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Clinch River RCRA Facility Investigation Plan

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Clinch River RCRA Facility Investigation Plan

Environmental Restoration Division
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NOTICE: This document contains information of a preliminary nature. It is subject to revision or correction and therefore does not represent a final report.

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MARTIN MARIETTA ENERGY SYSTEMS, INC.
operating the
Oak Ridge National Laboratory
Oak Ridge Y-12 Plant
Oak Ridge Gaseous Diffusion Plant
Paducah Gaseous Diffusion Plant
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

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Exhibit 12.1. Supervisor's Incident Report 368

Exhibit 12.2. Request for Pre-placement/Health Evaluation/Medical Restriction Form 368

ACRONYMS

%R	Percent recovery
ACD	Analytical Chemistry Division
ACF	Access Control Facility
ACGIH	American Conference of Governmental Industrial Hygienists
ADI	Allowabel daily intake
AEC	Atomic Energy Commission
ALARA	As Low As Reasonably Achievable
ANSI	American National Standards Institute
APR	Average percent recovery
ARAR	Applicable or Relevant and Appropriate Requirement
ARC/INFO	One kind of geographic information system
ASC	Analytical Services Coordinator
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AVLIS	Atomic Vapor Laser Isotopic Separation
BMAP	Biological Monitoring and Abatement Program
BNI	Bechtel National Incorporated
CA	Corrective Action
CAB	Cellulose Acetate Butyrate
CARS	Corrective Action Report and Status
CEC	Cation Exchange Capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CLP	Contract Laboratory Program
CM	Corrective measure
CMI	Corrective measures implementation
CMS	Corrective Measures Study
COD	Chemical oxygen demand
CPR	Cardiopulmonary Resuscitation
CR	Clinch River
CRK	Clinch River Kilometer
CRM	Clinch River Mile
CRQL	Contract required quantitation limit
CRRFI	Clinch River RCRA Facility Investigation
C_v	Coefficient of variation
CWA	Clean Water Act
DCG	Derived concentration guide
DI	Deionized
DMR	Discharge monitoring report
DOE	Department of Energy
DOT	Department of Transportation

EFPC	East Fork Poplar Creek
EFPCK	East Fork Poplar Creek Kilometer
EMC	Environmental Compliance Division
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Administration
ESD	Environmental Sciences Division
ESP	Environmental Surveillance Procedures
FDA	Food and Drug Administration
FEMA	Federal Emergency Management Agency
FS	Feasibility Study
GC/MS	Gas chromatography/mass spectroscopy
GIS	Geographic Information System
H&S	Health and Safety
HEA	Health and Environmental Assessment
HEEP	Health and Environmental Effects Profile
HEPA	High Efficiency particulate absolute
HFIR	High Flux Isotope Reactor
HP	Health Physics
HSWA	Hazardous and Solid Waste Amendments (RCRA)
HWM	Hazardous Waste Management
IAEA	International Atomic Energy Agency
IDL	Instrument detection limit
K-25	Same as ORGDP
LCS	Laboratory control sample
LLLW	Low level liquid wastes
LRM	Little River Mile
LTRM	Little Tennessee River Mil
M&TE	Measurement and test equipment
MCL	Maximum Contaminant Level
MDL	Method detection limit
MEK	Melton Branch
MHR	Melton Hill Reservoir
MIK	Mitchell Branch
MMES	Martin Marietta Energy Systems
MSDS	Material Safety Data Sheets
NBS	National Bureau of Standards
NCR	Nonconformance report
NDB	Numeric Data Base
NEPA	National Environmental Protection Act
NFPA	National Fire Protection Association
NFRRC	Nuclear Fuel Recovery and Recycling Center
NIOSH	National Institute for Occupational Safety and Health
NPDES	National Pollutant Discharge Elimination System
NPL	National Priority List
NQA	National Quality Assurance

NRC	Nuclear Regulatory Commission
NWT	Northwest Tributary
ORAU	Oak Ridge Associated University
ORGDP	Oak Ridge Gaseous Diffusion Plant
ORGDP-ACD	Oak Ridge Gaseous Diffusion Plant-Analytical Chemistry Department
ORNL	Oak Ridge National Laboratory
ORO	Oak Ridge Operations
ORR	Oak Ridge Reservation
ORTF	Oak Ridge Task Force
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Environmental Response
PAH	Polycyclic aromatic hydrocarbon
PARCC	precision, accuracy, representativeness, completeness, and comparability
PCB	Polychlorinated biphenyl
PCE	Poplar Creek Embayment
PCK	Poplar Creek Kilometer
PCM	Poplar Creek Mile
PE	Performance evaluation
PEL	Permissible Exposure Limits
PFD	Personal Flotation Device
PWTP	Process water treatment plant
QA	Quality assurance
QA/QC	Quality Assurance/Quality Control
QAC	Quality Assurance Coordinator
QAMS	Quality Assurance Management Staff
QAS	Quality Assurance Specialist
QC	Quality control
QER	Quality Event Report
QIR	Quality Investigation Report
RA	Remedial Action
RAA	Remedial Action Alternative
RAP	Remedial Action Plan
RCDB	Records Control Database
RCRA	Resource Conservation and Recovery Act
RCW	Recirculating cooling water
RD	Remedial Design
REL	Recommended Exposure Limits
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
RI	Request for Information
RPD	Relative percent difference
S&A	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act of 1986

SD	Standard deviation
SOP	Standard Operating Procedure
SOW	Statement of work
STP	Sewage treatment plant
SWMU	Solid Waste Management Unit
TBC	To be considered
TCL	Target Compound List
TDHE	Tennessee Department of Health and Environment
TDPH	Tennessee Department of Public Health
TLD	Thermoluminescent dosimeter
TLV	Threshold Limit Values
TP	Technical Procedure
TPP	Transuranic Processing Plant
TRM	Tennessee River Mile
TRU	Transuranic elements
TSCA	Toxic Substance Control Act
TVA	Tennessee Valley Authority
TWRA	Tennessee Wildlife Resources Agency
USCG	United States Coast Guard
USGS	U.S. Geological Survey
UV	Ultraviolet
WBGT	Wet Bulb Globe Temperature
WOC	White Oak Creek
WOCE	White Oak Creek Embayment
WOD	White Oak Dam
WOL	White Oak Lake
X-10	Same as ORNL
Y-12	The Oak Ridge Y-12 Facility

1. INTRODUCTION

1.1 REGULATORY BACKGROUND AND PURPOSE

The Oak Ridge National Laboratory (ORNL), the Oak Ridge Gaseous Diffusion Plant (ORGDP), and the Y-12 Plant are U.S. Department of Energy (DOE) facilities located on the Oak Ridge Reservation (ORR) in eastern Tennessee. In compliance with Section 3004(u) of the Hazardous and Solid Waste Amendments (HSWA) (1984) to the Resource Conservation and Recovery Act (RCRA) (1976), numerous individual operations and waste management units located within the boundaries of these facilities are currently being investigated to determine the nature and extent of hazardous releases to the environment and, where appropriate, to initiate corrective actions.

The Clinch River RCRA Facility Investigation (CRRFI) is being initiated in compliance with Section 3004(v) of the Hazardous and Solid Waste Amendments (HSWA) of 1984 to the Resource Conservation and Recovery Act (RCRA) of 1976. Section 3004(v) addresses requirements for corrective actions for releases of hazardous wastes or constituents beyond the boundaries of RCRA-permitted facilities.

The ORR was added to the National Priorities List (NPL) in December 1989. A Federal Facilities Agreement [under Section 120 of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) and Section 6001 of RCRA] between the DOE, the U.S. Environmental Protection Agency (EPA), Region IV, and the Tennessee Department of Health and Environment (TDHE) is under negotiation. These parties intend to coordinate the DOE's CERCLA/RCRA response obligations with the corrective measures required and conducted by DOE under its current HSWA permit, and they expect that the response actions under this Federal Facilities Agreement, together with the corrective measures under the permit, will achieve comprehensive remediation of releases and threatened releases of hazardous substances, hazardous wastes, pollutants, or contaminants at or from the ORR. The RCRA Corrective Action Process and the CERCLA Remedial Action Process are similar and operate in a parallel manner, as shown in Fig. 1.1.

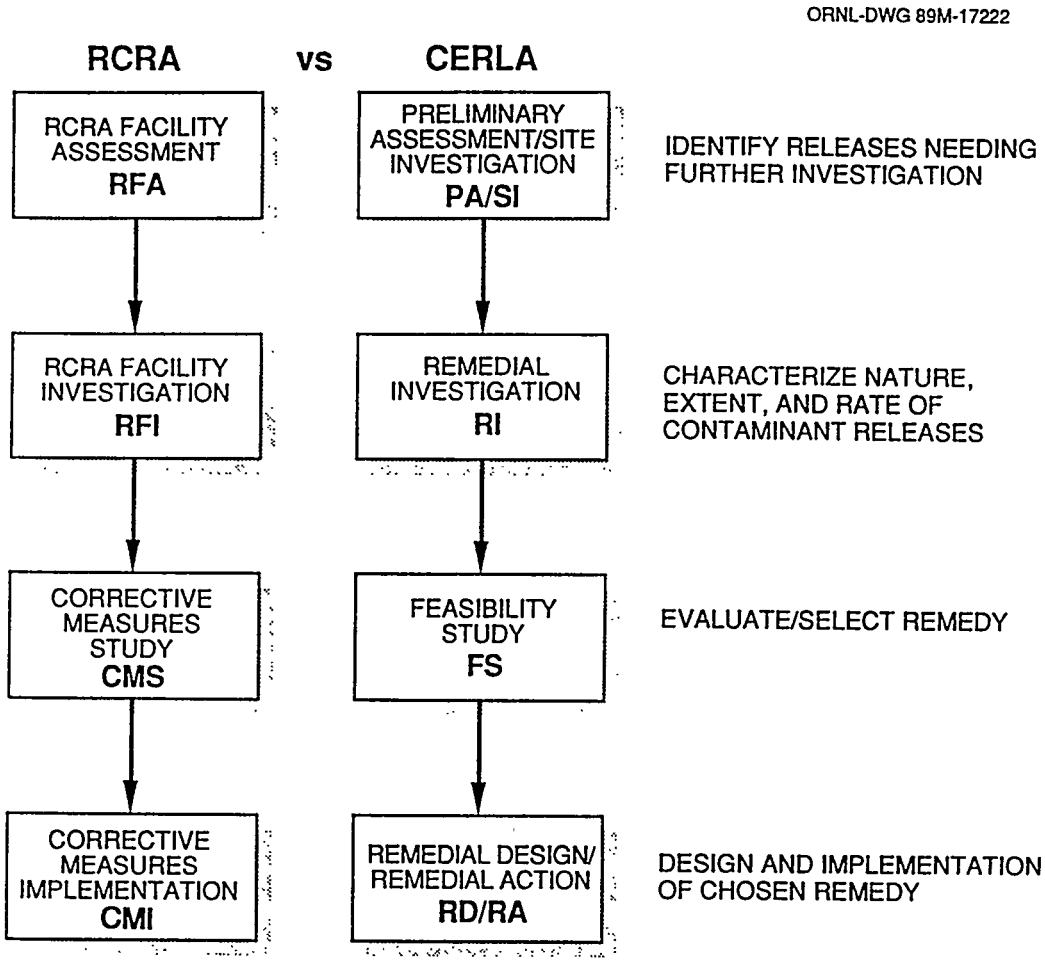

Fig. 1.1. Comparison of the RCRA Corrective Action Process and the CERCLA Remedial Action Process. Interim corrective measures or remedial actions may be performed at any point in both processes.

Additionally, the requirements of the National Environmental Policy Act (NEPA) will be integrated into the RCRA Corrective Action and CERCLA Remedial Action Processes.

On August 2, 1988, the DOE Office of the Assistant Secretary for Environment, Safety, and Health issued DOE Notice 5400.4, which established DOE's policy of integrating the statutory requirements of the NEPA and CERCLA. Such integration is intended to (1) avoid duplicative effort and the associated larger commitment of resources that would be needed to implement both NEPA and the CERCLA Remedial Investigation/Feasibility Study (RI/FS) separately; (2) avoid conflicts in analysis and the choice of a remedial alternative; and (3) minimize the risk of delaying remedial actions on procedural grounds. Levine et al., (1989) have provided specific guidance for the integration of NEPA and CERCLA requirements during corrective action/remedial action responses at DOE facilities.

1.2 SCOPE OF THE CLINCH RIVER RFI

The CRRFI will focus on the portions of the Clinch and Tennessee Rivers that may have been adversely affected by contaminants released from the mid-1940s to present from the DOE ORR. The contaminants released from the ORR originate from research, industrial, and waste disposal activities conducted at:

- the Oak Ridge National Laboratory (ORNL), an energy research and development laboratory;
- the Oak Ridge Gaseous Diffusion Plant (ORGDP), a uranium enrichment facility until its closure in 1986; and
- the Y-12 Plant, a facility for producing nuclear-weapons components.

The contaminants released from these facilities include a variety of radionuclides, metals, and organic compounds. Some liquid wastes are discharged to streams on the ORR, which drain into the Clinch River; however, much of the water-borne contamination is derived from seepage into the shallow groundwater from old waste storage pits and

trenches. The contaminated groundwater drains into ORR streams and ultimately into the Clinch River.

The Clinch River enters the Tennessee River system of multiple-purpose impoundments near Kingston, Tennessee, 34 km downstream from the Oak Ridge complex. Watts Bar Reservoir is located on the Tennessee River just below its confluence with the Clinch River, and is the first impoundment downstream of the ORR.

The CRRFI will address the potential human-health and environmental risks associated with (1) current and recent contaminant releases to the Clinch River from the Oak Ridge facilities, and (2) long-term contaminant accumulations in the river and reservoir sediments downstream from the ORR. Remediation of existing contamination problems is the ultimate goal of the RCRA Corrective Action Process, of which the RFI is the site characterization and risk assessment component (Fig. 1.2). During the CRRFI, data will be collected for site characterization, risk assessment, and preliminary identification and evaluation of potential remedial alternatives. To ensure that the combination of existing data and new data to be collected will be adequate for these purposes, the potential pathways leading to human health and environmental risks, potential off-site problem areas that could require remediation, and categories of potential remediation alternatives have been preliminarily identified. Existing data relevant to off-site contamination have been evaluated and used in designing the CRRFI Work Plan (Section 7) and the CRRFI Sampling and Analysis Plan (Section 9).

1.3 OBJECTIVES AND APPROACH

The primary objectives of the CRRFI are to:

- define the nature and extent of contamination of the off-site surface-water and sediment environment downstream from the ORR,
- quantify any risk to human health and to the environment resulting from the existing off-site contamination,

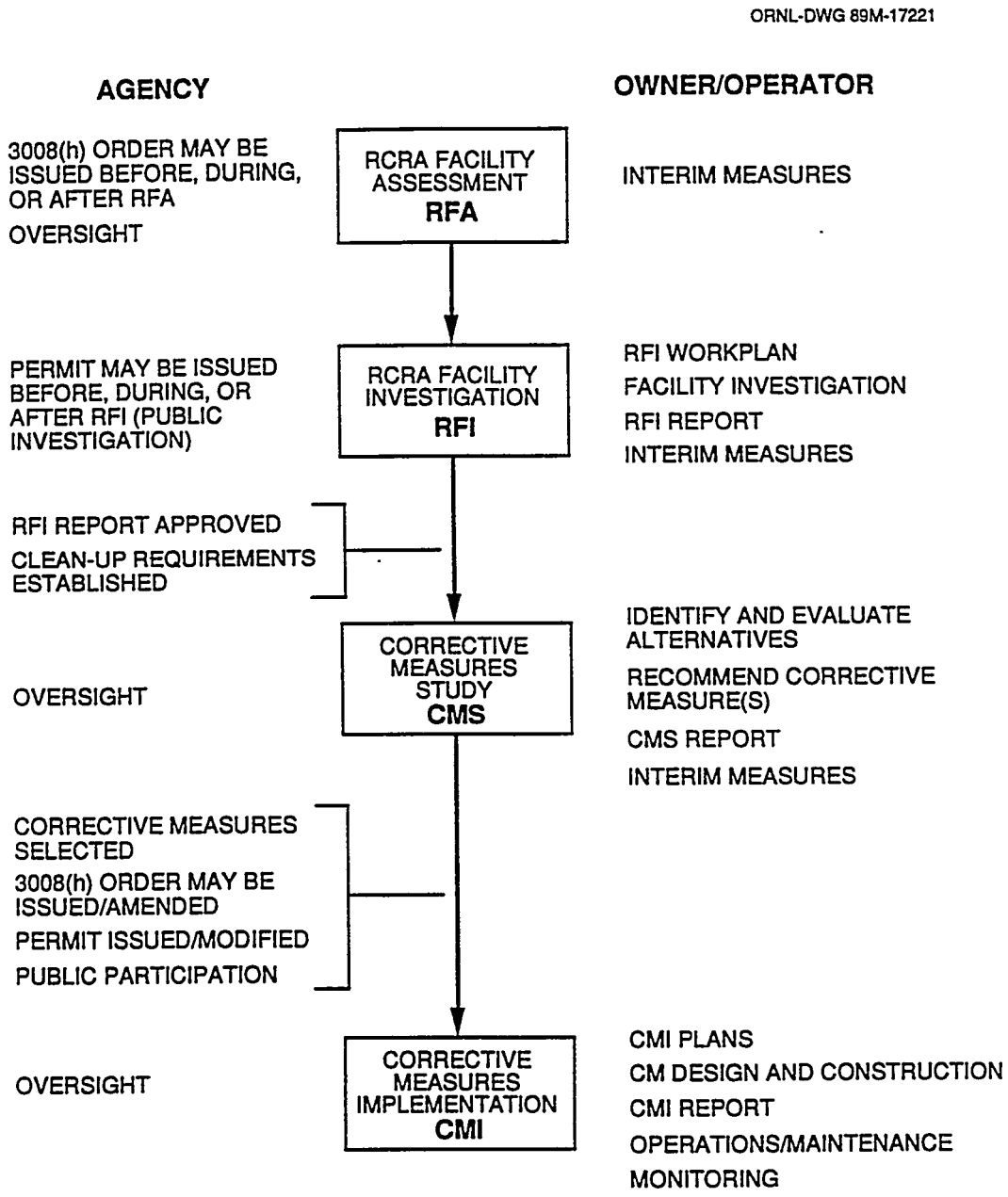

Fig. 1.2. The RCRA Corrective Action Process.

- preliminarily identify and evaluate potential corrective measures / remedial action alternatives.

A phased approach will be employed throughout the CRRFI. The phased approach relies heavily on risk analysis for estimating human health and environmental risks, and is based on obtaining the data needed for risk analyses and for evaluating remediation alternatives. The phased approach includes the following components:

1. Synthesis of extant data and a screening-level risk analysis to identify areas in which additional data collection is necessary for purposes of site characterization, risk assessment, and evaluation of remediation alternatives.
2. Preliminary sampling and analysis in selected areas that are representative of differing levels of contamination (including reference sites located upstream from the Oak Ridge DOE facilities) to determine the range of contaminant concentrations present in the off-site environment, to identify the contaminants of concern, and to establish the reference concentrations for those contaminants.
3. Iterative risk analysis, as additional data become available, to quantitatively estimate potential risks to human health and to the environment, and to focus additional sampling efforts.
4. More extensive sampling and analysis guided by results of the risk analyses.
5. Preliminary evaluation of potential remediation alternatives and identification of effective and acceptable corrective measures. If needed, detailed evaluation and implementation of remedial actions will be accomplished through the RCRA Corrective Measure Study/Corrective Measure Implementation process (Fig. 1.2).

The CRRFI will be coordinated with environmental monitoring and remedial action programs now being conducted at ORNL, ORGDP, and Y-12 in compliance with the provisions of RCRA, CERCLA, NEPA, and State of Tennessee environmental protection regulations. On-site monitoring programs and remedial action investigations will provide much data relevant to the CRRFI.

1.4 ORGANIZATION OF THE CLINCH RIVER RFI PLAN

The Clinch River RFI Plan has been developed in accordance with EPA (1987b) [RCRA Facility Investigation (RFI) Guidance, OSWER Directive 9502.00-6C, July 1987] and EPA (1988) [Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, OSWER Directive 9335.3-01, issued by the Office of Solid Waste and Environmental Response (OSWER) of the U.S. Environmental Protection Agency.

