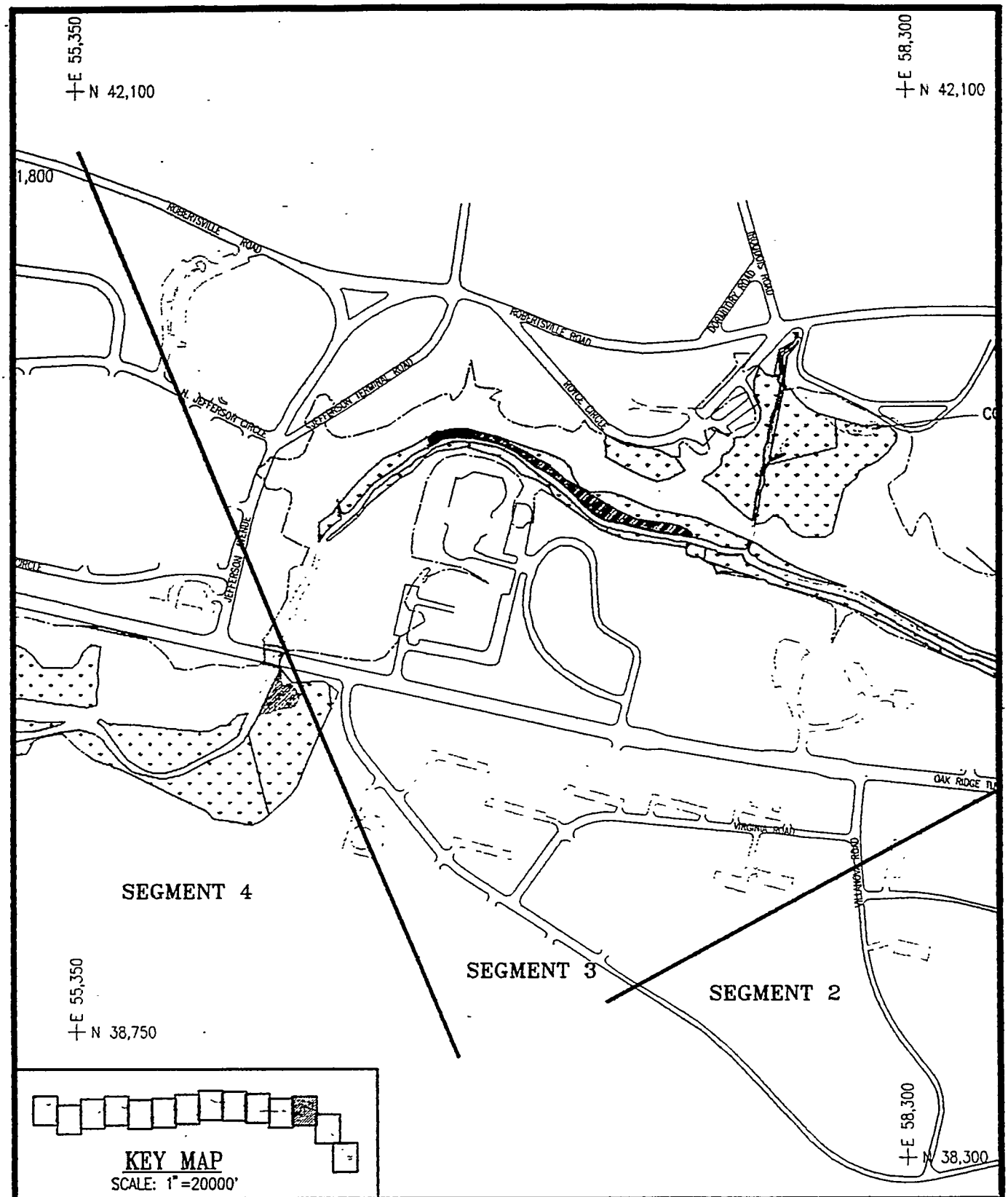


Fig. G.4 (b). Contaminated forest areas along East Fork Poplar Creek (SWA 7).

This page intentionally left blank.

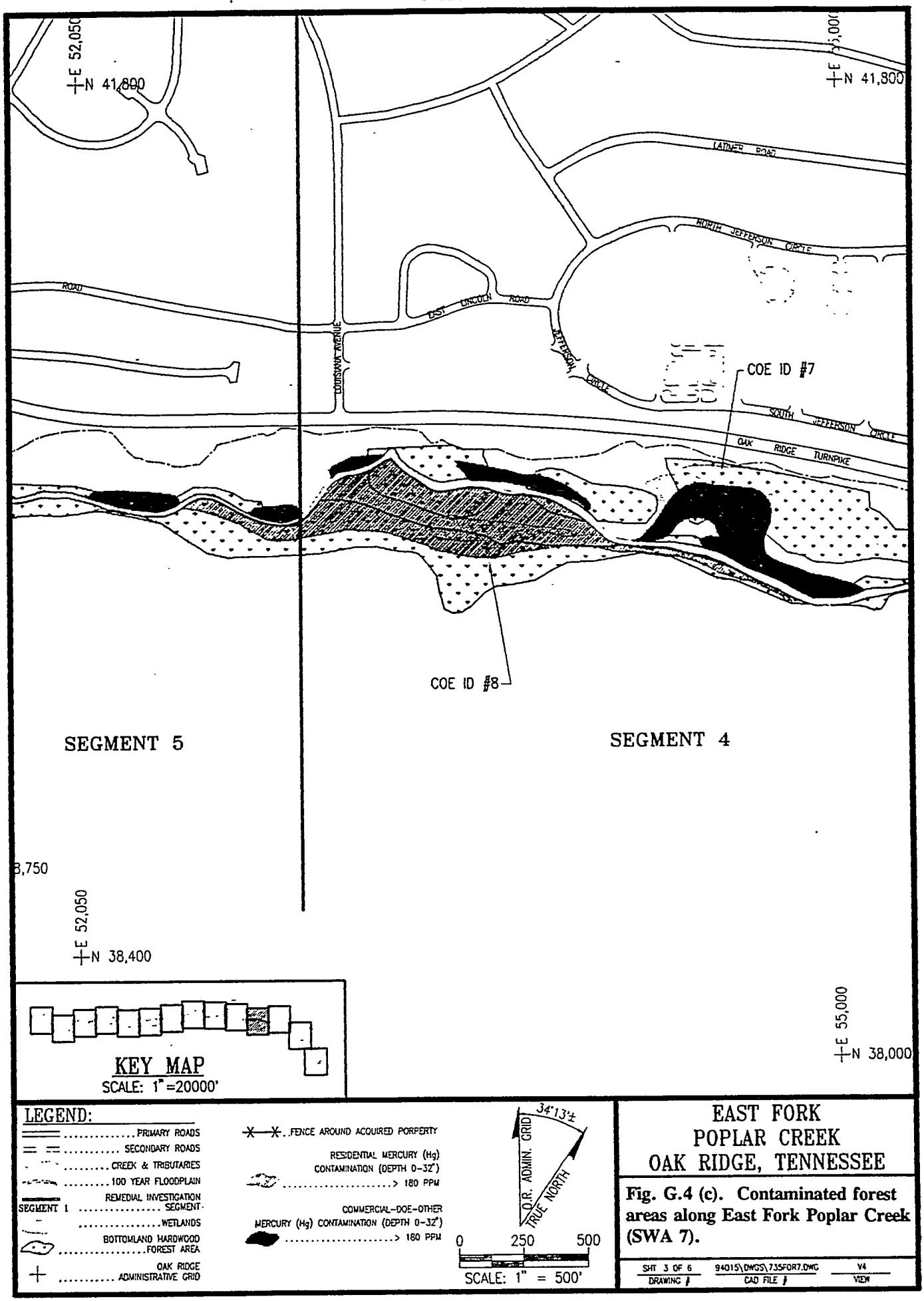


Fig. G.4 (c). Contaminated forest areas along East Fork Poplar Creek (SWA 7).

This page intentionally left blank.

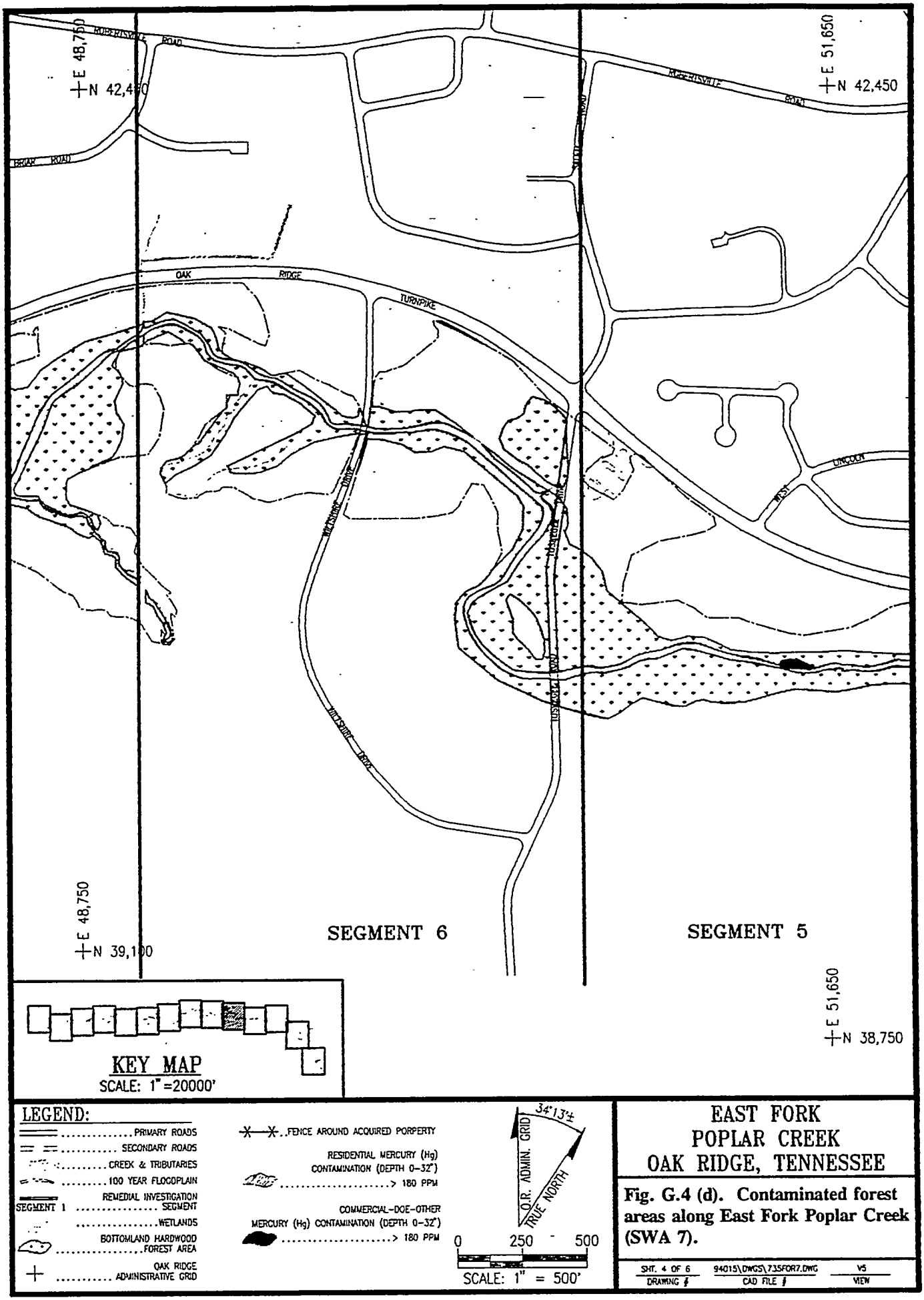


Fig. G.4 (d). Contaminated forest areas along East Fork Poplar Creek (SWA 7).

This page intentionally left blank.

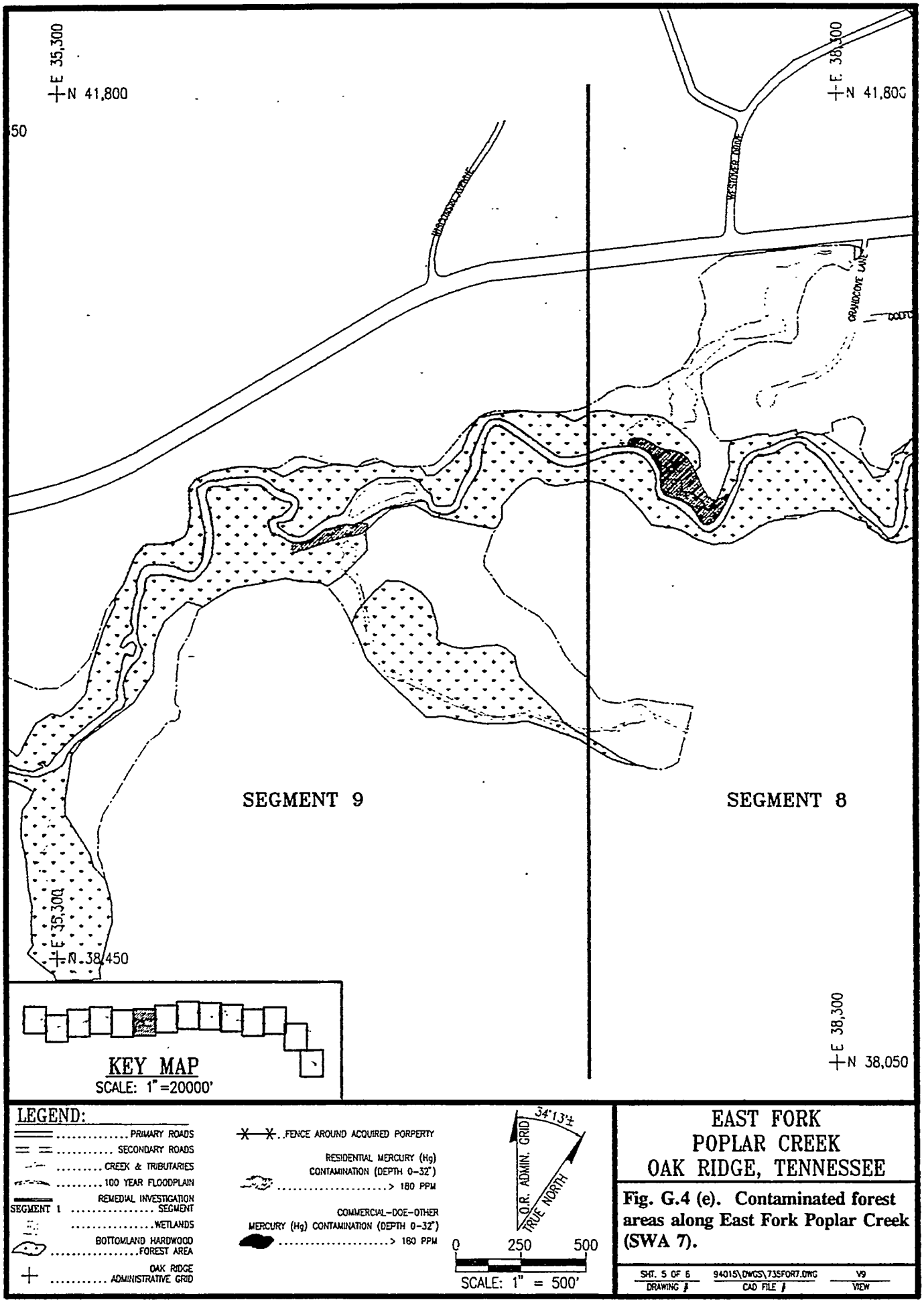


Fig. G.4 (e). Contaminated forest areas along East Fork Poplar Creek (SWA 7).

This page intentionally left blank.

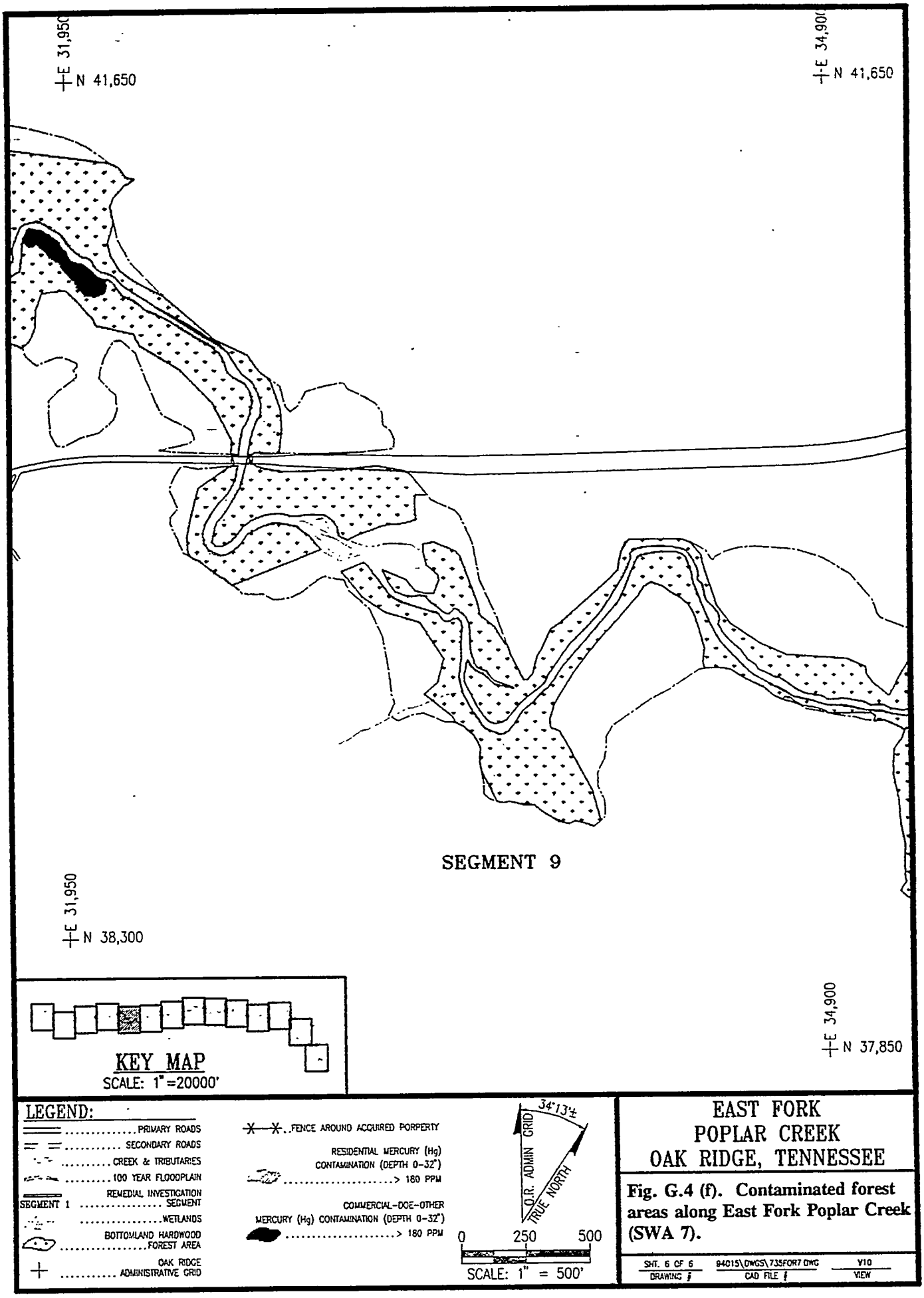
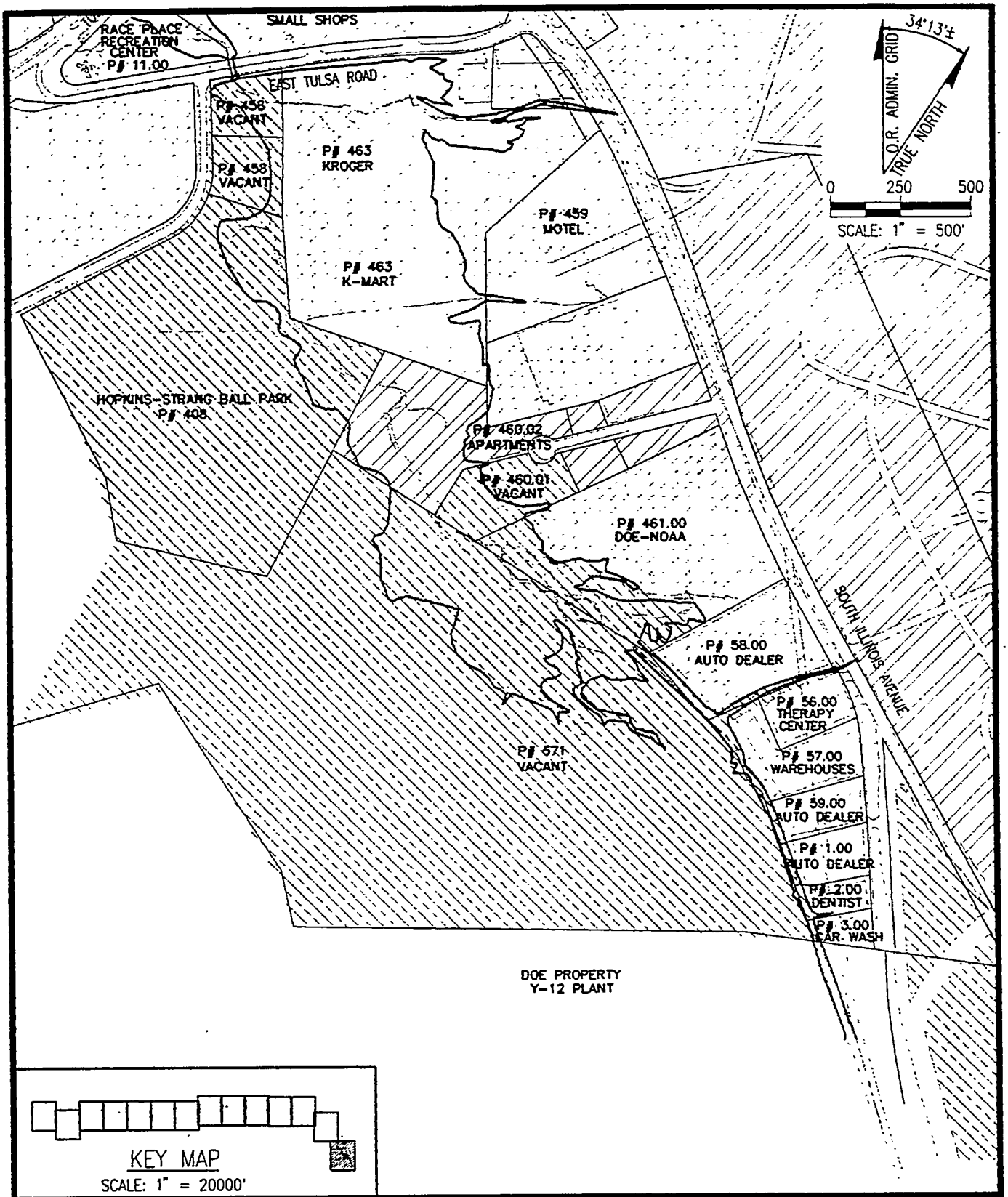


Fig. G.4 (f). Contaminated forest areas along East Fork Poplar Creek (SWA 7).

APPENDIX H

LAND USE MAPS



KEY MAP
SCALE: 1" = 20000'

LEGEND:

- CREEK & TRIBUTARIES
- FLOODPLAIN
- PARCEL BOUNDARIES
- RESIDENTIAL
- AGRICULTURAL
- COMMERCIAL
- OPEN

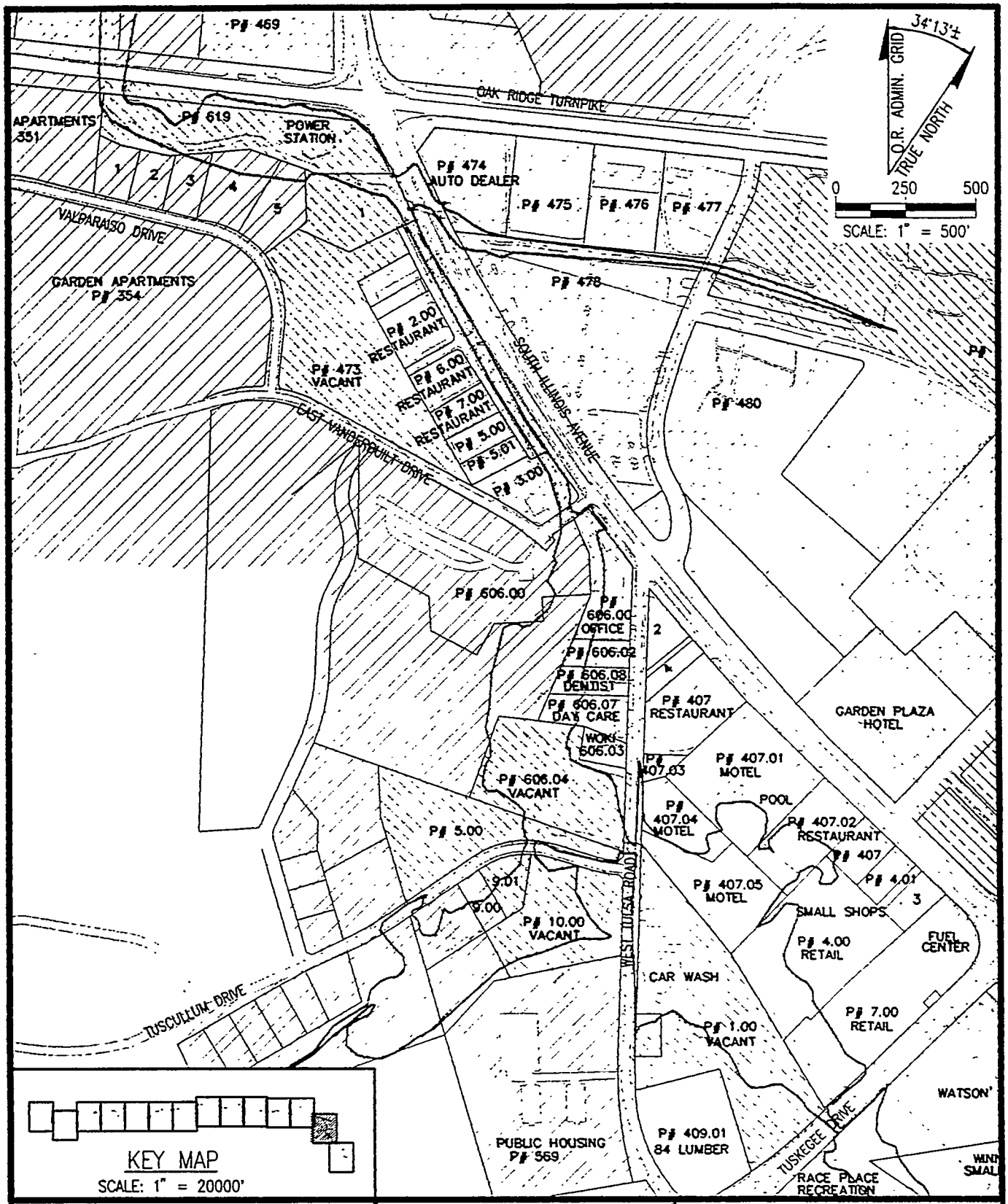
REVISION	DRAWN BY:	CHKD. BY:	DATE:
0	J. CHISMAN		02-04-94

EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE

APPENDIX H
PARCEL & CURRENT
LAND USE MAPS (a)

SHT 1 OF 14	\Z-0001\DWGS\420-LU.DWG	N/A
DRAWING #	CAD FILE #	ROT. ANGLE

This page intentionally left blank.



LEGEND:

- CREEK & TRIBUTARIES
- FLOODPLAIN
- PARCEL BOUNDARIES
- RESIDENTIAL
- AGRICULTURAL
- COMMERCIAL
- OPEN

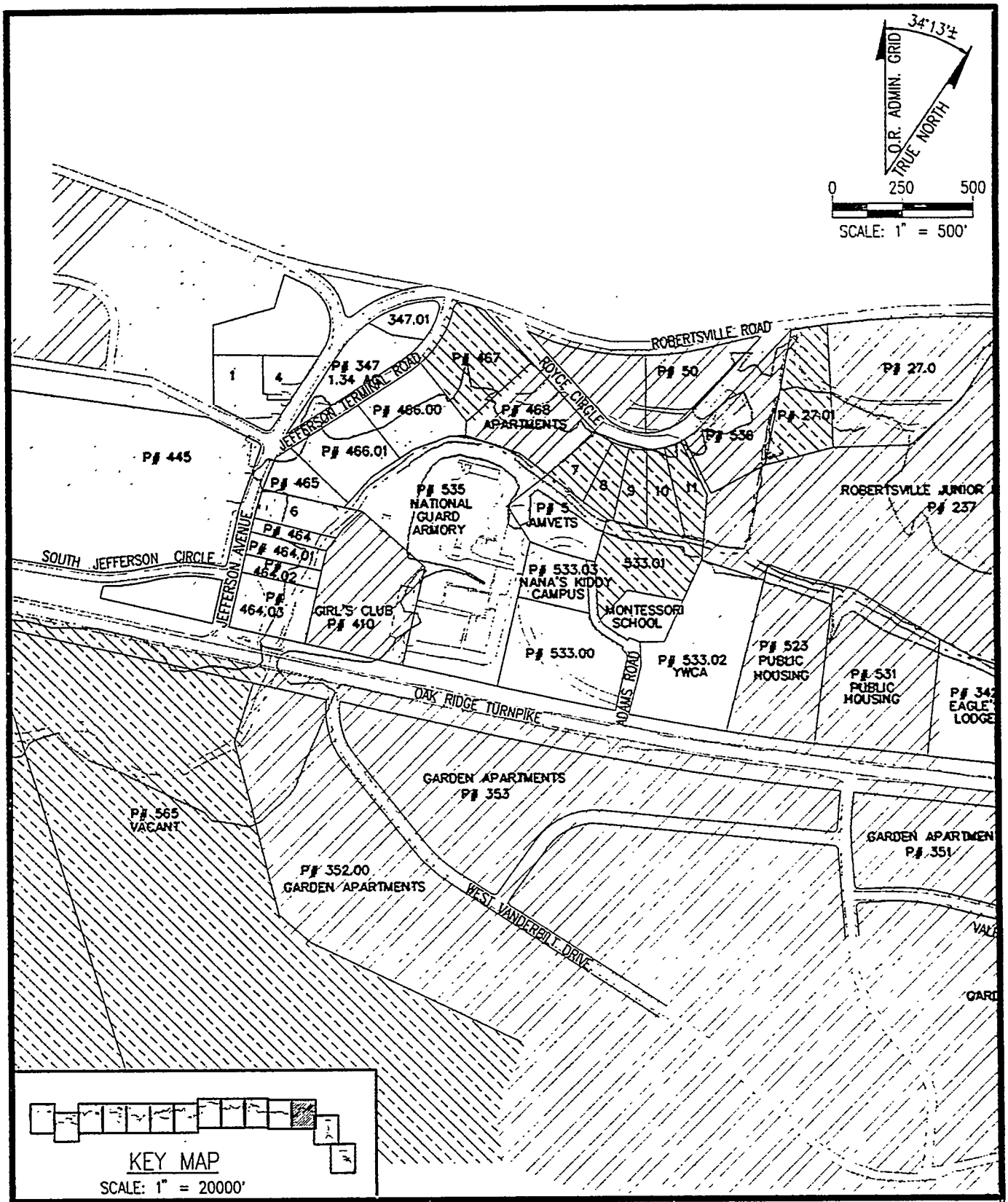
REVISION	DRAWN BY:	CHKD. BY:	DATE:
0	J. CHISMAN		02-04-94

EAST FORK POPLAR CREEK OAK RIDGE, TENNESSEE

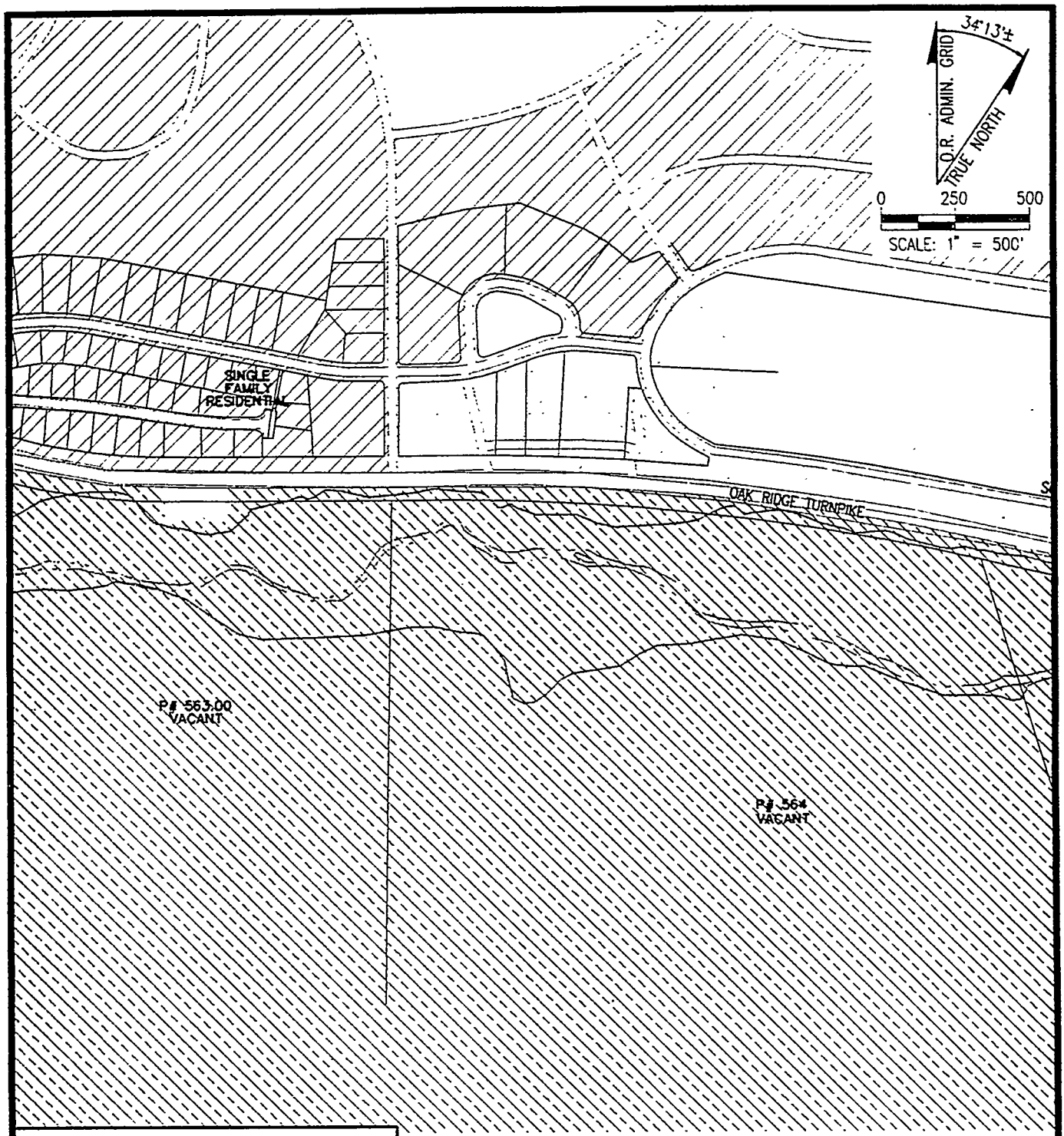
APPENDIX H PARCEL & CURRENT LAND USE MAPS (b)

SHT 2 OF 14	\Z-0001\DWGS\420-LU.DWG	N/A
DRAWING #	CAD FILE #	ROT. ANGLE

This page intentionally left blank.


34°13'±
O.R. ADMIN. GRID
TRUE NORTH
0
250
500
SCALE: 1" = 500'
ROBERTSVILLE ROAD
JEFFERSON TERMINAL ROAD
ROYCE CIRCLE
SOUTH JEFFERSON CIRCLE
JEFFERSON AVENUE
OAK RIDGE TURNPIKE
ADAMS ROAD
WEST VANDERBILT DRIVE
P# 347
1.34 ACL
347.01
P# 467
P# 50
P# 27.0
P# 27.01
P# 538
P# 466.00
P# 468
APARTMENTS
P# 466.01
P# 445
P# 465
P# 535
NATIONAL
GUARD
ARMORY
P# 5
AMVETS
ROBERTSVILLE JUNIOR
P# 237
P# 464
P# 464.01
P# 464.02
P# 464.03
GIRL'S CLUB
P# 410
P# 533.03
NANA'S KIDDY
CAMPUS
533.01
MONTESSORI
SCHOOL
P# 533.00
P# 533.02
YWCA
P# 523
PUBLIC
HOUSING
P# 531
PUBLIC
HOUSING
P# 342
EAGLE'
LODGE
GARDEN APARTMENTS
P# 353
P# 565
VACANT
P# 352.00
GARDEN APARTMENTS
GARDEN APARTMEN
P# 351
KEY MAP
SCALE: 1" = 20000'
LEGEND:
CREEK & TRIBUTARIES
FLOODPLAIN
PARCEL BOUNDARIES
RESIDENTIAL
AGRICULTURAL
COMMERCIAL
OPEN
Science Applications International Corporation
REVISION
DRAWN BY:
CHKD BY:
DATE:
0
R. BEELER
08-16-93
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE
APPENDIX H
PARCEL & CURRENT
LAND USE MAPS (c)
SHT 3 OF 14
DRAWING #
Z-0001\DWGS\420-LU.DWG
CAD FILE #
N/A
ROT. ANGLE

This page intentionally left blank.



KEY MAP

SCALE: 1" = 20000'

LEGEND:

- CREEK & TRIBUTARIES
- FLOODPLAIN
- PARCEL BOUNDARIES
- RESIDENTIAL
- AGRICULTURAL
- COMMERCIAL
- OPEN

Science Applications International Corporation

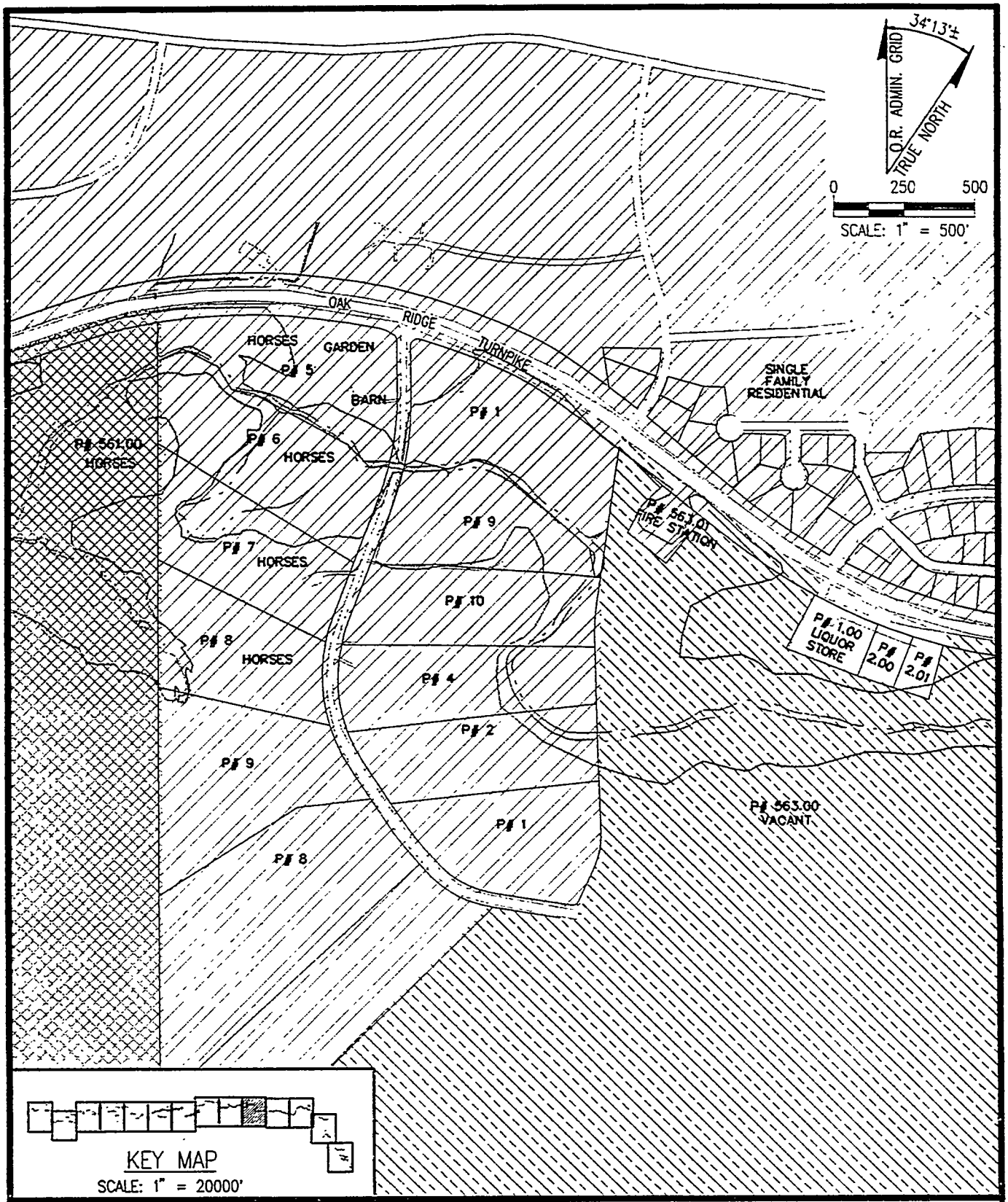
REVISION	DRAWN BY:	CHKD. BY:	DATE:
0	R. BEELER		08-16-93

EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE

APPENDIX H
PARCEL & CURRENT
LAND USE MAPS **(d)**

SHT 4 OF 14	\Z-0001\DWGS\420-LU.DWG	N/A
DRAWING #	CAD FILE #	ROT. ANGLE

This page intentionally left blank.



KEY MAP

SCALE: 1" = 20000'

LEGEND:

- CREEK & TRIBUTARIES
- FLOODPLAIN
- PARCEL BOUNDARIES
- RESIDENTIAL
- AGRICULTURAL
- COMMERCIAL
- OPEN

Science Applications International Corporation

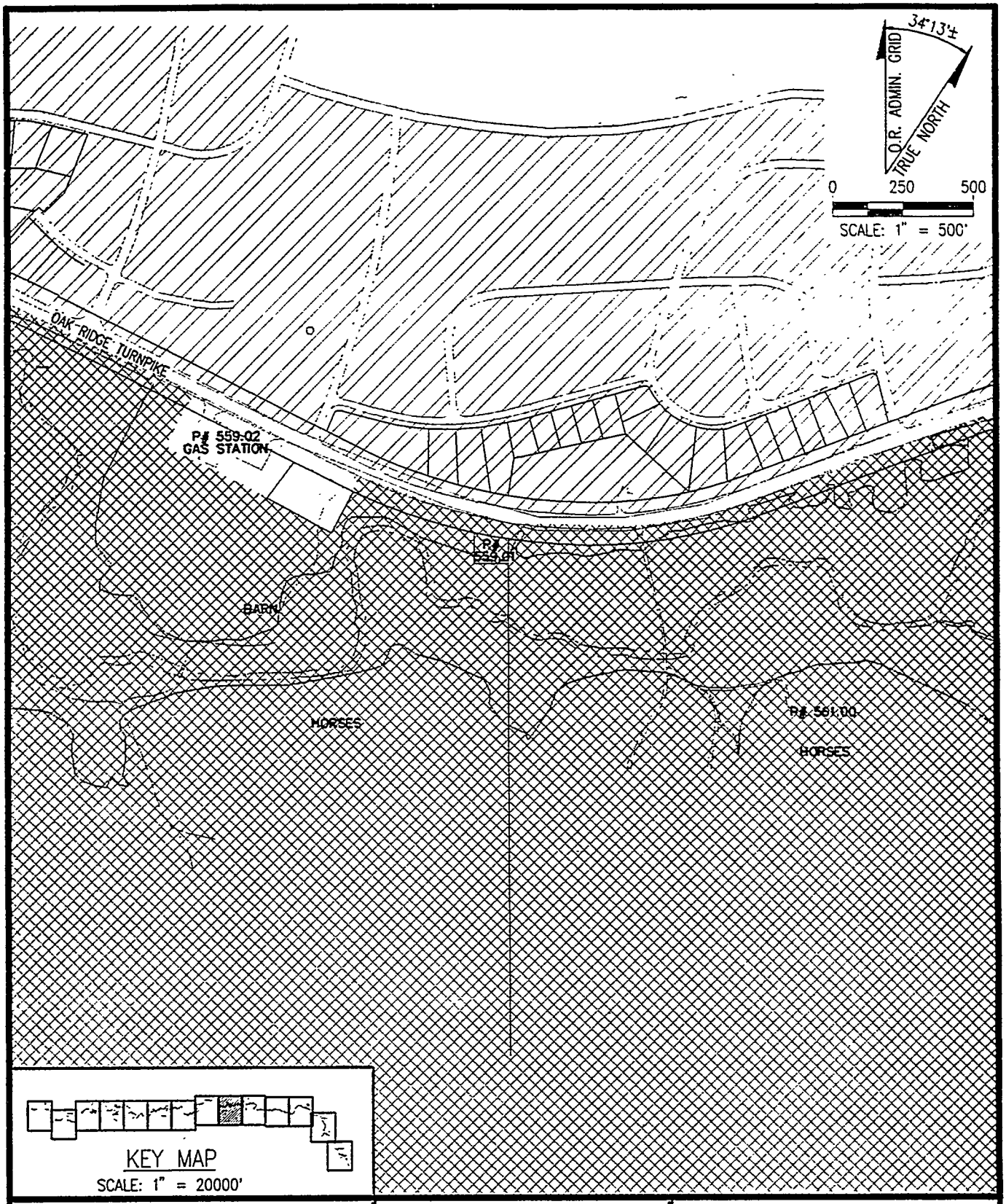
REVISION	DRAWN BY:	CHKD. BY:	DATE:
0	R. BEELER		06-16-93

EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE

APPENDIX H
PARCEL & CURRENT
LAND USE MAPS (e)

SHT 5 OF 14	\Z-0001\DWGS\420-LU.DWG	N/A
DRAWING #	CAD FILE #	ROT. ANGLE

This page intentionally left blank.



KEY MAP

SCALE: 1" = 20000'

LEGEND:

- CREEK & TRIBUTARIES
- FLOODPLAIN
- PARCEL BOUNDARIES
- RESIDENTIAL
- AGRICULTURAL
- COMMERCIAL
- OPEN

Science Applications International Corporation

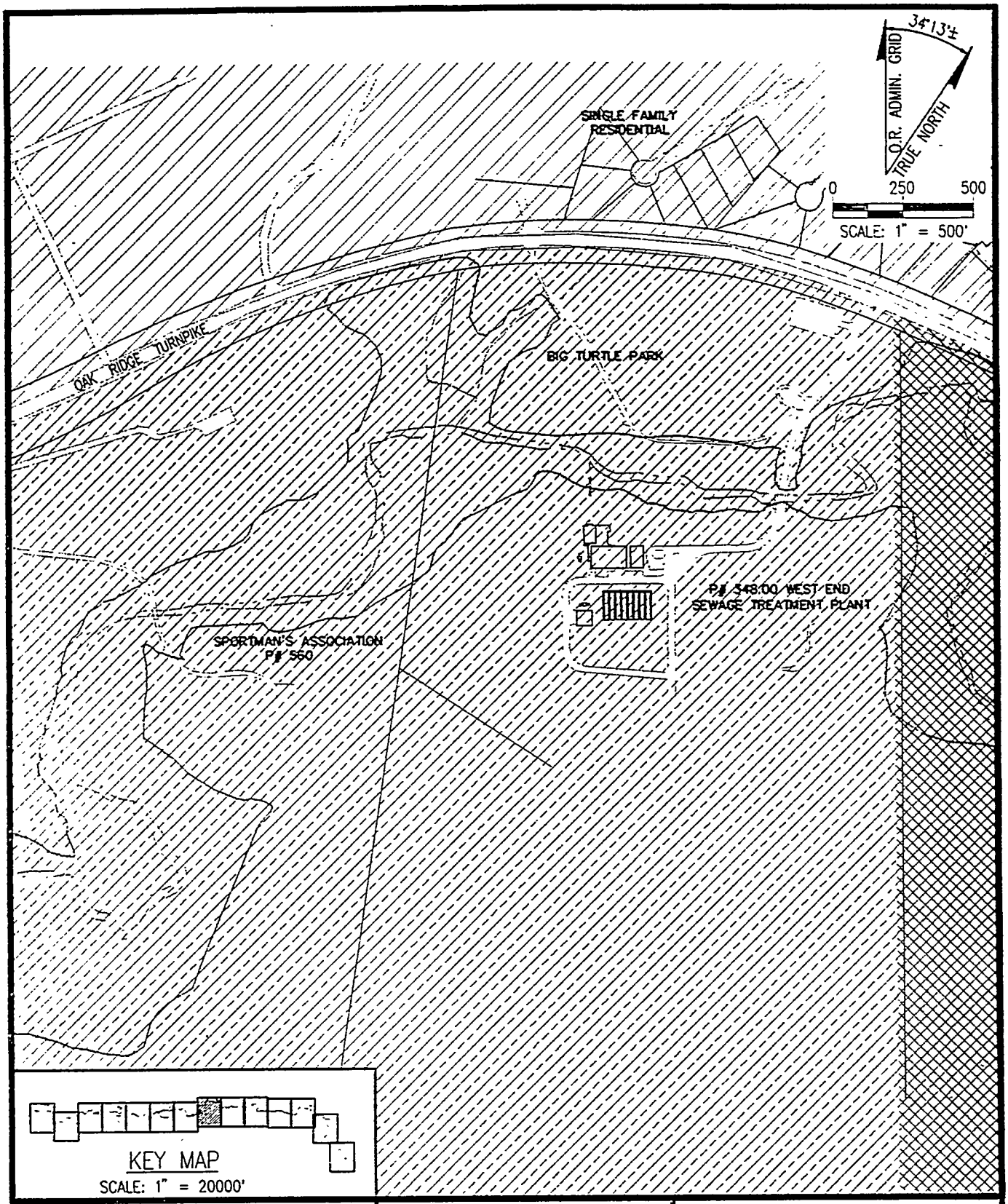
REVISION	DRAWN BY:	CHKD. BY:	DATE:
0	R. BEELER		08-16-93

EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE

APPENDIX H
PARCEL & CURRENT
LAND USE MAPS (f)

SHT 6 OF 14	\Z-0001\DWGS\420-LU.DWG	N/A
DRAWING #	CAD FILE #	ROT. ANGLE

This page intentionally left blank.



KEY MAP

SCALE: 1" = 20000'

LEGEND:

- CREEK & TRIBUTARIES
- FLOODPLAIN
- PARCEL BOUNDARIES
- RESIDENTIAL
- AGRICULTURAL
- COMMERCIAL
- OPEN

Science Applications International Corporation ©

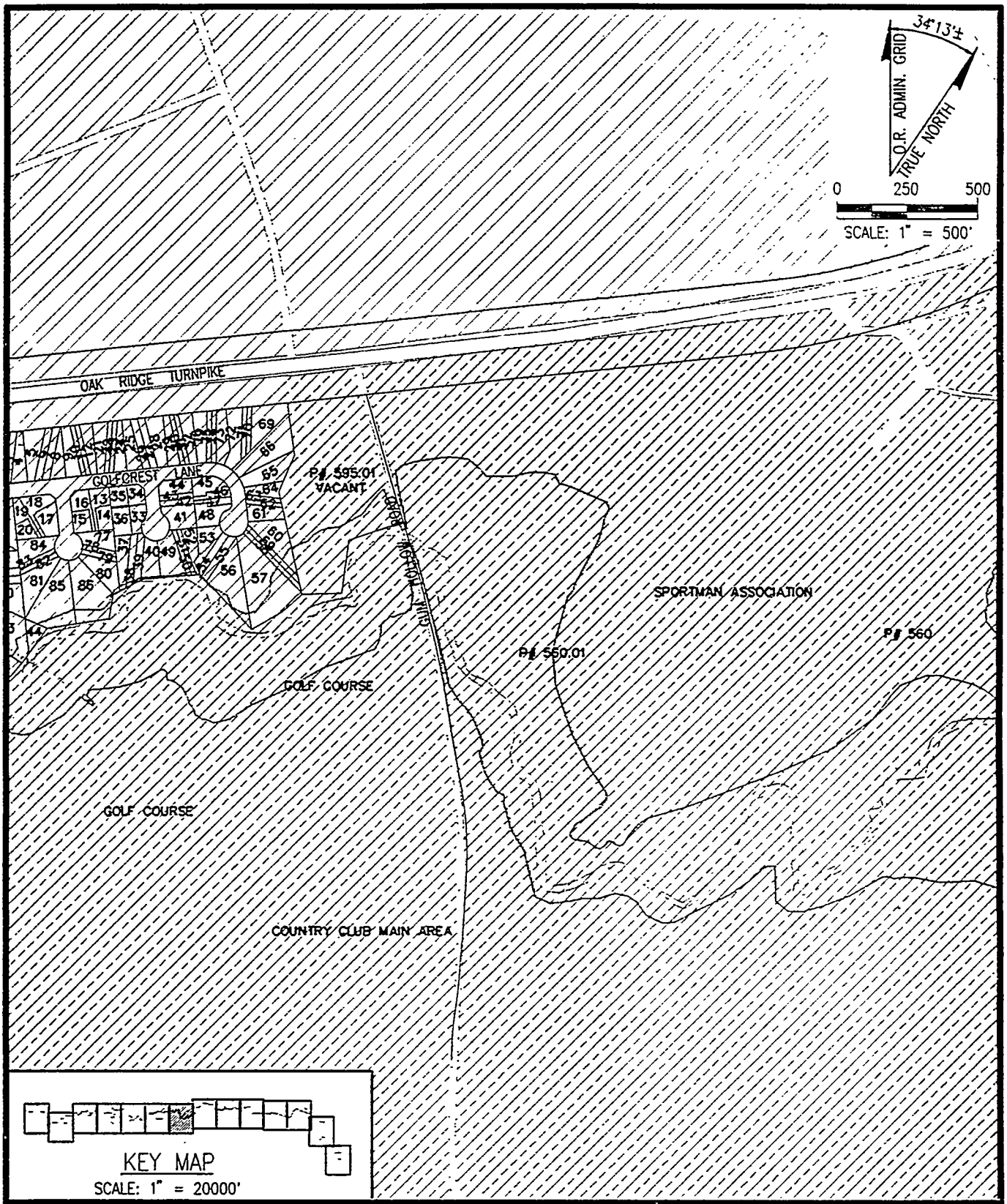
REVISION	DRAWN BY:	CHKD. BY:	DATE:
0	R. BEELER		08-16-93

EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE

APPENDIX H
PARCEL & CURRENT LAND USE MAPS (g)

SHT 7 OF 14	\Z-0001\DWGS\420-LU.DWG	N/A
DRAWING #	CAD FILE #	ROT. ANGLE

This page intentionally left blank.



KEY MAP
SCALE: 1" = 20000'

LEGEND:

- CREEK & TRIBUTARIES
- FLOODPLAIN
- PARCEL BOUNDARIES
- RESIDENTIAL
- AGRICULTURAL
- COMMERCIAL
- OPEN

Science Applications International Corporation

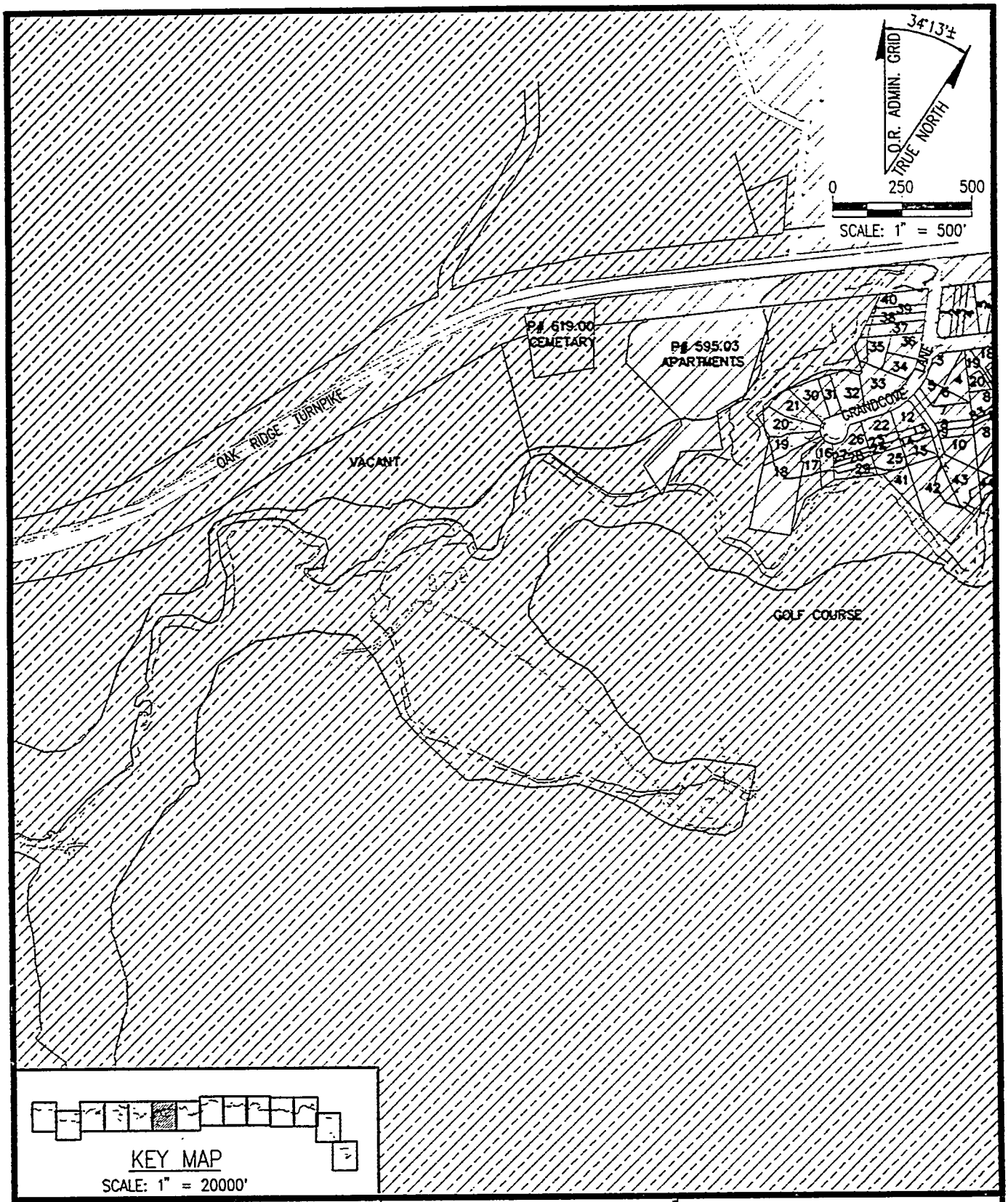
REVISION	DRAWN BY:	CHKD. BY:	DATE:
0	R. BEELER		08-16-93

EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE

APPENDIX H
PARCEL & CURRENT
LAND USE MAPS (h)

SHT 8 OF 14	\Z-0001\DWGS\420-LU.DWG	N/A
DRAWING #	CAD FILE #	ROT. ANGLE

This page intentionally left blank.



KEY MAP

SCALE: 1" = 20000'

LEGEND:

- CREEK & TRIBUTARIES
- FLOODPLAIN
- PARCEL BOUNDARIES
- RESIDENTIAL
- AGRICULTURAL
- COMMERCIAL
- OPEN

Science Applications International Corporation

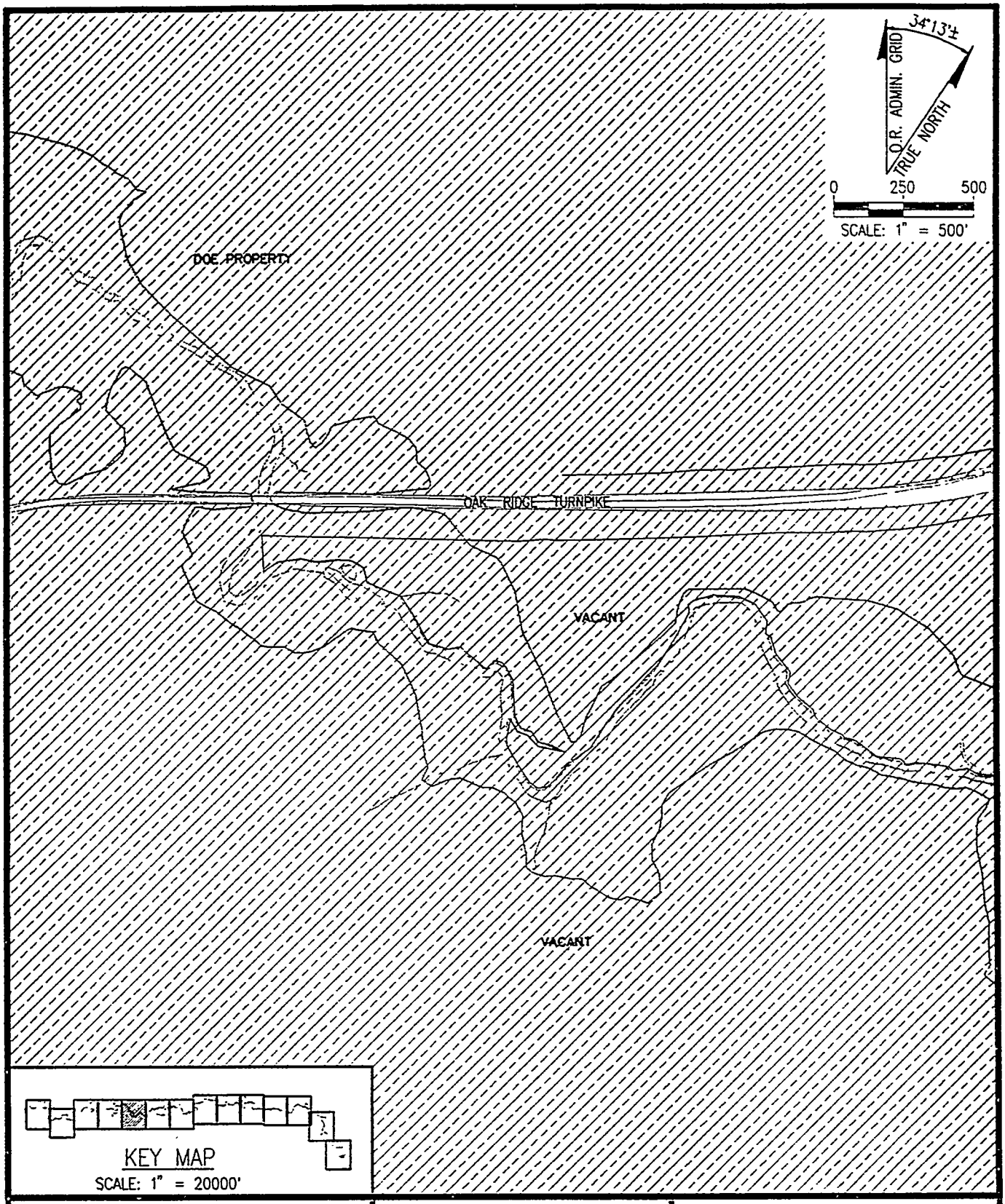
REVISION	DRAWN BY:	CHKD. BY:	DATE:
0	R. BEELER		08-16-93

EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE

APPENDIX H
PARCEL & CURRENT
LAND USE MAPS (i)

SHT 9 OF 14	\Z-0001\DWGS\420-LU.DWG	N/A
DRAWING #	CAD FILE #	ROT. ANGLE

This page intentionally left blank.



KEY MAP

SCALE: 1" = 20000'

LEGEND:

- CREEK & TRIBUTARIES
- FLOODPLAIN
- PARCEL BOUNDARIES
- RESIDENTIAL
- AGRICULTURAL
- COMMERCIAL
- OPEN

Science Applications International Corporation

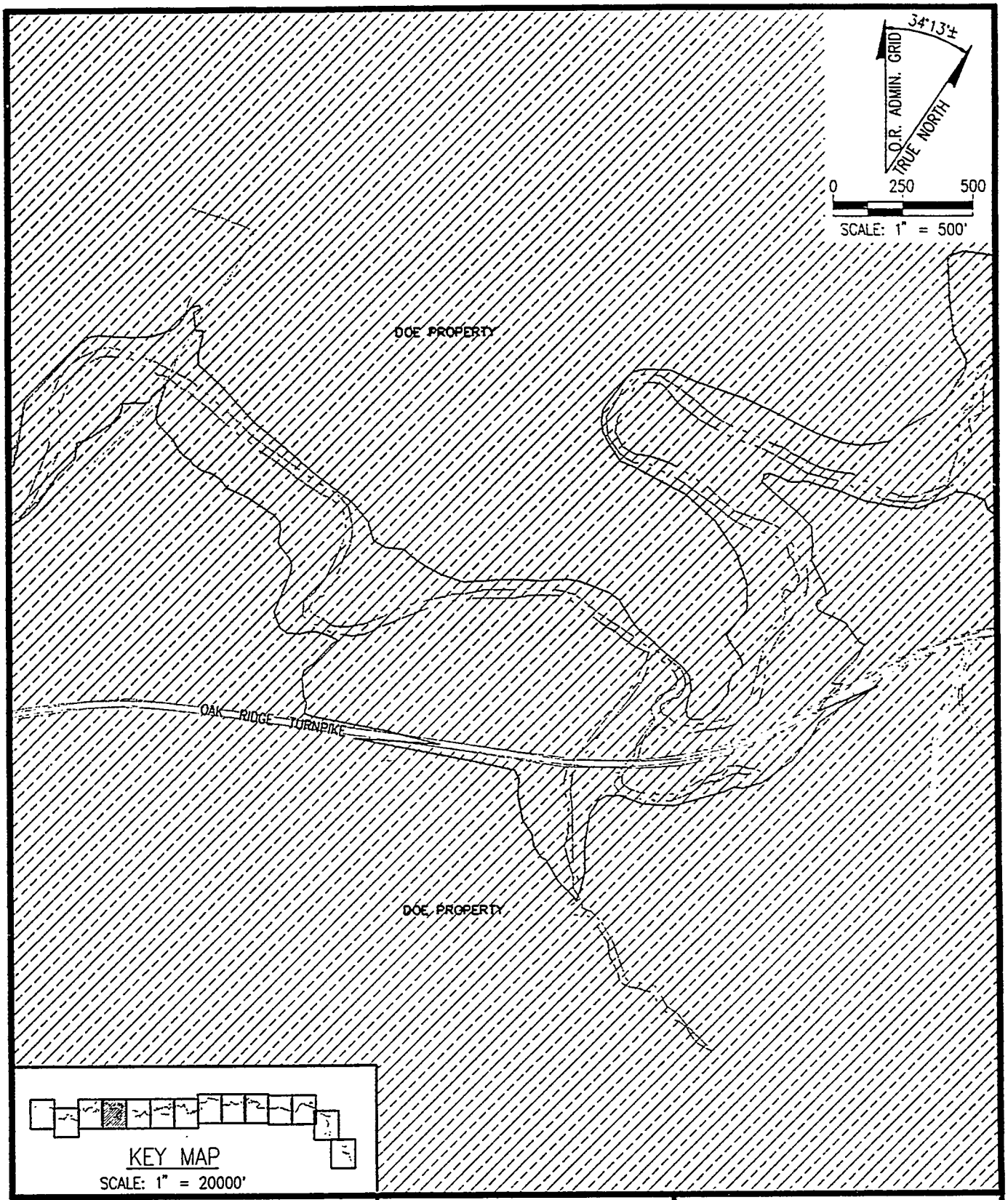
REVISION	DRAWN BY:	CHKD BY:	DATE:
0	R. BEELER		08-16-93

EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE

APPENDIX H
PARCEL & CURRENT
LAND USE MAPS (j)

SHT 10 OF 14	\Z-0001\DWGS\420-LU.DWG	N/A
DRAWING #	CAD FILE #	ROT. ANGLE

This page intentionally left blank.