The Clinch River RFI Plan is organized as follows:

Sections 1-6 include an introduction, a description of current conditions, characterization of the environmental setting, description of wastes released to the off-site environment, a summary of previous investigations of off-site contamination, identification of important environmental pathways, and ecological risk endpoints of concern.

Section 7 presents the Clinch River RFI Work Plan. The plan consists of four major tasks:

Task 1	Site Characterization
Task 2	Human-Health Risk Assessment
Task 3	Environmental Risk Assessment
Task 4	Preliminary Identification and Evaluation of Remedial Action Alternatives

Details of each task and its relationship to the other major tasks are described in Section 7.

Section 8 presents the project organization and management plan. Section 9 details the field sampling and analysis plan. Section 10 outline the Quality Assurance/Quality Control procedures to be followed during the project. Section 11 describes the data management plan to be instituted for the project. Section 12 presents the Health and Safety Procedures to be implemented as part of the project.

Supporting documents and exhibits are appended to the plan. Additional plans that may be required by the EPA or the Tennessee Department of Health and Environment (TDHE) will be prepared as needed.

2. DESCRIPTION OF CURRENT CONDITIONS

2.1 HISTORY OF THE OAK RIDGE FACILITIES

The Oak Ridge Reservation (ORR) includes three major facilities: the Oak Ridge National Laboratory (ORNL) for energy research and development; the Oak Ridge Y-12 Plant (Y-12) for the production of weapons components; and the Oak Ridge Gaseous Diffusion Plant (ORGDP), formerly for the production of enriched uranium.

The ORR was acquired by the U.S. Army Corps of Engineers for the Manhattan Project in 1942. The Oak Ridge site was chosen for the production of fissionable material in September 1942 (Hewlett and Anderson 1962, Fiedler et al., 1977). Construction of the Clinton Laboratories (now known as ORNL) was initiated in February 1943; K-25 (now the ORGDP) construction began in September 1943. By November of the same year, operations had begun. Construction of the Y-12 facility began in February 1943, and the plant was in production by January 1944. At the height of the Manhattan Project in 1944-1945, the population of Oak Ridge was approximately 75,000 persons.

The U.S. Atomic Energy Commission (AEC), established in 1947, took charge of the Oak Ridge facilities and administered a new program for developing nuclear energy for beneficial peacetime applications. The AEC became the Energy Research and Development Administration (ERDA) and the Nuclear Regulatory Commission (NRC) in 1975, and the mission of the agency was expanded to include additional non-nuclear aspects of energy development and use. In 1977, all ERDA programs became part of the newly created U.S. Department of Energy (DOE). As the goals of the government agencies changed, the emphasis of activities at the Oak Ridge facilities also changed to include investigation of both nuclear and non-nuclear energy technologies and the environmental consequences of energy technology development.

2.2 LOCATION OF THE OAK RIDGE RESERVATION

The City of Oak Ridge and the DOE ORR are located 40 km to the west of Knoxville, Tennessee, (Fig. 2.1).

The ORR is located within the corporate city limits of the City of Oak Ridge, in Roane and Anderson counties, in eastern Tennessee. The ORR consists of approximately 14,260 ha (35,236 acres) of federally owned lands, and is bounded on the north and east by the populated portion of the City of Oak Ridge and on the south and west by the Clinch River (Fig. 2.2). Except for the City of Oak Ridge (population 28,000 - U.S. Census 1980), the land within 8 km of the ORR is predominantly rural, and is used largely for residences, small farms, and pasture land.

The approximate location and population (1980 census data) of other towns near the ORR are Oliver Springs (pop. 3600), 11 km to the northwest; Clinton (pop. 5300), 16 km to the northeast; Lenoir City (pop. 5400), 11 km to the southeast; Kingston (pop. 4400), 11 km to the southwest; and Harriman (pop. 8300), 13 km to the west. Figure 2.1 shows the locations of these towns in relation to the ORR. Knoxville is the nearest major metropolitan center, and has a population of about 183,000 (Petrick et al., 1984; Baumgardner and Chance 1984).

2.3 GENERAL DESCRIPTION OF THE PLANT FACILITIES

2.3.1 Oak Ridge National Laboratory

ORNL (Fig. 2.3), located toward the west end of Bethel Valley, is a large, multipurpose laboratory for basic and applied research in energy technology development. ORNL's facilities include nuclear reactors, chemical pilot plants, research laboratories, radioisotope production laboratories, and support facilities. The Oak Ridge National Environmental Research Park, which encompasses much of the non-plant area of the ORR, is managed by ORNL.

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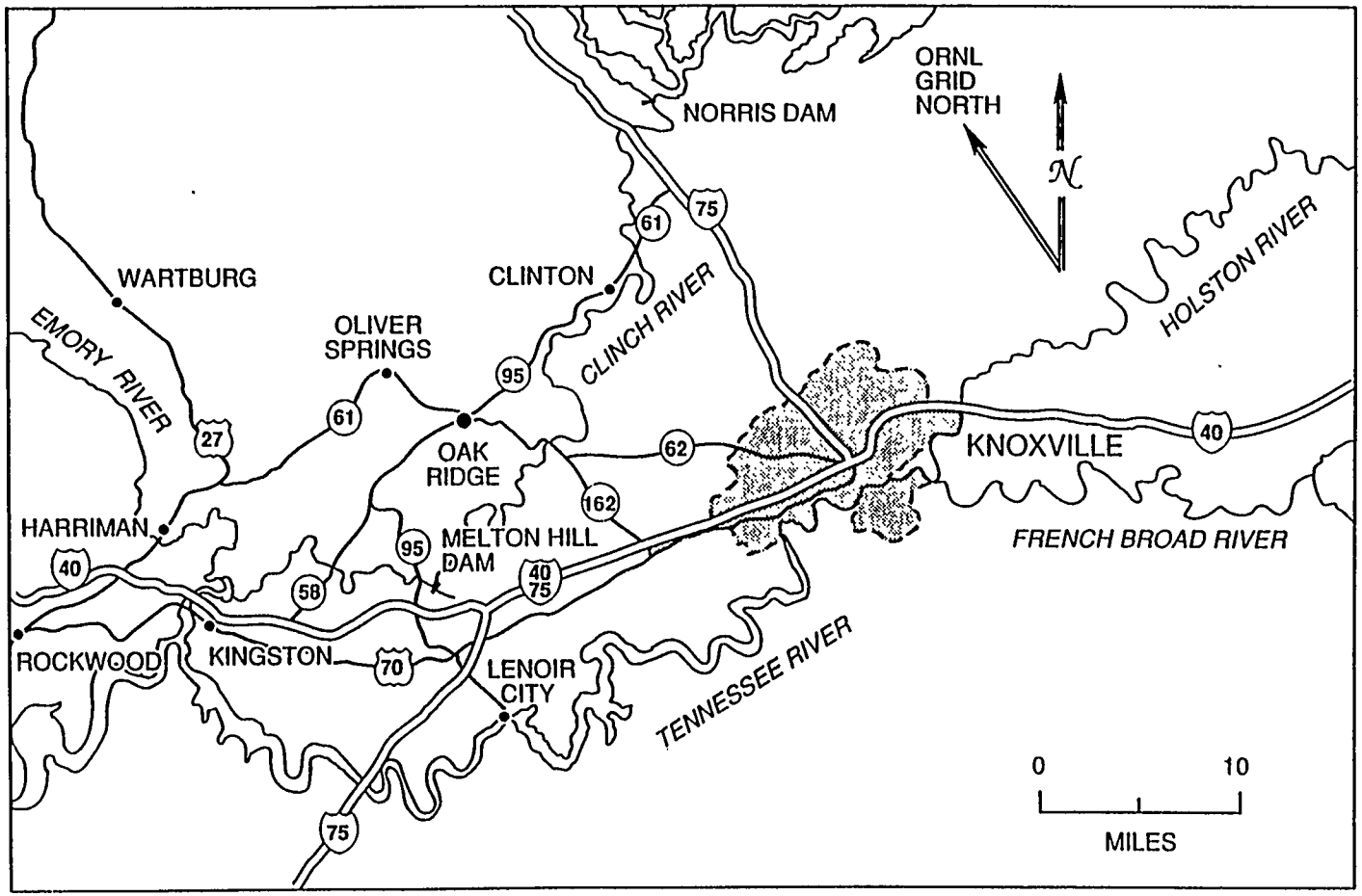

Fig. 2.1. Map of the Oak Ridge, Tennessee area showing the locations of the U.S. DOE Oak Ridge Reservation (ORR), the cities of Oak Ridge and Knoxville, and other nearby population centers.

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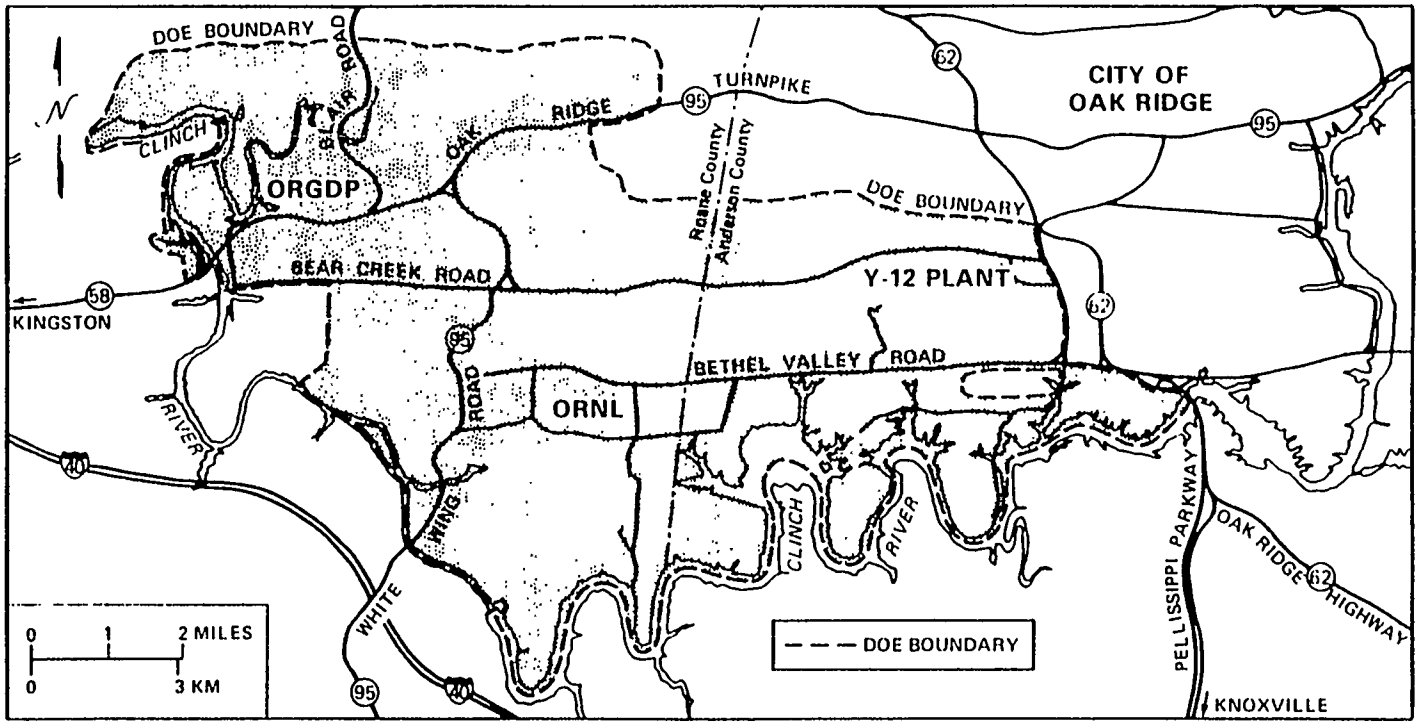

Fig. 2.2. Map of the U.S. DOE Oak Ridge Reservation showing the locations of the Y-12 Plant, ORNL, ORGDP, and the Clinch River.

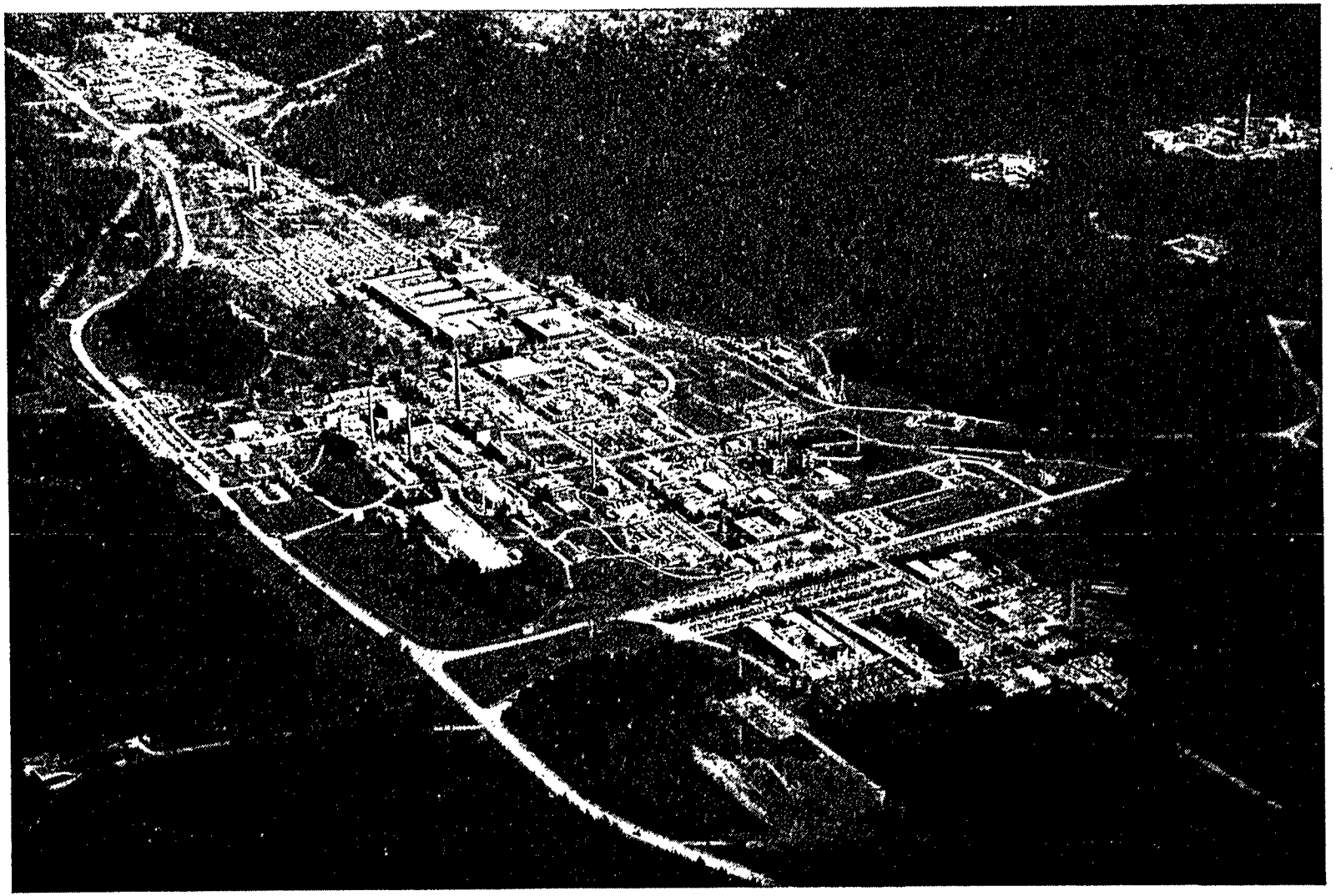

Fig. 2.3. Aerial view (looking southeast) of the Oak Ridge National Laboratory, Oak Ridge, Tennessee.

2.3.2 Y-12 Plant

The Oak Ridge Y-12 Plant (Fig. 2.4), which is located in the eastern end of Bear Creek Valley and immediately adjacent to the City of Oak Ridge, has five major responsibilities: (1) to fabricate nuclear weapons components, (2) to process source and special nuclear materials, (3) to provide support to the weapons-design laboratories, (4) to provide support to other DOE installations, and (5) to provide support to other government agencies. Activities associated with these functions include production of lithium compounds, recovery of enriched uranium and other materials into finished parts and assemblies. Fabrication operations include vacuum casting, arc melting, powder compaction, rolling, forming, heat treating, machining, inspection, and testing (Welch 1987).

2.3.3 Oak Ridge Gaseous Diffusion Plant

Until the summer of 1985, the primary mission of the ORGDP (Figs. 2.2 and 2.5) was ^{235}U-enrichment of uranium hexafluoride (UF_6) for eventual use as a fuel in nuclear reactors. The gaseous-diffusion process was used to accomplish the isotopic enrichment. In August 1985, the gaseous-diffusion process at ORGDP was placed in a "ready-standby" mode because of a declining demand for enriched uranium. In December 1987, the decision was made to permanently shut down the gaseous-diffusion cascade and the plant was placed in "permanent shutdown" status.

ORGDP personnel were also involved in developing and demonstrating more energy-efficient and cost-effective methods for uranium enrichment. Two such methods under development at ORGDP were the gas-centrifuge process and the atomic vapor laser isotopic separation (AVLIS) system. In 1985 the gas centrifuge process was shut down, and in 1986 the AVLIS work at ORGDP was significantly reduced.

Although much of ORGDP is now shut down, some waste continues to be generated and wastes now in storage will require disposal (ORGDP 1987; Rogers et al., 1988). Waste management activities at ORGDP are increasing. Low-level radioactive waste

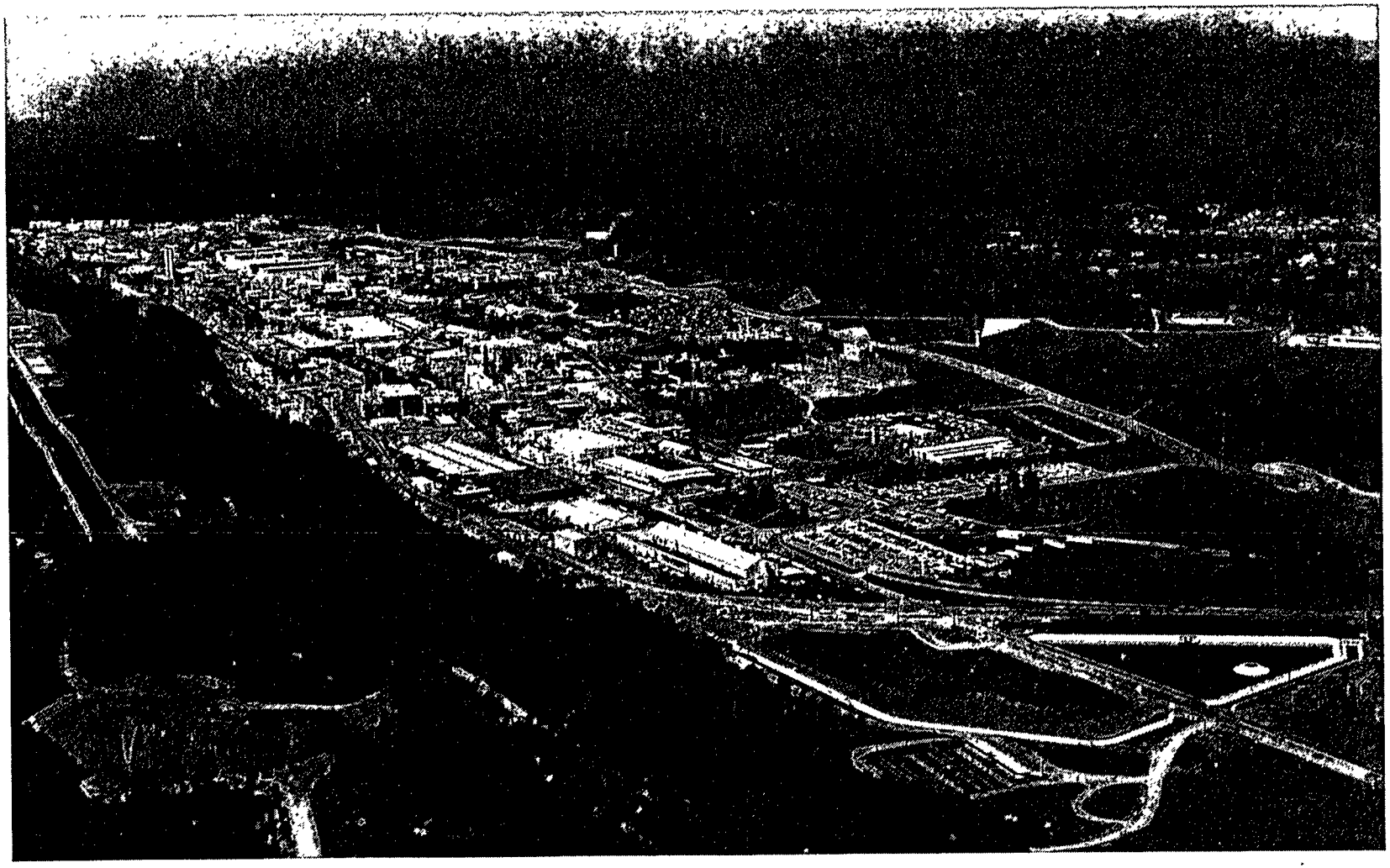

Fig. 2.4. Aerial view (looking northwest) of the Y-12 Plant, Oak Ridge, Tennessee.