KEY MAP
SCALE: 1" = 20000'

LEGEND:

- CREEK & TRIBUTARIES
- FLOODPLAIN
- PARCEL BOUNDARIES
- RESIDENTIAL
- AGRICULTURAL
- COMMERCIAL
- OPEN

Science Applications International Corporation

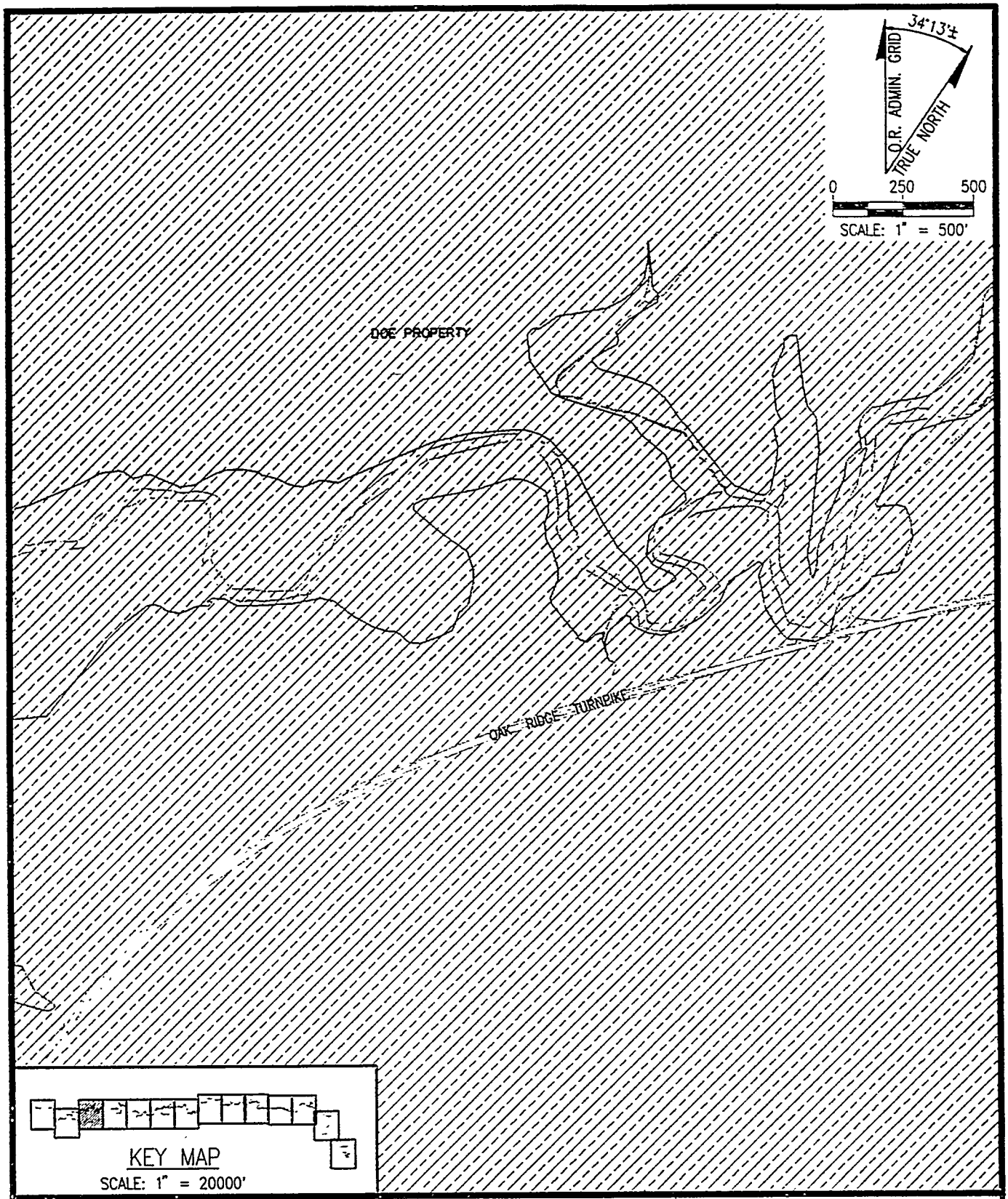
REVISION	DRAWN BY:	CHKD. BY:	DATE:
0	R. BEELER		08-16-93

EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE

APPENDIX H
PARCEL & CURRENT LAND USE MAPS (k)

SHT 11 OF 14 | \Z-0001\DWGS\420-LU.DWG | N/A
DRAWING # | CAD FILE # | ROT. ANGLE

This page intentionally left blank.



KEY MAP
SCALE: 1" = 20000'

LEGEND:

- CREEK & TRIBUTARIES
- FLOODPLAIN
- PARCEL BOUNDARIES
- RESIDENTIAL
- AGRICULTURAL
- COMMERCIAL
- OPEN

Science Applications International Corporation

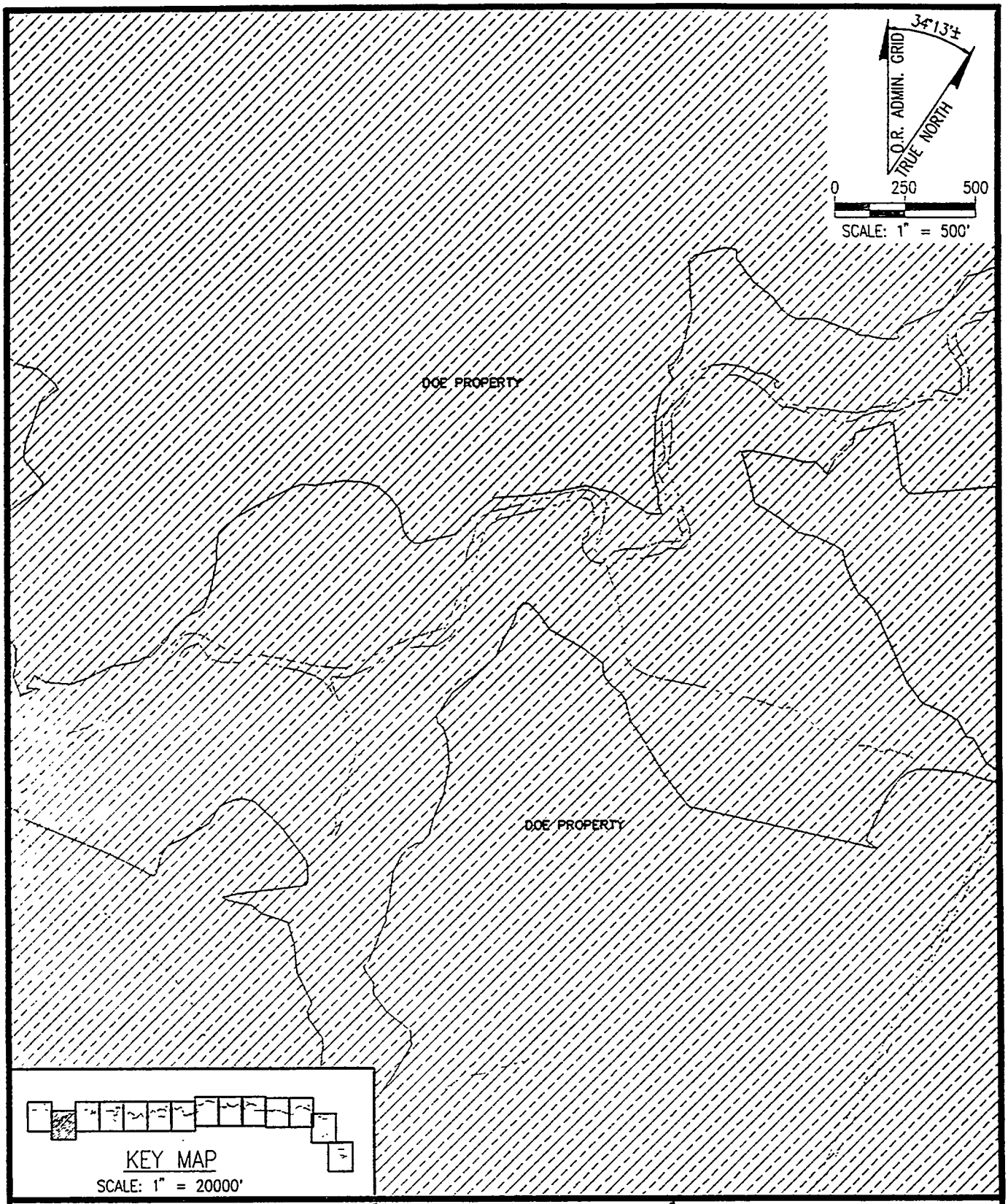
REVISION	DRAWN BY:	CHKD. BY:	DATE:
0	R. BEELER		06-16-93

EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE

APPENDIX H
PARCEL & CURRENT
LAND USE MAPS (I)

SHT 12 OF 14 | DRAWING # | \Z-0001\DWGS\420-LU.DWG | CAD FILE # | N/A | ROT. ANGLE

This page intentionally left blank.



LEGEND:

- CREEK & TRIBUTARIES
- FLOODPLAIN
- PARCEL BOUNDARIES
- RESIDENTIAL
- AGRICULTURAL
- COMMERCIAL
- OPEN

Science Applications International Corporation ©

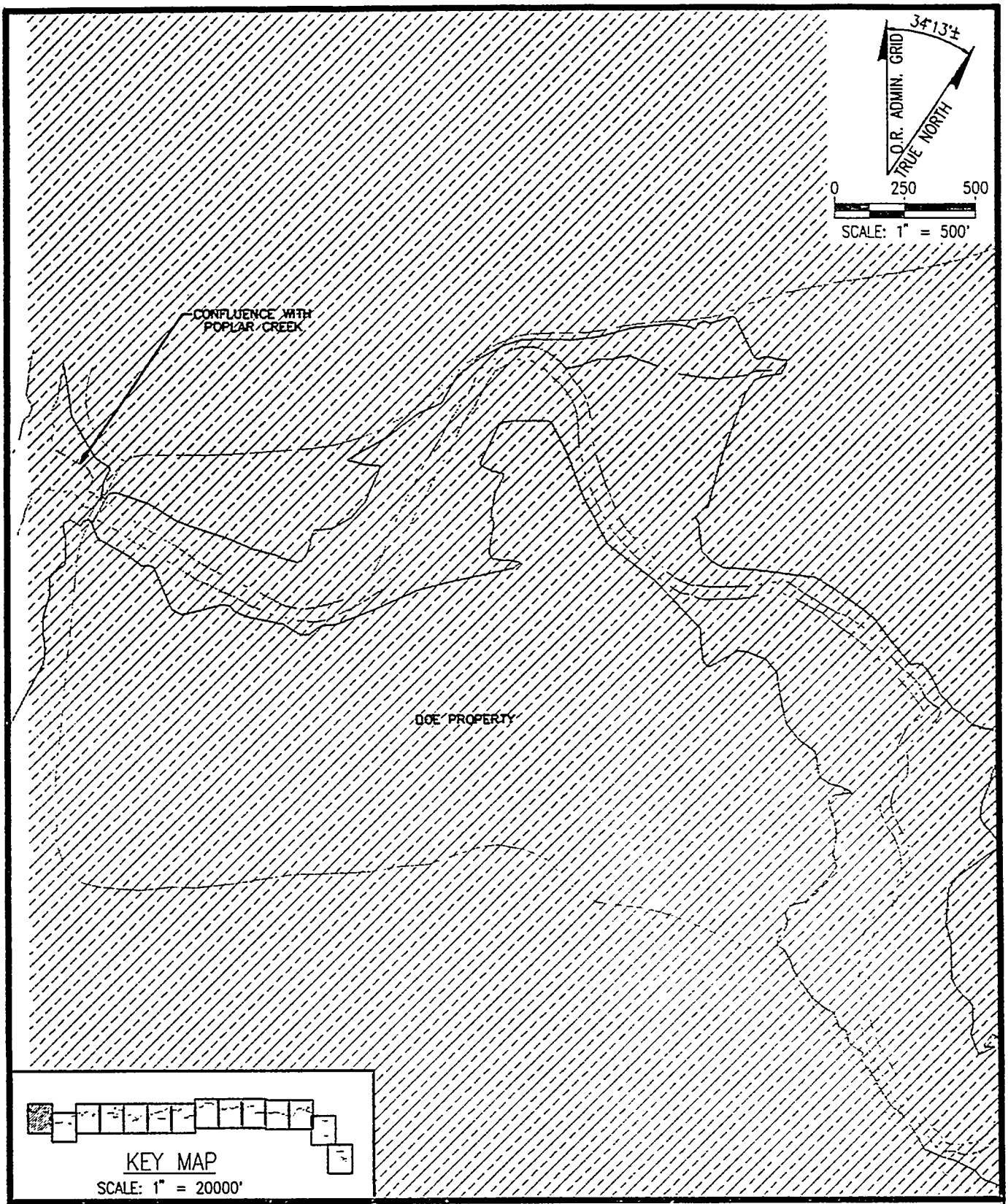
REVISION	DRAWN BY:	CHKD. BY:	DATE:
0	R. BEELER		08-16-93

EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE

APPENDIX H
PARCEL & CURRENT
LAND USE MAPS (m)

SHT 13 OF 14 | \Z-0001\DWGS\420-LU.DWG | N/A
DRAWING # | CAD FILE # | ROT ANGLE

This page intentionally left blank.



KEY MAP
SCALE: 1" = 20000'

LEGEND:

- CREEK & TRIBUTARIES
- FLOODPLAIN
- PARCEL BOUNDARIES
- RESIDENTIAL
- AGRICULTURAL
- COMMERCIAL
- OPEN

Science Applications International Corporation

REVISION	DRAWN BY:	CHKD. BY:	DATE:
0	R. BEELER		08-16-93

EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE

APPENDIX H
PARCEL & CURRENT
LAND USE MAPS **(n)**

SHT 14 OF 14	\Z-0001\DWGS\420-LU.DWG	N/A
DRAWING #	CAD FILE #	ROT. ANGLE

APPENDIX I

COMMUNITY AND PUBLIC INVOLVEMENT PROGRAM FOR EAST FORK POPLAR CREEK

CONTENTS

ACRONYMS . . . . . I-v

APPENDIX I: COMMUNITY AND PUBLIC INVOLVEMENT PROGRAM FOR EAST FORK POPLAR CREEK I-1

I.1 INTRODUCTION I-1
I.1.1 Goal of the EFPC Community Relations Program I-1
I.1.2 Community Relations Within the CERCLA Process I-1

I.2 EFPC COMMUNITY RELATIONS APPROACH I-2
I.2.1 NEPA Scoping Meeting I-2
I.2.2 Relations with Property Owners I-2
I.2.3 Sources of Public Information About EFPC I-3
I.2.4 Educational Outreach Programs I-4
I.2.5 Technical Workshop I-5
I.2.6 Work-Force Task Groups I-6
I.2.7 Public Meeting I-7
I.2.8 Citizens' Working Group I-8

I.3 SUMMARY I-14

ACRONYMS

ATSDR	Agency for Toxic Substances and Disease Registry
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COE	U.S. Army Corps of Engineers
D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
EFPC	East Fork Poplar Creek
EIS	environmental impact statement
Energy Systems	Martin Marietta Energy Systems, Inc.
EPA	U.S. Environmental Protection Agency
ER	environmental restoration
NEPA	National Environmental Policy Act
PP	proposed plan
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
SAIC	Science Applications International Corporation
SWA	sitewide alternative
TDEC	Tennessee Department of Environment and Conservation
Y-12 Plant	Oak Ridge Y-12 Plant

APPENDIX I

COMMUNITY AND PUBLIC INVOLVEMENT PROGRAM FOR EAST FORK POPLAR CREEK

I.1 INTRODUCTION

Community involvement is vital to the determination of an acceptable remediation method for the contaminated areas around East Fork Poplar Creek (EFPC). Federal environmental laws such as the Resource Conservation and Recovery Act and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) require that public comments be solicited for proposed remediation plans; such input from the communities and people affected by past environmental practices directly affects the remediation decisions that are made. The community relations program for EFPC provides many activities to promote communication between the U.S. Department of Energy (DOE) and members of the surrounding communities. Such communication keeps DOE apprised of the changing needs and attitudes of the communities, identifies emerging issues and concerns, and more readily involves citizens in decision-making processes. For EFPC, DOE has undertaken a multifaceted program to widely disseminate information and solicit input from affected citizens.

The DOE community relations program for EFPC provides channels of communication between technical experts and the public and identifies methods for addressing citizens' concerns. The successful implementation of a community relations program and an effective response from DOE to community concerns will help ensure that the remediation method selected is acceptable to the community.

I.1.1 Goal of the EFPC Community Relations Program

The goal of the community relations program for EFPC is to keep area residents informed of and involved in activities and decisions that affect them; the objectives of the program are to

- inform the public of planned and ongoing remedial actions,
- encourage and help the public to provide input to technical decisions, and
- identify and resolve conflicts or differences of opinion.

I.1.2 Community Relations Within the CERCLA Process

Section 117 of CERCLA emphasizes the importance of involving communities in the early stages of decision-making, keeping residents apprised of plans, and responding to citizens' concerns. Additionally, the law requires that a notice of any proposed remedial action [Proposed Plan (PP)] be published in a local newspaper and that local citizens be given a "reasonable opportunity" to comment on the PP and other contents of the administrative record, particularly the remedial investigation (RI) report and feasibility study (FS) reports. A public meeting is usually held during this public comment period. After receiving public comments and comments from other agencies, DOE, the Lead Agency, selects a remedy and documents it in a Record of Decision. In the Record of Decision, the two CERCLA modifying criteria—state acceptance and community acceptance—are evaluated in relation to the concerns the state and the public may have regarding each alternative. The objective of community relations is to inform local citizens

about the alternatives and the specific issues DOE must consider in selecting an alternative so that the citizens can provide meaningful input during the public comment period.

I.2 EFPC COMMUNITY RELATIONS APPROACH

The following sections describe the steps DOE took to implement the community relations program for EFPC. The sections begin with a discussion of the National Environmental Policy Act (NEPA) scoping meeting in 1988; describe ongoing relations with the property owners; identify sources of information about EFPC; describe educational activities conducted with local schools; discuss the issues that arose from the May 1993 public meeting; and conclude with a discussion of the Citizens' Working Group, a group of concerned citizens who have volunteered to provide input to the CERCLA decision documents.

I.2.1 NEPA Scoping Meeting

DOE held a public scoping meeting in December 1988, as required by CERCLA and NEPA, to encourage citizens' input to the Environmental Impact Statement (EIS), a document required before remediation of the creek can begin. Members of the public brought comments and suggestions to the meeting to help DOE identify significant environmental issues concerning the remediation of the creek and the surrounding area; those comments were considered when DOE prepared an initial list of remedial alternatives.

Citizens at the scoping meeting expressed a number of concerns about the contamination in EFPC and its floodplain. Among those concerns were the nature and extent of contamination in residential areas along the creek, short- and long-term health effects from exposure to the contaminants, marketability of property along the floodplain, present and future land uses, the effect that sediments and soil disturbed during proposed remedial activities could have on downstream areas, and the effects of flooding in certain areas of Oak Ridge. These concerns are part of the public record for the restoration process for EFPC and will be taken into consideration when a final remediation solution is selected for the area. These concerns were included in the Final Implementation Plan for the FS-EIS issued in May 1990.

I.2.2 Relations with Property Owners

EFPC property owners have been the focus of an extensive community outreach program since the Oak Ridge Reservation was placed on the National Priorities List in 1989.

In 1990-1991, property access agreements were obtained from 136 landowners so that remedial investigation activities could be performed. The process of obtaining the access agreements allowed the community relations staff to explain the EFPC program to the property owners and to create a mailing list so that further information could be disseminated in the future. Status letters have been sent periodically to property owners to inform them of all major on-site sampling activities (1991-1992) and results (1992-1993). DOE held numerous one-on-one meetings with property owners to hear their concerns, present the sampling results, and discuss related issues.

In November and December of 1991, two workshops were conducted to address property owners' concerns and to explain

- the decision-making process,
- regulatory requirements of the CERCLA process,
- program milestones and schedules,
- the community relations program,
- the sampling and investigation program,
- human health and ecological risk assessments,
- potential alternatives for remediation, and
- the purpose of the U.S. Army Corps of Engineers (COE) Real Estate Planning Document.

In 1992, more than 50 Oak Ridge realtors attended DOE's RI/FS briefing, which was followed by a question-and-answer session.

A property owners' workshop was held in May 1993 after the draft RI report was submitted to the U.S. Environmental Protection Agency (EPA) and the Tennessee Department of Environment and Conservation (TDEC) in April of that year. The workshop presenters explained the results of the RI report, identified principal areas of contamination on the basis of the remediation goal options, and discussed anticipated remedial actions that would be evaluated in the FS.

DOE prepared written responses to the questions asked at the property owners' meetings and mailed those responses to property owners. Copies of the responses and the presentation materials are available at the Information Resource Center.

DOE has also worked closely with the City of Oak Ridge by providing data and status briefings on a regular basis. The City, in addition to being a property owner, is responsible for zoning and approving developments along most of the creek.

In addition to its outreach activities, DOE has gathered input from property owners, realtors, city representatives, and business leaders for socioeconomic and institutional assessments in the FS report.

The COE, a cooperating agency on the EIS, has extensive expertise in dealing with federal real estate statutes and has agreed to prepare a real estate plan and to advise DOE about the acquisition of real estate rights for the implementation of the selected remedial alternative.

I.2.3 Sources of Public Information About EFPC

I.2.3.1 Information Resource Center

The Information Resource Center, located at 105 Broadway in Oak Ridge, opened its doors in 1991. The Center gives the public access to information about environmental restoration (ER) activities, relevant documents, and the Administrative Records for EFPC and other ER programs (those records contain information on which decisions about remediation are based). Additionally, small public workshops and ER program staff meetings are held at the Center.

I.2.3.2 Community newsletter

The activities of EFPC are prominently featured in *The Environmental Update*, which is a periodic newsletter (usually about 8 pages long) that is mailed to more than 2000 individuals in the community and is inserted in two local newspapers, *The Oak Ridger* and *The Roane County News*; total distribution of the newsletter exceeds 30,000. In general, *The Update* contains information about the status of remedial sites; schedules of upcoming events, activities, and meetings in the ER Program; and answers to public inquiries.

I.2.3.3 EFPC fact sheets

Fact sheets that describe remedial activities being conducted at EFPC and other sites on the Oak Ridge Reservation and that explain relevant regulatory requirements are distributed to the community by mail, in visitor packets, and at public meetings. The Information Resource Center and public libraries also maintain copies for public use. The following fact sheets, which are specific to EFPC, are updated as work progresses:

- *The Community Relations Plan for the East Fork Poplar Creek Remedial Investigation Feasibility Study*,
- *The Environmental Restoration Program for East Fork Poplar Creek*, and
- *Remediation Alternatives for East Fork Poplar Creek.*

I.2.3.4 News releases and advisories

News articles and interviews by DOE staff inform the media and public about the progress of the EFPC Program. News releases are used to announce public meetings and will be used to discuss remedial alternatives, review progress (i.e., contractor awards, costs, schedules, and completion), and announce the availability of the Administrative Record and specific documents for public review and comment.

I.2.3.5 Legal advertisements

Advertisements placed in local newspapers announce public comment periods, meetings, and the availability of documents related to remediation at EFPC.

I.2.4 Educational Outreach Programs

I.2.4.1 EFPC sampling video

Two videos are available to the public through DOE. One highlights the history of EFPC contamination and describes the regulations affecting remediation; the other features footage of actual sampling activities being conducted along the creek.

I.2.4.2 EFPC school curriculum

A program has been designed to help area junior high and high school students better understand scientific and environmental issues related to activities under way in the EFPC RI/FS.

I.2.4.3 Environmental Fair

An annual Environmental Fair is held for several thousand area middle school students to help them understand DOE's environmental work, as well as global environmental problems, and to increase their awareness of career opportunities. A booth sponsored by the EFPC Program describes the contamination along the creek and shows students the sampling methods and equipment used in the RI. General methods expected to be used for remediating the creek were also presented.

I.2.5 Technical Workshop

As the results of the RI became available in early 1993 and developmental work began on the FS, several issues that could significantly affect the selection of the remedial actions to be evaluated in the FS were identified. Because of the unique, complex nature of the 14-mile-long creek, many political, regulatory, and technical issues appeared to be unresolvable without the involvement or concurrence of several interested and affected agencies.

In March 1993, DOE sponsored a 2-day Technical Workshop about EFPC to obtain the input and identify the concerns of a cross-section of federal, state, and local agencies. The agencies represented included regulating agencies (EPA and TDEC), cooperating agencies in the integrated FS process; Natural Resource Damage Assessment Trustees; and other anticipated formal reviewers of the FS. The following agencies and companies attended the workshop.

Federal Agencies:

- EPA,
- U.S. Fish and Wildlife Service,
- Agency for Toxic Substances and Disease Registry (ATSDR),
- DOE, and
- COE.

State Agencies:

- Tennessee Department of Health,
- TDEC, and
- Tennessee Wildlife Resources Agency.

Local Agencies:

- City of Oak Ridge and
- Oak Ridge Regional Planning Commission.

Contractors:

- Radian Corporation,
- Martin Marietta Energy Systems (Energy Systems),
- Science Applications International Corporation (SAIC),
- Ebasco,
- Booz-Allen & Hamilton, Inc., and
- Labat-Anderson.

The workshop was structured to stimulate discussion by providing an overview of the current status of the project, then having the participants divide into six groups to address known issues such as balancing human health versus ecological risk, long-term protection versus short-term habitat destruction, statutory preference for treatment versus direct disposal, and effectiveness of institutional controls versus long-term protection. Following the discussion session, the groups were reassembled to review and critique the recommendations and additional concerns cited in the discussion groups.

The review of the current status of the project included a tour of the creek; comprehensive discussions on the RI; and a review of (1) risk assessment methodologies for both human health and ecological receptors, (2) technologies undergoing treatability studies, and (3) the approach to defining the remedial alternatives. In general, the workshop attendees agreed with the basic technical approach and the proposed plan for development of the FS. The workshop provided valuable input and insight to the project staff responsible for directing the development of the FS.

I.2.6 Work-Force Task Groups

After the Technical Workshop concluded, several significant issues, some of which were identified by the workshop participants, still remained. As an outgrowth of the workshop, and in an effort to continue the involvement of the affected agencies, nine focused work groups were established to provide recommendations and input to the performance of the detailed analysis in the FS. Each of the work groups was composed of agency, DOE, and contractor personnel with special expertise or permitting authority, whose assignments varied depending on the time available, topic, and purpose of the agency. The nine work group topics were:

- Property Acquisition and Institutional Controls,
- Balancing Human Health and Ecological Risk Assessments,
- Disposal Options,
- Stabilization of Creek Banks,
- Greenways and Greenbelts,
- Investigation of Other CERCLA Projects,
- National Resource Damage Assessment,
- Waste Characterization, and
- Wetlands.

Each work group was directed to focus on its specific assigned topic and the applicability of that topic to EFPC in the FS process. To help focus the group, each Chairperson was given guidance on the CERCLA evaluation criteria, and the groups were given only a short time to accomplish their tasks.

Because of the variety of topics and participants, the work groups were given wide latitude in deciding how best to research, evaluate, coordinate, and present their conclusions or recommendations. Several groups had working meetings to analyze their respective topics; other groups prepared and commented on a position paper. It was not necessary for the work groups to reach consensus or well-formulated conclusions; it was considered more important for the groups to identify the important facets of the topic, particularly those factors that could affect the evaluation and selection of remedial options. Open-ended or unresolvable issues, as well as those issues on which no consensus was reached during discussions, could also be identified and referred to the FS project staff for evaluation and resolution within the context of the overall FS document.

The work groups wrote final, concise summaries of their efforts and presented them in July 1993 to the FS team for use in performing the engineering and environmental analysis. The summary reports (1) identified the areas that each work group felt were the major decision criteria, decision points, or concerns that were important to the topic and (2) discussed possible approaches or options that the FS team could use to deal with the topic. When possible, the work groups identified potential unknowns that may affect the analysis in the FS, presented the pros and cons of various facets of the subject, and provided recommendations for further consideration in the FS.

The work groups provided valuable information to the FS team that helped them approach and frame the various topics with consideration of the broader perspectives that the work group participants provided.

I.2.7 Public Meeting

More than 150 people attended a public meeting on May 18, 1993, to hear the updated status of the EFPC RI studies and to learn about the potential technologies for remediation of the floodplain soils. The meeting presented the findings of the RI Report submitted to EPA and TDEC 3 weeks earlier. DOE and representatives of Radian Corporation and SAIC gave presentations on the details of the investigative studies and identified the areas that were considered to be contaminated on the basis of the preliminary remediation goals recommended to the regulators. Also presented and discussed were the technologies and remedial actions that were under consideration: the treatment actions of solidification, chemical washing, and thermal desorption (soil roasting); "No Action"; containment; institutional controls; excavation; and disposal. The final presentation outlined the future steps to be taken and the anticipated schedule.

After the presentations, the group was subdivided into small discussion groups of 8 to 12 people for direct interactions with DOE and support staff. Facilitators and technical personnel responded to the questions and concerns expressed in the small groups. Summaries of the questions were recorded and compiled for project staff to use in identifying major areas of concern. After the public meeting, the questions and concerns were categorized, and DOE wrote responses for these main topics:

- remedial alternatives,
- remedial investigation,
- regulations,
- costs,

- human health and ecological risks,
- land use,
- legal issues, and
- continuing discharges from the Y-12 Plant.

I.2.8 Citizens' Working Group

Volunteers to serve on a Citizens' Working Group for EFPC were solicited through advertisements and announcements at the Property Owner's Workshop and the Public Meeting in May 1993. The Citizens' Working Group is an informal, project-specific organization of interested and concerned citizens formed to provide DOE with feedback about the proposed remedial alternatives for the creek's floodplain soils. Because its membership is voluntary, it is not believed that the Citizens' Working Group reflects all opinions of the community.

The EFPC Citizens' Working Group was not formed to be a decision-making or consensus-building group. It was, however, involved in reviewing the proposed remedial alternatives, identifying concerns, and suggesting options that may not have been considered. Because of the cumulative informational nature of the meetings and the difficulty in ensuring that newcomers acquire this information, membership in the Citizens' Working Group was open until only the first meeting on June 17th. Meetings were open to the public and observers were welcome to attend and voice their opinions.

The group's activities were sequenced to maximize their ability to help DOE gain new perspectives about potential remedial alternatives that were under consideration and to perhaps even introduce new alternatives. Input from the group helped DOE better understand citizens' concerns related to remediation of the floodplain soils and the potential impacts to the community. Concurrently, the group gained a more in-depth awareness and a better understanding of the many steps required in the EFPC RI/FS process.

I.2.8.1 Initial questionnaire

To obtain a better picture of the expectations and specific concerns of the Citizens' Working Group, each group member was asked to complete and mail in a questionnaire before the first meeting. The members cited a number of specific expectations that included their desire to better understand where and how much contamination there is and the associated health risks. They have expressed a desire to influence the development of remediation alternatives and anticipated future land use.

In trying to help define group accomplishments, the majority of the members responding agreed that they wanted to help DOE ensure that the public understands the health risks associated with contamination in and along the creek and to assist in the selection of remedial alternatives that best fit the expected land use. Several responses cited the desire to ensure that government funds are spent wisely.

I.2.8.2 Summary of Citizens' Working Group meetings

Beginning in the summer of 1993, the Citizens' Working Group held a series of meetings designed to acquaint the group with the major regulatory requirements and the status of the

project, then to undertake the process of understanding the building blocks of the sitewide remedial alternatives. The format of most meetings was to walk through prepared presentations and respond to questions and comments. Meeting notes have been maintained for all the Citizens' Working Group meetings; copies of the notes and any handouts from each meeting were mailed to those unable to attend. Mailings often included preparatory material for the Citizens' Working Group members to review to acquaint themselves with the topics of upcoming meetings. The meeting dates and their topics are as follows:

- **June 17, 1993.** Much of the first meeting was devoted to outlining DOE's intended nature and scope of the group, reviewing the results of the initial questionnaire, and obtaining input from the Citizens' Working Group members on their thoughts about what the structure, purpose, meeting frequency, and duration of the working group should be. Questions from the May 1993 Property Owners' Workshop and the Public Meeting were discussed. The presentation for the first meeting expanded on the regulatory process required under CERCLA and the potential remedial alternatives as presented at the Public Meeting. Additional topics that were raised by Citizens' Working Group members and discussed included the regulatory requirements under which DOE must act, the health hazards associated with mercury in its various chemical forms, and the impacts from continuing releases from the Y-12 Plant.

- **June 30, 1993.** The second meeting of the Citizens' Working Group focused on institutional controls and their potential use at EFPC. The descriptions and examples explaining institutional controls are and the steps that might be required to ensure that they are properly implemented were presented. Also discussed was the significance of using institutional controls to alter the assumptions that drive the setting of remediation goals and the concerns about ensuring long-term protectiveness. During the second half of the meeting, a facilitator was teamed with a technical project person to elicit the thoughts of the Citizens' Working Group members on what they would consider to be the "ideal" characteristics of a remediation alternative, assuming that regulatory, monetary, and other constraints were removed.

- **July 21, 1993.** "Active Remedial Alternatives" was the theme for the third Citizens' Working Group meeting. During this meeting, members continued building their understanding of the basic components that are aggregated to compose a sitewide alternative. Descriptions and likely adverse impacts and advantages of the various active remediation actions under consideration were presented and discussed with the Citizens' Working Group members. The subjects covered included the concept of containing the contaminated soils with a soil cover, methods for removal or excavation of the contaminated soils, process and auxiliary equipment for treatment of the soil by low-temperature thermal desorption (soil roasting), and the options for disposal of the mercury-contaminated soils or treatment residuals.

- **August 4, 1993.** At all of the previous Citizens' Working Group meetings, a significant number of the questions and a moderate amount of discussion revolved around the related topics of human health risk assessment and health or epidemiological studies. In response to the suggestions by the Citizens' Working Group, the August 4th meeting included two presentations, followed by a panel discussion by technical experts and regulatory authorities in these fields.

Dr. Elmer Akin, Chief of the Office of Health Assessment in Region IV for EPA, provided a background explanation of the fundamental basics of how and why EPA has chosen the methods for using risk assessment in the Superfund process. He also distinguished between risk assessments (a look into the future at potential health effects or risks) and health and epidemiological studies (a look backward to evaluate current health effects from past exposures). Dr. Akin also explained the difference between these two types of studies and how risk assessment feeds into the risk management decision that ultimately selects the remedial alternatives. Next, Mr. Fred Zafran of SAIC, the company responsible for performing the risk assessment, covered the application of EPA's requirements at EFPC. He explained the objectives of the risk assessment for EFPC and the methods used (including a discussion of toxicity measures for mercury) and then provided a summary of the results of the risk assessment performed to date and the derivation of the preliminary remedial (cleanup) goals. After the presentations concluded, Dr. Akin and Mr. Zafran were joined in the panel discussion by Jack Hanley of ATSDR (a sister agency to EPA that is responsible for performing health assessments), Clayton Gist of DOE, and Bob Young, an Energy Systems scientist.

- **August 21-28, 1993.** On these two days, tours of the creek were conducted for Citizens' Working Group members and other interested parties. The tours began at Lake Reality on the Y-12 Plant site and included several locations along the creek, in addition to its confluence with Poplar Creek. Areas of high contaminant concentrations, sites where remedial investigation sampling was performed, and locations of ecological interest were visited and discussed by project staff.

- **September 14, 1993.** The building blocks of remedial actions that were presented at the June 30 and July 21 meetings were reviewed, and members were electronically polled to gauge their understanding of each remedial action and its effects.

The electronic polling tool used allows participants to register on individual keypads their opinions about a particular question or issue. It provides immediate and anonymous feedback about the question or issue posed; the results are displayed instantly in a chart, graph, or table by an overhead projector on a large screen. (Results can be saved and printed later, if desired.) The system helps reduce the bias that occurs in some meetings; anonymous voting helps ensure that pressure by peers or opinion leaders does not color participants' votes, and gives all voices an opportunity to be heard.

After the poll confirmed that group members had a good base understanding of the remedial alternatives and their impacts, seven sitewide alternatives currently under consideration by the FS team were presented and explained to the group. The remedial actions for each land use type within a sitewide alternative, the underlying assumptions, and the expected human injuries or fatalities and identifiable ecological disruptions were described. Estimates of comparative costs and other distinguishable criteria (soil volumes, surface areas, and transportation truckloads) were also stated for each of the sitewide alternatives.

The group members then used the polling tool to conduct a "paired comparison" of CERCLA's five balancing criteria. The comparison helps determine how much value or importance is placed on each of the five criteria relative to one another. The results

indicated that all of the criteria deserve consideration; however, long-term effectiveness and costs were considered most important.

- **October 13, 1993.** The electronic polling tool played a central role at the October 13, 1993, meeting. First the Citizens' Working Group was lead through a review of the steps in the CERCLA process, an explanation of the general action components, and the development of sitewide alternatives in the FS. Each alternative then was addressed individually to determine how acceptable it was to the group; acceptability was based on a four-level relative scale ranging from "Completely unacceptable to me" to "Completely acceptable." An additional response of "I need more information" was also possible. The exercise was not an attempt to build consensus but rather asked the group only to weigh the acceptability level of each SWA. After all seven SWAs were overviewed, the group was polled to determine what their response would be if they chose an alternative that evening. The question posed was "Which alternative is your preferred Sitewide Alternative, recognizing there is still additional information on the five balancing criteria that is yet to be discussed?" The group could respond with their preference of SWAs 1 through 7; "None of the above;" or "I need more information." Generally, the group indicated their preference for remedial actions that minimized the excavation of soils and disruption of surface areas by favoring SWAs 1, 7, and 6.