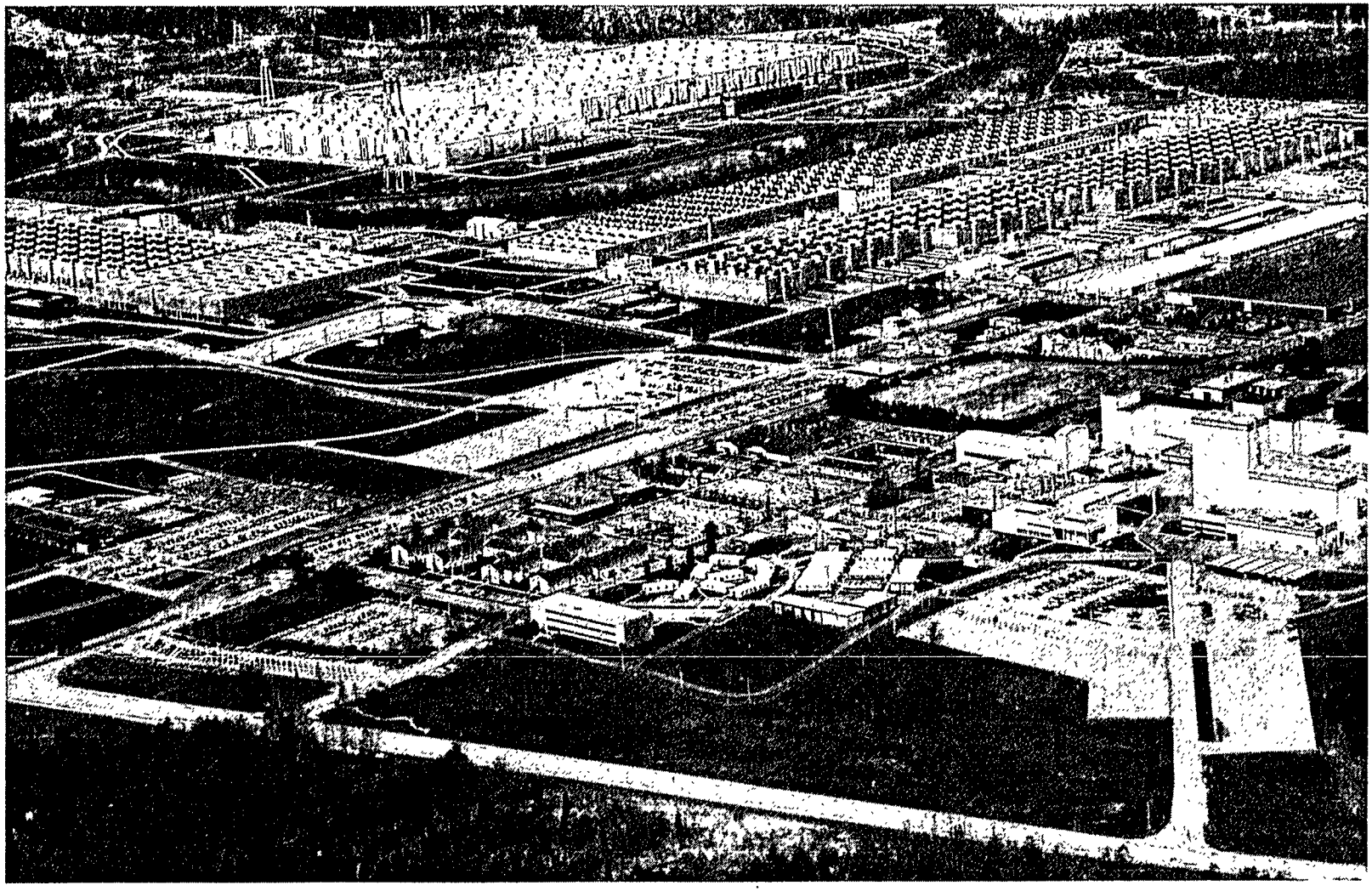

Fig. 2.5. Aerial view (looking northwest) of the Oak Ridge Gaseous Diffusion Plant, Oak Ridge, Tennessee.

from other DOE-Oak Ridge Operations (DOE-ORO) sites are now being placed in interim storage facilities in the K-25 Building vaults until the final disposition strategy is identified. Also polychlorinated biphenyl (PCB)-contaminated wastes began arriving from other DOE-ORO sites in 1987 for incineration in the new K-1435 Toxic Substance Control Act (TSCA) incinerator. Other remaining missions at ORGDP include advanced enrichment technology research and development, various analytical laboratory programs, engineering and computer support, and various waste treatment services.

2.4 CONTAMINANT RELEASES BEYOND THE ORR BOUNDARY

The ORNL, ORGDP, and the Y-12 Plant are all located on the Oak Ridge Reservation. Production, research, and waste disposal operations at all three of these facilities have resulted in releases of hazardous and radioactive wastes which potentially impact the surrounding environment by contaminating air, soils, sediments, vegetation, animals, ground water, and surface water. Wastes from the ORNL, ORGDP, and the Y-12 Plant enter local streams (primarily, White Oak Creek from ORNL, East Fork Poplar Creek and Bear Creek from Y-12, and Poplar Creek from ORGDP) which drain into the Clinch River and then into the Tennessee River and Watts Bar Reservoir (Fig. 2.6).

This CRRFI specifically addresses the contamination of off-site surface waters by past and present waste releases from the ORR. Waste releases to the off-site aquatic environment are characterized and previous investigations of off-site surface water contamination are summarized in Sections 4 and 5.

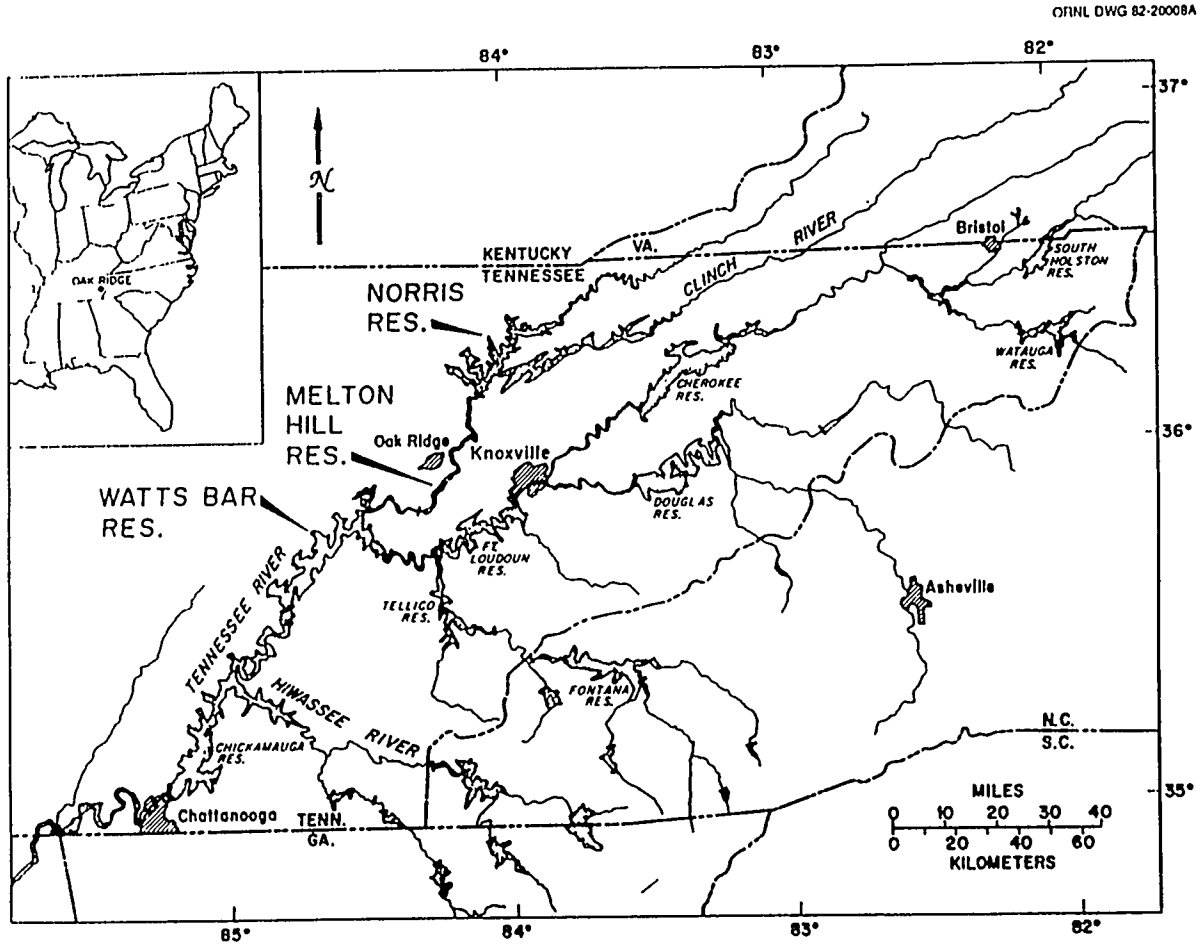

Fig. 2.6. Map of eastern Tennessee showing the location of the U.S. DOE Oak Ridge Reservation in relation to the Norris, Melton Hill, and Watts Bar reservoirs. Inset shows the location of Oak Ridge in the eastern U.S.

3. CHARACTERIZATION OF THE ENVIRONMENTAL SETTING

3.1 CLIMATE

The Oak Ridge area has a temperate climate with warm, humid summers and cool winters. The Blue Ridge Mountains to the east and the Cumberland Plateau to the west have a protective and moderating influence on the region's climate. 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 prevailing winds in the Oak Ridge area follow the general topography of the surrounding ridges: daytime, up-valley winds come from the southwest and night-time, down-valley winds come from the northeast (Fig. 3.1). The Cumberland Plateau to the west and the Smoky Mountains to the southeast divert severe storms and tornados and high-velocity windstorms are rare. The mountains similarly divert hot, southerly winds which develop along the south Atlantic Coast. Slow-moving high pressure cells suppress rain in the fall, remain nearly stationary for days, and provide for mild weather. 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).

Precipitation in this area of the Tennessee Valley is seasonally distributed (McMaster 1967). Peaks in precipitation usually occur in late winter-early spring and in mid- to late-summer. Winter storms are generally of low intensity and long duration; brief, heavy rains associated with thunderstorms are common in the summer. The annual minimum in precipitation usually occurs in the fall. The mean annual rainfall in the Oak Ridge area is about 136 cm (Fig. 3.2); however, during the recent drought of 1981 - 1988, the annual precipitation was about 30 to 35 cm less than the annual average.

An isohyetal map of the Oak Ridge area (Fig. 3.3) shows that mean annual precipitation ranges from more than 150 cm in the west to about 115 cm 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 (also see Fig. 3.4).

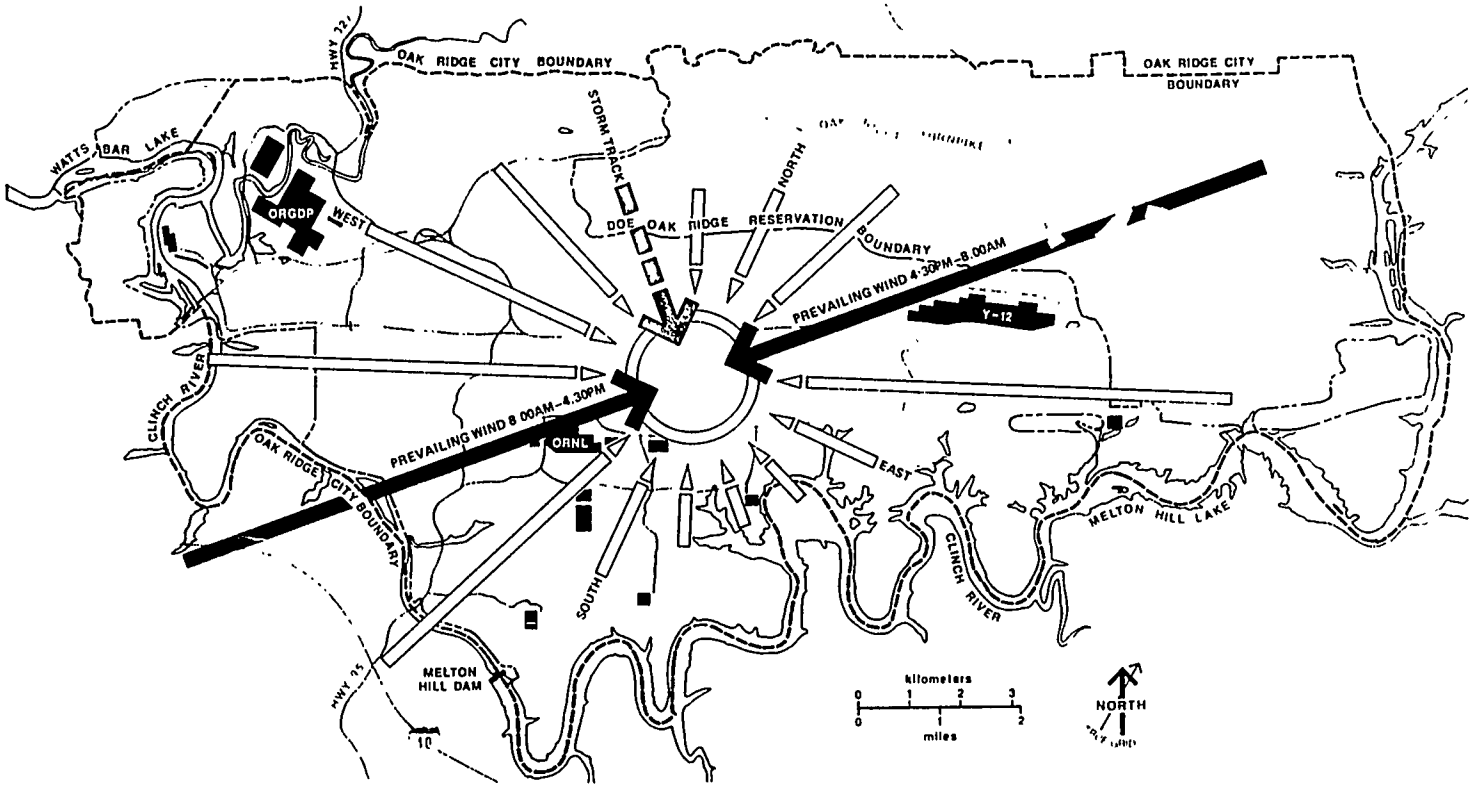

Fig. 3.1. Average wind frequency and direction for the DOE Oak Ridge Reservation and vicinity.

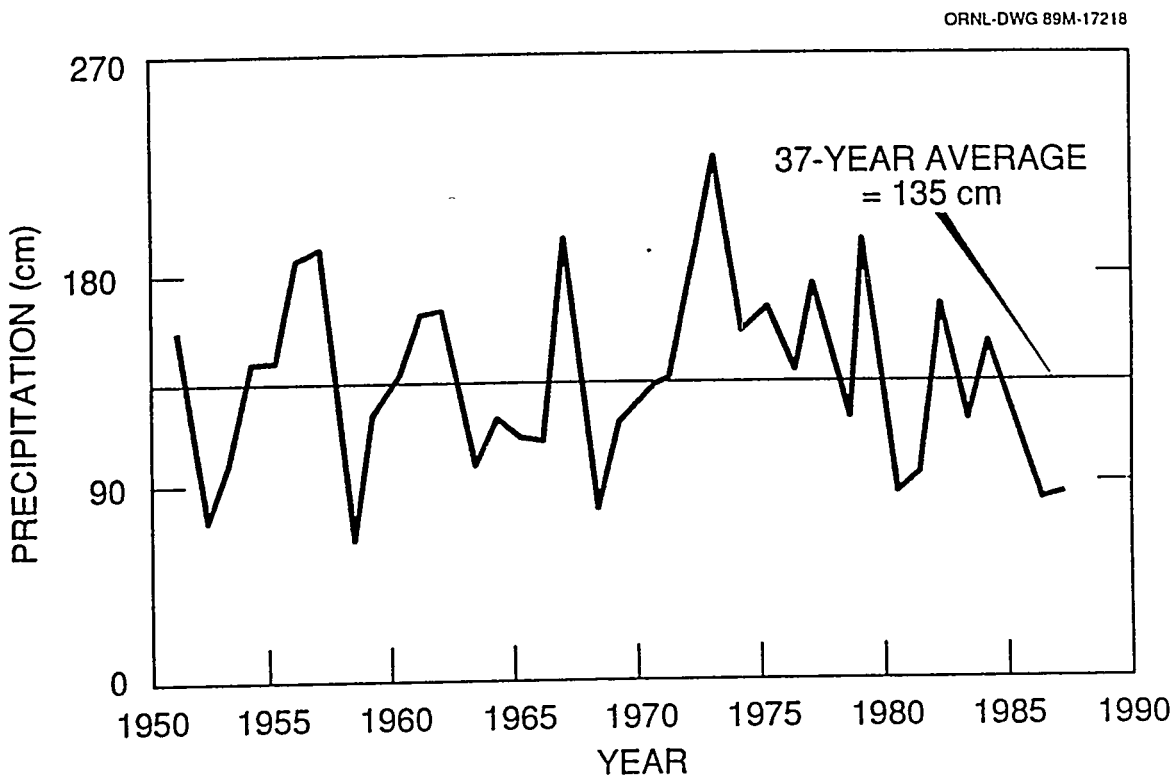

Fig. 3.2. The annual precipitation history of the Oak Ridge, Tennessee area.

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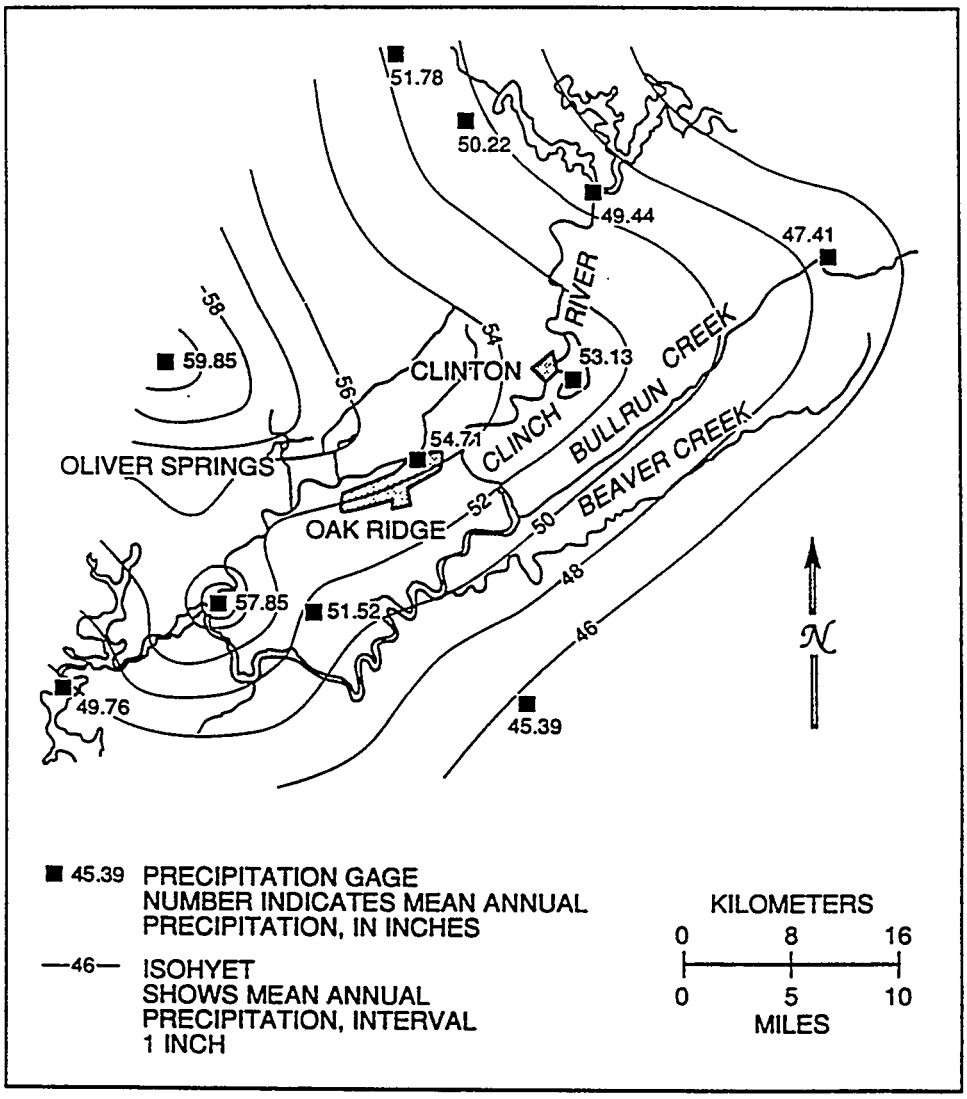

Fig. 3.3. Isohyetal map of the Oak Ridge, Tennessee area showing a northwest-to-southeast decline in average precipitation. Map based on mean annual precipitation data for 1936-1960 (McMaster 1967).

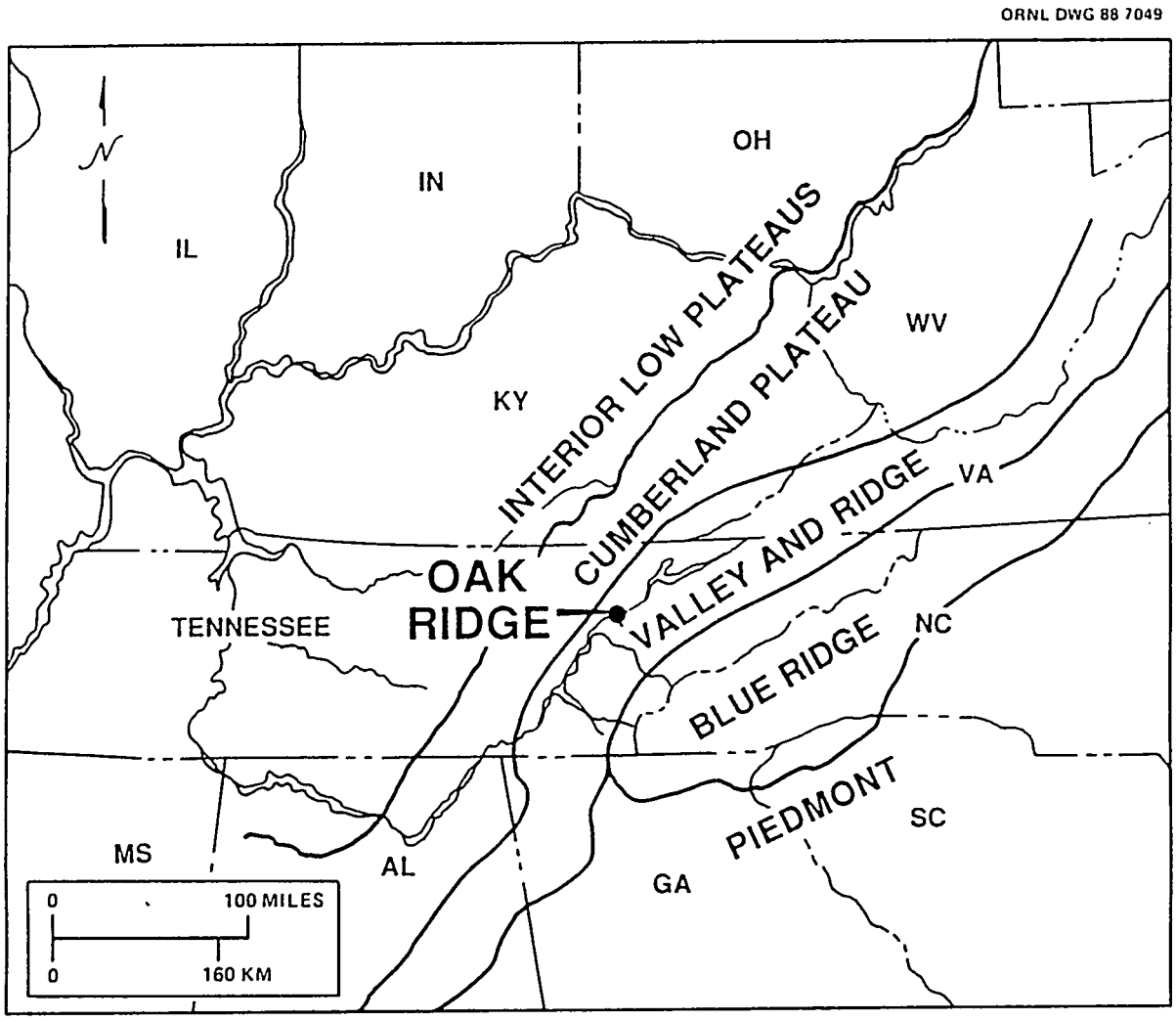

Fig. 3.4. Regional physiographic map of eastern Tennessee showing the location of Oak Ridge in the Valley and Ridge Province.

Loss of water to the atmosphere by evapotranspiration is about 76 cm annually in the Oak Ridge area, or about 55% of the total annual precipitation. Evapotranspiration is at a maximum from July to September during the vegetation 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 to streams percolates through the soil and eventually recharges the ground-water system.

3.2 TOPOGRAPHY, GEOLOGY, AND SOILS

3.2.1 Topography

The ORR is located in the Valley and Ridge Physiographic Province of eastern Tennessee between the Cumberland Plateau and the Blue Ridge Mountains (see Fig. 3.4) (Britz 1987). The Valley and Ridge Province is a geologically complex zone characterized by a succession of northeast-to-southwest ridges and valleys that extends approximately 2000 km from the Canadian St. Lawrence lowland to Alabama, and is 13 to 20 km wide in the Oak Ridge area.

The topography of the Oak Ridge area is influenced by both the underlying geologic structures and differential erosion. The bedrock is a series of highly faulted and folded sedimentary units visible on the surface as long parallel ridges and narrow valleys. Regional compression produced thrust faulting throughout the Valley and Ridge Province and resulted in its characteristic belted pattern of rock formations (Figs. 3.5 and 3.6).

The ORR is characterized by a rolling ridge and valley topography with gentle-to-steep slopes and little or no expanse of flat land. The ridges are generally underlain by resistant sandstones, siltstones and siliceous limestones and solostones. Valleys are generally underlain by shales and more soluble carbonate formations. Elevations range from 226 to 415 m above mean sea level, a maximum topographic relief of 189 m.

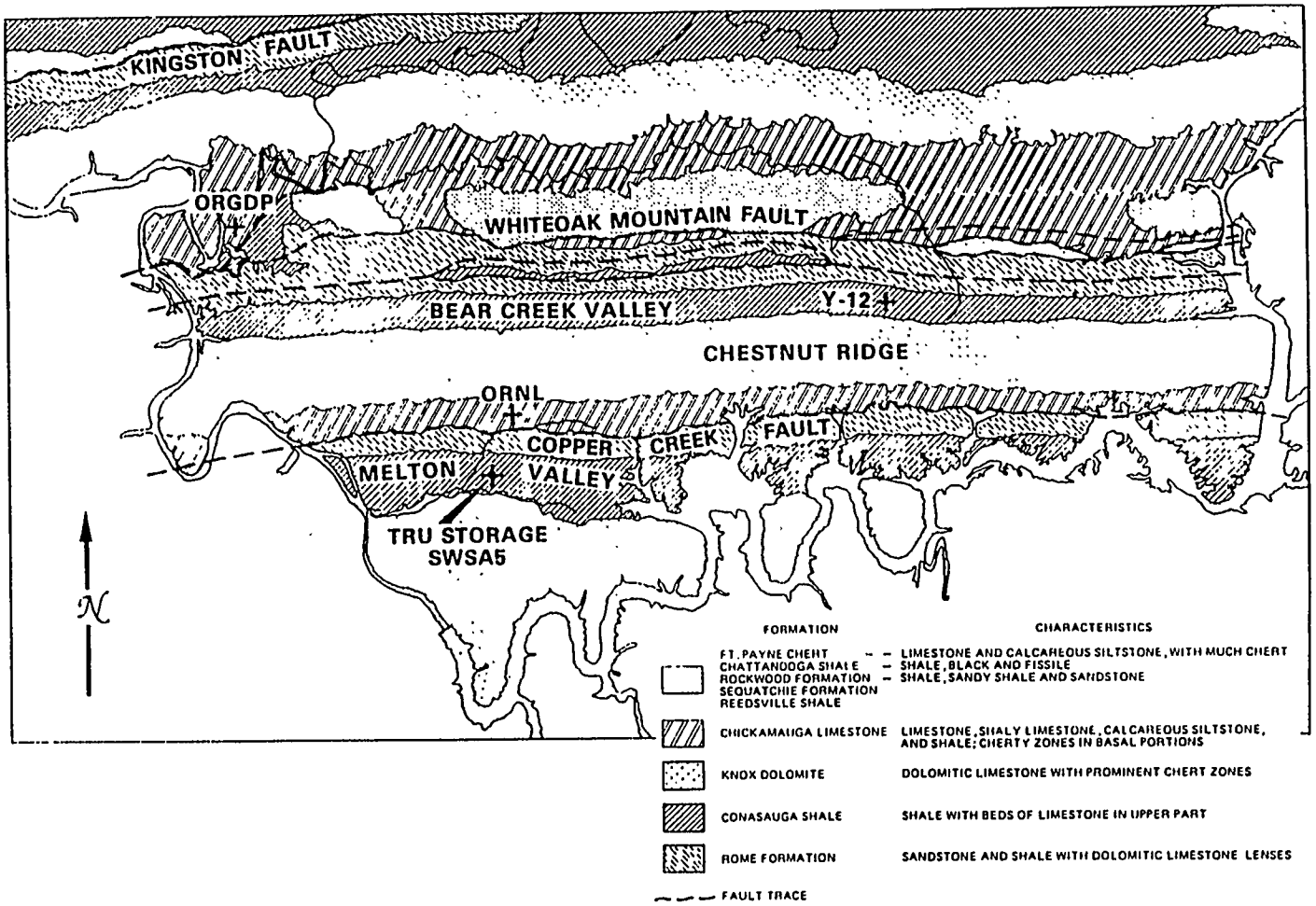

Fig. 3.5. Generalized geologic map of the U.S. DOE Oak Ridge Reservation.

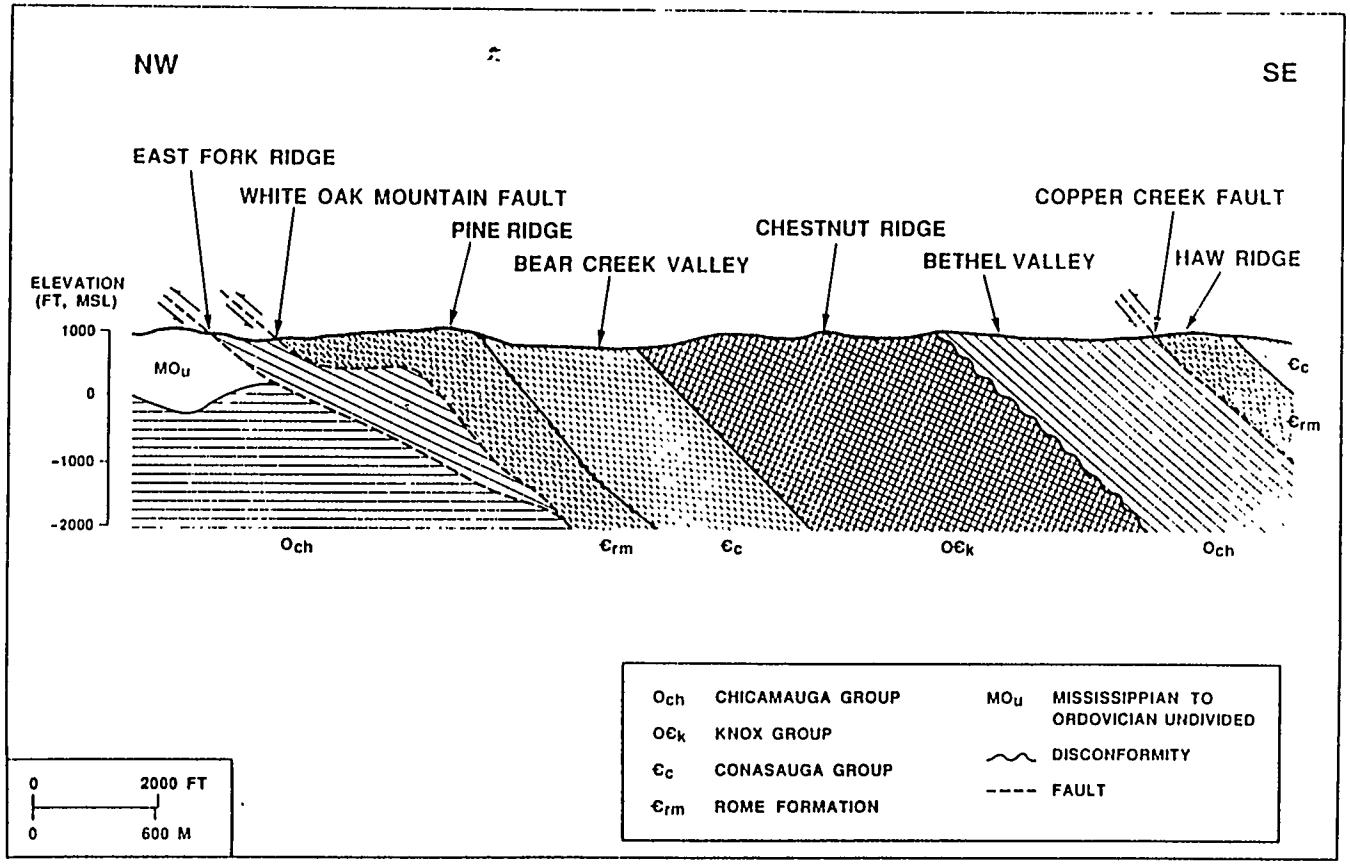

Fig. 3.6. Generalized geologic cross-section of the U.S. DOE Oak Ridge Reservation.

3.2.2 Geology

The ORR is underlain by ten different geologic formations or groups of formations ranging in age from early Cambrian to early Mississippian (Fig. 3.7). These formations are of sedimentary origin. From the oldest to the youngest they include the Shady Dolomote, Rome Formation, the Conasauga Group, the Knox Group, the Chickamauga Group, the Sequatchie Formation, the Rockwood Formation, the Chattanooga Shale, and the Fort Payne Formation. In terms of outcrop area on the ORR, the most important formations are the Rome Formation, the Conasauga Group, the Knox Group, and the Chickamauga Group. The other formations are of limited areal extent.

Description of Geologic Formations on the ORR

Shady Dolomite

The Shady Dolomite is the oldest formation exposed in the Valley and Ridge Province of Tennessee. The outcrop area is generally restricted to the eastern side of the province. However, exposures have been found along the hanging wall of the White Oak Mountain Thrust Fault near the western border of the ORR in the vicinity of ORGDP (D'appolonia 1981). The Shady Dolomite consists of white to blue-gray dolostone and magnesian limestones. Silica as chalcedonic chert and brown to gray jasperoid in a yellow to red clay identify the weathered Shady Dolomite areas. The complete thickness of the Shady Dolomite is not preserved on the ORR because of faulting; where it is found, the Shady Dolomite exhibits a large degree of fracturing and dissolution.

Rome Formation

The Rome Formation underlies Pine Ridge and Haw Ridge on the ORR. Lithologically, the Rome Formation is predominantly a siltstone and shale with fine-grained sandstones and zones of impure dark-colored dolostone and magnesian limestone. The clastic rocks are variegated; maroon to gray-green colors are common.

ORNL-DWG 89M-17290

PERIOD	GROUP	FORMATION	THICKNESS	CHARACTERISTICS OF ROCKS
MISSISSIPPIAN		FT. PAYNE	25 METERS	IMPURE LIMESTONE AND CALCAREOUS SILTSTONE, WITH ABUNDANT CHERT
		CHATTANOOGA SHALE	7 METERS	SHALE, BLACK, FISSILE
DEVONIAN	?			
SILURIAN		ROCKWOOD	200 METERS	SILTSTONE, SANDSTONE, AND SHALE; YELLOW TO TAN AND BROWN
ORDOVICIAN		SEQUATCHIE	90 METERS	SHALE, SHALY LIMESTONE, SANDY SHALE, CALCAREOUS; MAROON TO GRAY OLIVE
	CHICKAMAUGA		600 METERS	LIMESTONE, SHALY LIMESTONE, CALCAREOUS SILTSTONE, AND SHALE; MOSTLY GRAY, PARTLY MAROON, WITH CHERTY ZONES IN BASAL PORTIONS
	KNOX		900 METERS	DOLOSTONE AND DOLOMITIC LIMESTONE; LIGHT TO DARK GRAY; WITH PROMINENT CHERT ZONES
CAMBRIAN	CONASAUGA	MAYNARDVILLE LIMESTONE NOLICHUCKY SHALE MARYVILLE LIMESTONE ROGERSVILLE SHALE RUTLEDGE LIMESTONE PUMPKIN VALLEY SHALE	550 METERS	LIMESTONE, SILTSTONE, AND SHALE; GRAY, OLIVE, BROWN
		ROME	250+ METERS	SANDSTONE AND SHALE; VARIEGATED WITH BRILLIANT YELLOW, BROWN, RED, MAROON, OLIVE-GREEN; WITH DOMESTIC LIMESTONE LENSES

Fig. 3.7. Generalized stratigraphic profile of the U.S. DOE Oak Ridge Reservation. These geologic formations are of sedimentary origin and range from early Cambrian (oldest) to early Mississippian (most recent) in age.

Glauconite and mica are typical accessory minerals. Where entirely preserved, the Rome Formation is at least 1,200 ft (360 m) thick. Internal deformation and faulting make accurate measurement difficult.

Conasauga Group

Rocks of the Conasauga Group underlie Bear Creek Valley and Melton Valley of the ORR. The Conasauga Group consists primarily of calcareous shales interbedded with limestones and siltstones. The total thickness of the group varies from 1500 to 1900 ft (450 to 580 m). Six formations can be recognized within the group. They are, in ascending order, the Pumpkin Valley Shale, the Rutledge Limestone, the Rogersville Shale, the Maryville Limestone, the Nolichucky Shale, and the Maynardville Limestone. Thicknesses of each formation vary throughout the area.

The Pumpkin Valley Shale ranges from 260 to 320 ft (80 to 98 m) in thickness throughout the valley and consists of massive to thinly bedded, maroon-brown to gray mudstones and shales interbedded with thinly bedded to laminated glauconitic siltstones. Two members can be identified, with the upper one being richer in shale and mudstone than the lower one. The lower member contains abundant zones of mottled, bioturbated shaley siltstones interbedded with thinly bedded shales and siltstones (Law Engineering 1975, Haase et al. 1987).

The Rutledge Limestone is 90 to 120 ft (28 to 37 m) thick and consists of light gray to white, medium to thinly bedded limestones and shaley limestones interbedded with medium to dark gray, thinly bedded to laminated, calcareous mudstone and shales. A persistent, 5- to 10-ft-thick interval of maroon to maroon-gray mudstone occurs toward the base of this formation and serves as a marker bed within the lower Conasauga Group (Law Engineering 1975, Haase et al. 1987).

The Rogersville Shale is composed predominantly of massive to medium-bedded gray to maroon mudstones interbedded with medium to very thinly bedded, gray to maroon-brown shales. The shales and mudstones contain subordinate amounts of thinly bedded,

glauconite-rich, locally calcareous siltstone. The Rogersville Shale varies from 90 to 120 ft (28 to 37 m) in thickness (Law Engineering 1975, Haase et al. 1987).