  At the November 3, 1993, meeting, the Citizens' Working Group broke into small groups to evaluate the seven site-wide alternatives. Three breakout groups were formed; each was composed of 6 or 7 members and had a facilitator to assist in the evaluation. The purpose of the exercise was to provide the FS project team with a better understanding of what factors were considered important when responses to the sitewide alternatives were given in the October 13, 1993, meeting. A clear understanding of what aspects of the alternatives are acceptable or unacceptable, and why, would help the FS team judge whether their work is in line with public interests and concerns.

  The question to be answered by the small breakout groups during the 45-min session was "What are the major factors (2-3), both pros and cons, you considered important at the last meeting when you selected an alternative? We would like to hear both positive and negative considerations for all 7 SWAs." Each facilitator wrote the comments of his or her group on a flipchart for all to see and discuss.

  At the end of the breakout group session, the Citizens' Working Group reassembled and a member from each of the small groups reviewed and discussed the findings of their group. After the meeting the pros and cons on the flipcharts from each of the small groups were compiled and issued as part of the meeting minutes.

- **December 1, 1993.** The main topic was the Comparative Analysis of the seven sitewide alternatives using the CERCLA balancing criteria. After the strengths and weaknesses of each SWA were reviewed, the approach was to define and walk through each of the criteria and then have the Citizens' Working Group members give their opinions on how well each SWA meets the intent of an individual CERCLA criterion. A progressive scale from 1 (low compliance) to 5 (high compliance) was used. The group members used the electronic polling tool, so their assessment of the degree of compliance for each SWA was instantly available. Using an overhead viewgraph, the results of this poll were then compared with

the results of the comparative analysis performed by the FS engineers and scientists in the draft FS. The results from the two sources were essentially equivalent throughout in the relative rankings of high, medium, and low for the CERCLA criteria. The exercise demonstrated to the group members that choosing a recommended remedial alternative is neither clear-cut nor easy.

- **January 26, 1994.** The Integrated Mercury Remediation Team provided the Citizens' Working Group with an overview of the many activities that are or have been undertaken by the Y-12 Plant to control and reduce the amount of mercury leaving the plant, particularly through discharges to EFPC. The key points noted were that on-site and off-site mercury remediation activities are being coordinated; mercury releases from the Y-12 Plant are steadily being reduced; and that current releases from the Y-12 Plant should not affect the remediation of EFPC. The presentation identified the primary DOE and contractor organizations that are implementing the strategies for removal, isolation, and treatment of mercury in the remediation and abatement activities. Summarized data from the daily sampling of EFPC were presented to illustrate that the amount of mercury leaving the Y-12 Plant has continually decreased during the last decade.

  Complementing the Integrated Mercury Remediation Team's presentation was a second presentation describing the decontamination and decommissioning (D&D) program at the Y-12 Plant. The talk, focussing on Building 9201-4 (commonly known as Alpha 4), gave an overview of the ongoing surveillance and maintenance program, characterization and assessment activities, and the removal actions for reduction of risks, hazards, and surveillance and maintenance costs. According to ballpark figures cited, D&D activities have reduced the amount of mercury in Alpha 4 from ~465,000 pounds to an estimated 35,000 pounds.

  The common theme throughout the evening was that the releases of mercury from the Y-12 Plant, both current and in the future during D&D activities, would not be significant enough to defer the decision to remediate the EFPC floodplain soils.

- **February 24, 1994.** The meeting focused on understanding the species of mercury in EFPC floodplain soils and how this information is used to establish cleanup criteria [remediation goal options (RGOs)]. Most studies have indicated that mercury is not in a very bioavailable form but rather in a less soluble and less toxic form (mercuric sulfide). This evidence has been circumstantial only and not unequivocal proof of mercury form. Dr. Ralph Turner, an ORNL scientist, gave a presentation on the chemical nature of mercury and explained how the species (form) controls how toxic, bioavailable, and mobile mercury is. Dr. Turner and Mark Barnett, a Ph.D. student working at ORNL, then discussed the different approaches taken to characterize mercury forms in the EFPC soil. These include past studies conducted by Nat Revis in the mid 1980s and those conducted in the early 1990s as part of the RI. Dr. Turner and Mr. Barnett also discussed ongoing studies that were intended to provide unequivocal evidence of the actual mercury form.

  Finally, Mark Stack, of Martin Marietta Energy Systems, Inc.'s risk assessment group, explained how the information on mercury form would be used by the risk assessment analyst to derive new remediation goal options for cleanup.

- **May 25, 1994.** The results of the mercury speciation studies that had been conducted since the February Citizens' Working Group meeting were presented. These studies revealed that mercuric sulfide and elemental mercury are the predominant forms of mercury in EFPC soil. The test results have resulted in DOE recommending to EPA and TDEC that a bioavailability factor of 30% be incorporated for the human health risk assessment. This revises the human health remediation goal option to the most sensitive receptor to 180 ppm for Residential and Agricultural land uses and 938 ppm for Commercial, DOE, and Other land uses. It was stated that changing the remediation goal options would reduce adverse environmental impacts to the creek; would reduce the volume and surface area of contaminated soil that would have to be remediated; and would reduce the costs of remediation.

  After viewing the EFPC remedial alternatives video, the group proceeded with "Open Mike" night; three individuals (Fred Maienschein, Bob Peelle, and Al Brooks) made presentations.

  Fred Maienschein told the group that the goal of his presentation was to quantify the factors of safety used in EPA's risk assessment process. He said that, once the critical pathway is determined, deriving remediation goal options for mercury is apparently simple, but there is actually a great, "shocking" arbitrariness because of the uncertainties, which results in a tremendous factor of safety. Maienschein said he would like for the risk assessment team to develop the best value for remediation adding a known factor of safety rather than "piling conservatism on top of conservatism until there is no resemblance to reality."

  Bob Peelle then presented his concerns to the group. He said that the problem is (1) finding a plan that EPA and the public will accept at not too great an expense and disruption and (2) discovering how to prevent risks to people and the environment, both now and in the future.

  Al Brooks then made his presentation to the group. The first part of his presentation dealt with optimization theory. He pointed out that EFPC does not stand alone as a single project but is part of—and tied to—other environmental projects across the country. Mr. Brooks then talked about the "EFPC Risk Assessment Error in a Nutshell." He discussed the solubilities of different forms of mercury, their concentrations in EFPC soils, their absorption factors and the acceptable levels in soil. He reminded the group that using EPA's reference dose without using the proper absorption factor based on the species of mercury present in EFPC soil is wrong.

- **June 29, 1994.** Barney Cornaby, an environmental scientist at SAIC, gave a presentation on the ecological risk assessment that was performed for EFPC. He stated that the overall objective of the ecological risk assessment was to support the RI, which would lead to a sitewide cleanup action. He pointed out that mercury and methyl mercury move up from organism to organism through the food web. He explained the methods and approaches used to study this phenomenon and subsequently to draw conclusions that could be used by the regulatory decision makers to determine the need for cleanup. Dr. Cornaby emphasized that there is no clear-cut regulatory guidance establishing ecological remediation goal options. He reviewed many of the technical issues that could modify the approach and for which much input and consultation was received from experts and regulatory authorities.

On the basis of this and a common sense approach used by the EFPC project team, it is recommended that an remediation goal option of 200 ppm be used to protect the most sensitive group, mid-level predators, which will ultimately protect all other organisms in the ecological system.

I.2.8.4 Citizens' Working Group issues summary table

To ensure that all items identified by the Citizens' Working Group are fully addressed by DOE at some point in the project, a Citizens' Working Group issues summary table was developed. The table was also used to provide feedback and to demonstrate to the Citizens' Working Group how and where their input was used in the FS and subsequent processes. The table, organized by the main subject of the comment, explains the comment and either provides a response or tells when or where a response can be found. The purpose of the table was to identify and track the items rather than provide a response to every item, because many items would take several pages to discuss fully.

The FS team periodically reviewed the table to ensure that all items were properly addressed and that no discontinuities develop between the table and actual project activities. The table was maintained with the intent of passing it on to the remedial design contractor so that those items that need to be addressed in later stages of the project will not be forgotten or overlooked.

Major issues and concerns identified by the Citizens' Working Group focused on costs, health effects, hydrologic impacts, institutional actions, land use, property issues, transportation risks, treatment options, mercury form, and the continuing releases from the Y-12 Plant.

I.3 SUMMARY

From the very early stages of the EFPC project, DOE has taken proactive steps to ensure that the concerns and issues of those potentially affected by the remediation of EFPC have been taken into consideration. As noted above, multiple measures have been implemented to ensure widespread dissemination of information regarding the remedial program for EFPC. Additionally, DOE has initiated extensive public dialogue, well before it is required under CERCLA legislation, and much earlier in the CERCLA process than is traditional. A prime example of DOE's proactive stance is the Citizens' Working Group; numerous citizens have donated their time, and DOE has brought them into the process during the developmental stages of the FS and before the issuance of the PP. These actions should provide significant opportunities to gauge and fully consider the concerns of the local community, thereby enhancing the assessment of CERCLA's modifying criterion of community acceptance.

APPENDIX J

FLOODPLAINS AND WETLANDS ASSESSMENT FOR REMEDIATION OF EFPC

Floodplains and Wetlands Assessment for Remediation of East Fork Poplar Creek

Oak Ridge, Tennessee

Prepared for
U.S. Department of Energy
under contract DE-AC05-91OR21950; ESC

August 29, 1994

93-008P/081394

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

contributed to the preparation of this document and should not be considered an eligible contractor for its review.

CONTENTS

FIGURES . . . . . J-vii
ACRONYMS . . . . . J-ix
PREFACE . . . . . J-xi

J.1. INTRODUCTION J-1

J.2. DESCRIPTION OF THE PROPOSED ACTION J-1
J.2.1 Site Description J-1
J.2.1.1 Floodplains J-1
J.2.1.2 Wetlands J-2
J.2.2 Project Description J-2

J.3. EFFECTS ON FLOODPLAINS AND WETLANDS J-2
J.3.1 Floodplain Effects J-3
J.3.2 Wetlands Effects J-3

J.4. ALTERNATIVES J-4
J.4.1 SWA 1: No Action J-4
J.4.2 SWA 2: Partial Excavation and Disposal J-4
J.4.3 SWA 3: Complete Excavation and Disposal J-5
J.4.4 SWA 4: Partial Excavation and Treatment J-5
J.4.5 SWA 5: Complete Excavation and Treatment J-6
J.4.6 SWA 6: Containment and Institutional Actions J-6
J.4.7 SWA 7: Limited Actions and Land Use Restrictions J-6

J.5. MITIGATION J-7

J.6. SUMMARY AND CONCLUSIONS J-8

REFERENCES J-9

FIGURES

J.1. Location of DOE's Oak Ridge Reservation, EFPC, and Oak Ridge, Tennessee J-13
J.2. EFPC 100-year floodplain and wetlands J-14
J.3. EFPC FS SWAs 1-5 (a-n) J-15
J.4. EFPC FS SWA 6 (a-f) J-29
J.5. EFPC FS SWA 7 (a-f) J-35

ACRONYMS

CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CFR	Code of Federal Regulations
COE	U.S. Army Corps of Engineers
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
EFPC	East Fork Poplar Creek
FEMA	Federal Emergency Management Agency
FS	Feasibility Study
FWS	U.S. Fish and Wildlife Service
PRG	preliminary remediation guideline
RGO	remediation goal objective
RI	Remedial Investigation
RU	Remedial Unit
SAIC	Science Applications International Corporation
SWA	sitewide alternative
TDEC	Tennessee Department of Environment and Conservation
TVA	Tennessee Valley Authority

PREFACE

This Floodplains and Wetlands Assessment has been prepared in accordance with the Code of Federal Regulations (CFR), Title 10, Part 1022, to fulfill the U.S. Department of Energy's (DOE's) responsibilities under Executive Orders 11990, Wetlands Protection, and 11988, Floodplain Management.

The Orders encourage measures to preserve and enhance the natural and beneficial functions of floodplains and wetlands. These orders also require federal agencies to take action to minimize or mitigate the destruction, loss, or degradation of floodplains and wetlands. The sequence of mitigation measures should emphasize the importance of:

- avoiding new construction or work in floodplains and wetlands unless there is no practicable alternative to that action; and

- minimizing the harm should the only practicable alternative require the proposed action to take place in a floodplain or wetland.

Finally, the Orders seek to provide early and adequate opportunities for public review of plans and proposals involving new construction or similar projects in floodplains or wetlands.

On October 4, 1993, DOE published a Notice of Floodplain and Wetland Involvement (58 *Federal Register* 51623-4) announcing that DOE would conduct environmental restoration activities in floodplains and wetlands within and adjacent to the Oak Ridge Reservation. DOE proposes to remediate contaminated soils in the floodplain and wetlands of East Fork Poplar Creek (EFPC) in Oak Ridge, Tennessee. EFPC is a National Priorities List site, and remediation would proceed in accordance with provisions of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended.

The floodplains and wetlands assessment serves to inform the public of proposed site remediation activities and to present measures or alternatives to the proposed action that will lessen or mitigate adverse effects. This floodplains and wetlands assessment evaluates potential remedial actions that may occur in the 100-year floodplains of adjacent surface waters or wetlands in the vicinity of EFPC. Information on the following topics is presented: Project Description, Effects on Floodplains and Wetlands, Alternatives, and Mitigation. The 100-year flood was chosen as the criterion of evaluation for floodplain effects because no critical actions, as defined in 10 CFR, Part 1022, would occur as a result of remediation of the EFPC site.

APPENDIX J

FLOODPLAINS AND WETLANDS ASSESSMENT FOR REMEDIATION OF EFPC

J.1 INTRODUCTION

The U.S. Department of Energy's (DOE's) Y-12 Plant in Oak Ridge, Tennessee, contains the headwaters of East Fork Poplar Creek (EFPC) (Fig. J.1). Releases of mercury used to produce nuclear weapons at the plant between 1950 and 1965 contaminated portions of EFPC and its floodplain. Process water discharges from the Y-12 Plant contribute a large portion of the total base flow of EFPC. The creek leaves the Y-12 Plant and flows through the city of Oak Ridge in Anderson and Roane counties before reentering the Oak Ridge Reservation and discharging into Poplar Creek ~23.3 km (14.5 miles) from its origin. EFPC passes through many residential, agricultural, and commercial areas, although much of the floodplain remains undeveloped. All land in the EFPC floodplain is federally, municipally, or privately owned.

The addition of the Oak Ridge Reservation and its environs to the National Priorities List in 1989 required DOE to plan the remediation of EFPC under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). DOE entered into a Federal Facilities Agreement with the U.S. Environmental Protection Agency (EPA) and Tennessee Department of Environment and Conservation (TDEC). A Remedial Investigation (RI) to document the nature and extent of contamination began in 1990. A baseline risk assessment in the RI characterized potential risks that contaminants may pose to human and environmental health. In 1992, DOE initiated a Feasibility Study (FS) to evaluate sitewide alternatives for remediation of the EFPC floodplain and also the effects of remediation on the environment.

J.2 DESCRIPTION OF THE PROPOSED ACTION

J.2.1 Site Description

J.2.1.1 Floodplains

The 100-year floodplain of EFPC (Fig. J.2) contains ~271 ha (670 acres). Approximately 58% of the floodplain is forested with bottomland hardwoods or pine and hardwood plantations. About 17% is grasslands, lawns, pastures, and old fields. The remaining 25% is in commercial development or other land uses. Predominant land uses are residential, agricultural, commercial, and undeveloped open land.

The Tennessee Valley Authority (TVA) conducted a Flood Insurance Study of EFPC to determine the flood profiles for the Federal Emergency Management Agency (FEMA) (FEMA 1984). FEMA used this information to revise existing Flood Insurance Rate Maps of EFPC (FEMA 1985). TVA and the U.S. Army Corps of Engineers (COE) amended this study to include changes in the floodplain and floodway boundaries resulting from commercial and residential development in the floodplain and changes in discharge from the Y-12 Plant (TVA 1991; COE 1992a).

J.2.1.2 Wetlands

The COE identified 17 wetlands in and around the floodplain of EFPC (COE 1992b); 16 of those are in the creek's 100-year floodplain (Fig. J.2). These wetlands, ranging in size from 0.01 ha (0.02 acre) to 1.14 ha (2.81 acres), comprise a total of 5.17 ha (12.72 acres), 5.16 ha (12.70 acres) of which are in the EFPC floodplain.

The EFPC floodplain wetlands contain bottomland hardwood forest, scrub-shrub, and permanently ponded habitats. Approximately 2.49 ha (6.16 acres) of wetlands occupy the bottomland hardwood forests and are composed principally of green ash (*Fraxinus pennsylvanica*), American sycamore (*Platanus occidentalis*), and boxelder (*Acer negundo*); 2.47 ha (6.10 acres) are dominated by shrubs such as dogwood (*Cornus* spp.), alder (*Alnus* spp.), or buttonbush (*Cephalanthus occidentalis*); and 0.18 ha (0.45 acre) is a shallow pond dominated by duckweed (*Lemna* spp.). The wetlands in the EFPC floodplain provide productive wildlife habitat, attenuate floodwaters, and retain sediment (COE 1992a).

J.2.2 Project Description

The implementation of the sitewide alternatives described in the EFPC FS (DOE 1994a) would involve activity in the floodplain and wetlands. Remedial actions considered include no action, partial or complete excavation and disposal of contaminated soils, partial or complete excavation and treatment, containment actions with institutional actions, or limited actions with land use restrictions. Section 4 contains detailed descriptions and evaluations of the remedial alternatives.

The baseline risk assessment (1) recommended maximum levels for contaminants in soils to protect human and ecological health (DOE 1994b) and (2) evaluated current and future exposure for five general land use categories or remedial units (RUs): Residential, Agricultural, Commercial, DOE property, and open undeveloped land (Other). Remediation guidelines vary according to land use and exposure pathways to humans and ecological receptors. Potential exposure was greatest in the Residential and Agricultural RUs, and the baseline risk assessment recommended a preliminary remediation guideline (PRG) of 180 ppm of mercury in soil. Potential exposure was less in the Commercial, DOE, and Other RUs, and the PRG for mercury was set at 200 ppm. The FS adopted these PRGs as remediation goal options for the detailed evaluation of alternatives.

The RI identified ~7.35 ha (18.16 acres) of floodplain soils that are contaminated in excess of remediation goal options and would require consideration for remediation. Mercury is present at various concentrations in 12 wetlands, although only 0.91 ha (2.25 acres) in 6 wetlands are in RUs that might require remediation.

J.3 EFFECTS ON FLOODPLAINS AND WETLANDS

DOE would avoid and minimize adverse impacts to floodplains and wetlands to the maximum extent practicable in the selection and implementation of remedial actions. However, most of the alternatives for remediation would alter the contaminated portions of the EFPC floodplain and wetlands and would cause a loss of some floodplain and wetland functions. Most

adverse environmental impacts are expected to be short-term and could be mitigated by site restoration and natural recolonization, although implementation of some remedial actions would result in permanent loss of some wetlands in the EFPC floodplain. Mitigation and compensation would counteract lost or degraded functions. Specific effects of remediation on EFPC floodplains and wetlands depend on the final remedial goal options and the remedial method selected and approved by DOE, EPA, TDEC, and the public.

J.3.1 Floodplain Effects

Excavation would require the use of heavy equipment in the floodplain to excavate and remove contaminated soils. Digging would lower the surface of the floodplain as much as 1 m (3.28 ft) in many places, thus exposing soil to erosion, particularly during floods.

The three containment options evaluated in Sect. 4 would require that fill material be placed in the floodplain in some areas and would raise the surface of the floodplain and some wetlands 0.45 m (18 in.). Contaminated areas are sufficiently dispersed throughout the length of the floodplain that containment would not add enough fill material to the floodplain surface to create dangerous flooding conditions (DOE 1994b).

Support activities for both excavation and containment would include construction of haul roads, construction equipment lay-down areas, and land clearing. Road construction would require placement of relatively small amounts of gravel, etc., to create a road bed for dump trucks and other heavy equipment. Haul roads would be located outside the floodplain as much as possible, but some roads would be required in the floodplain for equipment access. Road construction would disturb the floodplain surface only minimally and would not alter floodwater flow. Clearing land for excavation in contaminated areas would remove most of the native vegetation that helps stabilize the floodplain surface.

Institutional actions include the use of fences, warning signs, deed restrictions, and excavation permits to control access and exposure to contaminated portions of the EFPC floodplain and wetlands. Fences are the only institutional action that would physically alter the nature of the floodplain and interfere with stream flow during floods. Flood debris could accumulate against fences and alter flood flow patterns. This could lead to locally dangerous flood velocities, increased erosion, and increased flooding.

Contamination alone would not impair any floodplain functions, although effects of contamination may potentially affect ecological resources and receptors.

J.3.2 Wetlands Effects

Mercury contamination in the soils of six wetlands exceeds values determined in the baseline risk assessment to be protective. These wetlands may require excavation or containment of wetland soils to accomplish remediation goals. Remedial actions may destroy wetland habitat during excavation, alter the flow of water into wetlands (dewatering), or permanently displace wetlands by containing contaminated soils. Indirect effects of remedial actions include turbidity and siltation from increased erosion.

Remedial actions to remove contaminated soil from the six wetlands would affect ~0.91 ha (2.25 acres) of jurisdictional wetlands (DOE 1994a). The excavation of soil and sediment in the wetlands may diminish the characteristics and function of the wetland, at least during the implementation phase of remediation. Siting studies would include measures to avoid additional disturbance to wetlands from haul roads, construction equipment lay-down sites, or other support actions associated with remediation (DOE 1994a). Roads would avoid wetlands unless remedial plans specifically required excavation of wetland soils.

Most wetlands could be restored after remediations, but some would be permanently destroyed by some remedial actions. DOE would develop a wetlands mitigation plan for lost wetland acreage and functions, with the cooperation of COE and the U.S. Fish and Wildlife Service (FWS), before taking any remedial actions in wetlands.

J.4 ALTERNATIVES

Alternatives for remediation at the EFPC site include: no action, partial excavation and disposal, complete excavation and disposal, partial excavation and treatment, complete excavation and treatment, containment and institutional actions, and limited actions and land use restrictions.

J.4.1 SWA 1: No Action

Under sitewide alternative (SWA) 1, no action, no remediation would occur in the floodplains or wetlands of EFPC. This alternative would avoid any physical disturbance associated with excavation or with temporary dewatering, but because chemical and/or radiological contamination would remain in place, it would not protect human and environmental health (DOE 1994a) and therefore would not allow DOE to fulfill its regulatory obligations to EPA or TDEC.

Under SWA 1, contaminated soil in the floodplain or wetland could act as a potential receptor of contamination to soil, surface water, and groundwater as contaminants in floodplain soil erode, are transported downstream, and redeposited elsewhere in the floodplain or creek channel. In the same fashion, contaminated soil in the floodplain or wetlands could serve as a source of contaminants. In this way, contaminated soil in wetlands could adversely impact habitat quality and serve as a potential exposure source for ecological receptors in aquatic, riparian, terrestrial, and wetland ecosystems in and adjacent to the floodplain. There is no evidence that contaminants in soil are sufficiently mobile or soluble to affect groundwater quality (DOE 1994a, 1994b).

J.4.2 SWA 2: Partial Excavation and Disposal

SWA 2 involves (1) completely excavating from the Residential RU those soils contaminated with >180 ppm of mercury and (2) containing with a 0.45 m (18-in.) soil cover those soils contaminated with >200 ppm of mercury on the Commercial, DOE, and Other RUs (Fig. J.3). Excavation would temporarily disturb ~4.85 ha (11.97 acres) of the EFPC floodplain and ~0.44 ha (1.11 acres) of wetlands. Containment would disturb an additional 2.50 ha

(6.19 acres) of the floodplain and would destroy ~0.46 ha (1.14 acre) of wetlands (DOE 1994b). Approximately 14,800 m^3 (19,400 yd^3) of fill would be placed on areas to be contained.

Because containment areas are dispersed throughout the floodplain and the volumes of material used for the soil covers are relatively small, no adverse effects on stream flow would occur under base flow or storm flow conditions, and the flood storage capacity of the floodplain would not be reduced or otherwise adversely affected (DOE 1994b).

Mitigation of excavated areas would include stabilization to prevent erosion, backfill to the approximate original contour with clean soil from nearby borrow areas, and revegetation as soon as possible after excavation. Contained areas would require immediate stabilization and seeding with grasses and herbaceous plants as soon as soil covers were in place. Contained areas could contribute to recontamination in the future if the integrity of the soil covers were not protected and maintained. A monitoring and maintenance program would ensure that soil covers remained intact, and that contamination did not migrate after all removal, restoration, and revegetation were completed. Soil covers would require periodic mowing to prevent colonization by deep-rooted woody vegetation. Periodic monitoring and 5-year review are required under CERCLA when contaminants are left in place, and wetland monitoring could be part of that effort.

Wetlands would be affected only temporarily by excavation, and a wetland mitigation plan could include backfill to original contour and revegetation with wetland plants to restore disturbed wetlands. Containment would permanently displace wetlands and could require off-site mitigation to compensate for lost wetland functions. Development of a mitigation plan to establish mitigation ratios and other requirements to compensate for lost wetland area and functions would require close cooperation with COE and FWS.

J.4.3 SWA 3: Complete Excavation and Disposal

Under SWA 3, soils contaminated in excess of 200 ppm would be completely excavated from the Commercial, DOE, and Other RUs, and soils contaminated in excess of 180 ppm would be completely excavated from the Residential RU (Fig. J.3). Complete removal and disposal would temporarily disturb ~7.35 ha (18.16 acres) of the EFPC floodplain and ~0.90 ha (2.25 acres) of wetlands.

Complete excavation would remove all soils above RGOs that could potentially be a source of residual contamination in the future. After the initial disturbance from excavation and backfill, the adverse effects of excavation on floodplains and wetlands would be similar to those associated with partial excavation (see Sect. 4.2).

J.4.4 SWA 4: Partial Excavation and Treatment

SWA 4 is similar to SWA 2 except that contaminated soils excavated from the Residential RU would be treated off-site to remove mercury (Fig. J.3). Contaminated soils in the Commercial, DOE, and Other properties would be contained as described in Sect. 4.2. The preferred treatment technology is low temperature thermal desorption. Contaminated soils would be heated under relatively low temperatures (<400° F) to remove mercury. Treated, clean soil would be used as backfill. Concentrated waste residues from the treatment process would be

tested, classified, and disposed of at an appropriate facility. Treated soils may require additions of lime, fertilizer, and other soil amendments to sustain plant growth.

Excavation would temporarily disturb ~4.85 ha (11.97 acres) of the EFPC floodplain and ~0.44 ha (1.11 acres) of wetlands. Containment would disturb an additional 2.50 ha (6.19 acres) of the floodplain and would destroy ~0.46 ha (1.14 acres) of wetlands (DOE 1994a). Approximately 14,800 m^3 (19,400 yd^3) of fill would be placed on areas to be contained.

J.4.5 SWA 5: Complete Excavation and Treatment

Under SWA 5, the technologies described in Sect. 4.4 would be used to treat contaminated soils. Impacts associated with excavation are identical to those discussed in Sect. 4.3; the effects of treatment are similar to those described in Sect. 4.4. Complete removal and disposal would temporarily disturb ~7.39 ha (18.16 acres) of the EFPC floodplain and ~0.90 ha (2.25 acres) of wetlands (Fig. J.3).

J.4.6 SWA 6: Containment and Institutional Actions

Under SWA 6, containment and institutional actions would be used to accomplish remediation goals. DOE would acquire sufficient real estate interest to control access or land use and implement institutional actions (fences, warning signs, deed restrictions, etc.) in portions of the Residential RU containing >180 ppm of mercury and in the Commercial and Other RUs containing >200 ppm of mercury. A 0.45 m (18-in.) soil cover would be placed in all RU areas where mercury contamination exceeded 200 ppm (Fig. J.4).

Under SWA 6, 7.35 ha (18.16 acres) of the floodplain would be directly affected by containment in the Residential, Commercial, DOE, and Other RUs and 0.91 ha (2.25 acres) would be affected by remediation plans. In Segment 1, DOE would acquire and fence 5.53 ha (13.67 acres) of land. Of this land, 1.94 ha (4.79 acres) would be affected by containment, including 0.06 ha (0.17 acre) of wetland. An additional 3.52 ha (8.70 acres), including 0.38 ha (0.94 acre), of wetlands would be acquired, fenced, and contained in the Residential RU in other segments of the floodplain. On Commercial, DOE, and Other RUs, 1.89 ha (4.67 acres) would be contained, affecting 0.46 ha (1.14 acres) of wetlands. Under SWA 6, containment would add a combined volume of 43,500 m^3 (57,000 yd^3) of fill soil at various locations throughout the floodplain.

Periodic flooding could cause flood debris to accumulate against fences. Uncontrolled accumulation of flood debris would eventually impede flood flow and cause flooding in some areas to be more severe than normal. Periodic inspection and maintenance of fencing would be required to remove flood debris.

J.4.7 SWA 7: Limited Actions and Land Use Restrictions

SWA 7 involves the removal and disposal of soil from the Residential RU that is contaminated with >180 ppm of mercury (Fig. J.5). Institutional actions, such as future use restrictions, fencing, and excavation permits, would limit exposure on Commercial, DOE, and Other properties contaminated with >200 ppm of mercury.

Excavation and disposal would affect ~3.52 ha (8.70 acres) of floodplain in the Residential RU. Excavation would temporarily disrupt ~0.38 ha (0.94 acre) of wetlands. Fencing would be placed on 5.53 ha (13.67 acres) of floodplain in Segment 1; this includes 0.46 ha (1.13 acres) of two wetlands. Specific consequences of excavation are identical to those previously discussed. Temporary disturbances to wetlands would require mitigation to restore wetland functions, and permanent destruction of wetlands would require compensation.

J.5 MITIGATION

Prior to remediation of the EFPC floodplains or wetlands, DOE would prepare a detailed, site-specific mitigation plan describing all measures necessary to restore or compensate for any temporary and permanent losses of floodplain and wetland functions. The COE and FWS would help develop and implement the mitigation plan; EPA and TDEC may also provide advice and guidance on its development.

Remediation plans for the floodplain would ensure that the proposed action would not expose people's lives or property to any increased risks from flooding. After completion of remediation activities, excavated floodplain areas would be restored by being backfilled with clean soils and regraded to their natural contours. Contained areas would require relatively small volumes of clean fill for soil covers, and these would not adversely affect stream flow or reduce the capacity of the floodplain to store flood waters. Both excavated and contained areas would require stabilization and revegetation in accordance with soil-erosion and sediment-control standards. Remediation plans would not require that any areas in floodplains be used for storage or that permanent or temporary structures be built or placed in the floodplain.

Proposed mitigation measures to lessen impacts to EFPC floodplains and wetlands include standard construction practices to control erosion and surface runoff and to prevent soil compaction. Such practices include the use of sediment control fences to minimize siltation of wetlands and other water resources. DOE would prepare a sediment control plan identifying best management practices to be employed during remedial action. Construction techniques to avoid or reduce adverse water quality impacts may include scheduling excavation during dry periods when no flow is expected, and temporarily diverting channels, dikes, siltation ponds, coffer dams, and drainage ditches to direct silt in runoff away from downstream or downgradient surface waters. Under SWAs 2 through 6, other techniques such as gabions and bio-engineering would permanently protect stream banks in excavated or contained areas from erosion after remediation. SWA 7 does not include any bank stabilization measures in contained areas, and excavated stream banks would be subject to normal channel erosion in the future (long term).

Other measures would be taken to minimize soil compaction and disturbance, such as requiring heavy equipment to work on mats in wetlands and using low ground pressure machines or extended-reach excavating equipment. Other mitigation techniques may include restoring surface flow patterns, minimizing easement widths, and selecting dust control measures that minimize adverse impacts to nearby streams and wetlands. Administrative and engineering controls would prevent releases of materials from storage areas, equipment, and supplies that could add to contamination in floodplain and wetland soils.

Wetland restoration activities would include, as necessary, compatible fill to replace excavated hydric soils, revegetation with hydrophytic plant species, and maintenance of water flow and water-level fluctuations to achieve the objectives of the wetland mitigation plan. Restoration of excavated wetlands would consist of grading wetland surfaces back to their original contours. Revegetation would require replanting with a suitable mix of hydrophytic emergent, shrub, and tree species to match and enhance the native plant communities that existed prior to remediation. Wetland mitigation should, at a minimum, maintain suitable habitat for a variety of wildlife species, provide for the aesthetic value of open space, and protect surface water quality.

J.6 SUMMARY AND CONCLUSIONS

The following conclusions can be made on the basis of this floodplain and wetlands assessment:

- Remediation of soils in and around the EFPC site would require activity in the floodplains and wetlands.

- The no action alternative would not involve actively disturb these resources but would allow contamination to remain in wetlands and floodplain soils. Residual contamination may impact the function of wetlands as wildlife habitat but would not affect floodplain functions.

- Partial excavation of contaminants either with or without treatment (SWAs 2 and 4) would temporarily disturb ~4.85 ha (11.97 acres) of floodplain soils and ~0.44 ha (1.11 acres) of wetlands.

- Under SWAs 2 and 4, containment of contaminants would permanently alter ~2.50 ha (6.19 acres) of floodplain soils and ~0.46 ha (1.14 acre) of wetlands.

- Complete excavation of contaminants either with or without treatment (SWAs 3 and 5) would temporarily disturb ~7.35 ha (18.16 acres) of floodplain soils and ~0.90 ha (2.25 acres) of wetlands.

- Under SWA 6, institutional actions and containment of contaminants would require fencing of 9.05 ha (22.37 acres) of floodplain, permanent alteration of ~7.35 ha (18.16 acres) of floodplain soils, and permanent alteration of ~0.90 ha (2.25 acres) of wetlands.

- Under SWA 6, containment would add a combined volume of 43,500 m^3 (57,000 yd^3) of fill soil at various locations throughout the floodplain.

- Under SWA 7, excavation of contaminants would temporarily disturb ~3.52 ha (8.70 acres) of floodplain soils and ~0.38 ha (0.94 acre) of wetlands.

- Under SWA 7, institutional actions would include erecting a fence to restrict access to one 5.53-ha (13.67-acre) area of the floodplain that includes 0.46 ha (1.13 acres) of two wetlands.

- Effects of excavation would result in minor short-term (1 to 2 years) temporary impacts to floodplains but would not (1) increase stream flow under base flow or storm flow conditions, (2) impede stream flow, or (3) cause upstream or downstream flooding.

- Effects of containment would not (1) increase stream flow under base flow or storm flow conditions, (2) impede stream flow, or (3) cause upstream or downstream flooding.

- Best management practices would control and mitigate erosion and siltation impacts to floodplains.

- Effects of excavation would result in moderate to severe short-term (5- to 10-year) disturbances of wetlands because of the loss of hydric soils and hydrophytic vegetation. These impacts would result in the loss of habitat for a variety of wildlife species and reduce the ability of these wetlands to function as sediment or retention basins for suspended sediments.

- A proactive wetlands mitigation plan designed specifically to restore and enhance the current functions of all affected wetlands at the EFPC site could control impacts to wetlands. Such a plan would need to return wetlands to their original contours, replace suitable soil or sediment substrate, and revegetate with a suitable mix of hydrophytic species of trees, shrubs, and herbaceous plants. Development of the wetland and floodplain mitigation plan would include the expertise of COE and FWS.