The Maryville Limestone consists of light to dark gray, fine to coarsely crystalline limestone interbedded with subordinate amounts of dark gray, medium to thinly bedded, calcareous shales and shaley siltstones. Zones of limestone-pebble conglomerates and oolite-rich beds are locally abundant in the upper portion (Haase et al. 1987). The lower portion consists of medium to thinly bedded calcareous shales and siltstones with subordinate amounts of crystalline limestones. Thicknesses of the Maryville Limestone vary from 346 to 445 ft (105 to 135 m).

The Nolichucky Shale ranges in thickness from 442 to 550 ft (135 to 168 m). The formation consists of maroon-brown to green-gray, massive to very thinly bedded, locally calcareous mudstones and shales interstratified with thinly bedded, medium gray limestones and calcareous siltstones. The maroon-brown color of the shales is characteristic of the Nolichucky Shale and serves to differentiate shales of this formation from those of the underlying Maryville Limestone (Haase et al. 1987). The interbedded limestones typically contain limestone-pebble conglomerates and oolite-rich beds similar to those occurring in the underlying Maryville Limestone.

The Maynardville Limestone is composed of light gray to tan, massive to thinly bedded limestone with subordinate amounts of dolostone. This formation can be divided into members on the ORR (Haase et al. 1985). The uppermost Chances Branch member contains subordinate amounts of interbedded dolostone, and the lower Low Hollow member is locally dolomitic and contains abundant oolite-rich horizons. Both members are locally stylolitic. Within the study area, the Maynardville Formation varies from 418 to 450 ft (127 to 137 m) in thickness.

Knox Group

The Knox Group underlies the areas of Chestnut Ridge, Copper Ridge, and McKinney Ridge on the ORR. Rocks of the Knox Group have an aggregate thickness of 3000 to

3500 ft (915 to 1065 m) and constitute the most extensive outcrops in the Valley and Ridge Province.

The Lower Ordovician to Upper Cambrian Knox consists of gray to blue-gray, thin- to thick-bedded dolostone with interbeds of limestone, weathering to a reddish-orange to yellow-orange clayey soil commonly containing an abundance of chert.

Solution features such as sinkholes and caverns are common in the Knox Group, and the Lower Ordovician contact with the Conasauga Group and the Upper Cambrian contact with the Chickamauga Group are zones of discharge for springs in many places (Buchananne and Richardson 1956). This upper contact marks a major disconformity throughout the Valley and Ridge Province, and evidence of erosion of this surface is common.

Chickamauga Group

Rocks of the Chickamauga Group occur in Bethel Valley and East Fork Valley on the ORR. The Chickamauga Group ranges from 1800 to 2200 ft (550 to 670 m) in thickness in the ORR area and is composed of interbedded limestones, argillaceous limestones, calcareous shales, and calcareous siltstones with abundant chert in the lower portion. The rocks are commonly colored maroon or gray.

Sequatchie Formation

The Sequatchie Formation occupies an area at the base of the East Fork Ridge and consists of maroon to gray, silty to shaley limestone with calcareous, maroon siltstone. This formation is approximately 360 ft (110 m) thick (McMaster 1963).

Rockwood Formation

The Silurian-age Rockwood underlies the higher topographic areas of East Fork Ridge. On the ORR, the Rockwood consists of brown, tan, and yellow siltstone, shale,

sandstone, and minor hematitic limestone totaling about 700 ft (213 m) in thickness (McMaster 1963).

Chattanooga Shale

McMaster (1963) mapped the Chattanooga and Maury formations as one unit on the southern side of East Fork Ridge on the ORR. Here the two formations have a collective thickness of only 25 ft (8 m) and consist primarily of black, fissile shale.

Fort Payne Formation

Rocks of the Fort Payne overlie the Chattanooga Shale in the area of East Fork Ridge. McMaster (1963) states that less than 80 ft (24 m) of the formation is present and that it consists of extremely siliceous limestone.

Major Faults

The ORR is transected by two major thrust faults: the White Oak Mountain Fault and the Copper Creek Fault. These faults trend northeast-southwest and represent displacements of about 5-15 km during the Alleghenian Orogeny.

The White Oak Mountain Fault originates about 18 miles northeast of the ORNL site near Clinton, Tennessee, by the convergence of the Hunter Valley and Wallen Valley faults. It extends about 130 km to the southwest and merges with the Copper Creek Fault near Cleveland, Tennessee. In the Oak Ridge area, the White Oak Mountain Fault is a complex branching thrust fault along which siltstones and shales of the lower Rome Formation have been thrust over middle Cambrian and younger rocks. One result of the fault is the development of synclinal structures (East Fork Ridge) northwest of the main fault. The main White Oak Mountain Fault crosses the ORGDP site northwest of Pine Ridge and southeast of McKinney Ridge.

In contrast with the White Oak Mountain Fault, the Copper Creek Fault is, with a few exceptions, a single fault along which the Rome Formation is thrust onto Chickamauga rocks. The Copper Creek Fault extends southeast from Virginia and merges with the White Oak Mountain Fault near Cleveland, Tennessee. This fault emerges along the northwestern flank of Haw Ridge. The fault has an average strike of N 55°E in the Oak Ridge area.

The average strike and dip of bedding on the ORR is approximately N 55°E, and 45°SE, respectively. Locally, small-scale folding is common and contributes to the wide range of bedding orientations that can be observed in the area. The folds generally have axes parallel to the strike of the bedding.

The presence of joints in the rocks is one of the most important factors controlling the movement of groundwater through the subsurface. Joints provide pathways that may become enlarged by solution. This process is important in the carbonate rocks. Studies of joints in the ORR (Law Engineering 1975, Sledz and Huff 1981, Rothschild et al. 1984) indicate that joint orientations and spacing are quite variable. The studies generally agree that there is at least one major joint set that roughly parallels the geologic strike.

A second steeply dipping joint set that strikes approximately N 12°W has been documented (Law Engineering 1975, Rothschild et al. 1984). Other documented joint orientations in Bear Creek Valley include N 35°W with a dip of 35°NE; N 46°W, dipping 57°NE; and N 50 ° with a dip of 72°SW. The joint spacing may vary from fractions of inches to several feet. The greatest concentration of joints is observed in siltstones and sandstones, and the least in shales and limestones. The joint density was found to be inversely proportional to bed thickness in both shales and siltstones.

Faults, joints, and bedding planes in carbonate rock provide avenues along which solution can occur. Cavities commonly occur in the upper part of the rock. These cavities my be above or below the current water table and may be partly to completely

filled with clay or other detritus. Cavities are more common in the Knox Group than in the Chickamauga Group, the Conasauga Group, and the Rome Formation.

3.2.3 Soils

The Oak Ridge area is overlain primarily by residual soils and, to a much lesser extent, by alluvial (water-deposited) soils. Residual soils are formed in-place by the decomposition of the underlying rock through mechanical weathering and chemical action. The nature of a residual soil depends on the type of source rock, solubility of the source rock, degree of weathering, climate, vegetation, and drainage. Residual soils on the ridges are composed of relatively resistant sandstones, cherty limestones, and dolomites weathered to form fine-grained reddish clay soils with depths of up to 28 m and well-developed internal drainage. The alluvial soils occur in floodplains and along stream beds and are conglomerates of organic and mineral particles. The valley soils are generally much shallower than the residual soils on the ridges, and are a mix of clays, silts, and weathered shales.

Although some generalizations can be made about the nature of the soils in the Oak Ridge area, the characteristics of the soils are highly localized, and soil properties vary widely even within identical soil types. This variability is a result of the close relationship of the residual soils to the underlying rock, hydrologic conditions, slope, vegetation, and other factors. Residual soils also exhibit different characteristics after being disturbed by excavation and recompaction.

Soil series and groups found on the ORR and in the Oak Ridge vicinity are presented in Table 3.1 (Lietzke et al. 1986). Chemical properties of representative soil groups are highlighted in Table 3.2. Soil pH ranges from 4.5 to 7.8 resulting in the potential for corrosion of uncoated steel and concrete materials. This property is especially significant where filled metal drums and scrap metal are stored on the soil surface, or when pipelines are laid underground.

Table 3.1. Geologic formations and corresponding soil series prevailing at the Oak Ridge Reservation (adapted from Lietzke et al. 1986).

RESIDUUM	
Geologic Formation	Soil Series
Rome Group	Lehew, Armuchee-Muskingum, Calvin
Conasauga Group	Sequoia, Armuchee, Apison Montevallo, Calledgedale
Knox Group	Fullerton, Bodine, Clarkesville, Dunmore

COLLUVIUM	
Source of Colluvium	Soil Series
Rome and Conasauga Groups	Jefferson, Shouns, Leadvale, Shelocta
Knox Group	Minvale, Tasso, Roane, Emory, Greendale, Tarklin

ALLUVIUM	
Age of Soil Material	Soil Series
Holocene/Modern	Hamblen, Pope-Philo, Newark, Melvin
Pleistocene	Allen, Dewey, Claiborne Holston, Waynesboro, Etowah, Nolichucky

Table 3.2. Soil chemical properties.[a]

Soil Group	Corrosivity		pH range	Estimated Cation Exchange Capacity (CEC)[b]	
	Steel	Concrete		Surface	Subsoil
			Residuum		
Rome	low	mod-high	4.5-6.0	5-15	10-20
Conasauga	mod	mod	4.5-6.0	10-15	15-20
Knox	high	mod-high	4.5-5.5	5-10	8-20
			Colluvium		
Rome/Conasauga	low-mod	mod-high	4.5-6.0	5-10	5-10
Knox	mod	mod	4.5-5.5	5-10	5-10
			Alluvium		
Holocene/ Modern	mod-high	low-mod	4.5-7.8	5-10	5-10
Pleistocene	mod	mod	4.5-5.5	5-10	5-10

[a]Data from Lietzke et al. 1986.
[b]Milliequivalents per 100 g of soil.

The cation exchange capacity (CEC) defines the total amount of cations that can be held by a soil (meq/100g of soil) at a given pH. From a waste management perspective, CEC values higher than 15 are considered good, 5 to 15 fair, and less than 5, undesirable for the application of municipal sludge, radioactive wastes, or other chemical contaminants to the upper 25-to-50 cm of the soil. However, the beneficial effects of high soil CEC are counterbalanced by high concentrations of Ca^{2+} and Mg^{2+} in the groundwater, because these ions increase the mobility of some radionuclides.

Studies at low-level radioactive solid waste storage areas on the ORR have shown that hydrogeological conditions may allow radionuclides, such as ^{90}Sr and ^{60}Co, to be transported from disposal sites unless the wastes are stabilized. For example, the presence of Ca^{2+} and/or Mg^{2+} enhances the mobility of $^{90}Sr^{2+}$. Furthermore, the effective porosity of the regolith, which is associated mainly with micropores and mesopores, results in linear velocities of approximately 1 m/d for groundwater. The migration rate for ^{90}Sr is generally 10 to 100 times slower. Because contaminant mobility is influenced by geochemistry, hydrology, and individual chemical properties of the contaminants, the specific conditions for waste disposal must be examined on a case-by-case basis to evaluate the resulting risks (D. D. Huff, Environmental Sciences Division, ORNL, personal communication, 1989).

3.3 GROUNDWATER

Groundwater in the Oak Ridge area is derived directly from local precipitation. Nearly all precipitation infiltrates. The majority of infiltration (about 76 cm/yr of water) replenishes soil moisture within the root zone of vegetation, and is later returned to the atmosphere by evapotranspiration. The remaining 56-62 cm of water in an average year moves through the shallow groundwater to discharge locations at seeps, springs, and streams. Most springs are wet-weather types. Thus, groundwater discharge ceases after a few days to weeks of dry weather, and changes in streamflow are accompanied by changes in the total length of flowing channels.

Except for water imported from Melton Hill Reservoir onto the ORR for use and subsequent discharge as process water, nearly all streamflow on the ORR is derived from groundwater discharge. During drought conditions, however, the base flow of the primary recipient streams on the ORR (i.e., East Fork Poplar Creek, Bear Creek, Melton Branch, White Oak Creek) is comprised largely of ORR facility process-water discharge.

Most of the groundwater flows in a stormflow zone from the land surface to a depth of 1-2 m and in a zone from the water table to the base of fresh water (Fig. 3.8). Prolonged or intense precipitation results in a perched water table in the stormflow zone. Groundwater then moves laterally through the stormflow zone and percolates down, through the vadose zone, to the water table. The perched water table and the resulting groundwater flow are transient beneath the hills but may be nearly perennial at valley edges. The shallow stormflow zone is on average approximately 1000 times more permeable than the underlying material.

Shallow ground-water flow is generally from topographically high to lower areas. Local recharge from precipitation moves along relatively short flow paths to seeps and springs, and thereby, subsurface flow drains quickly into major surface-water drainage systems. There is no evidence for large-scale deep subsurface transport, although these data are limited. Flows from the surface streams ultimately augment the water supply of the Clinch River, which is the hydrologic sink for the ORR.

Groundwater storage is intergranular in the stormflow zone, and effective porosity (the decimal percentage volume of water that will drain by gravity) is about 0.1. However, the dominant openings for lateral groundwater flow and vertical drainage are macropores and mesopores. The configuration and pattern of these larger openings are unknown, but lateral flow paths generally follow the slope of the land surface. Average linear velocity is about 3 m/d for lateral flow toward downslope springs and streams. Based on relatively few data, water in the stormflow zone is acidic to nearly neutral and is a calcium bicarbonate type. However, the content of total dissolved solids generally is less

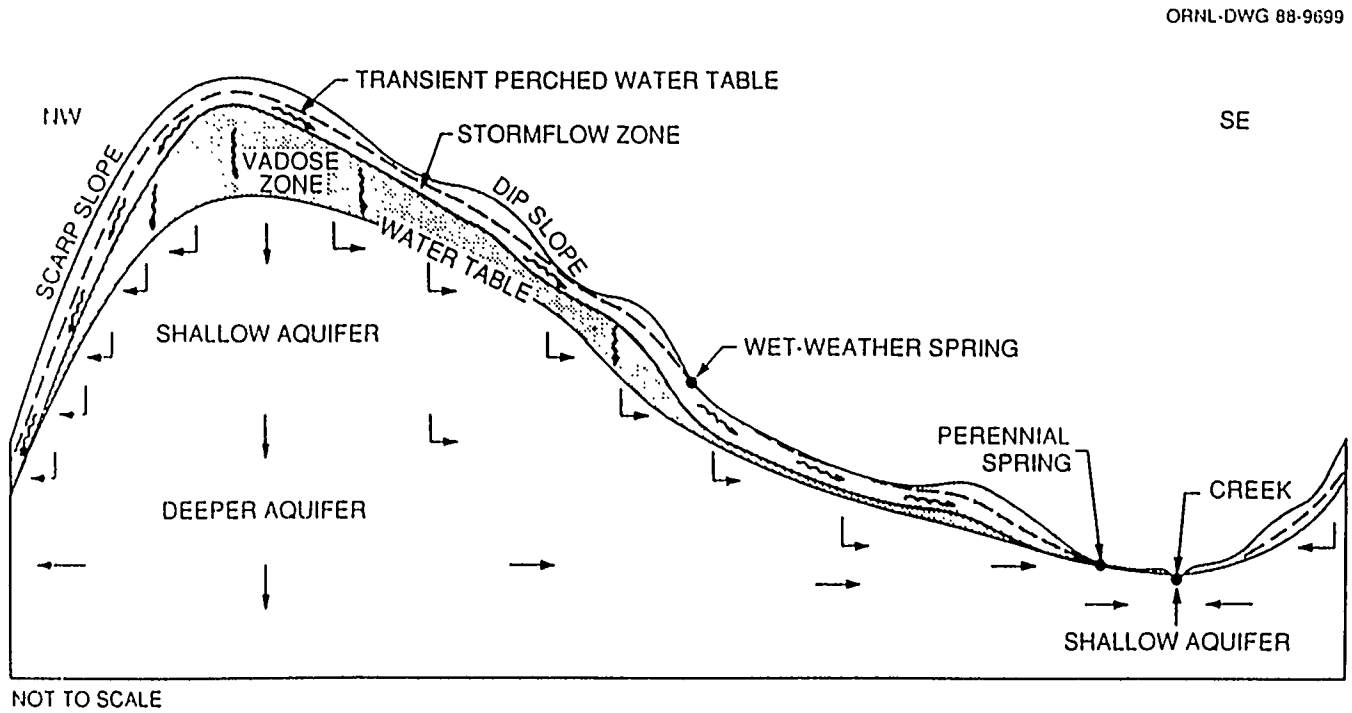

Fig. 3.8. Generalized diagram showing the occurrence and flow of groundwater on the Oak Ridge Reservation.

than 100 mg/L, and the concentrations of magnesium, sodium, and sulfate may be significant.

A thin vadose zone generally separates the stormflow zone and the shallow aquifer, but the water table is within the stormflow zone near discharge locations. The geometric mean depth to the water table in October is 4.1 m in areas underlain by the Conasauga and Chickamauga Groups. The water table generally is deeper in areas underlain by the Knox Group; it is 30-50 m below the land surface at a few locations on Chestnut Ridge.

The openings for groundwater flow in the vadose zone are fractures and a few cavities; effective porosity is probably about 0.003. Most flow paths are near vertical, and average linear velocity is in the range 0.1-1.0 m/d. However, cavities occur above or at the water table in a few areas, and lateral flow rates of 20-200 m/d have been documented. Cavities of this type are rare and occur only where the water table is below the top of a limestone or dolostone bedrock.

The openings for groundwater flow below the water table are also fractures and cavities. The effective porosity of these openings is about 0.003 at shallow depths and may be in the range 1E-5 to 5E-4 at deeper levels. Water-bearing fractures are ubiquitous below the water table, but enlarged fractures and cavities are common only at shallow depths. These enlarged openings are the targets for wells and constitute the water-producing intervals in wells. The geometric mean of hydraulic conductivity (a measure of aquifer permeability) is 0.041 m/d for the water/producing intervals but is only 0.00044 m/d for other intervals and deeper levels. The shallow aquifer (Fig. 3.8) is characterized by the occurrence of water-producing intervals but generally consists of several water-producing intervals in otherwise relatively impermeable material. In areas underlain by the Conasauga and Chickamauga Groups, the shallow aquifer extends to a depth of 20-30 m. In the Knox Group, enlarged openings are common at depths of 30-60 m, and one cavity was reported at a depth of 96 m. The average linear velocity of groundwater flow is about 1 cm/d to 1 m/d in the shallow aquifer.

Groundwater becomes gradually confined at deeper levels. Flowing wells occur in a few areas, and water levels in some of the deeper wells respond to earth tides and other loading forces. The geometric mean depth of the first water-producing interval in the Conasauga and Chickamauga Groups is 8.2 m; the average thicknesses of an interval is 3.9 m; and the geometric mean of the vertical spacing between intervals is 10.4 m. Similar information is not available for the Knox Group. Cavities occur in all units that have limey layers but are more common in the Knox Group. Both the lateral and vertical spatial frequencies of cavity occurrence are about 4-times larger in the Knox Group than in the Rome Formation, the Conasauga Group, and the Chickamauga Group. Based on relatively few data, cavities below the water table have a geometric mean of hydraulic conductivity that is not significantly larger than that of other water-producing intervals.

Flow paths in the shallow aquifer are complex. Thus, hydraulic gradients cannot easily be determined, and a contaminant introduced at one point in the aquifer may eventually occur in all fractures within a semicylindrical volume of the aquifer. Nevertheless, flow paths generally trend toward lower elevations and discharge locations at springs and streams. Groundwater in the shallow aquifer flows into the stormflow zone near these locations.

Groundwater in the shallow aquifer generally is neutral to moderately alkaline and is a calcium bicarbonate type (Table 3.3). Based on a correlation with specific conductance, the geometric mean content of total dissolved solids is 204 mg/L, ($\pm$1 one standard deviation, 93-414 mg/L). The properties and concentrations of chemical constituents in groundwater are not spatially correlated and are not constant through time. Nearby wells at all scales may have large differences in the specific conductance of water, for example, and monthly changes of more the 60% in specific conductance have been measured. Shallow wells generally have a smaller and more variable specific conductance of water than deep wells, but other relationships are also common.

Fractures in the deeper aquifer have a geometric mean of hydraulic conductivity about 0.01 times as large as in the shallow aquifer. Thus only about 10% of the groundwater

Table 3.3. Statistical summary of important constituents and properties in water from the shallow aquifer (Specific conductance in micromhos/cm at 25°C, alkalinity as mg/L of $CaCO_3$, and other units, except pH in mg/L).

Constituent or Property	Number of values	Mean[a]	Mean minus one standard deviation	Mean plus one standard deviation	Minimum value	Maximum value
Specific conductance	138	400	220	740	110	1930
pH	133	7.3	6.7	7.9	6.2	9.2
Calcium	187	91	38	220	12	1600
Magnesium	183	12	6.2	24	2.1	137
Sodium	198	14	4.1	45	0.7	420
Alkalinity	126	230	140	370	55	847
Sulfate	162	22	9.5	54	4.0	376
Chloride	167	7.9	2.4	27	0	200

[a]Arithmetic mean for pH; geometric mean for others.

that reaches the shallow aquifer follows flow paths through the deeper aquifer. This water eventually flows upward, back into the shallow aquifer, near discharge locations. Brine, which probably is connate (entrapped in sediments at time of deposition), occurs at depths below about 150 m in Melton Valley, and this is the approximate base of the deeper aquifer. Elsewhere, however, brine does not occur in wells at depths of 120 m in Bear Creek Valley, and only two wells at this depth produce an alkaline, sodium carbonate water that may be a transitional type. Neither brine nor a sodium carbonate water has been identified in wells up to 75 m deep in Bethel Valley. Thus, the base of fresh water has not been determined in most of the ORR area.

3.4 SURFACE WATER HYDROLOGY

3.4.1 On-Site and Off-Site Drainage Patterns

Surface water drains from the ORR by a network of tributaries to the Clinch River (Fig. 3.9). The primary surface waters on the ORR are small perennial streams that originate from springs in the limestone on the slopes. These are generally first- to third-order streams having drainage areas of less than 20 km^2 and average annual discharge of less than 0.5 m^3/s. Typically, these streams are less than 1 m in depth and consist of alternating series of riffles and pools (Loar 1981, Loar et al. 1981). A number of small streams on the ORR are now receiving intensive study and monitoring part of the Biological Monitoring and Abatement Program (BMAP) (e.g., see Loar 1988a,b, 1989).

Ultimately, surface water drainage from the ORNL area enters Melton Branch and White Oak Creek. White Oak Creek enters the Clinch River at CRK (Clinch River kilometer) 33.6, just downstream from the Melton Hill Dam. The Y-12 facility is drained by Bear Creek and East Fork Poplar Creek. Both streams are tributaries to Poplar Creek, which enters the Clinch River at CRK 19.3, near the ORGDP. The ORGDP area drains predominantly into lower Poplar Creek. Watershed areas and average annual discharge of these larger streams are listed in Table 3.4.

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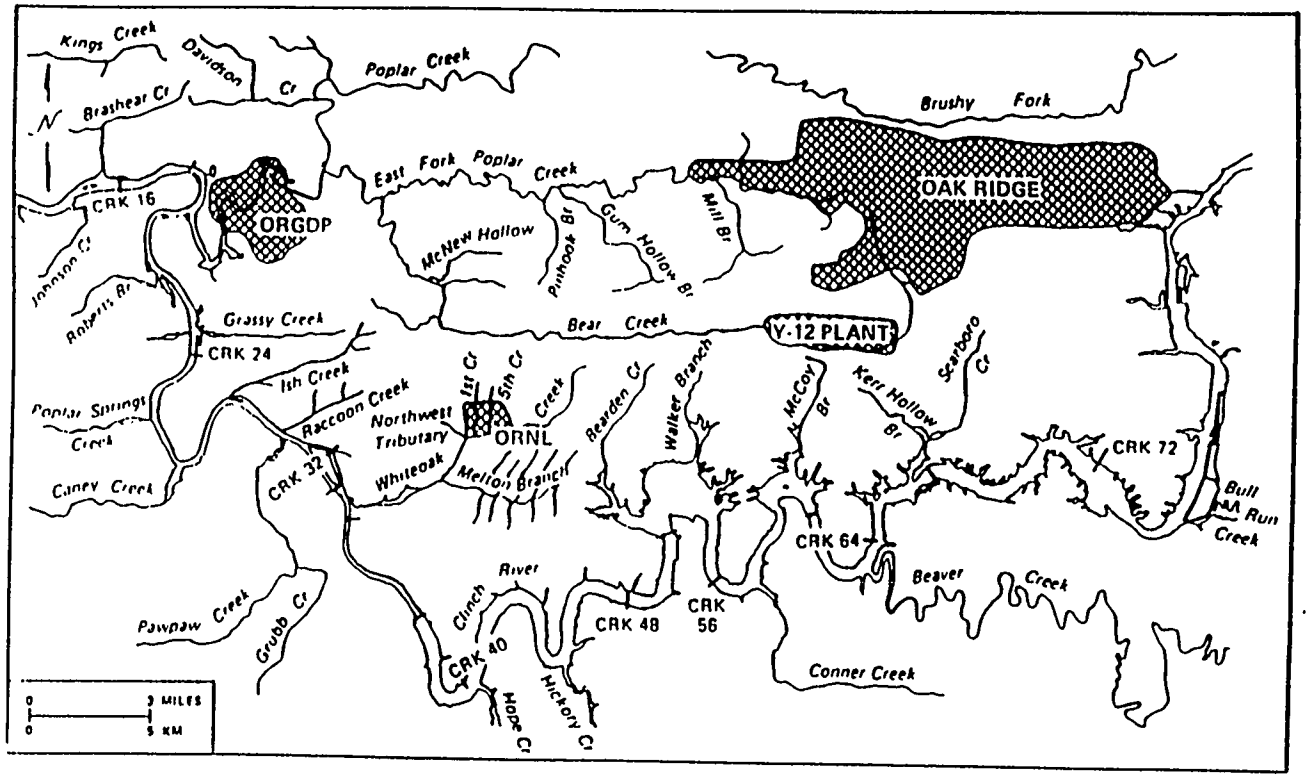

Fig. 3.9. Drainage patterns and aquatic environments occurring on and contiguous to the Oak Ridge Reservation. All streams shown ultimately drain into the Clinch River. Locations of the DOE facilities and the City of Oak Ridge are indicated. CRK (Clinch River kilometer) denotes distance from the confluence of the Clinch and Tennessee rivers.

Table 3.4. Location, drainage area, and average annual discharge of tributaries to the Clinch River in a 21-km reach below Melton Hill Dam (CRM 23.1). N/A = Information not available. Source: Project Management Corporation (1975), Section 2.5.1.1, unless noted otherwise. Source: Loar (1981).

Tributary	Confluence location (CRM)[a]	Drainage area (km^2)	Average annual discharge (m^3/s)[b]
White Oak Creek	20.8	15.5[c]	0.38 (13.5)[c,d]
Raccoon Creek	19.5	1.2[e]	N/A
Ish Creek	19.1	0.9[f]	0.05 (2)[f]
Caney Creek	17.0	21.4	0.40 (14)
Poplar Springs Creek	16.2	7.8	0.14 (5)
Grassy Creek	14.5	5.0	0.08
Poplar Creek	12.0	352.2	6.45 (228)[g]

[a]CRM = Clinch River Mile, with CRM 0.0 at the confluence with the Tennessee River.
[b]Discharge in cfs (cubic feet per second) in parentheses.
[c]At White Oak Dam (Edgar 1978).
[d]Estimated for the period 1953-55 and 1960-63 (5 water years). Source: U.S. Geological Survey (1963) as cited in Struxness et al. (1967)
[e]Source: Oak Ridge Operations Land-Use Committee (1975).
[f]At 0.56 km above the mouth. Source: McMaster (1967).
[g]Period of record: 1960-1977. Value represents the sum of the average annual discharge of West Fork Poplar Creek (4.98 m^3/s or 176 cfs) and East Fork Poplar Creek (1.47 m^3/s or 52 cfs). Source: U.S. Geological Survey (1978).

The impounded Clinch River (i.e., Melton Hill Reservoir, the tailrace below Melton Hill Dam, and the Clinch River arm of Watts Bar Reservoir) bounds the ORR on the south and west for a distance of approximately 63 km (Fig. 3.9). A few small streams flow directly from the ORR into embayments of Melton Hill Reservoir (e.g., Scarboro Creek, Kerr Hollow Branch, McCoy Branch, Walker Branch, Bearden Creek) and into the Clinch River downstream from the Melton Hill Dam (e.g., Raccoon Creek, Grassy Creek). However, most of the contaminants discharged from the ORR or seeping from waste disposal areas located on the ORR enter the Clinch River downstream from the Melton Hill Dam (at CRK 37) via White Oak Creek and Poplar Creek, and are ultimately transported downstream into Watts Bar Reservoir. The transport of contaminants down the Clinch River and their ultimate distribution in Watts Bar Reservoir are influenced by the flow regimes of the Clinch and Tennessee River, both of which are controlled primarily by hydropower dam operations and secondarily by major storm-flow events.

Watts Bar Reservoir is located on the Tennessee River below its confluence with the Clinch River, and is the first impoundment downstream of the ORR (Fig. 2.6). Watts Bar was impounded in 1942, just prior to the development of the Oak Ridge complex, and therefore, retains in its sediments a long-term accumulation and history of materials released from the Oak Ridge facilities (Cottrell 1959, Struxness et al. 1967, Turner et al. 1985). The results of a recent scoping study indicate that Watts Bar Reservoir is a highly efficient trap for particle-associated contaminants (Olsen and Kimmel 1987, 1988). See Section 5.7 for additional details.

3.4.2 Major Streams Draining the ORR

White Oak Creek Watershed

The White Oak Creek (WOC) watershed is located near the southern boundary of the ORR and has a drainage area of 16.9 km^2. WOC and its tributaries drain the ORNL area and also receives the drainage of Melton Valley through Melton Branch (Fig. 3.9). Three distinct environments can be identified within the WOC watershed: (1) WOC

and tributaries above the lake, (2) White Oak Lake (WOL), and (3) WOC embayment below WOL. WOL is a shallow impoundment that extends approximately 0.7 km upstream from the WOL dam and has a surface area of about 8 ha. The water level in WOC embayment is controlled by the operation of Melton Hill Dam and Watts Bar Dam. When Watts Bar Reservoir is maintained at or near full pool (approximately April to October) and discharges occur at Melton Hill Dam, the subsequent rise in water level in the Clinch River creates an embayment extending from the mouth of the creek to the White Oak Lake Dam. When water levels are low, a large portion of the areal extent of the embayment bottom is exposed and subject to erosion.

Detailed descriptions of the physical, chemical, and biological characteristics of the White Oak Creek watershed are provided in Loar et al. (1981), Loar (1984), Sherwood and Loar (1987), and Loar et al. (1987, 1988a).

Poplar Creek Watershed

Poplar Creek, with a drainage basin area of 352 km^2, is the only large stream on the ORR, and has three major tributaries: the "west fork" of Poplar Creek, East Fork Poplar Creek, and Bear Creek. The main branch (the west Fork Poplar Creek) originates off the ORR in the Cumberland Mountains and drains some strip mining areas. West Fork Poplar Creek enters the Reservation at Poplar Creek Kilometer (PCK) 9.3 north of the ORGDP and flows through the ORGDP area before entering the Clinch River near CRK 19.

East Fork Poplar Creek originates from a spring at the Y-12 Plant. Until recently, stream flow was controlled by New Hope Pond, a 0.2-ha settling basin located 1.6 km below the spring. In May 1989, New Hope Pond was closed and replaced by Lake Reality, a larger, lined settling basin installed as part of the Y-12 Remedial Action Program. The creek flows for approximately 0.9 km below Lake Reality before leaving the ORR and entering the City of Oak Ridge. After flowing approximately 15 km, East Fork Poplar Creek again enters the ORR and flows another 7.8 km before joining Poplar Creek at PCK 8.8.

The headwaters of the third tributary, Bear Creek, are also located at the Y-12 Plant, although numerous small tributaries originating along the southeast slope of Pine Ridge are located in the upper reaches of the watershed. The stream flows within the ORR for a distance of 11.3 km from the Y-12 Plant to the confluence with East Fork Poplar Creek at EFPCK 2.4. East Fork Poplar Creek and Bear Creek have been the subjects of extensive monitoring and study as a result of releases from the Y-12 Plant (Dahlman et al. 1977, Elwood 1984, Van Winkle et al. 1984, Turner and Kamp 1984).

Reservoir Embayments

Reservoir embayments are the hydrologic links between the streams draining the ORR and the Clinch River system (Fig. 3.9). Along the southern and western boundaries of the ORR, streams flow directly from the ORR into embayments of Melton Hill Reservoir (e.g., McCoy Branch, Scarboro Creek, Kerr Hollow Branch, Walker Branch, and Bearden Creek) and into the Clinch River downstream from the Melton Hill Dam (e.g., White Oak Creek, Raccoon Creek, Grassy Creek, Poplar Creek).

The largest is the Bearden Creek embayment of Melton Hill Reservoir with an approximate surface area of 48 ha. Descriptions of some of the larger embayments are available (Loar 1984). In addition to constituting areas of potential high contamination as a result of influx of materials from the ORR, the White Oak Creek and Poplar Creek embayments have been reported to be important habitats and productive nursery areas for the Clinch River - Watts Bar Reservoir fish community (Loar 1981, Loar et al. 1981).

3.4.3 The Clinch and Tennessee Rivers

As described above, water-borne contaminants from the ORR enter the Clinch River primarily via White Oak Creek (ORNL) and Poplar Creek (Y-12 and ORGDP) at points located downstream of the Melton Hill Dam, and are transported further downstream into Watts Bar Reservoir. The transport, distribution, and fate of those

contaminants are influenced by (1) their chemical characteristics and solubilities, and (2) water and sediment dynamics in the river-reservoir system.

The Clinch River

The Clinch River has its headwaters near Tazewell, Virginia, and empties into the Tennessee River at Kingston, Tennessee, 34 km downstream from the Oak Ridge complex. The Clinch River drainage constitutes 11% of the Tennessee River Watershed. The flow regimes of the Clinch and Tennessee Rivers are controlled primarily by flood-control and hydropower operations at (1) Norris and Melton Hill dams on the Clinch River, (2) Fort Loudoun Dam on the Tennessee River and, and (3) Watts Bar Dam farther downstream on the Tennessee River (Fig. 2.6). The Norris Dam, completed in 1936, is approximately 50 km (31 m) upstream from the ORR (Table 3.5). Norris Reservoir is a deep, tributary-storage reservoir which serves both flood-control and hydropower purposes. The Melton Hill Dam, completed in 1964, controls the flow of the river near the ORR. Melton Hill Reservoir is a narrow, "run-of-the-river" impoundment, and its primary function is hydropower generation. Watts Bar Dam, completed in 1942, is located on the Tennessee River downstream of the Clinch-Tennessee confluence and affects the flow of the lower reaches of the Clinch River. The Watts Bar Reservoir is the first large, mainstem impoundment in the Tennessee River system. The limnological dynamics resulting from the flood-control and hydropower operations in the Norris - Melton Hill - Watts Bar series of reservoirs were investigated by Elser and Kimmel (1984, 1985).

Peaking power is generated at the Melton Hill Dam, so water flow in the lower Clinch River is pulsed. Periods of zero discharge are followed by 4 to 6 hours of discharge up to about 500 m^3/s (20,000 cfs). Discharge rates also vary seasonally as a result of flood-control operations. Typical water releases for winter and summer are shown in Fig 3.10. The average discharge at the Melton Hill Dam between 1963 and 1979 was 150 m^3/s (5280 cfs). The average summer (June to September) discharge was 134 m^3/s (4720 cfs). The maximum reported discharge for the dam is 1215 m^3/s (42,900 cfs).

Table 3.5. Morphometric data for Norris, Melton Hill, and Watts Bar reservoirs, eastern Tennessee. Source: Elser and Kimmel (1985).

Parameter	Norris	Melton Hill	Watts Bar
Age (yr)	46	18	40
Drainage area, A_d(km^2)	7542	8658	44833
Surface area, A_o (km^2)	138	23	156
A_d:A_o ratio	55	376	287
Length (km)	208	71	154
Mean depth (m)	18	6	8
Maximum depth (m)	61	21	21
Depth of outlet (m)	46	14	15
Mean annual water level fluctuation (m)	18	3	2
Mean annual water residence time (d)	237	15	18

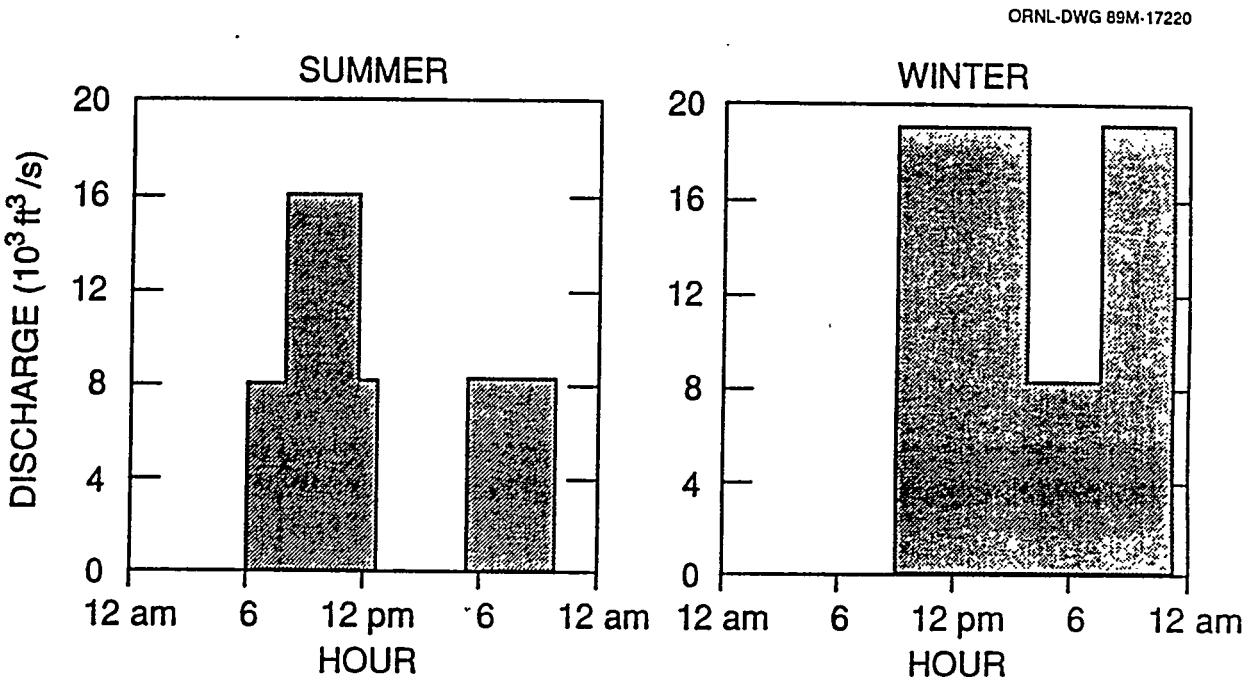

Fig. 3.10. Estimated daily peaking-power discharges from the Melton Hill Reservoir hydropower dam for summer and winter operating conditions (McMaster 1967).

Pulsation of flow in the lower Clinch River affects the tributaries on the reservation. During periods of power generation, backflow may occur into Poplar Creek, White Oak Creek, and other embayments (Loar 1981, Loar et al. 1981). Periods of no flow from the Melton Hill Dam have lasted as long as 29 days, but the average number of days of no flow per year is 13.

Intermittent discharges of water from hydroelectric dams result in scouring of the river channel, as has occurred downstream from Melton Hill Dam where bedrock is exposed on the river bed. Appreciable deposition of sediments on the bed of the Clinch River begins downstream from CRM 14. The amount of sediment deposition generally increases towards the mouth of the river, with deposition extending laterally over wider and wider parts of the river bed. Upstream from CRM 14, deposition is confined to parts of the channel immediately adjacent to the bank. Sediment deposition patterns are influenced by the effects of water impoundment in Watts Bar Reservoir on sediment transport capacity. The cross-sectional flow area of the reservoir increases in the downstream direction, and as a consequence, the flow velocity and sediment transport capacity of the river decrease.