REFERENCES

COE (U.S. Army Corps of Engineers). 1992a. *An Identification of the East Fork Poplar Creek Floodplain in Anderson and Roane Counties, Tennessee.* Final Report to the U.S. Department of Energy, December.

COE. 1992b. *An Inventory of Wetlands in the East Fork Poplar Creek Floodplain in Anderson and Roane Counties, Tennessee.* Final Report to the U.S. Department of Energy, December.

DOE (U.S. Department of Energy). 1994a. *Feasibility Study for the East Fork Poplar Creek - Sewer Line Beltway.* DOE/OR/02-1185&D2. Prepared by Science Applications International Corporation, August.

DOE (U.S. Department of Energy). 1994b. *East Fork Poplar Creek - Sewer Line Beltway Remedial Investigation.* DOE/OR/02-1119&D2. Prepared by Science Applications International Corporation, January.

FEMA (Federal Emergency Management Agency). 1984. *Flood Insurance Study for the City of Oak Ridge, Tennessee, Anderson and Roane Counties.* Community Panel No. 475441. National Flood Insurance Program, November.

FEMA. 1985. *Flood Insurance Rate Maps, City of Oak Ridge, Tennessee, Anderson and Roane Counties.* Community Panel Numbers 475441 0010 D, 475441 0015, 475441 0015 D, and 475441 0030 D, May 15.

TVA (Tennessee Valley Authority). 1991. *Flood Analysis for Department of Energy Y-12, ORNL, and K-25 Plants*, December.

APPENDIX J

FIGURES

This page intentionally left blank.

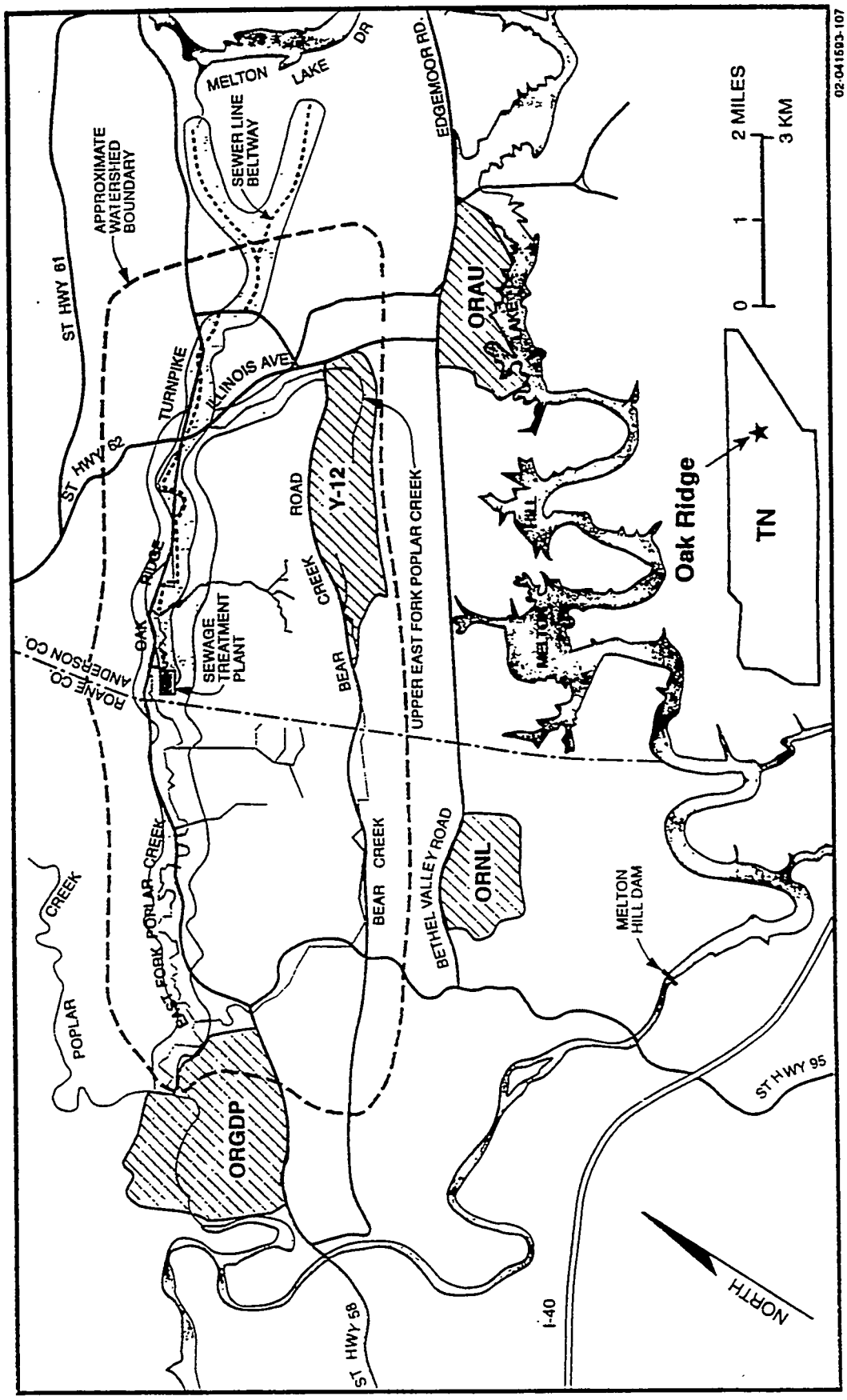


Fig. J.1. Location of DOE's Oak Ridge Reservation, EFPC, and Oak Ridge, Tennessee.

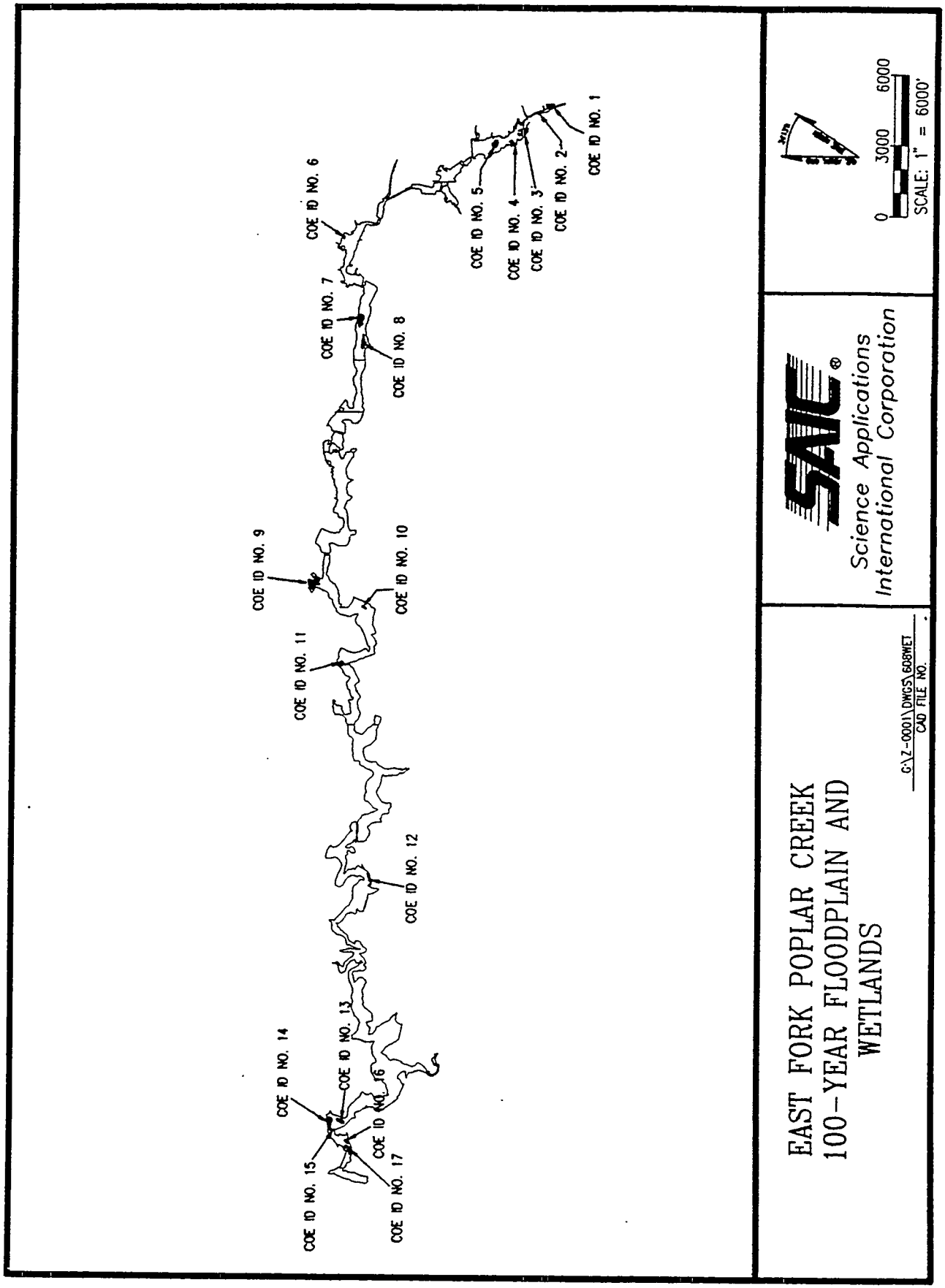
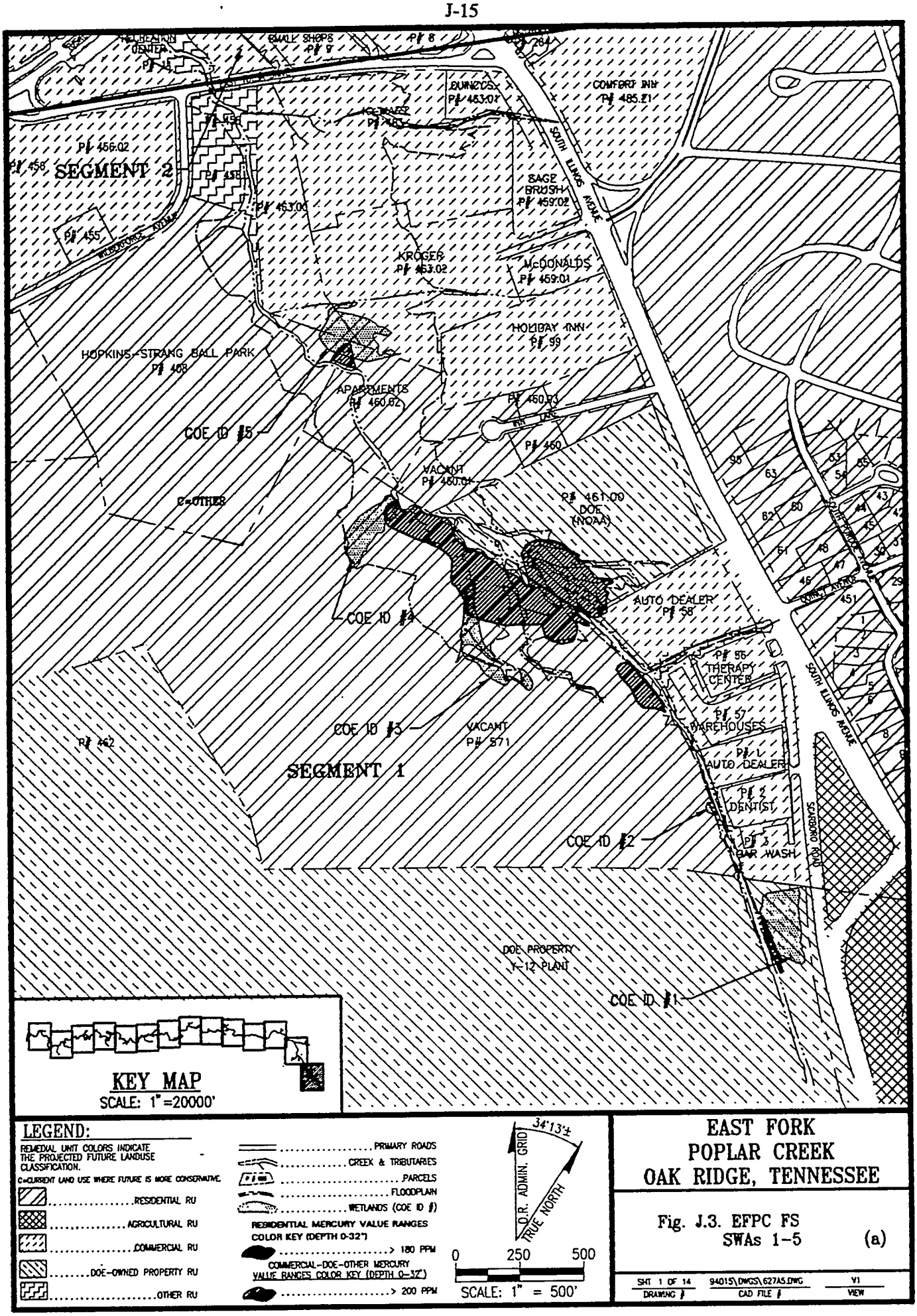


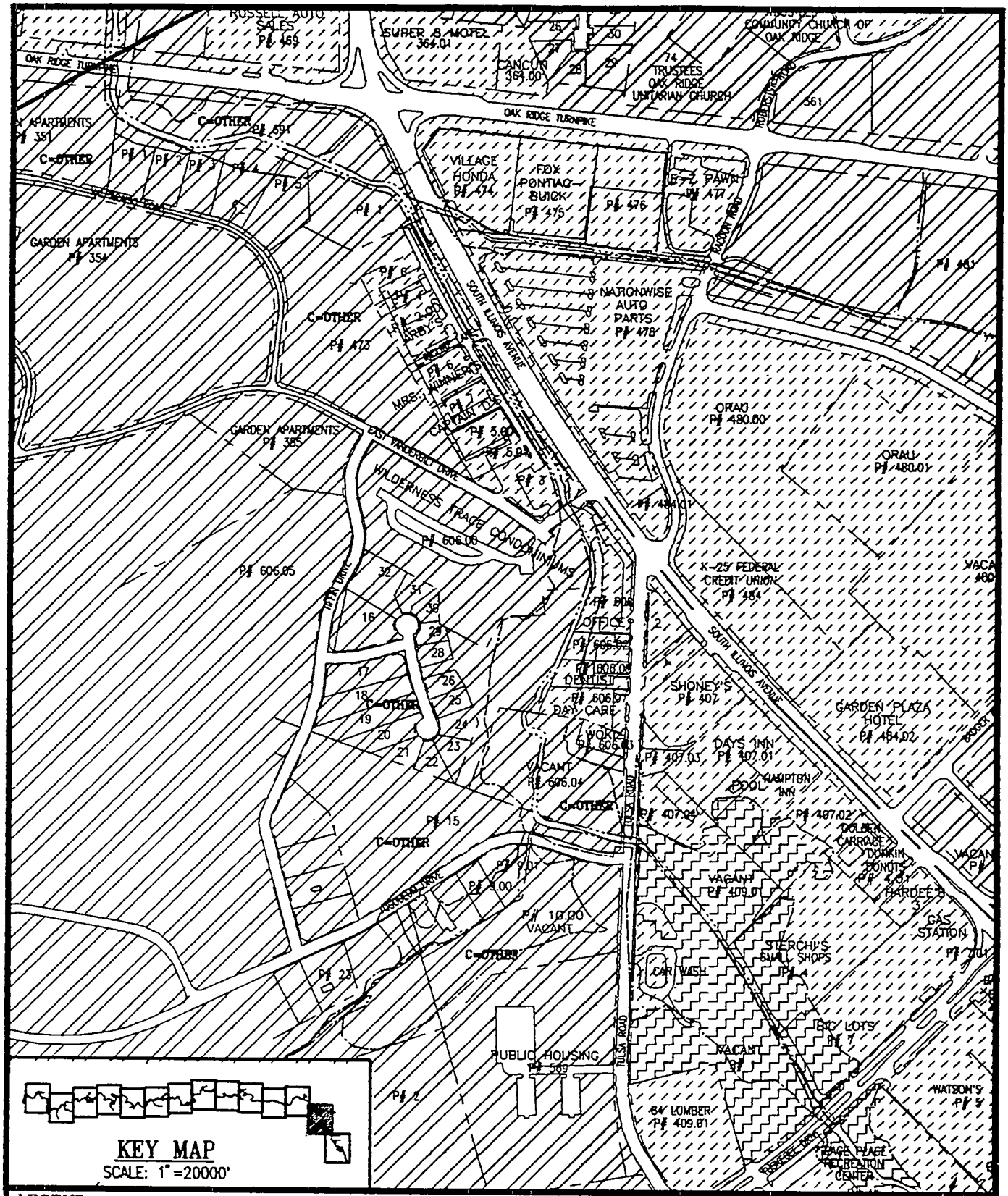
Fig. J.2. EFPC 100-yr floodplain and wetlands.



EAST FORK POPLAR CREEK OAK RIDGE, TENNESSEE

Fig. J.3. EFPC FS SWAs 1-5 (a)

SHT 1 OF 14	94015\DWGS\627A5.DWG	V1
DRAWING #	CAD FILE #	VIEW



LEGEND:

REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION

C=CURRENT LAND USE WHERE FUTURE IS MORE CONSERVATIVE.

- RESIDENTIAL RU
- AGRICULTURAL RU
- COMMERCIAL RU
- DOE-OWNED PROPERTY RU
- OTHER RU

- PRIMARY ROADS
- CREEK & TRIBUTARIES
- PARCELS
- FLOODPLAIN
- WETLANDS (COE ID #)

RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")

- > 180 PPM

COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")

- > 200 PPM

34°13'± O.R. ADMIN. GRID TRUE NORTH

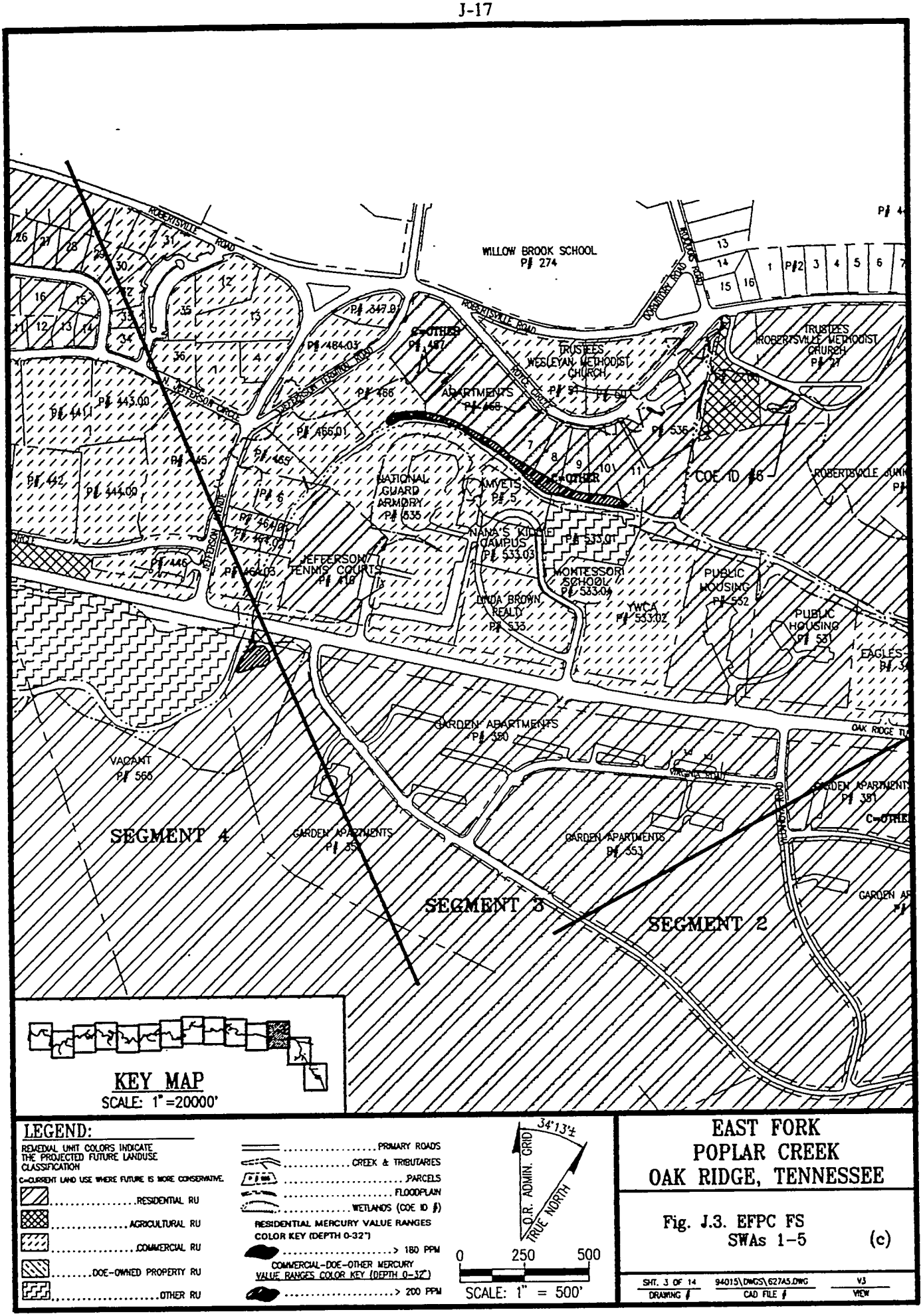
0 250 500

SCALE: 1" = 500'

EAST FORK POPLAR CREEK OAK RIDGE, TENNESSEE

Fig. J.3. EFPC FS SWAs 1-5 (b)

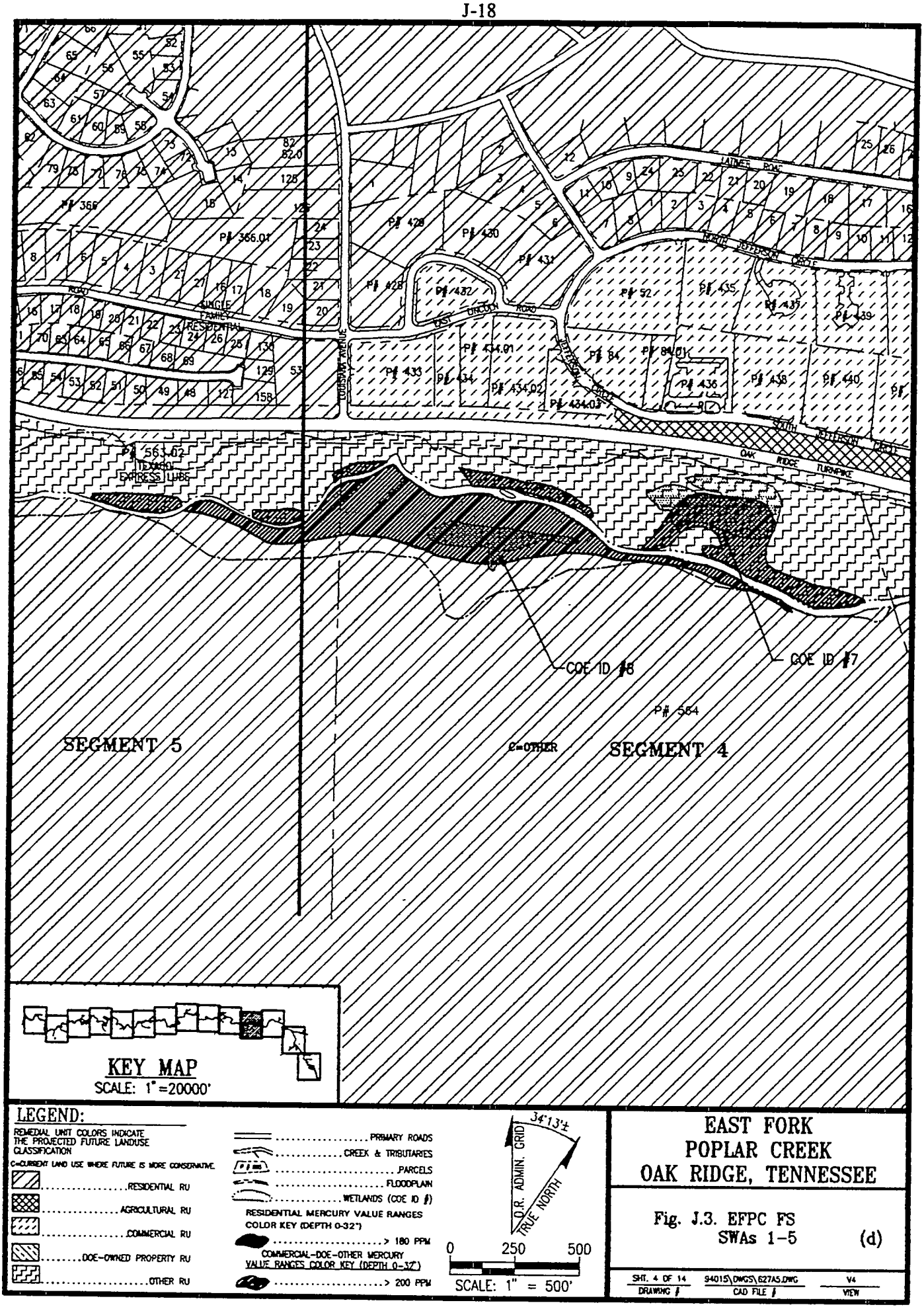
SHT. 2 OF 14	94015\DWGS\627A5.DWG	V2
DRAWING #	CAD FILE #	VIEW



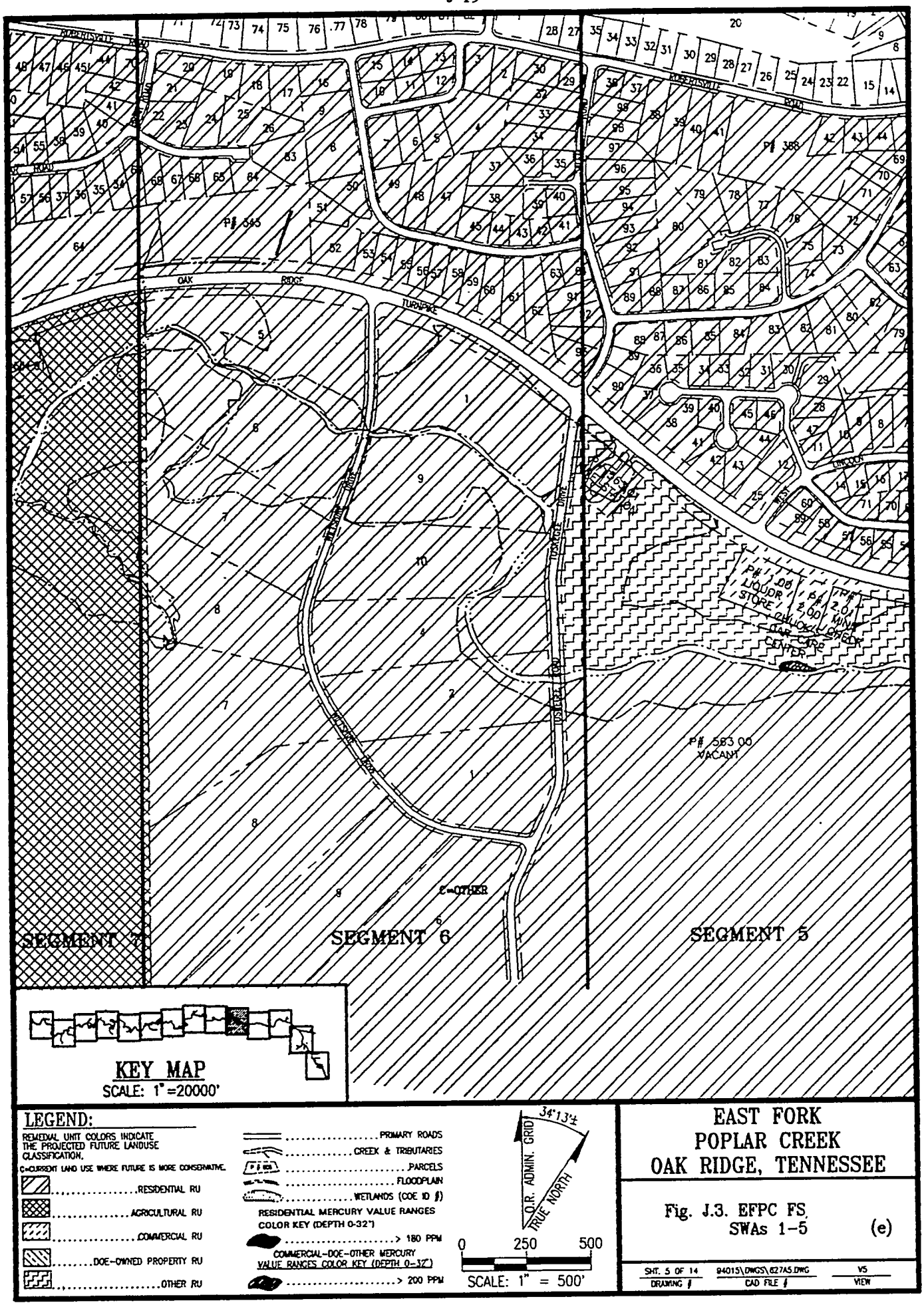
EAST FORK POPLAR CREEK OAK RIDGE, TENNESSEE

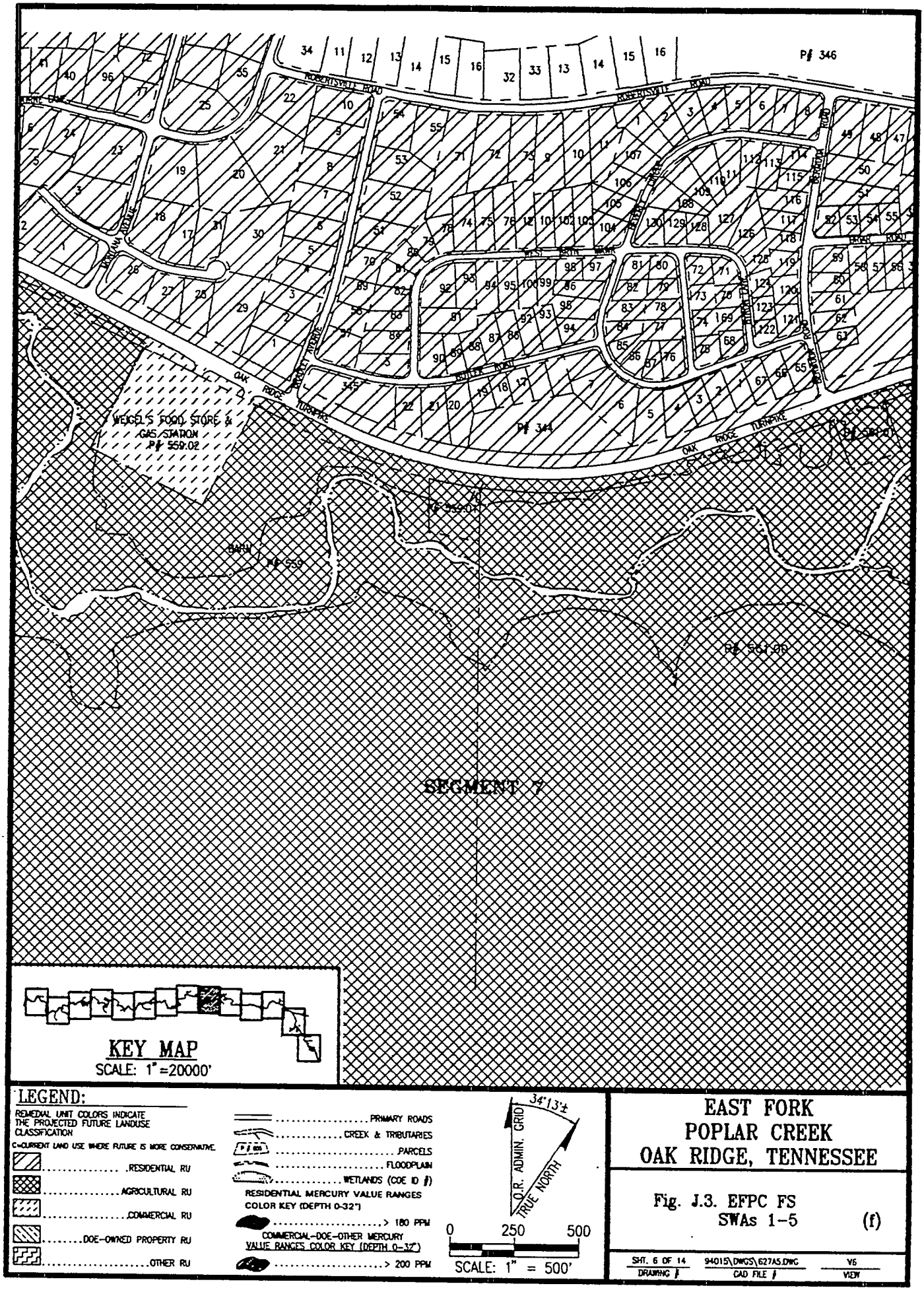
Fig. J.3. EFPC FS SWAs 1-5 (c)

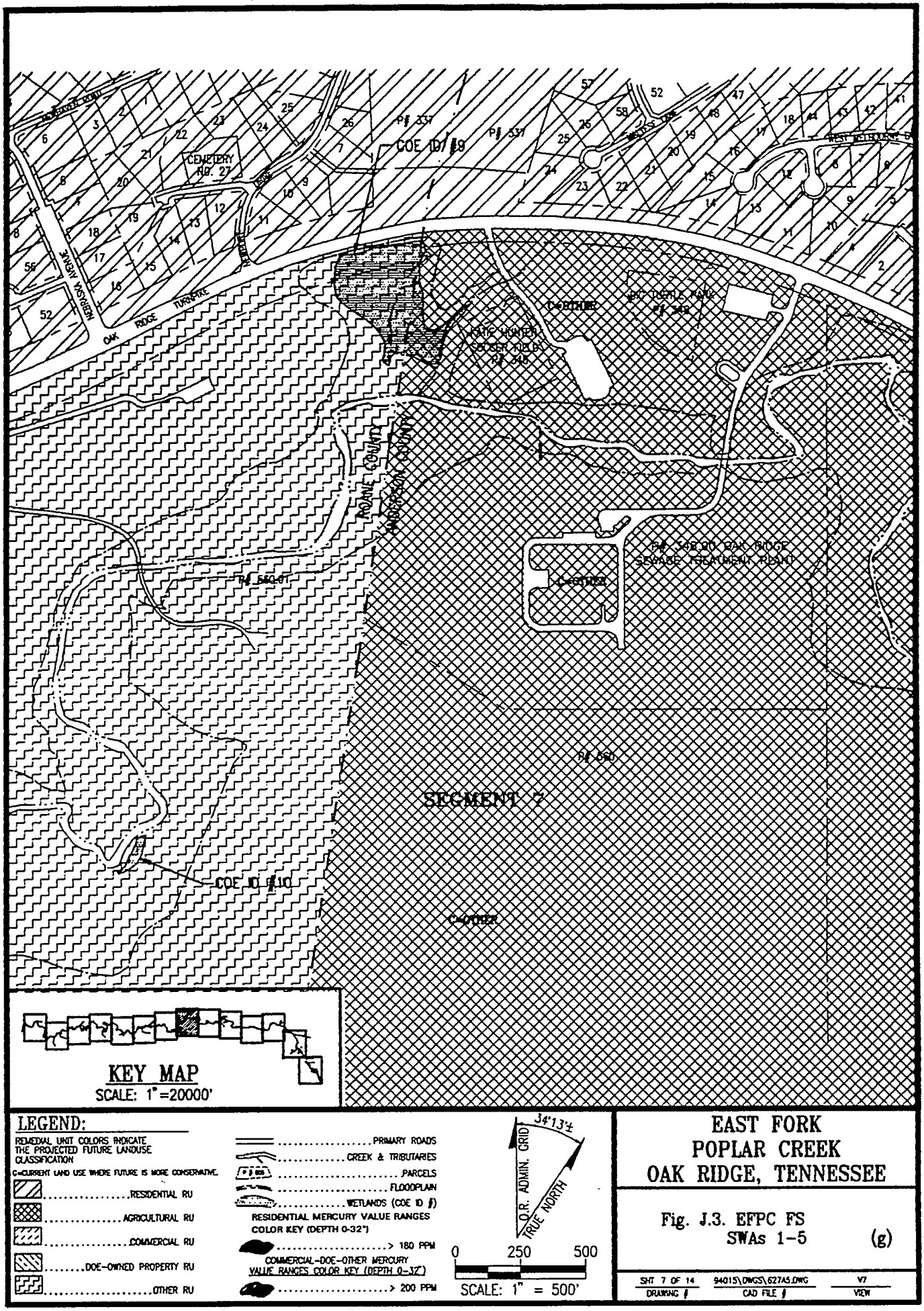
SHT. 3 OF 14 DRAWING # | 94015\DWGS\627A5.DWG CAD FILE # | V3 VIEW

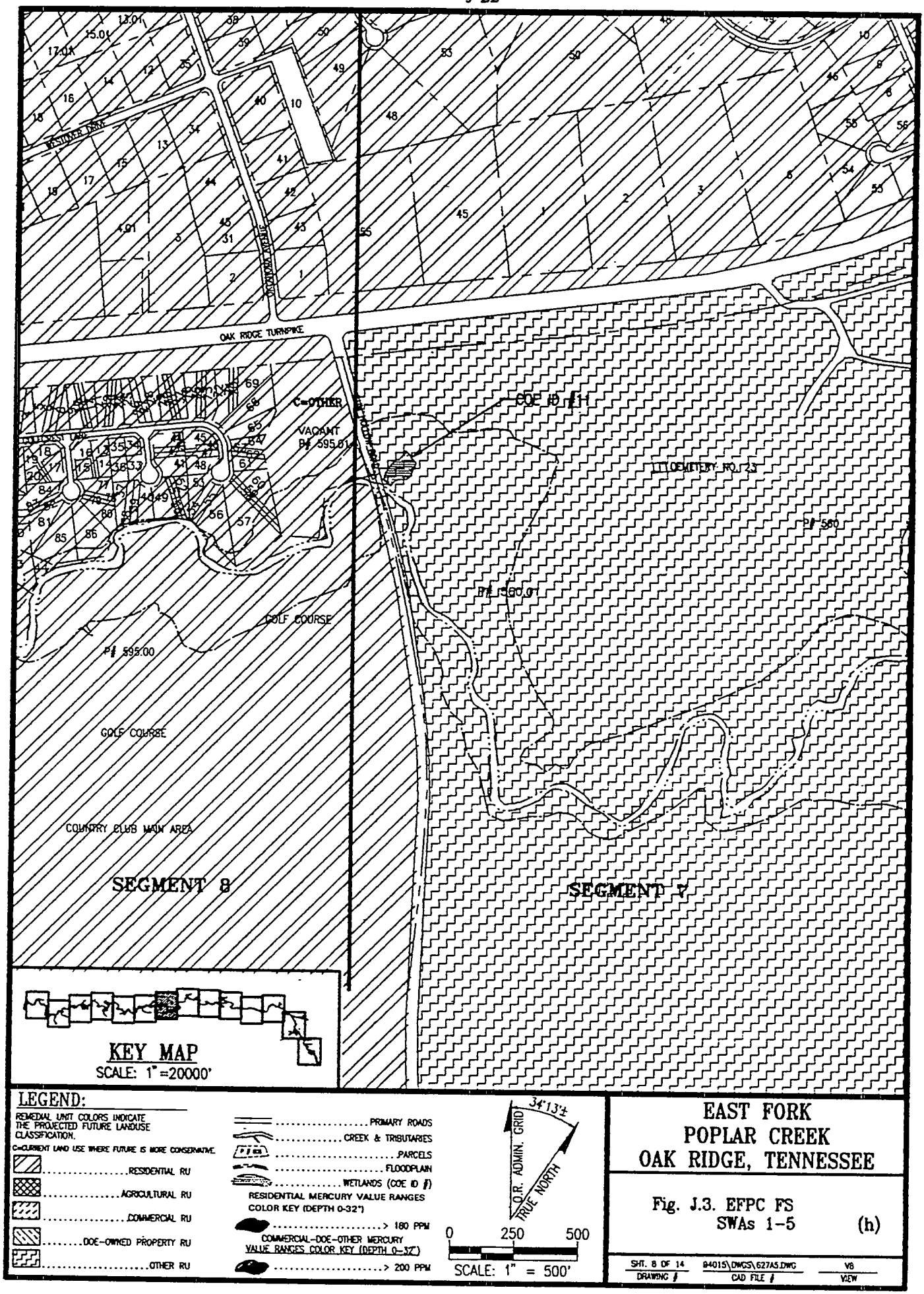


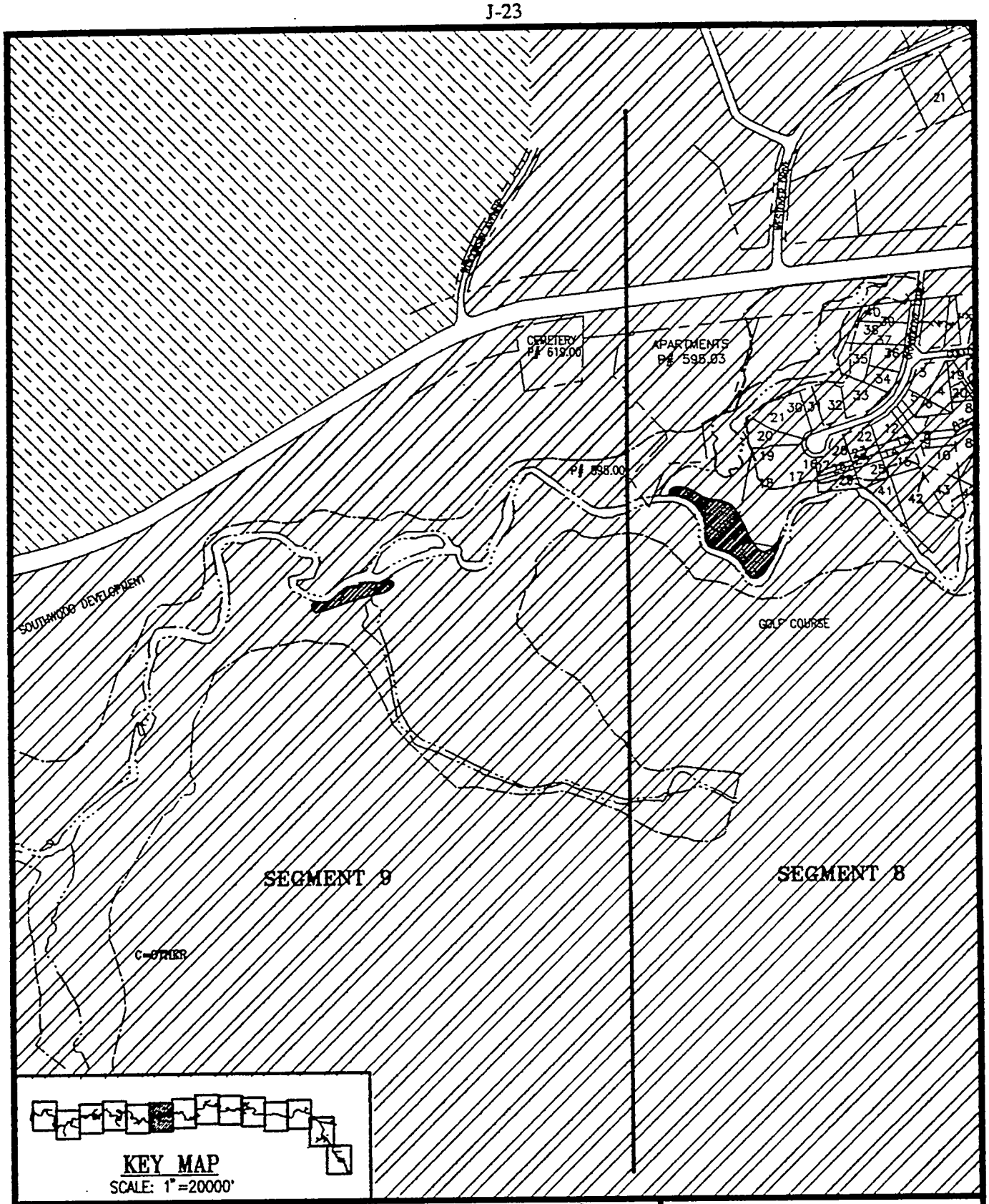
LATIMER ROAD
NORTH JEFFERSON CIRCLE
EAST LINCOLN ROAD
SINGLE FAMILY RESIDENTIAL
LOUISIANA AVENUE
SOUTH JEFFERSON CIRCLE
OAK RIDGE TURNPIKE
P# 366
P# 366.01
P# 428
P# 430
P# 431
P# 432
P# 433
P# 434
P# 434.01
P# 434.02
P# 434.03
P# 52
P# 435
P# 437
P# 439
P# 84
P# 84.01
P# 436
P# 438
P# 440
P# 563.02
TEXACO EXPRESS LUBE
COE ID #8
COE ID #7
P# 564
SEGMENT 5
C=OTHER
SEGMENT 4
KEY MAP
SCALE: 1"=20000'
LEGEND:
REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION
C=CURRENT LAND USE WHERE FUTURE IS MORE CONSERVATIVE
RESIDENTIAL RU
AGRICULTURAL RU
COMMERCIAL RU
DOE-OWNED PROPERTY RU
OTHER RU
PRIMARY ROADS
CREEK & TRIBUTARIES
PARCELS
FLOODPLAIN
WETLANDS (COE ID #)
RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 180 PPM
COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 200 PPM
34°13'±
O.R. ADMIN. GRID
TRUE NORTH
0
250
500
SCALE: 1" = 500'
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE
Fig. J.3. EFPC FS
SWAs 1-5
(d)
SHT. 4 OF 14
DRAWING #
94015\DWGS\627A5.DWG
CAD FILE #
V4
VIEW

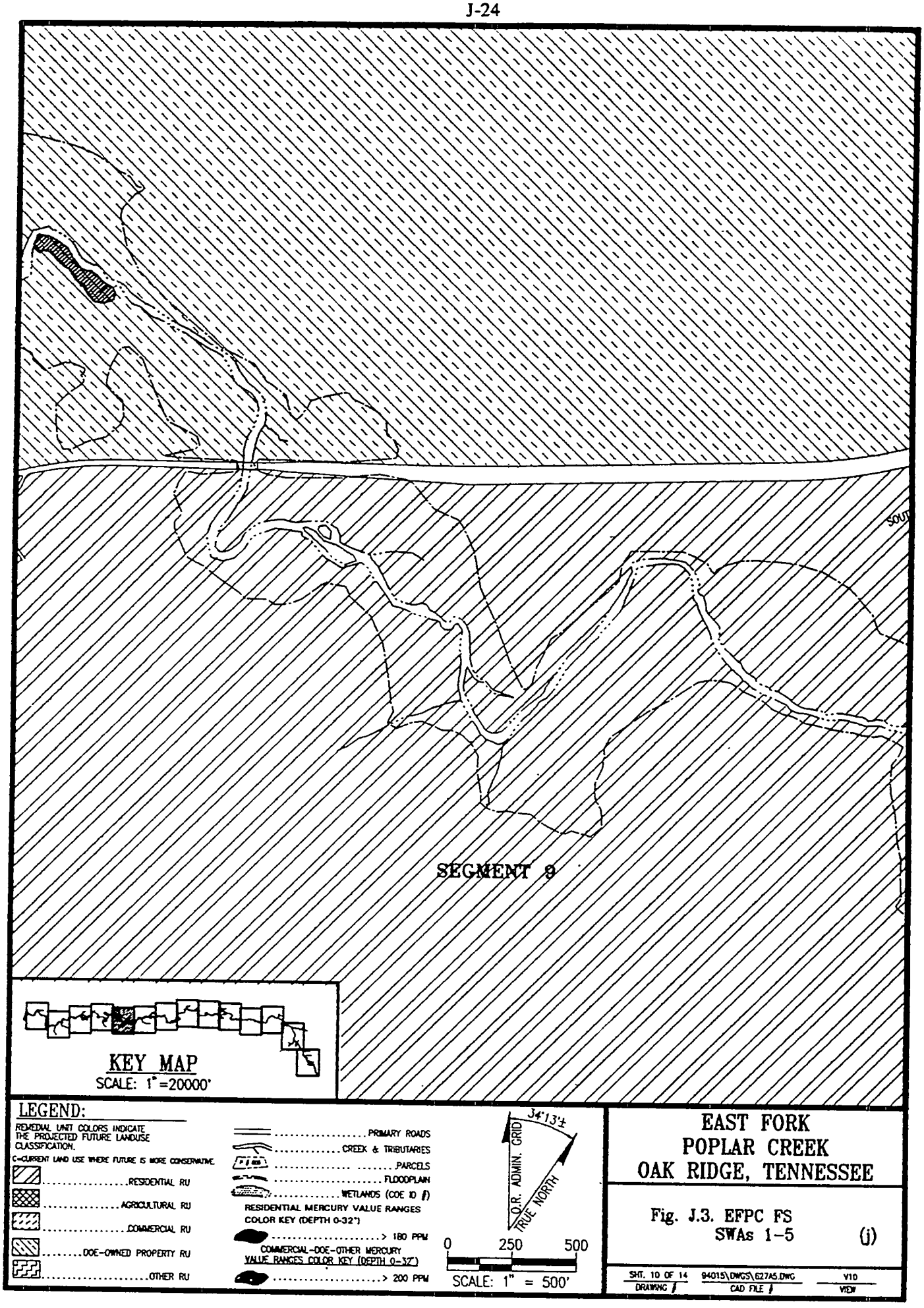

ROBERTSVILLE ROAD
OAK RIDGE TURNPIKE
P# 345
P# 388
P# 1.00 LIQUOR STORE
P# 2.00 CHUCK CHECK
P# 2.01 MINI CAR CARE CENTER
P# 583.00 VACANT
C=OTHER
SEGMENT 7
SEGMENT 6
SEGMENT 5
KEY MAP
SCALE: 1"=20000'
LEGEND:
REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION.
C=CURRENT LAND USE WHERE FUTURE IS MORE CONSERVATIVE.
RESIDENTIAL RU
AGRICULTURAL RU
COMMERCIAL RU
DOE-OWNED PROPERTY RU
OTHER RU
PRIMARY ROADS
CREEK & TRIBUTARIES
PARCELS
FLOODPLAIN
WETLANDS (COE ID #)
RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 180 PPM
COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 200 PPM
34°13'±
O.R. ADMIN. GRID
TRUE NORTH
0 250 500
SCALE: 1" = 500'
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE
Fig. J.3. EFPC FS
SWAs 1-5
(e)
SHT. 5 OF 14
DRAWING #
94015\DWGS\627A5.DWG
CAD FILE #
V5
VIEW

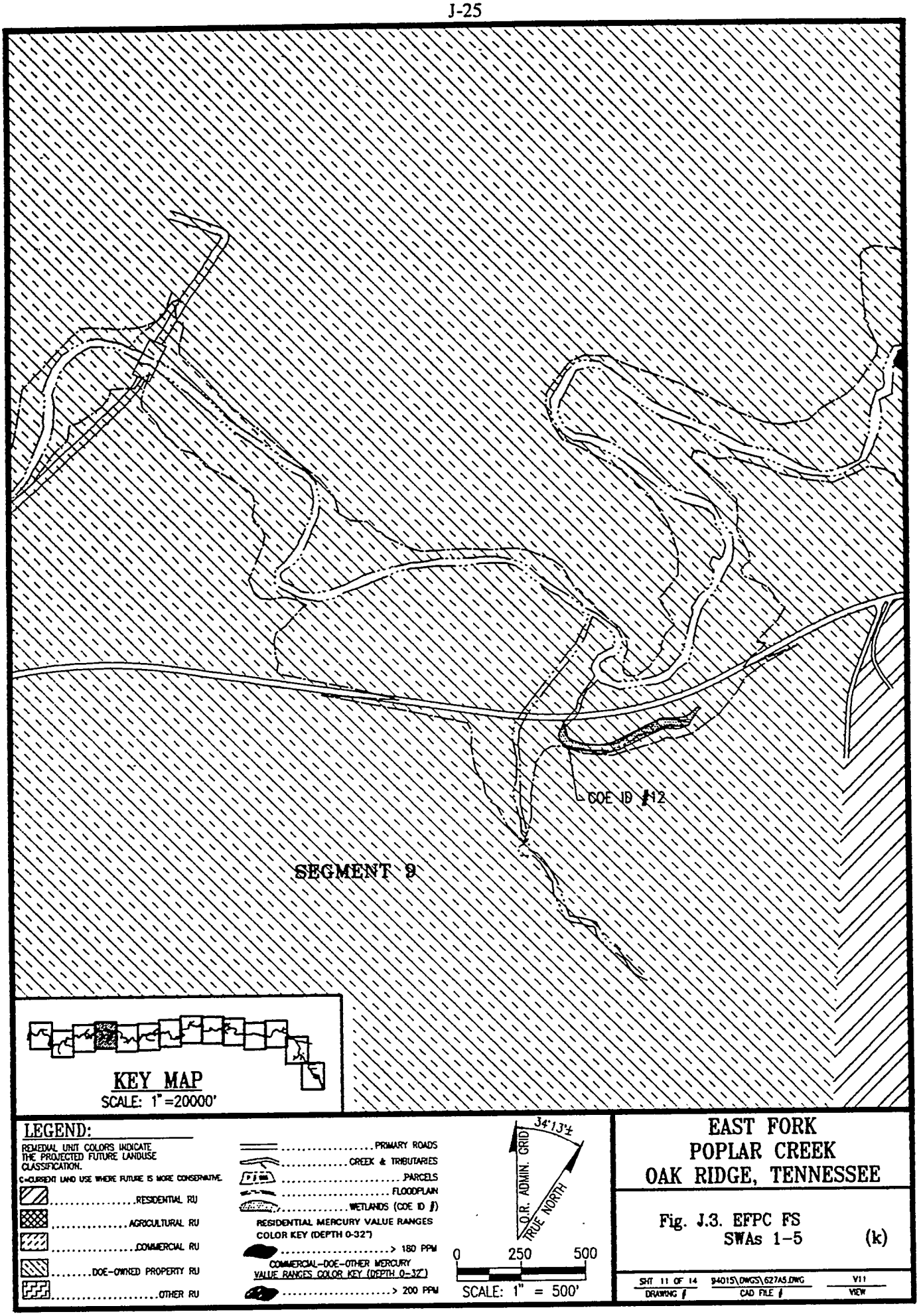

ROBERTSVILLE ROAD
P# 346
WEIGEL'S FOOD STORE & GAS STATION
P# 559.02
OAK RIDGE TURNPIKE
P# 344
BARN
P# 559
P# 561.00
SEGMENT 7
KEY MAP
SCALE: 1" =20000'
LEGEND:
REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION
C=CURRENT LAND USE WHERE FUTURE IS MORE CONSERVATIVE
RESIDENTIAL RU
AGRICULTURAL RU
COMMERCIAL RU
DOE-OWNED PROPERTY RU
OTHER RU
PRIMARY ROADS
CREEK & TRIBUTARIES
PARCELS
FLOODPLAIN
WETLANDS (COE ID #)
RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 180 PPM
COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 200 PPM
34°13'±
O.R. ADMIN. GRID
TRUE NORTH
0 250 500
SCALE: 1" = 500'
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE
Fig. J.3. EFPC FS
SWAs 1-5 (f)
SHT. 6 OF 14
DRAWING #
94015\DWGS\627A5.DWG
CAD FILE #
V6
VIEW

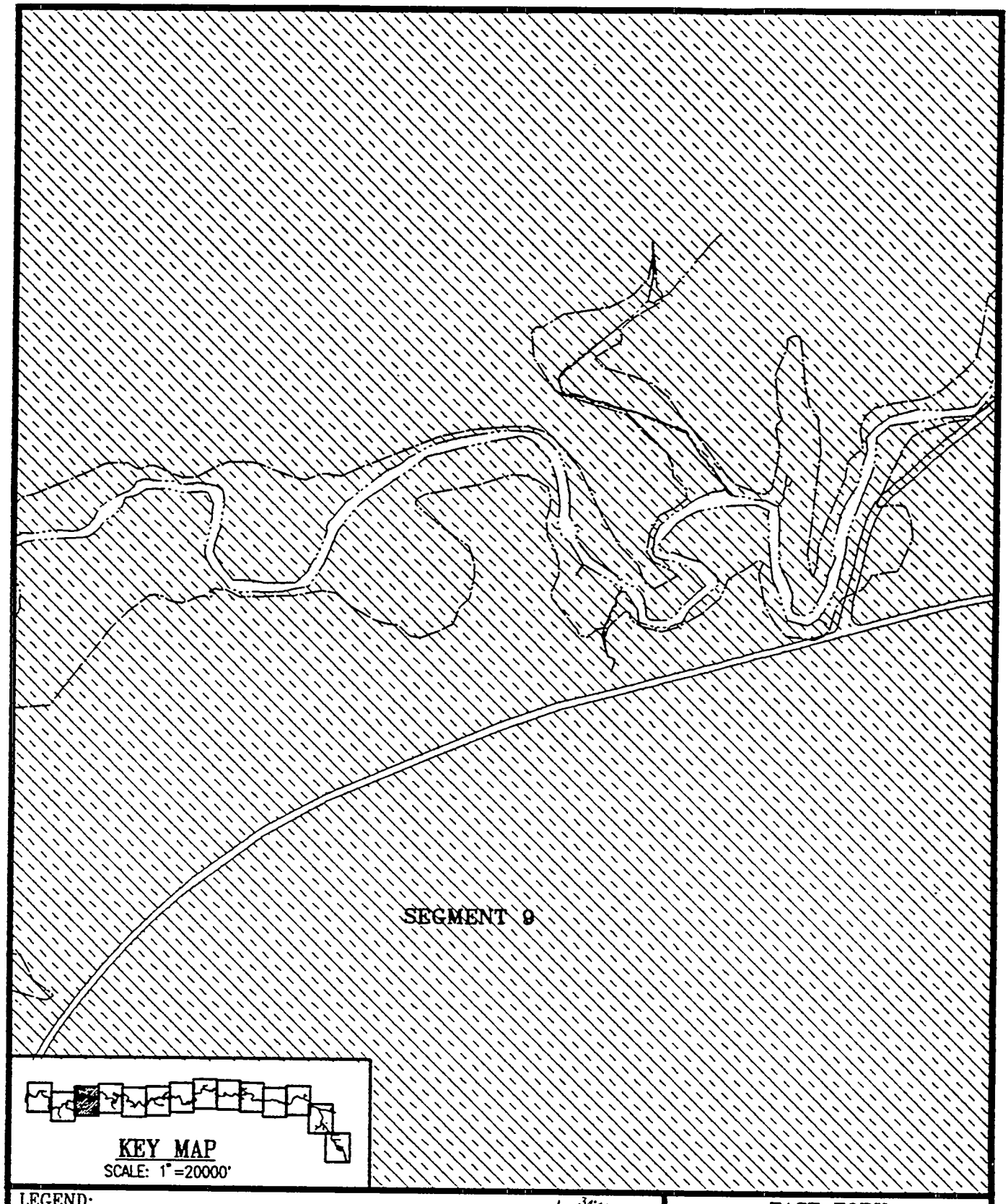

CEMETERY NO. 27
COE ID #9
P# 337
NEBRASKA AVENUE
OAK RIDGE TURNPIKE
KATIE HUNTER SOCCER FIELD
ROANE COUNTY
ANDERSON COUNTY
P# 348.00 OAK RIDGE SEWAGE TREATMENT PLANT
SEGMENT 7
COE ID #10
KEY MAP
SCALE: 1"=20000'
LEGEND:
REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION
C=CURRENT LAND USE WHERE FUTURE IS MORE CONSERVATIVE.
RESIDENTIAL RU
AGRICULTURAL RU
COMMERCIAL RU
DOE-OWNED PROPERTY RU
OTHER RU
PRIMARY ROADS
CREEK & TRIBUTARIES
PARCELS
FLOODPLAIN
WETLANDS (COE ID #)
RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 180 PPM
COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 200 PPM
34°13'±
O.R. ADMIN. GRID
TRUE NORTH
0 250 500
SCALE: 1" = 500'
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE
Fig. J.3. EFPC FS
SWAs 1-5
(g)
SHT 7 OF 14
DRAWING #
94015\DWGS\627A5.DWG
CAD FILE #
V7
VIEW


OAK RIDGE TURNPIKE
C=OTHER
VACANT
Pf 595.01
COE ID # 11
CEMETERY NO. 23
Pf 580
Pf 560.01
GOLF COURSE
Pf 595.00
GOLF COURSE
COUNTRY CLUB MAIN AREA
SEGMENT 8
SEGMENT 7
KEY MAP
SCALE: 1"=20000'
LEGEND:
REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION.
C=CURRENT LAND USE WHERE FUTURE IS MORE CONSERVATIVE
RESIDENTIAL RU
AGRICULTURAL RU
COMMERCIAL RU
DOE-OWNED PROPERTY RU
OTHER RU
PRIMARY ROADS
CREEK & TRIBUTARIES
PARCELS
FLOODPLAIN
WETLANDS (COE ID #)
RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 160 PPM
COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0-3')
> 200 PPM
34°13'
O.R. ADMIN. GRID
TRUE NORTH
0 250 500
SCALE: 1" = 500'
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE
Fig. J.3. EFPC FS
SWAs 1-5 (h)
SHT. 8 OF 14
DRAWING #
94015\DWGS\627A5.DWG
CAD FILE #
V8
VIEW


CEMETERY
PE 619.00
APARTMENTS
PE 595.03
PE 538.00
SOUTHWOOD DEVELOPMENT
GOLF COURSE
SEGMENT 9
SEGMENT 8
C=OTHER
KEY MAP
SCALE: 1"=20000'
LEGEND:
REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION.
C=CURRENT LAND USE WHERE FUTURE IS MORE CONSERVATIVE.
RESIDENTIAL RU
AGRICULTURAL RU
COMMERCIAL RU
DOE-OWNED PROPERTY RU
OTHER RU
PRIMARY ROADS
CREEK & TRIBUTARIES
PARCELS
FLOODPLAIN
WETLANDS (COE ID ∫)
RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 180 PPM
COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0-3')
> 200 PPM
34°13'±
O.R. ADMIN. GRID
TRUE NORTH
0
250
500
SCALE: 1" = 500'
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE
Fig. J.3. EFPC FS
SWAs 1-5
(i)
SHT. 9 OF 14
DRAWING #
94015\DWGS\627AS.DWG
CAD FILE #
V9
VIEW


SEGMENT 9
KEY MAP
SCALE: 1"=20000'
LEGEND:
REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION.
C=CURRENT LAND USE WHERE FUTURE IS MORE CONSERVATIVE.
RESIDENTIAL RU
AGRICULTURAL RU
COMMERCIAL RU
DOE-OWNED PROPERTY RU
OTHER RU
PRIMARY ROADS
CREEK & TRIBUTARIES
PARCELS
FLOODPLAIN
WETLANDS (COE ID #)
RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 180 PPM
COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0-3')
> 200 PPM
34°13'±
O.R. ADMIN. GRID
TRUE NORTH
0
250
500
SCALE: 1" = 500'
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE
Fig. J.3. EFPC FS
SWAs 1-5
(j)
SHT. 10 OF 14
DRAWING #
94015\DWGS\627A5.DWG
CAD FILE #
V10
VIEW


COE ID #12
SEGMENT 9
KEY MAP
SCALE: 1"=20000'
LEGEND:
REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION.
C=CURRENT LAND USE WHERE FUTURE IS MORE CONSERVATIVE.
RESIDENTIAL RU
AGRICULTURAL RU
COMMERCIAL RU
DOE-OWNED PROPERTY RU
OTHER RU
PRIMARY ROADS
CREEK & TRIBUTARIES
PARCELS
FLOODPLAIN
WETLANDS (COE ID #)
RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32')
> 180 PPM
COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0-3Z')
> 200 PPM
34°13'½
O.R. ADMIN. GRID
TRUE NORTH
0
250
500
SCALE: 1" = 500'
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE
Fig. J.3. EFPC FS
SWAs 1-5
(k)
SHT 11 OF 14
DRAWING #
94015\DWGS\627A5.DWG
CAD FILE #
V11
VIEW



KEY MAP
SCALE: 1"=20000'

LEGEND:

REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION

C=CURRENT LAND USE WHERE FUTURE IS MORE CONSERVATIVE

- RESIDENTIAL RU
- AGRICULTURAL RU
- COMMERCIAL RU
- DOE-OWNED PROPERTY RU
- OTHER RU

- PRIMARY ROADS
- CREEK & TRIBUTARIES
- PARCELS
- FLOODPLAIN
- WETLANDS (COE ID #)

RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")

- > 180 PPM

COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")

- > 200 PPM

34°13'± O.R. ADMIN. GRID TRUE NORTH

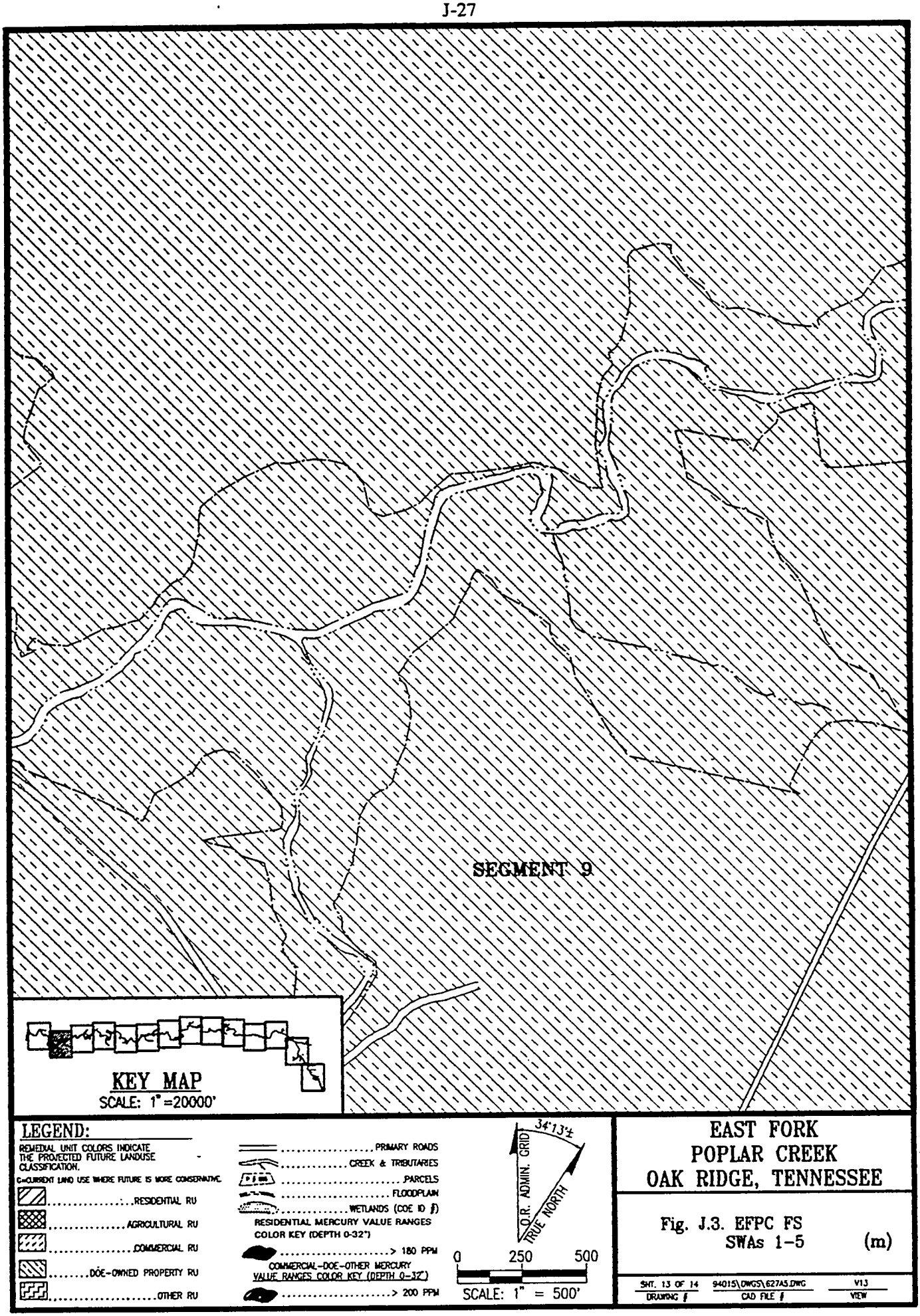
0 250 500

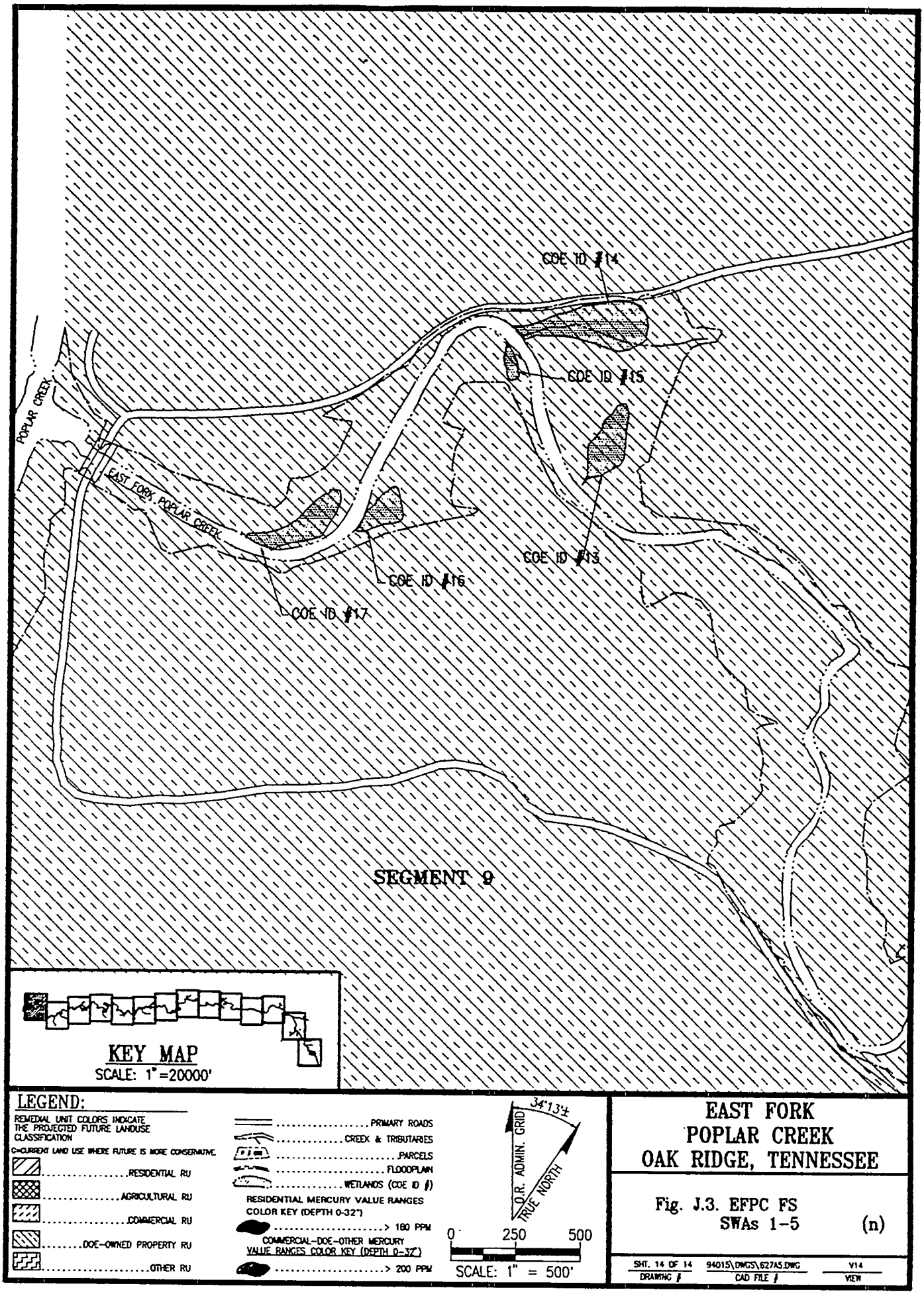
SCALE: 1" = 500'