The Tennessee River

The Tennessee River is one of the most extensively impounded river systems in the world. The TVA water-control system consists of 51 dams, including 36 hydropower projects. Nine large multiple-purpose reservoirs are located on the mainstem of the Tennessee River between Knoxville, Tennessee, and Paducah, Kentucky (Table 3.6). These mainstem, multiple-purpose reservoirs are used for flood control, hydropower generation, navigation, municipal and industrial water supply, and recreation. Each of these dams has a navigation lock, and together comprise a 650-mile navigation channel.

Of the nine mainstem impoundments on the Tennessee River, Watts Bar Reservoir is the first located downstream of the Oak Ridge facilities. The Watts Bar Dam was closed in 1942, just prior to the initiation of plant operations at Oak Ridge. River impoundments are usually efficient sediment and contaminant traps, and much of the

Table 3.6. Location and drainage area of dams on the Tennessee River. Source: TVA (1958).

Dam	Mile (TRM)[a]	Drainage Area (square miles)	Year Dam was Closed	Lake Length (miles)	Lake Area (acres)	Drawdown Range (feet)	Flood Storage (acre-feet)
Fort Loudoun	602.3	9,550	1943	56	14,600	6	111,000
Watts Bar	529.9	17,310	1942	72	39,000	6	379,000
Chickamauga	471.0	20,790	1940	59	35,400	7	345,300
Nickajack	424.7	21,790	1967	46	10,370	2	31,500
Guntersville	349.0	24,450	1939	76	67,900	2	162,400
Wheeler	274.9	29,590	1936	74	67,000	6	349,500
Wilson	259.4	30,750	1924	15	15,500	3	53,600
Pickwick Landing	206.7	32,820	1938	53	43,100	6	417,000
Kentucky	22.4	40,200	1944	184	160,300	5	4,800,000

[a]Tennessee River mile.

contamination released from the Oak Ridge facilities over the past 45 years can be expected to reside in and/or to be reflected in the Watts Bar Reservoir sediments. Recent efforts to determine the extent of contamination of the Watts Bar Reservoir sediments have provided evidence in support of this expectation (see Sections 5.6 and 5.7).

4. CHARACTERIZATION OF WASTE RELEASES TO THE AQUATIC ENVIRONMENT

4.1 INTRODUCTION

Operations at the Y-12 Plant, the Oak Ridge National Laboratory (ORNL), and the Oak Ridge Gaseous Diffusion Plant (ORGDP) on the DOE Oak Ridge Reservation (ORR) have been a source for a variety of airborne, liquid, and solid wastes characterized as nonhazardous, hazardous, and/or radioactive (Kelly 1984). Some of these wastes have impacted the surrounding ORR environment by contaminating soil, vegetation, ground water, and surface water. Wastes entering into local streams, which ultimately drain into the Clinch and Tennessee River System, may also impact off-site areas. Additional RFI and RI/FS projects are underway at each of the three facilities to correct deficiencies at specific processing units and waste disposal sites, and to mitigate the off-site migration of waste materials.

The purposes of this section are to: (1) briefly summarize information on waste generation, disposal operations, and contaminant releases at each of the three Oak Ridge DOE facilities, (2) describe current environmental sampling and surface-water monitoring activities, and (3) summarize previous investigations of off-site surface-water contamination. Most of the information presented in this section has been drawn from detailed reports concerning waste disposal operations (Bates et al. 1986, ORGDP K/HS-132 1987, Trabalka and Myrick, 1987, Welch, 1987), radionuclide releases (DOE 1988), and environmental monitoring programs (Oakes et al. 1984, Loar 1988a,b, Smith et al. 1988, Rogers et al. 1988), at each of these DOE facilities. This information is directly relevant to the scope and the technical approach of the Clinch River RFI for the following reasons:

1. Operations and waste disposal practices determine the nature and extent of contaminant releases to the Clinch River.
2. An extensive environmental monitoring program is routinely conducted and provides data for assessing the potential human health and environmental risks associated with contaminant releases to off-site areas, including the Clinch River.

3. Operational changes and corrective measures implemented as a result of ongoing remedial action programs at the Oak Ridge facilities will significantly influence both present and future contaminant releases from the ORR to the Clinch River.
4. Remedial actions implemented on the ORR (e.g., waste trench excavation, waste relocation and/or isolation) or off-site (e.g., stream channelization or dredging) could result in the redistribution or remobilization of prior contaminant deposits.

4.2 WASTE GENERATION AND HISTORY OF DISPOSAL OPERATIONS

The types and amounts of waste generated and released at each facility depend on its mission and on the specific process operations (Section 2.3). Past and present waste disposal operations at each of these facilities have established the need for further investigation of potential effects of surface and subsurface water drainage to off-site surface waters.

In this section, site-specific descriptions of wastes generated at each facility and their history of disposal are provided. Particular attention is given to liquid waste streams entering surface water systems (e.g., the Clinch River and off-site areas).

4.2.1 Non-Process Wastes Common to Each Facility

Non-Process Airborne Wastes. The major non-process airborne releases come from steam plant and cooling tower emissions. Each Oak Ridge facility maintains its own steam plant for heating and process operations. All three plants currently use coal as their primary fuel. Filters, electrostatic precipitators, and chemical traps remove nonradioactive and radioactive particulates and gases. None of these plants use emission controls for the removal of sulfur. In addition, each of the three facilities use mechanical draft cooling towers for heat dissipation. The ORGDP towers, however, had the greatest potential impact on the environment. The reason is twofold: (1) the ORNL and Y-12 towers are relatively small while the ORGDP system dissipated approximately 1900 MW of heat; and (2) unlike the towers at ORNL and at Y-12, the ORGDP cooling towers used a chromate system for corrosion inhibition. Drift losses

from these towers exceeded 341 m^3/d with an approximate chromium concentration of 9 mg/L. The ORGDP facility was shut down in 1987 and the cooling towers are no longer operational.

Non-Process Liquid Wastes. The major non-process liquid waste streams include storm-water runoff and sanitary wastewater. Each ORR facility has a system to collect storm-water runoff and to route it to nearby surface streams. The discharge of this water may create a pathway for chemicals or nuclides to reach the aquatic environment. Coal Yard Runoff is treated at both ORNL and ORGDP. Y-12 also plans to treat its runoff as part of a Steam Plant Wastewater Treatment System. Each facility also maintains a collection system for sanitary sewage. The Y-12 Plant sends its sewage to the Oak Ridge West Sewage Treatment Plant. ORNL and ORGDP maintain on-site sewage treatment plants.

Non-Process Solid Wastes. The major non-process solid wastes are derived from construction debris and sanitary operations. Construction debris is normally handled by each facility. Sanitary waste is disposed of in sanitary landfills.

4.2.2 Process Waste Generation and History of Disposal at ORNL

Airborne Wastes. Process waste emissions have four major sources at ORNL: (1) operations of the two research reactors onsite; (2) isotope production activities; (3) pilot plant operations; and (4) research and process hoods. Emissions from these sources are predominantly radioactive, and all are treated similarly. Particulate emissions are treated by a combination of roughing and high efficiency particulate absolute (HEPA) filters. Certain isotopes, such as radioiodine and tritium, are collected on chemical traps. Other discharges are pretreated by scrubbers prior to filtration. Annual releases of noble gases and tritium amount to 0.1 Ci and 200 Ci, respectively.

Liquid Wastes. There are three main sources of wastewater at ORNL: (1) corrosive solutions generated by the treatment of water needed for plant operations (e.g., boiler feedwater, reactor coolant water); (2) process wastewater, which comes from sources

(e.g., laboratory drains) where radioactivity might be present; and (3) low level liquid waste (LLLW) which is generated by radioactive operations throughout ORNL and which is known to contain radioactivity. The annual volume of process waste liquids generated is about 100-200 million gallons of corrosive and process wastewater, and about 1 million gallons of radioactive wastewater.

The corrosive solutions are neutralized prior to discharge. Process wastewater is checked for radioactivity at a water treatment plant that was installed in 1957 and replaced in 1976. If radioactivity is found, the process water is treated with demineralizers prior to discharge. If no radioactivity is found, the solutions are currently discharged without treatment. Methods for treatment of this process wastewater are under intensive study.

From 1943 to 1949, radioactive waste liquids were treated by being held in tanks and settling basins for radioactive decay and for settling of particulate material before discharge to White Oak Lake. The lake provided further settling and additional time for radioactive decay prior to release into the Clinch River. From 1949 to 1954, an evaporator was used to concentrate the most radioactively contaminated liquid waste before storage in concrete tanks. Beginning in 1951, much of the liquid waste was placed into pits and trenches for disposal. These pits and trenches were designed to retain the radionuclides until the radioactivity could decay to low levels. The evaporator was taken out of service in 1954 and all of the liquid radioactive waste went directly to pits and trenches until 1963. During the late 1950s and early 1960s, ruthenium-106 was the primary radionuclide released from trenches into White Oak Creek because of its poor absorption in soil.

Beginning in 1964, hydrofracture technology was used for liquid radioactive waste disposal. With this technique, wastes were mixed with a cement grout and injected into shale at a depth of about 1,000 feet. Since 1965, with the cessation of the hydrofracture procedure, radioactive wastewater was again reduced in volume with an evaporator. Condensate from the evaporator is sent to the process wastewater treatment system and the concentrated residue from the evaporator is presently being stored.

Solid Wastes. Radioactive solid wastes have been placed in shallow land burial areas. Although records of waste volume were maintained, detailed estimates for the radionuclide content of these wastes were not recorded until 1977. Much of the data recorded prior to 1977 are only rough estimates. Mixed radioactive and hazardous wastes are treated in two ways: storage until acceptable disposal options are developed, or treatment to remove or destroy hazardous components prior to disposal. Nonradioactive hazardous wastes are stored or disposed of in solid waste storage areas, or shipped to commercial disposal facilities.

4.2.3 Process Waste Generation and History of Disposal at ORDGP

Airborne Wastes. Primary airborne wastes include uranium, technetium-99, krypton-85, and chromium. Airborne uranium and Tc-99 have been released through gaseous diffusion process vents, the feed plants, and accidental releases. The feed plants, where uranium from spent fuel was fluoridated to uranium hexafluoride from 1950 to 1968, were also a primary source for neptunium-237 and plutonium-239 at ORGDP. Solid-chemical traps and liquid potassium hydroxide scrubbers have been used since 1977 to reduce radioactive air emissions. Kr-85 was released during a five-year period (1976-1980) when staff members at ORGDP were conducting research and development activities for ORNL. Since August 1985, the uranium enrichment operations at ORGDP have been discontinued, and presently airborne uranium emissions are from laboratories and the Decontamination Facility. Nonradioactive emissions have included fluorides, freon, and organic vapors.

Liquid Wastes. When the ORGDP was at full operation, liquid effluent discharges resulted from five major sources: (1) wastes generated in the treatment of raw water for process usage, sources including makeup water, clean-up wastes, and boiler blowdown; (2) chromated recirculating cooling water (RCW) blowdown; (3) nickel plating and metal cleaning facility wastes; (4) uranium decontamination solutions; and (5) laboratory discharges. Annual discharges ranged from 100 to 200 million gallons for sources (1), (2), and (5) to 10-20 million gallons for sources (3) and (4). Raw water treatment, nickel plating, and metal cleaning wastes are neutralized where necessary and

routed to settling ponds for solids removal prior to discharge. RCW blowdown is electrolytically reduced to remove chromium prior to settling and discharge. Decontamination solutions are routed either to a settling pond or to a biodenitrification facility at Y-12. During the decontamination and solvent cleaning processes, residual concentrations of uranium, technetium-99, neptunium-237, and plutonium-239 were released through a settling pond where insoluble compounds settled out. Soluble compounds were discharged to Poplar Creek which flows into the Clinch River.

Solid Wastes. Solid process wastes at the ORGDP, except for thorium-232, resulted from uranium enrichment activities. Floor sweepings, rags, and waste paper from general cleanup operations in the process buildings contained trace quantities of uranium and other radionuclides. Wastewater treatment sludges, airborne effluent treatment residuals (such as filter and trapping media), and scrubber solids, were disposed of onsite. The reconditioning and/or replacement of processing equipment and facilities generated large amounts of scrap metal for decontamination and subsequent storage. The radioactively contaminated scrap metal is now being stored and evaluated to determine the appropriate disposal method. Materials that might have been disposed of by shallow-land burial in the past are currently being collected and stored as low-level waste. Thorium-232 is also present in ORGDP solid wastes as a result of certain Y-12 production programs.

4.2.4 Process Waste Generation and History of Disposal at Y-12

Airborne Wastes. The major source of airborne emissions at the Y-12 facility is from metal machining and chemical processing operations. Major emissions include small uranium particles, fluorides, nitrogen oxides, and organic solvents. Treatment of the uranium released is accomplished by HEPA filtration. New emissions sampling/monitoring equipment was installed and began operating in early 1987 on 85 process exhaust stacks. Nitrogen oxide discharges are treated with scrubbers. New scrubbers are planned to control hydrogen fluoride emissions.

Liquid Wastes. Y-12 Plant process discharges originate from five major sources; (1) discharges from the biodenitrification facility, (2) cleaning solutions and contaminated mop water, (3) plating shop wastes, (4) photographic wastes, and (5) hydrogen fluoride scrubber solutions. ORNL facilities at Y-12 (Biology Division and Isotopes Separation Facility) contribute to the process discharges. Annual discharges from these sources are less than 379 million liters from source (2), 4 million liters from sources (1) and (4), and less than 0.4 million liters from sources (3) and (5). Some 98 million liters per year is generated at the Biology Division complex. Most of this wastewater is processed at Y-12's new Central Pollution Control Facility. Some of the cleaning solutions and wastewater from the Biology Division are discharged directly to East Fork Poplar Creek (EFPC) which drains into the Clinch River. Photographic waste is shipped to ORNL for treatment.

Liquid effluent releases of radioactivity from the Y-12 Plant primarily result from uranium which is derived from the same sources which result in airborne emissions. In addition, precipitation runoff may leach some uranium from outside storage facilities. Liquid wastes containing economically recoverable uranium have historically been recycled in Y-12 Plant production operations. Liquid wastes that did not contain recoverable uranium were discarded. Until recent years, treatment facilities were not generally available and the waste was discharged into the storm sewer system and into East Fork Poplar Creek (EFPC). Beginning in 1951 and continuing until 1984, some liquid wastes were discharged into the S-3 ponds located at the western end of the Y-12 Plant site. Leakage from the S-3 pond area contributed to uranium releases into Bear Creek, as did precipitation runoff from the Bear Creek Burial Grounds. Both EFPC and Bear Creek flow into Poplar Creek and ultimately discharge into the Clinch River near ORGDP. In addition to liquid releases of uranium, some thorium process solutions from ORNL research programs and Y-12 Production operations have been discharged to storm drains and ultimately to EFPC.

Mercury contaminated liquid wastes were produced beginning in 1953 when Y-12 undertook the first production-scale separation of lithium isotopes for use in hydrogen bombs. This separation process (called "COLEX") is a chemical exchange process in which lithium isotopes are separated as they are transferred between two chemical

phases. One of these phases is a solution of lithium in mercury, and as a result, many millions of pounds of mercury were used in this separation project. Floor drains were installed in the process building which emptied into special mercury collection tanks in the basement. Here mercury could be separated from mop water and other solutions before passing into other water-collecting sumps before entering East Fork Poplar Creek.

In March 1984, when the ORGDP received a permit to process Y-12 Plant waste, the discharge of wastes into the S-3 ponds was discontinued. The material contained in the ponds has recently been treated to remove contaminants and discharged under the Y-12 National Pollutant Discharge Elimination System (NPDES) permit. Remediation of the S-3 ponds is now underway to eliminate them as a source of contaminant releases in the future. Some liquid wastes such as oils, solvents, and mop water were also buried with solid wastes in the Bear Creek Burial Ground. Disposal of liquid waste to the burial ground was terminated in 1982.

Solid Wastes. Solid wastes generated at the Y-12 Plant include uranium and contaminated materials. Uranium wastes include depleted uranium metal and oxide in the form of chips, turnings, powders, scrap, and process residues with uranium contamination, resulting from the milling and machining processes. Contaminated materials include gloves, floor sweepings, filters, and demolition debris. Most of these solid wastes have been buried in the Bear Creek Burial Ground, with some deposited in burial areas within the plant perimeter fence and on Chestnut Ridge. Because most of the uranium waste buried is depleted uranium metal chips and since this metal ignites spontaneously, the chips have been placed in dumpsters that contain water to prevent spontaneous burning. A uranium chip oxidation facility is expected to be put into routine service to replace this method. Oxidized uranium chips will be stored in concrete vaults, eliminating burial in unlined shallow trenches for a major portion of the Y-12 Plant uranium waste. In addition, because the oxidized chips do not ignite, water will be eliminated from the storage process.

4.3 CONTAMINANT DISPOSAL AND RELEASES TO THE CLINCH RIVER

Summaries for the total amount of radionuclides released or disposed of at ORNL, ORGDP, and Y-12 are presented in this section. More detailed information on the historical (annual) releases of radionuclides in liquid effluents are also presented, because of their greater potential for directly entering surface water systems, the Clinch River, and off-site areas.

Radionuclide quantities in these tables are expressed in curies, which is a measure of the amount of radioactivity present. The mass associated with a curie varies among different radioisotopes and is related to the half-life of the material. For example, only 0.011 grams of cesium-137 will yield one curie, but 2,993 kilograms of uranium-238 are required to yield one curie. In some of the tables, uranium releases are given in terms of curies and of mass, expressed in kilograms, since the mass of uranium per curie is significantly higher than for other radionuclides. Few historical data exist concerning releases of metals and organic contaminants from the three DOE facilities.

4.3.1 Radionuclide Releases from ORNL

A summary of the total amount of radionuclides released or disposed of at ORNL is presented in Table 4.1. Airborne releases of xenon-133, liquid releases of tritium (H-3), and the burial disposal of the fission products, cesium-137 and strontium-90, account for most of the radioactivity released to the environment. Since Xe-133 is a chemically inert gas which decays rapidly, the quantity released from ORNL does not significantly contribute to individual or population doses. As a hydrogen isotope of water, tritium behaves conservatively as it moves through the groundwater and surface water system on the Oak Ridge Reservation. Of the total Cs-137 and Sr-90 quantities listed in Table 4.1, 59 percent of the Cs-137 and 78 percent of the Sr-90 were disposed of by the hydrofracture method from 1964 to 1979 and from 1982 to 1984 (Table 4.2). Of the remaining amount, 39 percent of the Cs-137 and 17 percent of the Sr-90 were disposed in pits and trenches from 1951 to 1976 (Table 4.3). The remaining small percentages were contained in solid wastes.

Table 4.1. Estimated Radionuclides Released to Air and Water or Buried at ORNL from 1944 through 1987 (from DOE 1988).

ORNL	AIR[b] (Curies)	WATER (Curies)	BURIAL[a] (Curies)
H-3	224,071	166,300	98,000
Co-60		325	8,961
Kr-85	215,629		
Sr-89	11		
Sr-90		1,198	880,557
Nb-95		287	
Zr-95		377	
Ru-103			13
Ru-106		6,93	216,104
1-131	404	175	
Xe-133	1,041,100		
Cs-134		636	
Cs-137		693	1,174,709
Ce-144		342	
Th-232			4.9
Pu-238			1.4
Pu-239			173.9
Cm-243/244			6,568
Uranium			160
Unidentified alpha	0.000045	3,860	
Unidentified beta		2,694	
Total rare earth		1,295[c]	2,784
Transuranics		5.2	3,100[d]
Mixed fission products			14,570

[a]Burial includes material placed in pits and trenches from 1951 to 1976, and material put into hydrofracture facilities during 1964 to 1979 and 1982 to 1984.
[b]Quantities shown for airborne releases of H-3, Kr-85, I-131, and unidentified alpha are from 1961 to 1987.
[c]Excluding cerium.
[d]Excluding plutonium-239.

Table 4.2. Estimated Quantities of Radionuclides in Liquid Disposed of by Shale Hydrofracture[a,b] (Curies)[c]. Source: DOE (1988).