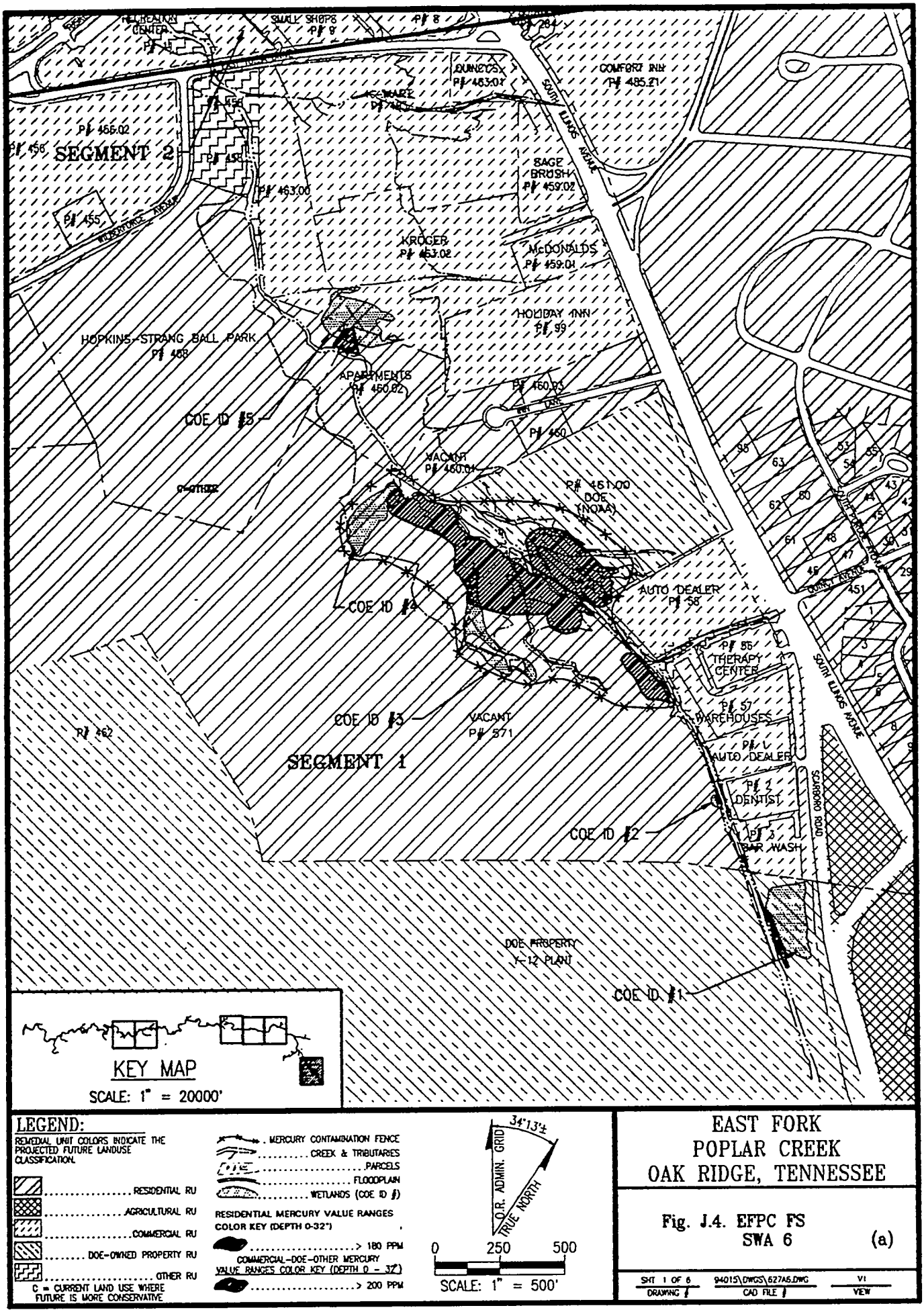
EAST FORK POPLAR CREEK OAK RIDGE, TENNESSEE

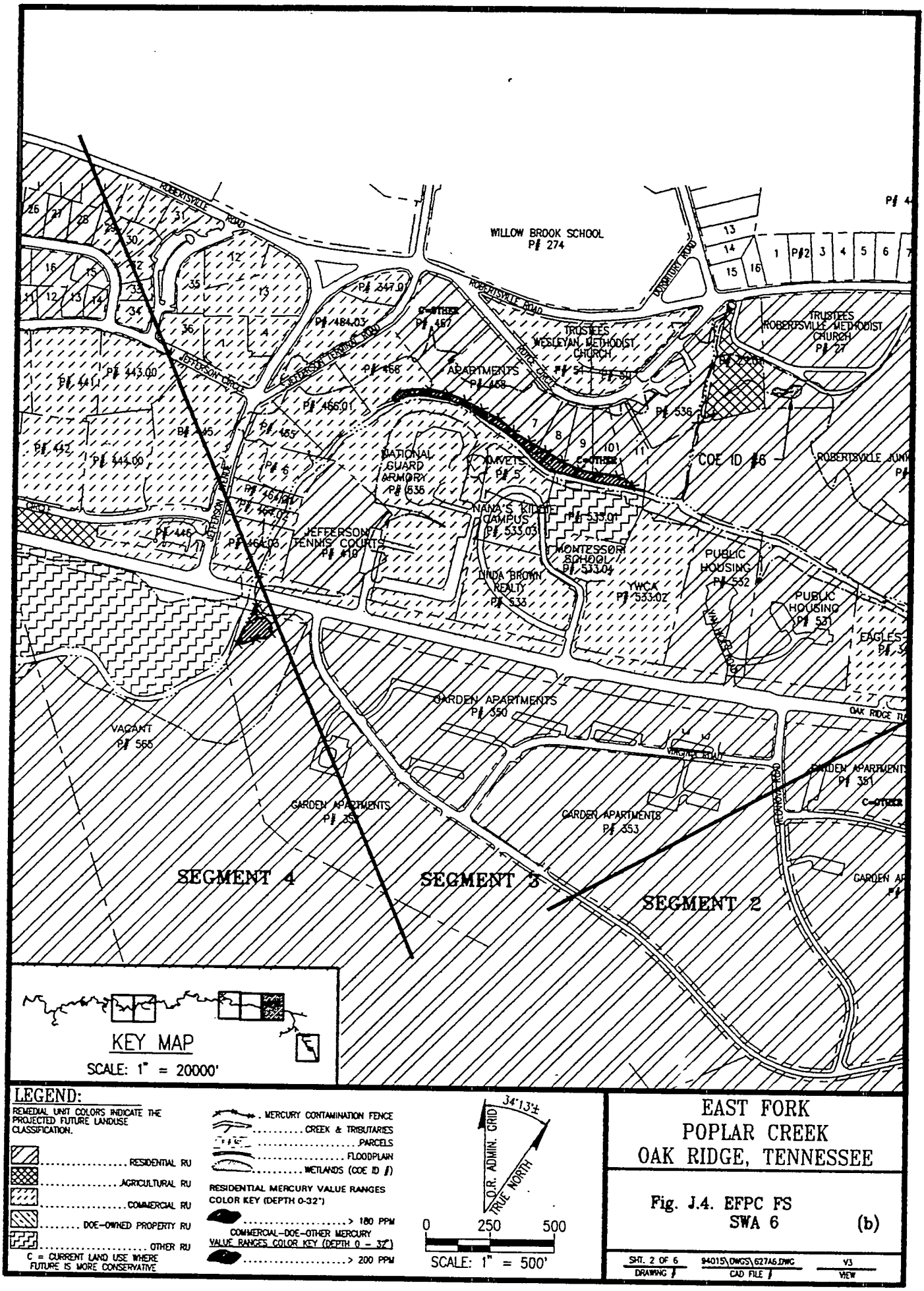
Fig. J.3. EFPC FS SWAs 1-5 (1)

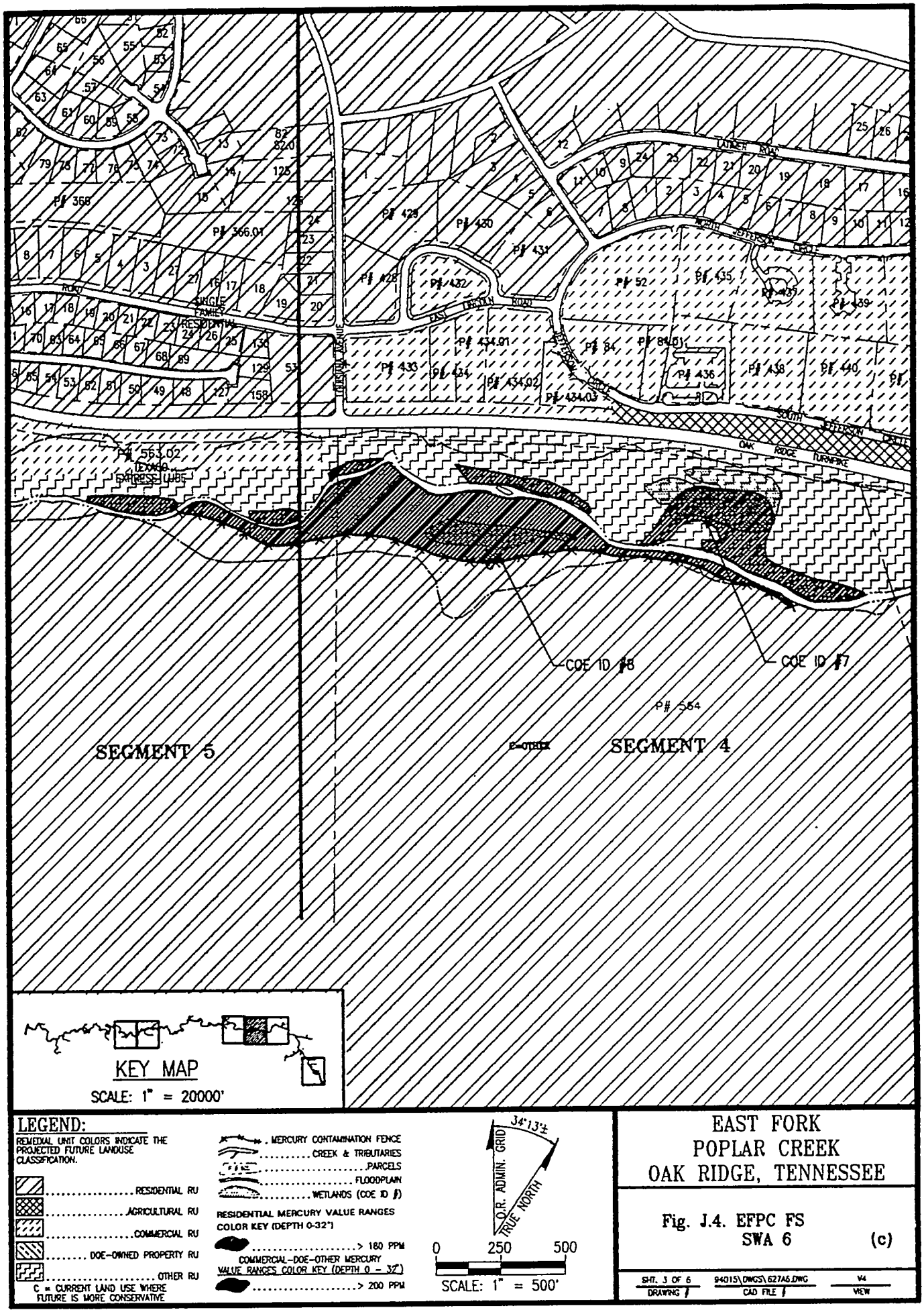
SHT. 12 OF 14 DRAWING # | 94015\DWGS\627A5.DWG CAD FILE # | V12 VIEW


SEGMENT 9
KEY MAP
SCALE: 1"=20000'
LEGEND:
REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION.
C=CURRENT LAND USE WHERE FUTURE IS MORE CONSERVATIVE.
RESIDENTIAL RU
AGRICULTURAL RU
COMMERCIAL RU
DOE-OWNED PROPERTY RU
OTHER RU
PRIMARY ROADS
CREEK & TRIBUTARIES
PARCELS
FLOODPLAIN
WETLANDS (COE ID #)
RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 180 PPM
COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 200 PPM
34°13'±
O.R. ADMIN. GRID
TRUE NORTH
0
250
500
SCALE: 1" = 500'
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE
Fig. J.3. EFPC FS
SWAs 1-5
(m)
SHT. 13 OF 14
DRAWING #
94015\DWGS\627A5.DWG
CAD FILE #
V13
VIEW

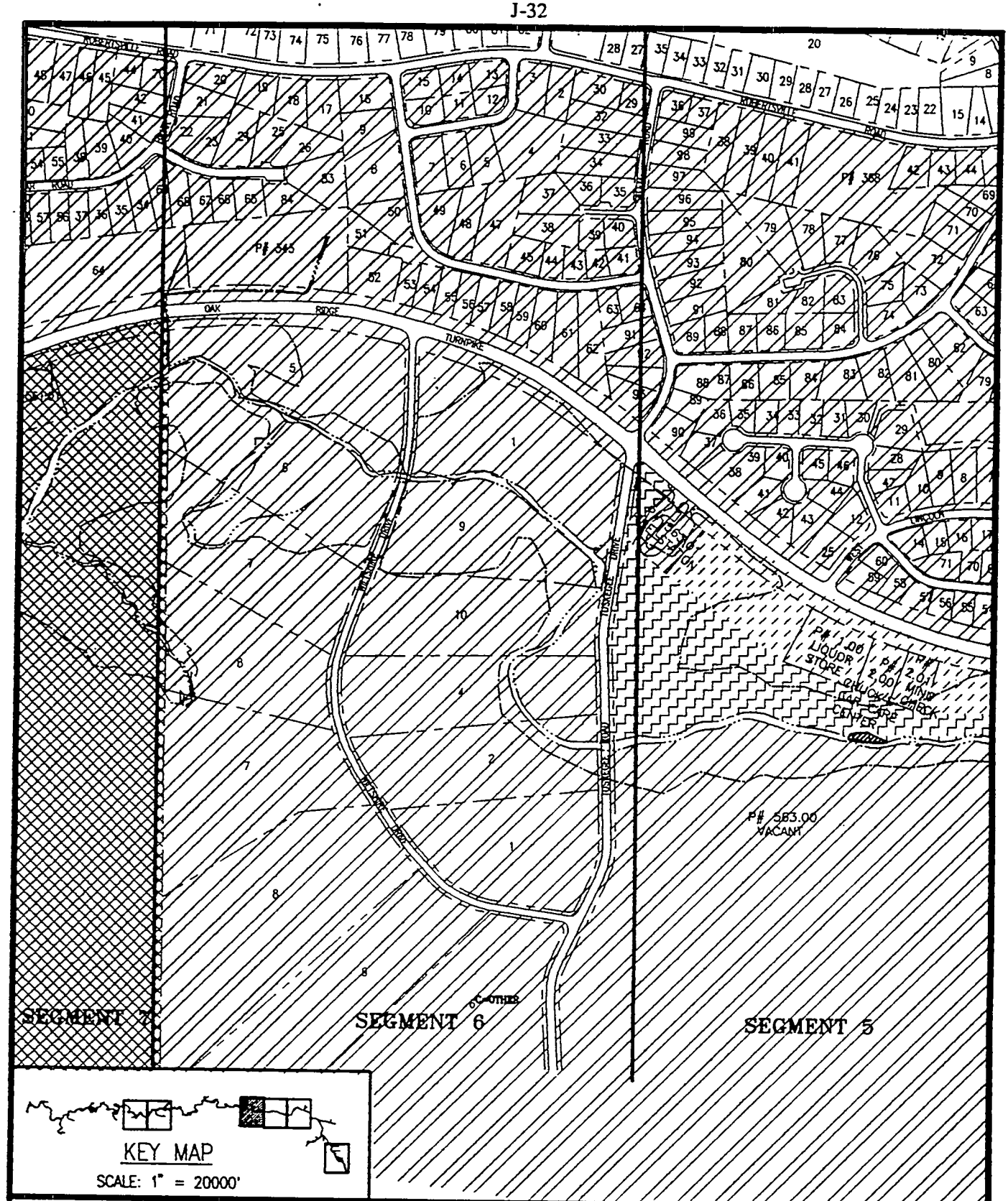

COE ID #14
COE ID #15
COE ID #13
COE ID #16
COE ID #17
POPLAR CREEK
EAST FORK POPLAR CREEK
SEGMENT 9
KEY MAP
SCALE: 1"=20000'
LEGEND:
REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION
C=CURRENT LAND USE WHERE FUTURE IS MORE CONSERVATIVE
RESIDENTIAL RU
AGRICULTURAL RU
COMMERCIAL RU
DOE-OWNED PROPERTY RU
OTHER RU
PRIMARY ROADS
CREEK & TRIBUTARIES
PARCELS
FLOODPLAIN
WETLANDS (COE ID #)
RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 180 PPM
COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0-3')
> 200 PPM
34°13'±
O.R. ADMIN. GRID
TRUE NORTH
0
250
500
SCALE: 1" = 500'
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE
Fig. J.3. EFPC FS
SWAs 1-5 (n)
SHT. 14 OF 14
DRAWING #
94015\DWGS\627A5.DWG
CAD FILE #
V14
VIEW


SEGMENT 2
SEGMENT 1
SMALL SHOPS
P# 9
P# 8
QUINCY'S
P# 463.01
COMFORT INN
P# 485.21
SOUTH ILLINOIS AVENUE
P# 455.02
P# 456
P# 458
P# 463.00
P# 455
WILBERFORCE AVENUE
SAGE BRUSH
P# 459.02
KROGER
P# 463.02
McDONALDS
P# 459.01
HOLIDAY INN
P# 99
HOPKINS-STRANG BALL PARK
P# 468
APARTMENTS
P# 460.02
P# 460.03
P# 460
COE ID #5
VACANT
P# 460.01
P# 461.00
DOE
(NOAA)
C=OTHER
COE ID #4
AUTO DEALER
P# 58
P# 56
THERAPY CENTER
P# 57
WAREHOUSES
P# 1
AUTO DEALER
P# 2
DENTIST
P# 3
BAR WASH
SCARBORO ROAD
COE ID #3
VACANT
P# 571
P# 462
COE ID #2
DOE PROPERTY
Y-12 PLANT
COE ID #1
KEY MAP
SCALE: 1" = 20000'
LEGEND:
REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION.
RESIDENTIAL RU
AGRICULTURAL RU
COMMERCIAL RU
DOE-OWNED PROPERTY RU
OTHER RU
C = CURRENT LAND USE WHERE FUTURE IS MORE CONSERVATIVE
MERCURY CONTAMINATION FENCE
CREEK & TRIBUTARIES
PARCELS
FLOODPLAIN
WETLANDS (COE ID #)
RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 180 PPM
COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0 - 32")
> 200 PPM
34°13'±
O.R. ADMIN. GRID
TRUE NORTH
0
250
500
SCALE: 1" = 500'
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE
Fig. J.4. EFPC FS
SWA 6
(a)
SHT 1 OF 6
DRAWING #
94015\DWGS\627A6.DWG
CAD FILE #
V1
VIEW


WILLOW BROOK SCHOOL
P# 274
ROBERTSVILLE ROAD
DORMITORY ROAD
TRUSTEES WESLEYAN METHODIST CHURCH
TRUSTEES ROBERTSVILLE METHODIST CHURCH
P# 27
APARTMENTS
P# 468
NATIONAL GUARD ARMORY
P# 535
AMVETS
P# 5
NANA'S KIDDIE CAMPUS
P# 533.03
MONTESSORI SCHOOL
P# 533.04
YWCA
P# 533.02
PUBLIC HOUSING
P# 532
PUBLIC HOUSING
P# 531
COE ID #6
ROBERTSVILLE JUNK
JEFFERSON TENNIS COURTS
P# 410
LINDA BROWN REALTY
P# 533
GARDEN APARTMENTS
P# 350
VACANT
P# 565
GARDEN APARTMENTS
P# 351
GARDEN APARTMENTS
P# 353
OAK RIDGE TU
SEGMENT 4
SEGMENT 3
SEGMENT 2
KEY MAP
SCALE: 1" = 20000'
LEGEND:
REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION.
RESIDENTIAL RU
AGRICULTURAL RU
COMMERCIAL RU
DOE-OWNED PROPERTY RU
OTHER RU
C = CURRENT LAND USE WHERE FUTURE IS MORE CONSERVATIVE
MERCURY CONTAMINATION FENCE
CREEK & TRIBUTARIES
PARCELS
FLOODPLAIN
WETLANDS (COE ID #)
RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 180 PPM
COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0 - 32")
> 200 PPM
34°13'±
O.R. ADMIN. GRID
TRUE NORTH
0 250 500
SCALE: 1" = 500'
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE
Fig. J.4. EFPC FS
SWA 6
(b)
SHT. 2 OF 6
DRAWING #
94015\DWGS\627A6.DWG
CAD FILE #
V3
VIEW



P# 366
P# 366.01
P# 429
P# 430
P# 431
P# 428
P# 432
P# 52
P# 435
P# 437
P# 439
P# 434.01
P# 84
P# 84.01
P# 433
P# 434
P# 434.02
P# 434.03
P# 436
P# 438
P# 440
P# 563.02
TEXACO EXPRESS LUBE
SINGLE FAMILY RESIDENTIAL
EAST LINCOLN ROAD
NORTH JEFFERSON CIRCLE
SOUTH JEFFERSON CIRCLE
OAK RIDGE TURNPIKE
COE ID #8
COE ID #7
P# 564
SEGMENT 5
SEGMENT 4
KEY MAP
SCALE: 1" = 20000'
LEGEND:
REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION.
RESIDENTIAL RU
AGRICULTURAL RU
COMMERCIAL RU
DOE-OWNED PROPERTY RU
OTHER RU
C = CURRENT LAND USE WHERE FUTURE IS MORE CONSERVATIVE
MERCURY CONTAMINATION FENCE
CREEK & TRIBUTARIES
PARCELS
FLOODPLAIN
WETLANDS (COE ID #)
RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 180 PPM
COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0 - 32")
> 200 PPM
34°13'±
O.R. ADMIN. GRID
TRUE NORTH
0
250
500
SCALE: 1" = 500'
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE
Fig. J.4. EFPC FS
SWA 6
(c)
SHT. 3 OF 6
DRAWING #
94015\DWGS\627A6.DWG
CAD FILE #
V4
VIEW



LEGEND:

REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION.

- RESIDENTIAL RU
- AGRICULTURAL RU
- COMMERCIAL RU
- DOE-OWNED PROPERTY RU
- OTHER RU

C = CURRENT LAND USE WHERE FUTURE IS MORE CONSERVATIVE

- MERCURY CONTAMINATION FENCE
- CREEK & TRIBUTARIES
- PARCELS
- FLOODPLAIN
- WETLANDS (COE ID #)

RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")

- > 180 PPM

COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0 - 32")

- > 200 PPM

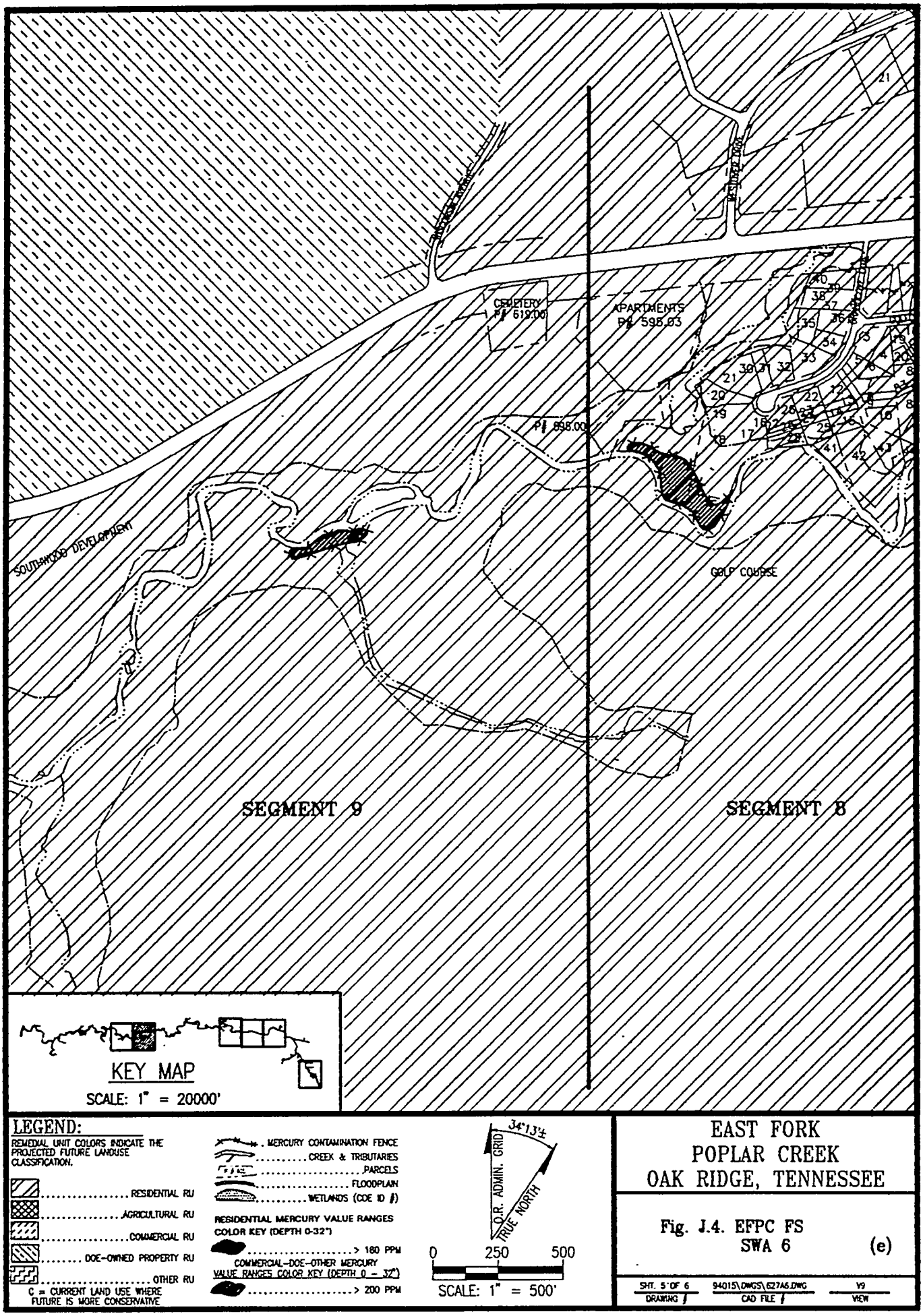
34°13'±
O.R. ADMIN. GRID
TRUE NORTH

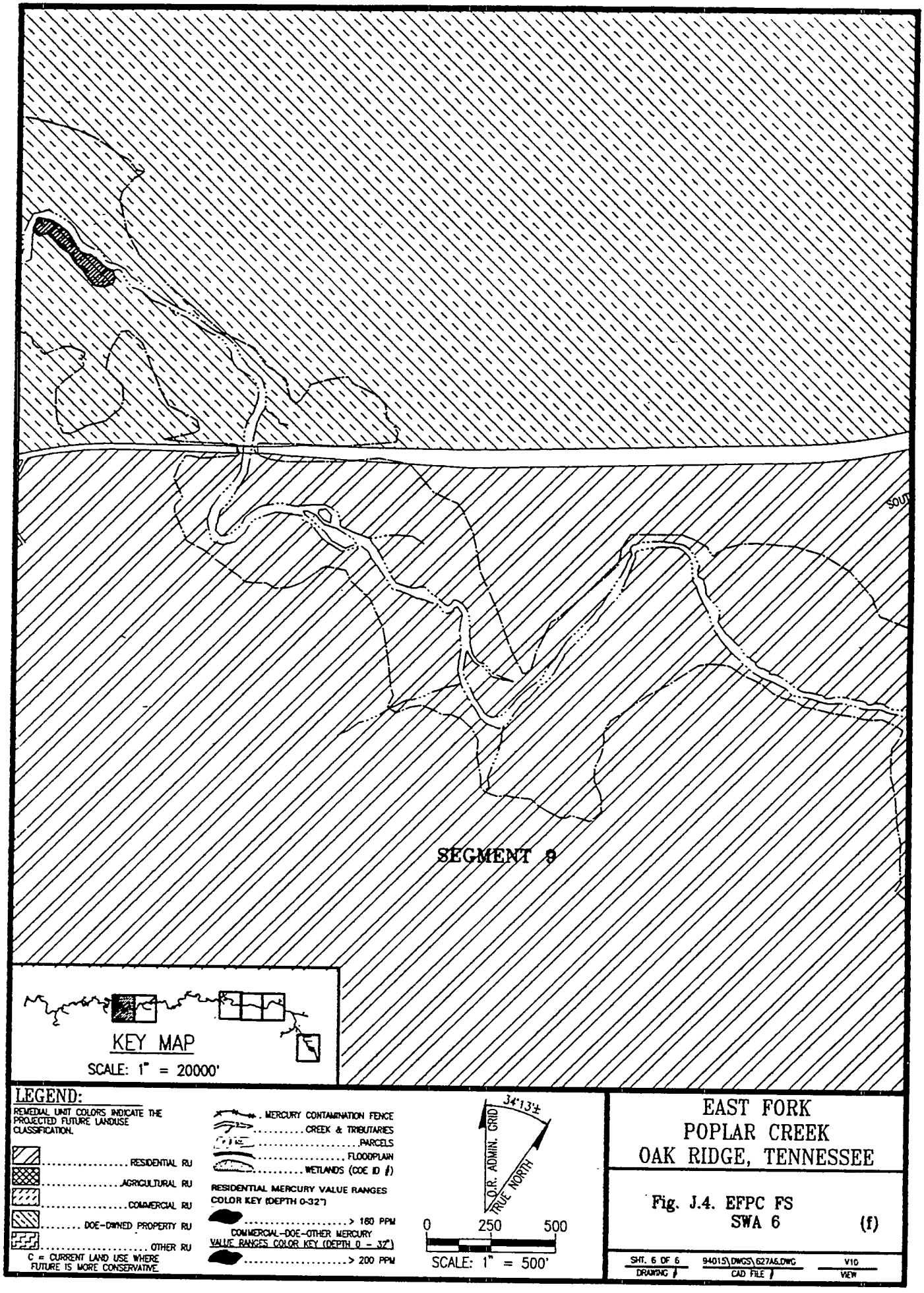
0 250 500
SCALE: 1" = 500'

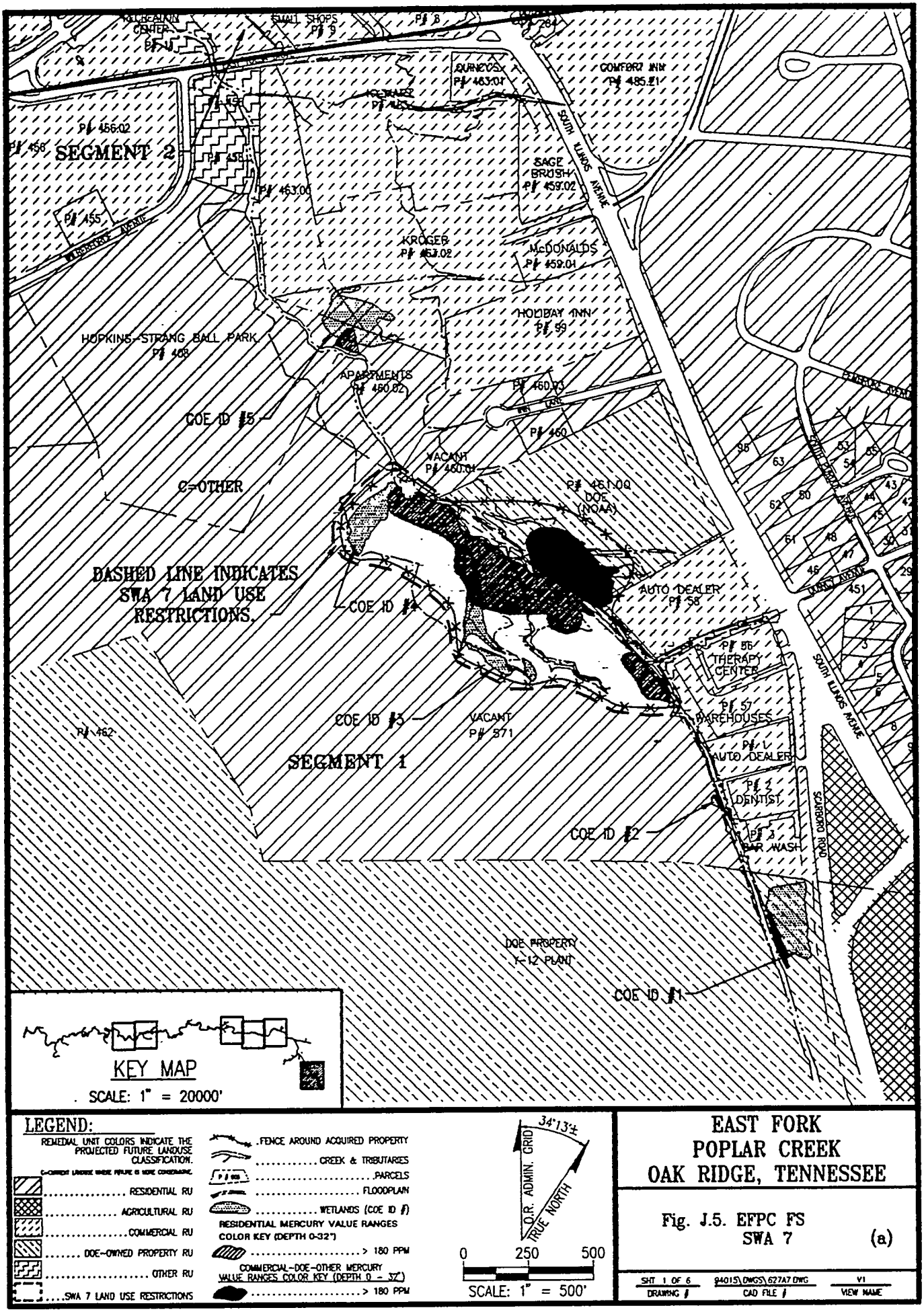
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE

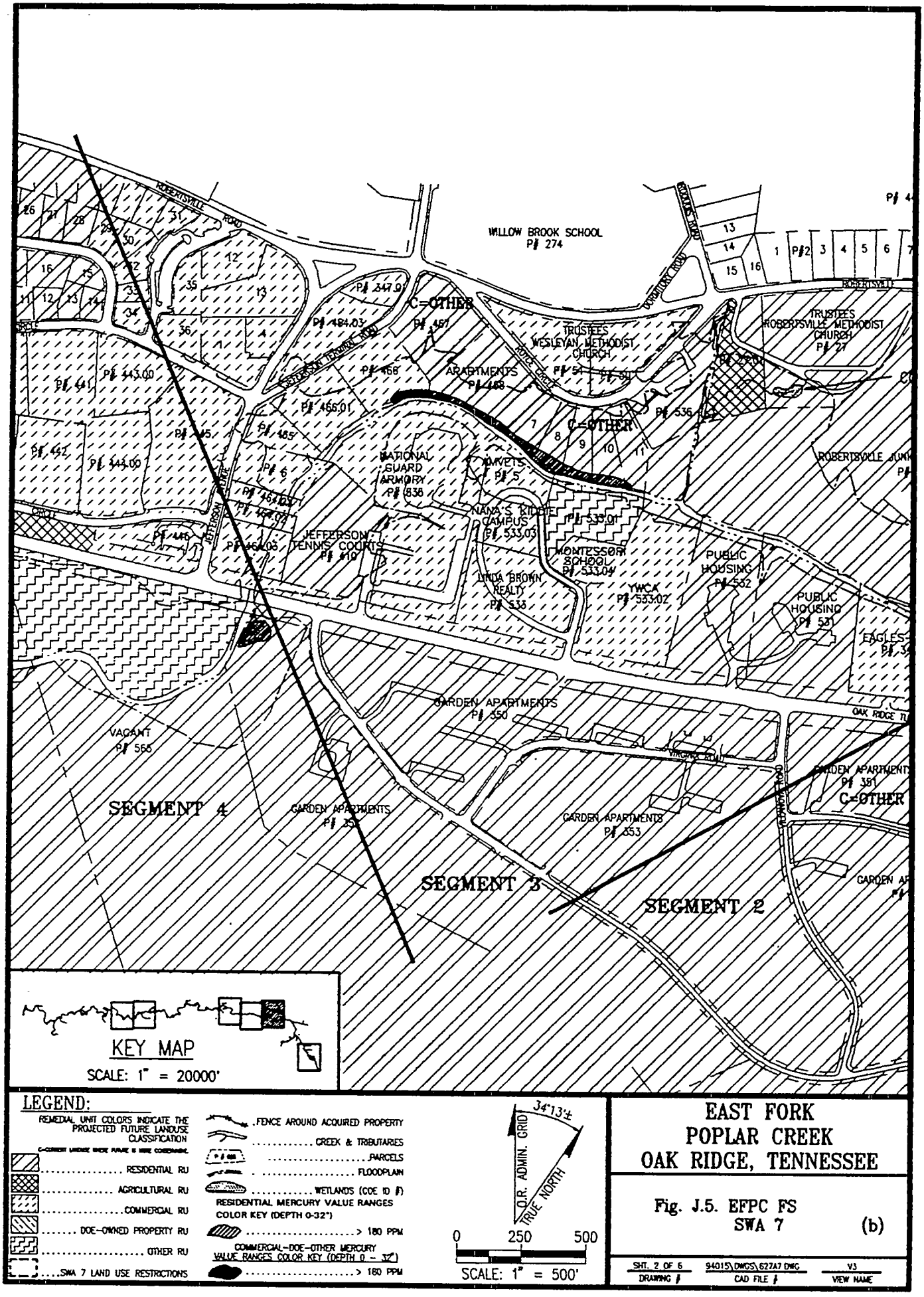
Fig. J.4. EFPC FS
SWA 6 (d)

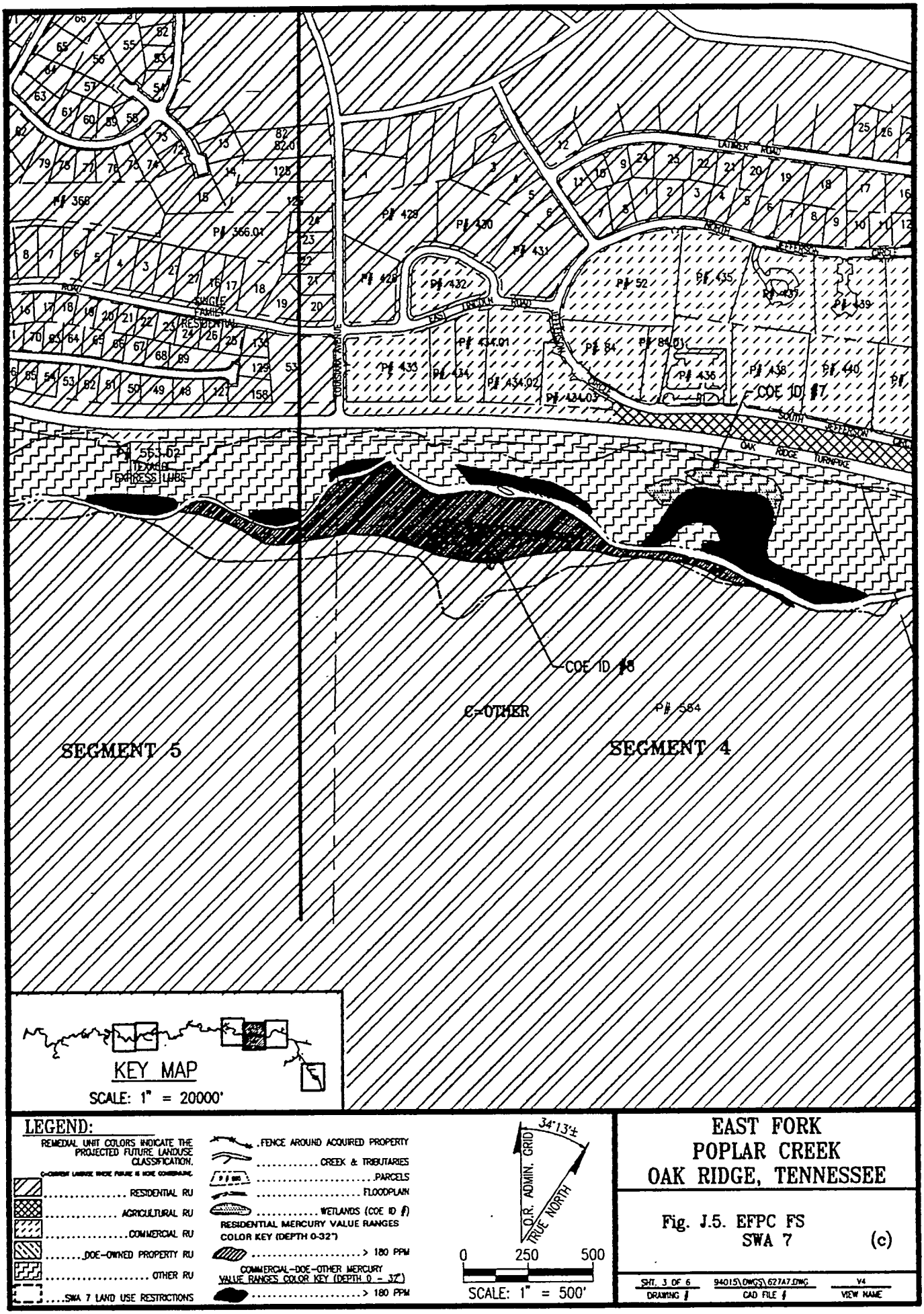
SHT. 4 OF 6	94015\DWGS\627A8.DWG	V5
DRAWING #	CAD FILE #	VIEW

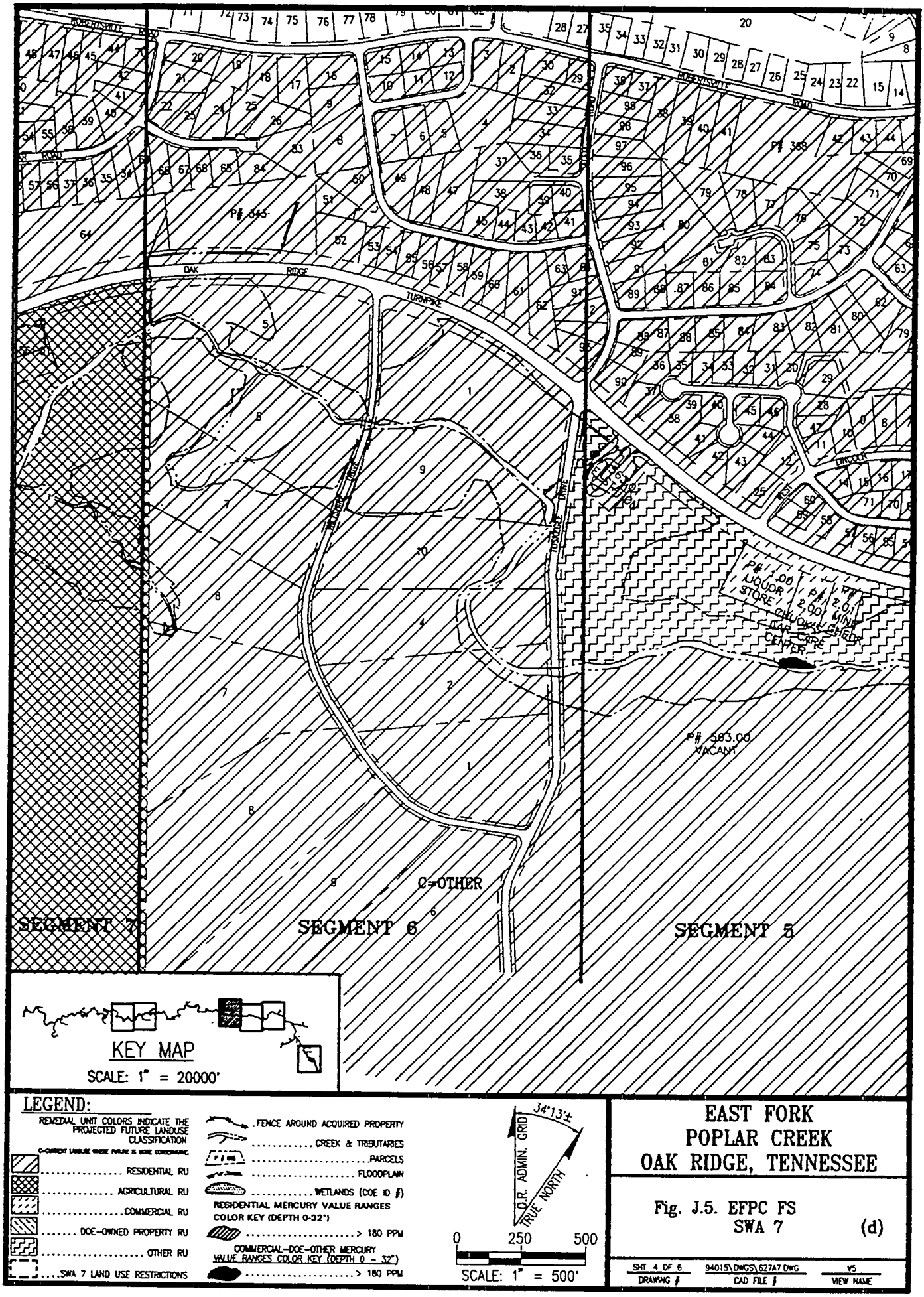

CEMETERY
PI 619.00
APARTMENTS
PI 595.03
PI 695.00
SOUTHWOOD DEVELOPMENT
GOLF COURSE
SEGMENT 9
SEGMENT 8
KEY MAP
SCALE: 1" = 20000'
LEGEND:
REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION.
RESIDENTIAL RU
AGRICULTURAL RU
COMMERCIAL RU
DOE-OWNED PROPERTY RU
OTHER RU
C = CURRENT LAND USE WHERE FUTURE IS MORE CONSERVATIVE
MERCURY CONTAMINATION FENCE
CREEK & TRIBUTARIES
PARCELS
FLOODPLAIN
WETLANDS (COE ID #)
RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 180 PPM
COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0 - 32")
> 200 PPM
34°13'±
O.R. ADMIN. GRID
TRUE NORTH
0
250
500
SCALE: 1" = 500'
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE
Fig. J.4. EFPC FS
SWA 6
(e)
SHT. 5 OF 6
DRAWING #
94015\DWGS\627A6.DWG
CAD FILE #
V9
VIEW

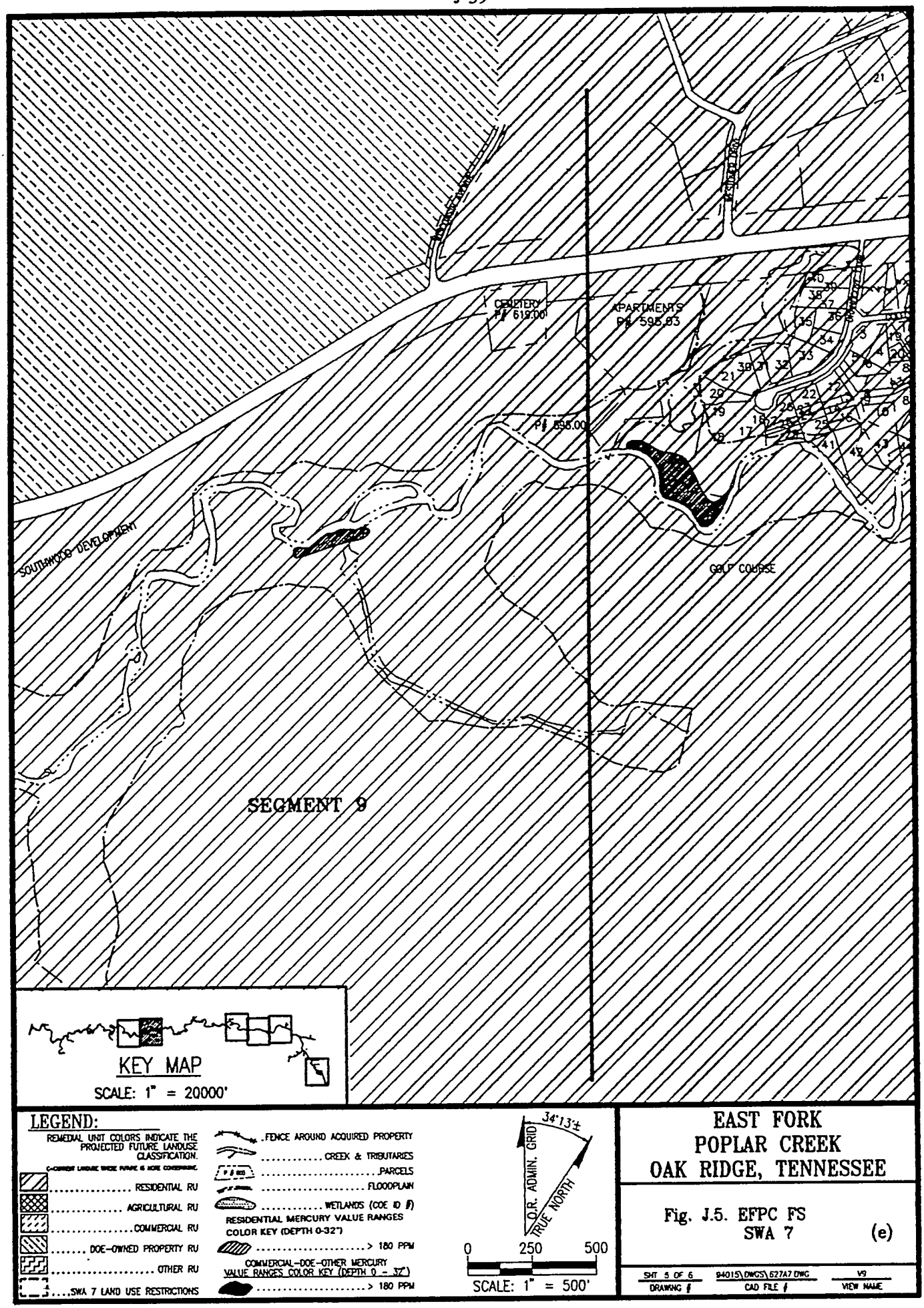

SEGMENT 9
KEY MAP
SCALE: 1" = 20000'
LEGEND:
REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION.
RESIDENTIAL RU
AGRICULTURAL RU
COMMERCIAL RU
DOE-OWNED PROPERTY RU
OTHER RU
C = CURRENT LAND USE WHERE FUTURE IS MORE CONSERVATIVE
MERCURY CONTAMINATION FENCE
CREEK & TRIBUTARIES
PARCELS
FLOODPLAIN
WETLANDS (COE ID #)
RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 160 PPM
COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0 - 32")
> 200 PPM
34°13'±
O.R. ADMIN. GRID
TRUE NORTH
0
250
500
SCALE: 1" = 500'
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE
Fig. J.4. EFPC FS
SWA 6
(f)
SHT. 6 OF 6
DRAWING #
94015\DWGS\627A6.DWG
CAD FILE #
V10
VIEW

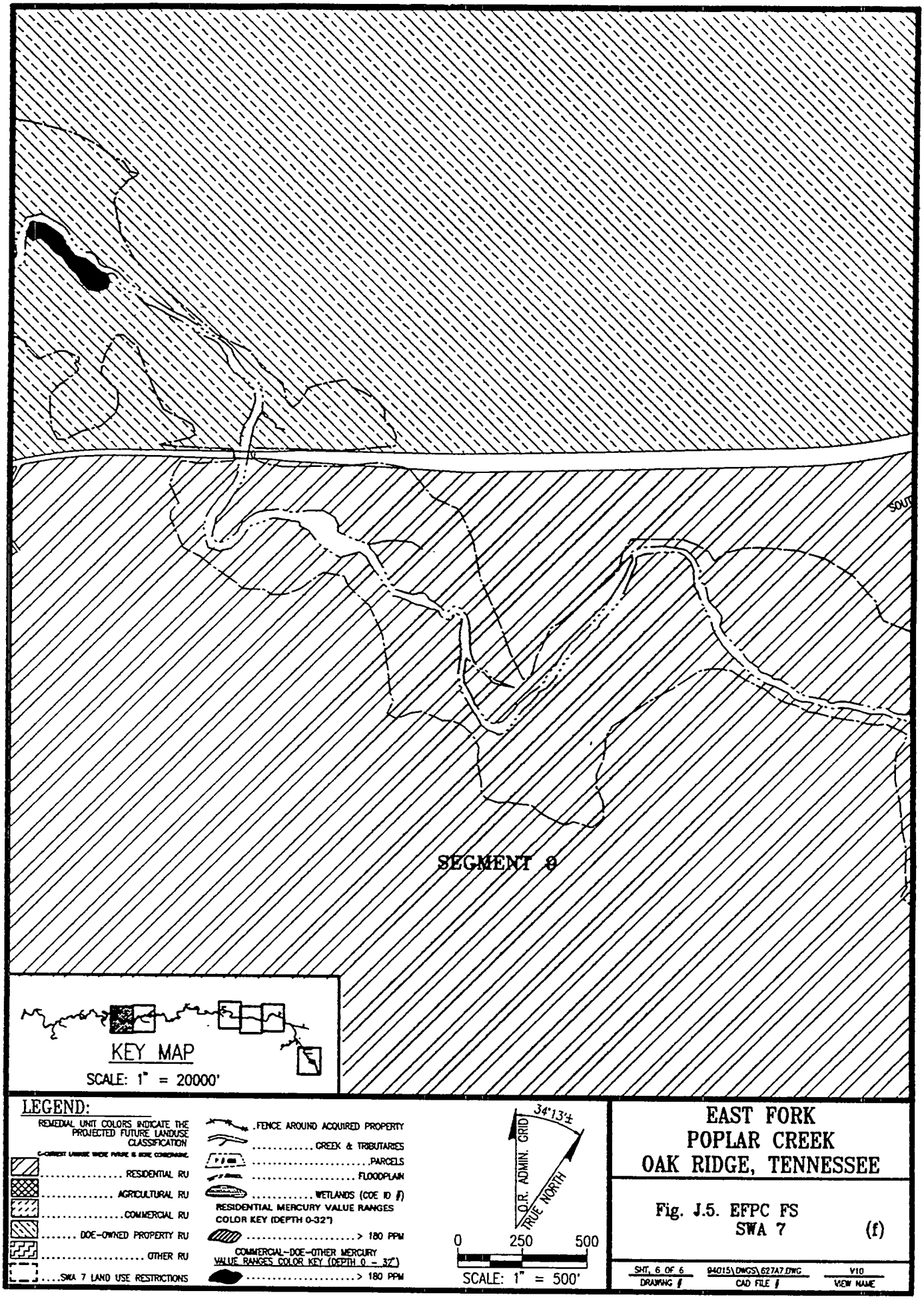

SEGMENT 2
SEGMENT 1
SMALL SHOPS
P# 9
P# 8
QUINCY'S
P# 463.01
COMFORT INN
P# 485.21
P# 456.02
P# 456
P# 455
P# 463.00
SAGE BRUSH
P# 459.02
SOUTH ILLINOIS AVENUE
KROGER
P# 463.02
McDONALDS
P# 459.01
HOLIDAY INN
P# 99
HOPKINS-STRANG BALL PARK
P# 408
APARTMENTS
P# 460.02
P# 460.03
P# 460
COE ID #5
VACANT
P# 460.01
C=OTHER
P# 461.00
DOE
(NOAA)
DASHED LINE INDICATES
SWA 7 LAND USE
RESTRICTIONS.
COE ID #4
AUTO DEALER
P# 58
P# 56
THERAPY
CENTER
P# 57
WAREHOUSES
P# 1
AUTO DEALER
P# 2
DENTIST
P# 3
BAR WASH
COE ID #3
VACANT
P# 571
P# 462
COE ID #2
SCARBORO ROAD
DOE PROPERTY
Y-12 PLANT
COE ID #1
KEY MAP
SCALE: 1" = 20000'
LEGEND:
REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION.
RESIDENTIAL RU
AGRICULTURAL RU
COMMERCIAL RU
DOE-OWNED PROPERTY RU
OTHER RU
SWA 7 LAND USE RESTRICTIONS
FENCE AROUND ACQUIRED PROPERTY
CREEK & TRIBUTARIES
PARCELS
FLOODPLAIN
WETLANDS (COE ID #)
RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 180 PPM
COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0 - 32")
> 180 PPM
34°13'±
O.R. ADMIN. GRID
TRUE NORTH
0
250
500
SCALE: 1" = 500'
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE
Fig. J.5. EFPC FS
SWA 7
(a)
SHT 1 OF 6
DRAWING #
94015\DWGS\627A7.DWG
CAD FILE #
V1
VIEW NAME


WILLOW BROOK SCHOOL
P# 274
C=OTHER
TRUSTEES WESLEYAN METHODIST CHURCH
TRUSTEES ROBERTSVILLE METHODIST CHURCH
P# 27
APARTMENTS
P# 468
C=OTHER
NATIONAL GUARD ARMORY
P# 838
AMVETS
P# 5
NANA'S RIDGE CAMPUS
P# 533.03
JEFFERSON TENNIS COURTS
P# 410
MONTESSORI SCHOOL
P# 533.04
LINDA BROWN REALTY
P# 538
YWCA
P# 533.02
PUBLIC HOUSING
P# 532
PUBLIC HOUSING
P# 531
EAGLES
GARDEN APARTMENTS
P# 350
VACANT
P# 565
SEGMENT 4
GARDEN APARTMENTS
P# 351
GARDEN APARTMENTS
P# 353
C=OTHER
SEGMENT 3
SEGMENT 2
KEY MAP
SCALE: 1" = 20000'
LEGEND:
REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION
RESIDENTIAL RU
AGRICULTURAL RU
COMMERCIAL RU
DOE-OWNED PROPERTY RU
OTHER RU
SWA 7 LAND USE RESTRICTIONS
FENCE AROUND ACQUIRED PROPERTY
CREEK & TRIBUTARIES
PARCELS
FLOODPLAIN
WETLANDS (COE ID #)
RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 180 PPM
COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0 - 32")
> 180 PPM
34°13'±
O.R. ADMIN. GRID
TRUE NORTH
0
250
500
SCALE: 1" = 500'
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE
Fig. J.5. EFPC FS
SWA 7
(b)
SHT. 2 OF 6
DRAWING #
94015\DWGS\627A7.DWG
CAD FILE #
V3
VIEW NAME


SEGMENT 5
SEGMENT 4
COE ID #7
COE ID #8
C=OTHER
P# 564
KEY MAP
SCALE: 1" = 20000'
LEGEND:
REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION.
RESIDENTIAL RU
AGRICULTURAL RU
COMMERCIAL RU
DOE-OWNED PROPERTY RU
OTHER RU
SWA 7 LAND USE RESTRICTIONS
FENCE AROUND ACQUIRED PROPERTY
CREEK & TRIBUTARIES
PARCELS
FLOODPLAIN
WETLANDS (COE ID #)
RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 180 PPM
COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0 - 3')
> 180 PPM
34°13'±
O.R. ADMIN. GRID
TRUE NORTH
0
250
500
SCALE: 1" = 500'
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE
Fig. J.5. EFPC FS
SWA 7
(c)
SHT. 3 OF 6
DRAWING #
94015\DWGS\627A7.DWG
CAD FILE #
V4
VIEW NAME


ROBERTSVILLE ROAD
OAK RIDGE TURNPIKE
P# 343
P# 368
P# 1.00 LIQUOR STORE
P# 2.00 CHUCK'S CAR CARE CENTER
P# 2.01 MINI CHECK
P# 563.00 VACANT
C=OTHER
SEGMENT 7
SEGMENT 6
SEGMENT 5
KEY MAP
SCALE: 1" = 20000'
LEGEND:
REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION
RESIDENTIAL RU
AGRICULTURAL RU
COMMERCIAL RU
DOE-OWNED PROPERTY RU
OTHER RU
SWA 7 LAND USE RESTRICTIONS
FENCE AROUND ACQUIRED PROPERTY
CREEK & TRIBUTARIES
PARCELS
FLOODPLAIN
WETLANDS (COE ID #)
RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 180 PPM
COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0 - 32")
> 180 PPM
34°13'±
O.R. ADMIN. GRID
TRUE NORTH
0 250 500
SCALE: 1" = 500'
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE
Fig. J.5. EFPC FS
SWA 7
(d)
SHT 4 OF 6
DRAWING #
94015\DWGS\627A7.DWG
CAD FILE #
V5
VIEW NAME


CEMETERY
PE 619.00
APARTMENTS
PE 595.03
PE 595.00
SOUTHWOOD DEVELOPMENT
GOLF COURSE
SEGMENT 9
KEY MAP
SCALE: 1" = 20000'
LEGEND:
REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION.
RESIDENTIAL RU
AGRICULTURAL RU
COMMERCIAL RU
DOE-OWNED PROPERTY RU
OTHER RU
SWA 7 LAND USE RESTRICTIONS
FENCE AROUND ACQUIRED PROPERTY
CREEK & TRIBUTARIES
PARCELS
FLOODPLAIN
WETLANDS (COE ID #)
RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 180 PPM
COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0 - 32")
> 180 PPM
34°13'±
O.R. ADMIN. GRID
TRUE NORTH
0
250
500
SCALE: 1" = 500'
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE
Fig. J.5. EFPC FS
SWA 7
(e)
SHT 5 OF 6
DRAWING #
94015\DWGS\627A7.DWG
CAD FILE #
V9
VIEW NAME


SEGMENT 9
KEY MAP
SCALE: 1" = 20000'
LEGEND:
REMEDIAL UNIT COLORS INDICATE THE PROJECTED FUTURE LANDUSE CLASSIFICATION
RESIDENTIAL RU
AGRICULTURAL RU
COMMERCIAL RU
DOE-OWNED PROPERTY RU
OTHER RU
SWA 7 LAND USE RESTRICTIONS
FENCE AROUND ACQUIRED PROPERTY
CREEK & TRIBUTARIES
PARCELS
FLOODPLAIN
WETLANDS (COE ID f)
RESIDENTIAL MERCURY VALUE RANGES COLOR KEY (DEPTH 0-32")
> 180 PPM
COMMERCIAL-DOE-OTHER MERCURY VALUE RANGES COLOR KEY (DEPTH 0 - 32")
> 180 PPM
34°13'±
O.R. ADMIN. GRID
TRUE NORTH
0
250
500
SCALE: 1" = 500'
EAST FORK
POPLAR CREEK
OAK RIDGE, TENNESSEE
Fig. J.5. EFPC FS
SWA 7 (f)
SHT. 6 OF 6
DRAWING #
94015\DWGS\627A7.DWG
CAD FILE #
V10
VIEW NAME

APPENDIX K

FLOODPLAIN STATEMENT OF FINDINGS FOR EFPC

DEPARTMENT OF ENERGY

Floodplain Statement of Findings
for
East Fork Poplar Creek

AGENCY: Department of Energy

SUBJECT: Floodplain Statement of Findings

SUMMARY: This is a Floodplain Statement of Findings prepared in accordance with 10 CFR Part 1022. DOE proposes to remediate mercury contaminated soil from the 100-year floodplain of East Fork Poplar Creek in Anderson and Roane counties, Tennessee. DOE prepared a Floodplain and Wetlands Assessment describing the effects, alternatives, and measures designed to avoid or minimize potential harm to or within the affected floodplain. DOE will endeavor to allow 15 days of public review after publication of the statement of findings before implementation of the proposed action.

FOR FURTHER INFORMATION, CONTACT:

Mr. Robert Sleeman, Director
Environmental Restoration Division (EM-91)
U.S. Department of Energy
P.O. Box 2001
Oak Ridge, Tennessee 37831-8541
(615) 576-3534
(615) 676-6074

FOR FURTHER INFORMATION ON GENERAL DOE FLOODPLAIN/WETLANDS ENVIRONMENTAL REVIEW REQUIREMENTS, CONTACT:

Carol M. Borgstrom, Director
Office of NEPA Assistance, EH-25
Office of the Assistant Secretary for Environment, Safety, and Health
Room 3E-080
Forrestal Building
Washington, D.C. 20584
(202) 586-4600 or (800) 472-2756

SUPPLEMENTARY INFORMATION:

This is a Floodplain Statement of Findings prepared in accordance with 10 CFR Part 1022. DOE published a Notice of Floodplain and Wetlands Involvement in the *Federal Register* on October 4, 1993 (58 FR 51623-4), and the Feasibility Study prepared for the East Fork Poplar Creek site incorporated a Floodplain and Wetlands Assessment of the proposed action. DOE proposes to remediate mercury contaminated soil in the floodplain of East Fork Poplar Creek in Anderson and Roane counties, Tennessee. The proposed action would occur in a floodplain because the levels of contamination in the floodplain soils are in excess of guidelines determined to be protective of human and environmental health. Alternative remedial actions for the East Fork site are no action, partial removal and disposal, complete removal and disposal, partial removal and treatment, complete removal and treatment, containment and institutional actions, and limited actions and land use restrictions. The proposed action would affect between 3.52 and 7.35 ha (8.70 and 18.16 acres), depending on which alternative is selected as a final remedial option. There is no practicable alternative to the proposed action. The proposed action would conform to applicable state and local floodplain protection standards.

DOE would take the following steps to minimize potential harm to or within the affected floodplain:

1. Remediation operations would confine the area of soil disturbance to the minimum necessary for successful completion of the cleanup.

2. Detailed soil erosion and sediment control plans prepared prior to any remedial actions would minimize site damage and mitigate disturbance to floodplains. Remedial design would incorporate established best management practices to prevent or control erosion and siltation.

3. Remediation would strive to minimize exposure of floodplain soils to erosion. All soil erosion and sediment barriers would remain in place until successful stabilization and revegetation of the soil surface.

4. Riprap, sandbags, sod, or approved mulch netting placed within 48 hours of disturbance would provide immediate temporary protection of stream banks from erosion. Permanent stabilization techniques such as gabions or bio-engineered methods would provide long-term protection of stream banks in areas prone to erosion or siltation after excavation or containment.

5. Construction techniques to avoid or reduce adverse water quality impacts may include scheduling excavation during dry periods when flooding is not likely to occur. Temporary diversion channels, siltation ponds, coffer dams, drainage ditches, and dikes would provide additional protection to the creek, its tributaries, and any areas sensitive to erosion damage and siltation during remediation.

6. Remedial plans would prevent discharges of sediment-laden water from the dewatering of trenches, siltation ponds, drainage ditches, or other excavations directly into the creek.

7. Remediation would not obstruct any streams and all streams would retain their original capacity for floodwaters. The proposed action would not impede flood flow or increase flooding. Periodic inspections of fencing after floods and removal of flood debris would prevent the accumulation of debris that could intensify flooding.

8. Restoration of all excavated areas in the floodplain would include regrading to original contours and the proposed activities would not subject lives or property to any increased risk of flooding.

9. Remedial contractors would locate equipment storage areas and associated buildings or structures outside of the 100-year floodplain. Access roads to work sites would follow routes established outside the floodplain. Haul roads would avoid following shoreline routes.

10. Use of mats, low ground pressure machines, or extended reach excavating equipment would minimize soil compaction and disturbance to areas of the floodplain sensitive to erosion or siltation.

11. Other mitigation techniques may include restoring surface flow patterns, minimizing easement widths, and selecting dust control measures that minimize adverse impacts to streams or floodplains.

12. Minimal disturbance to trees, shrubs, grasses, and other existing vegetation within 25 feet of the stream bank or 25 feet from the edge of the low water flow, where the bank is not well defined, would occur only where necessary for the remediation activities. Where feasible, construction equipment would work from one stream bank, leaving vegetation on the opposite bank.

13. Remedial contractors would dispose of vegetative waste outside of the floodplain unless the vegetation waste has value as mulch to control erosion. Disposal of vegetative waste would avoid discharges of material into streams or wetlands.

14. Restoration would include soil stabilization and revegetation with native species, if commercially available, suited to the constraints of the final remedial option selected. Revegetation of affected floodplain areas would include permanent seeding and mulching in accordance with established soil erosion and sediment control standards.

DOE will endeavor to allow 15 days of public review after publication of the statement of findings before implementation of the proposed action.

Issued in _____ on _____

_____
Program Office Official