Year	Sr-90	Cs-134	Cs-137	Ru-106	Co-60	Pu-238	Pu-239	Cm[d]	UN-ID Alpha[e]	Mixed F.P.[f]
1964	610		317	36	4					
1965	822		4,920	4	15					
1966	3		19,950	21	8					
1967	10,050		75,500	594	642					
1968	4,800		121,300	500	100		2.2			
1969	8,900		89,000	100	200		0.2			
1970	2,747		44,830	236	72		1.8			
1971										
1972	3,024		93,130	3,819	157		0.8	2.0		
1973										
1974										
1975	5,197	409	72,750	1,313	159			0.1	1.4	
1976										
1977	1,700		34,000	384	2,700	1.4	0.6	2.0		
1978	165		18,480	593	212				0.1	
1979	23	227	13,600		129				0.6	
1980										
1981										
1982	148,000		34,000					1,220.0[h]	438.0	6,800
1983	453,000		43,300					4,510.0	1,290.0	6,500
1984	44,600	—	7,700	—	—	—	—	834.0	2,130.0	1,270
Total[g]	683,641	636	672,777	7,600	4,398	1.4	5.6	6,568.0	3,860.0	14,570

[a]Data from DOE/OR-890.
[b]The first shale fracture facility was operated from 1964 to 1979. The second shale fracture facility was operated from 1982 to 1984.
[c]Blanks indicate that no data was reported.
[d]Cm-243 and Cm-244.
[e]Unidentified alpha emitters consisting of transuranics excluding Cm-243 and Cm-244.
[f]Unidentified beta and gamma emitters consisting primarily of mixed fission products.
[g]No injections during, 1971, 1973, 1974, 1976, 1980, and 1981.
[h]All digits carried through to avoid rounding errors. Only first two are significant.

Table 4.3. Estimated Quantities of Radionuclides in Liquid Disposed of in Pits and Trenches[a] (Curies) Source: DOE (1988).

Year	Sr-90	UID Beta	Pu-239	Cs-137	Co-60	TRE[c]	Ru-106	Ru-103
1953	[d]	390						
1952		953	0.0					
1953		77,165	0.2					
1954		7,224	1.0					
1955		21,390	1.6					
1956		34,990	2.6					
1957		41,920	2.9					
1958		52,790	3.1					
1959		280,000	3.5					
1960		25,026	3.1					
1961	2,913		3.4	26,675	24	1,024	1,638	13
1962	2,963		4.0	35,586	284	2,030	2,680	
1963	10,121		3.9	100,360	1,587		3,207	
1964	22,764	37	4.5	147,970	329		433	
1965	93,107	20	4.1	119,975	2,110		495	
1966	8,345	61	0.8	16,386	229		51	
1967	16	42						
1968	9	32						
1969	6	19						
1970	6	17						
1971	6	12						
1972	15	20						
1973	11	13						
1974	4	8						
1975	3	3						
1976	2	2						
Total	146,916	472,686	38.3	446,932	4,563	2,784	8,504	13

[a]Data from DOE/OR-890.
[b]Unidentified gross beta and gamma emitters.
[c]Total rare earths.
[d]Blanks indicate that no data was reported.
[e]Data for 1963 through 1976 are estimated values disposed in sludge. Data for previous dates are for liquid discharges.
[f]All digits carried through to avoid rounding errors. Only first two are significant.

Currently, the most significant radionuclide releases from ORNL to the water pathway result from leakage of strontium-90 and cesium-137 from waste disposal areas. These are significant because of their radiotoxicity, their mobility in the environment, and the quantities released. Other radionuclides of significance are tritium and transuranics. The current (through 1986) releases of all radionuclides are divided roughly by source as follows:

- Seventy to eighty percent of the radioactive material released leaches from waste disposal areas to White Oak Creek or Melton Branch with subsequent drainage into White Oak Lake and eventually into the Clinch River.

- Approximately ten percent of the radioactive releases result from operating facilities such as research reactors, laboratories, and processing plants. Some of these liquid wastes are discharged to temporary hold-up basins for testing and treatment before release to White Oak Creek. Improvements in process-water treatment have reduced the amount discharged from these sources.

- Approximately ten percent of the radioactive releases including 25% of the ^{90}Sr result from contaminated surfaces and soils in the vicinity of operating facilities. These areas are contaminated from previous spills and leaking underground pipes and tanks. Release occurs through storm water runoff or groundwater discharge to White Oak Creek.

Uncertainties in Tabulated Historical Data. The values presented in Tables 4.1-4.3, and in each of the following Tables 4.4-4.7 should be interpreted as reasonable estimates of the amounts of material released or buried. Accurate records from early years of operation, are not available to document the exact quantities released. Sampling or monitoring for specific isotopes or of several release points was not begun until recent years. Because of these assumptions and estimations, the data presented in these tables should not be considered to be exact. Specific areas of uncertainty associated with these data include:

Table 4.4. Summary of Radionuclides Released to Air and Water or Buried at ORGDP from 1944 through 1987 (from DOE 1988).

Y-12	AIR (Curies)	WATER (Curies)	BURIAL[a] (Curies)
Uranium	15.6 (10,500 Kg)	14.8 (16,700 Kg)	24.4 (32,800 Kg)
Tc-99	10.0	91.3	
Kr-85	106.5		
Np-237		0.0073	
Th-232			7.7a

[a]Burial records indicate presence of thorium, however, quantities were not recorded. This is a maximum estimate.

Table 4.5. Estimated Liquid Releases of Radioactivity from ORGDP.[a]

Year	Uranium (Ci)	Uranium (kg)	Technetium (Ci)	Neptunium (Ci)
1946	<0.01	<1		
1947	--	--		
1948	<0.03	4		
1949	<0.01	3		
1950	--	--		
1951	0.05	80		
1952	<0.01	4		
1953	0.10	26		
1954	0.23	84		
1955	0.05	16		
1956	0.24	90		
1957	0.18	40		
1958	<0.01	<1		
1959	<0.01	5		
1960	<0.01	<1		
1961	0.02	2		
1962	0.01	2		
1963	5.10[c]	1,576[d]		
1964	1.10	1,826[d]		
1965	0.01	33		
1966	0.01	21		
1967	<0.01	12		
1968	0.26	330		
1969	0.04	3,180[d]		
1970	0.86	88		
1971	0.44	76		
1972	0.40	1,601		
1973	0.44	570		
1974	0.4	508	3.5	
1975	1.70	564	9.0	
1976	0.54	306	24.1[e]	
1977	0.42	2,201[d]	5.8	
1978	0.63	688	4.0	
1979	0.47	537	7.3	0.0015
1980	0.09	803	5.1	0.0014
1981	0.18	601	3.5	0.0021
1982	0.09	114	1.7	0.0019
1983	0.18	233	17.0[f]	0.0004
1984	0.20	240	10.1[f]	
1985	0.07	80	0.03	
1986	0.04	37	0.02	
1987	0.12	116	0.07	
Total	14.77[g]	16,700[d]	91.3	0.0073

--indicates data not available.
[a]Data from DOE (1988).
[b]The ratio of Ci/Kg varies due to different isotopic enrichments.
[c]Enriched material.
[d]A major portion of the quantities reported in 1963, 1964, 1969, 1972, and 1977 have been from discharges to a pond from the decontamination facility.
[e]This elevated value may be due to increased decontamination efforts associated with the beginning of a large equipment change out program.
[f]In 1983 and 1984, there was a great amount of decontamination work being done on equipment from an area of the cascade that is highly contaminated with technetium-99.
[g]This total includes the actual stated value for any quantity which was reported as a less than (<) value.

Table 4.6. Summary of Radionuclides Released to Air and Water or Buried at Y-12 from 1944 through 1987 (from DOE 1988).

Y-12	AIR (Curies)	WATER (Curies)	BURIAL[a] (Curies)
Uranium	13.9 (6300 Kg)	117 (182,400 Kg)	7,097 (17,291 Mg)
Thorium		0.680	18.6
Np-237		< 0.053	b
Tc-99			56.6[c]
Cs-137		< 1.45	
Co-57/60		<320	
Nb-95		<654	
Pu-238/239		< 0.87	
Ru-106		< 0.056	
Zr-95		<350	

[a]Prior to 1972, liquid wastes containing uranium that were transferred to the S-3 ponds were recorded as burials.

[b]Radionuclides other than uranium and thorium were contained in liquid waste streams discharged to S-3 ponds. Then annual quantities for each were below the accountability reporting threshold for security purposes, so no record of exact quantities exist. The individual fission products and transuranics have been qualitatively identified in this waste stream, and the data presented are less than (<) threshold levels.

[c]600 g received from ORGDP and disposed at Y-12 burial grounds.

Table 4.7. Estimated Liquid Releases of Uranium and Thorium from Y-12[a]

Year	Uranium[b] (Ci)	Uranium[b] (kg)	Thorium[c] (Ci)	Thorium[c] (kg)
CY 1944	22.30		33,000	
1945	4.70	7,000		
1946				
1947	0	0		
1948	0.10	155		
1949	0.30	454		
1950	0.10	144		
1951	0.06	98		
FY 1952	0.002	3		
1953	0.651	953		
1954	0.71	1,118	0.001	11
1955	0.62	1,058	0.003	26
1956	2.26	4,987	0.005	44
1957	5.65	8,448	0.005	49
1958	5.85	10,019	0.008	70
1959	5.15	10,410	0.367	3363
1960	4.55	10,067	0.031	283
1961	2.00	3,064	0.101	927
1962	0.86	1,333	0	0
1963	0.82	1,248	0.002	20
1964	4.42	6,605	0.001	7
1965	5.91	8,852		
1966	5.34	7,985		
1967	10.20	15,217		
1968	11.75	17,525		
1969	2.80	4,189		
1970	5.88	8,775		
1971	2.37	3,546		
1972	2.03	3,042		
1973	0.74	1,119		
1974	1.04	1,561	0.007	65
1975	1.09	1,638	0.021	195
1976	0.91	1,368	0.020	203
1977	0.50	755	0.019	176
1978	0.27	410	0.013	120
1979	0.24	366	0.010	93
1980	0.10	158	0.009	80
1981	0.45	687	0.009	85
1982	0.56	846	0.006	52
1983	0.14	222	0.005	49
1984	1.20	1,799	0.010	90
1985	0.72	783	0.017	153
1986	0.67	652	0.007	64
1987	0.57	715	0.003	27
Total	116.58	182,374	0.680	6,253

[a]Data from DOE (1988).
[b]Ratio of Ci/Kg varies due to different isotopic enrichment.
[c]Thorium data unavailable for 1965 to 1973.

- Many of the specific radionuclides were not monitored in early years of operation.
- Radionuclide-specific information on the composition of wastes placed into trenches and pits are only estimates based on knowledge of processes involved in generating wastes, the quantities typically generated by the process, and the measurement of gross radioactivity.
- Solid waste quantities were estimated from records of volume of waste disposal, not from records of quantities of radionuclides involved.
- Tritium discharge data prior to 1972 could only be estimated from the ratios of waste produced to production levels in more recent years.
- The uranium burial records include both the amount of uranium buried as well as the amount placed in retrievable storage.
- Estimates of ^{239}Pu and ^{233}U in solid waste were made using extrapolations and accountability records for the years prior to 1970.
- Verification of solid waste quantities was done, in part, by interviewing individuals who had worked in the ORNL program in earlier years, to supplement gaps in documentation.

4.3.2 Radionuclide Releases from ORGDP

A summary of the estimated amount of radionuclides released or disposed of at the ORDGP is presented in Table 4.4. Estimated annual releases of uranium, technetium, and neptunium are listed in Table 4.5. The most significant radionuclides released from ORGDP are uranium and technetium. Little historical data exists for releases of metals and organic contaminants from ORGDP, but sediments in the K1007B Pond and K1700 stream contained above-background levels of Ag, As, Cr, Ni, Pb, Se, Zn, and PCBs (Ashwood et al. 1986).

Uncertainties in ORGDP Data include:

- Uranium releases for all but recent years were based on accountability records

- Data for other radionuclides are intermittent at best. For example, no specific information on burials exists prior to 1958. Technetium-99 releases were not included in reports prior to 1974.

4.3.3 Radionuclide Releases from Y-12

A summary of the total amount of radionuclides released or disposed of at Y-12 is presented in Table 4.6. As could be expected from the plant operating history, the most significant releases have been of uranium. Estimated annual releases of uranium and thorium in liquid effluents are presented in Table 4.7. Several other radionuclides (listed in Table 4.6), were known to be associated with the reactor-product uranium solutions that were reprocessed at Y-12. It is expected that some of these radionuclides were discharged with the liquid reprocessing wastes to on-site (S-3) ponds.

Uncertainties in Y-12 radionuclide data include:

- The uranium quantities buried on site were estimated from the weight of dumpsters, containing uranium and water in which the uranium was placed prior to disposal.
- Deterioration of filter systems on the airborne uranium emission points was assumed to have occurred gradually since installation. Because the deterioration more than likely occurred at an uneven rate (very little during earlier years, when systems were new, most of the deterioration occurring within the recent past), estimates of earlier releases would be reported somewhat higher than the actual release concentration that occurred.
- Uranium discharge data from 1944 to 1954 were not as complete as in later years.

4.3.4 Off-Site Releases of Other Contaminants

Although the history of radionuclide releases is reasonably well known (e.g., DOE 1988), quantitative information on releases of most other contaminants is either absent or incomplete. During the 1950s and early 1960s, relatively large quantities of metallic mercury (Hg) were released to surface waters in association with weapons-component

production at the Y-12 Plant. Because information relevant to the Y-12 operations was classified, the mercury releases were not publicly acknowledged until 1983.

Measurement of aquatic discharges of Hg from the Y-12 Plant began in April 1954. The history for annual aquatic releases of Hg (Fig. 4.1) shows a sharp increase in 1955 when full-scale lithium isotope processing began, maximum releases of 33 and 29 metric tons of inorganic Hg in 1957 and 1958, followed by a sharp decline after 1958. Process changes in 1958 reduced releases and all production ended by 1963. The total Hg release to the environment, including estimates for the 1950 to 1954 period, has been estimated to be about 150 metric tons (Turner et al. 1984).

4.4 ENVIRONMENTAL MONITORING

Extensive environmental monitoring data have been and continue to be collected on the ORR. Since 1985, environmental surveillance/monitoring of air, groundwater, and surface water has been conducted in compliance with NPDES permits and RCRA-HSWA requirements. These monitoring data are reported quarterly and summarized annually in the Environmental Surveillance Report for the ORR. These documents provide annual discharge, sampling, and monitoring summaries for air, soil, sediment, surface water, ground water, and biological samples (milk, fish, wildlife, vegetation). The annual Environmental Surveillance Report also includes sections on potential radiation and chemical dose to the public, environmental monitoring of the Oak Ridge community, and progress in remedial action activities and special studies.

4.4.1 Surface Water Monitoring

Water quality and flow measurements are conducted and water samples are collected at numerous on-site locations (Figs. 4.2 and 4.3), and analyzed at various intervals (weekly, monthly, etc.) for both radionuclides and nonradioactive chemicals. Additionally, treated water samples are collected weekly at the Gallaher (ORGDP) and Kingston potable water treatment plants (Fig. 4.4) and are analyzed quarterly.

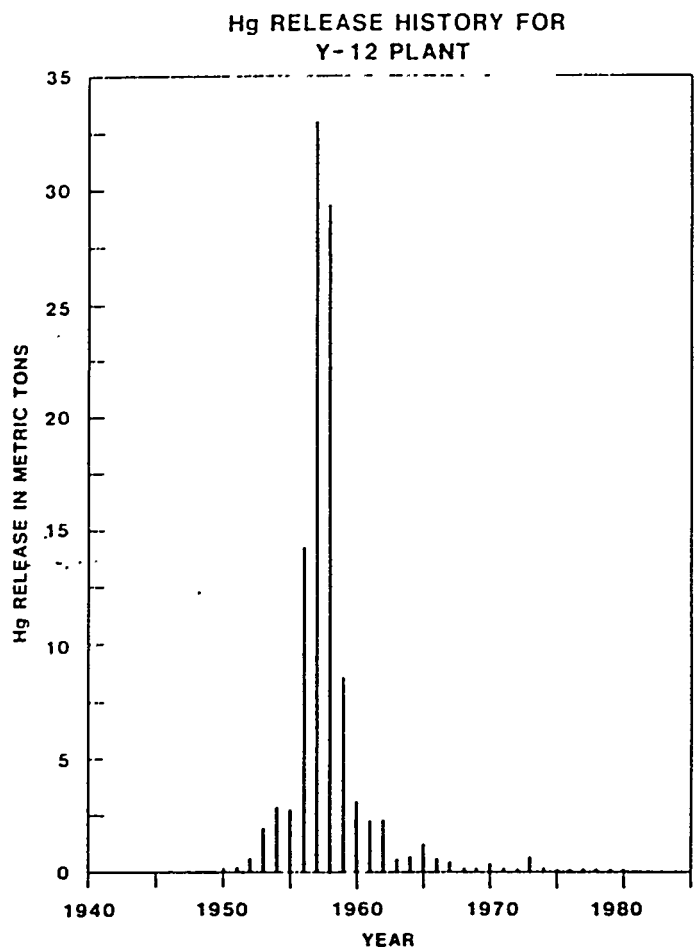

Fig. 4.1. Aquatic discharge history of mercury from the Y-12 Plant.

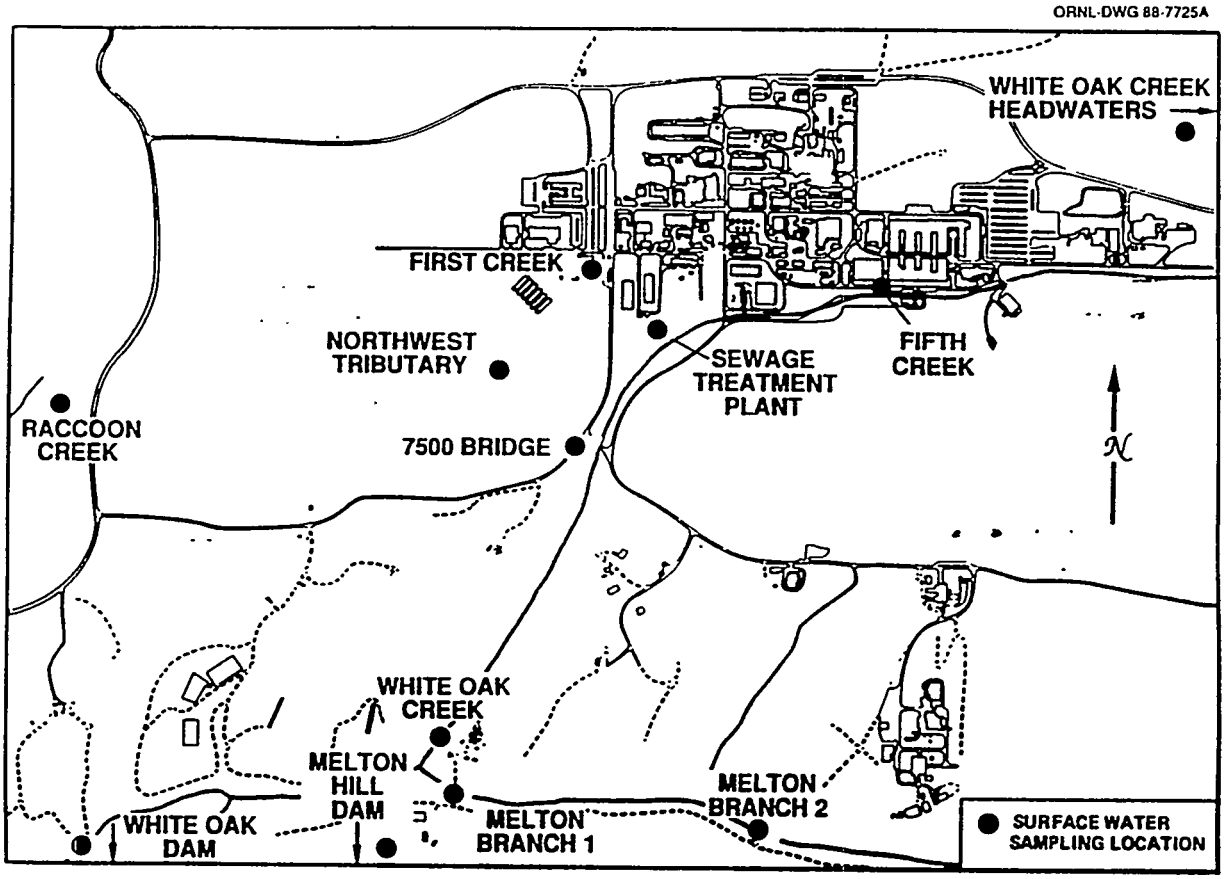

Fig. 4.2. ORNL surface water sampling locations.

ORNL-DWG 89M-14296

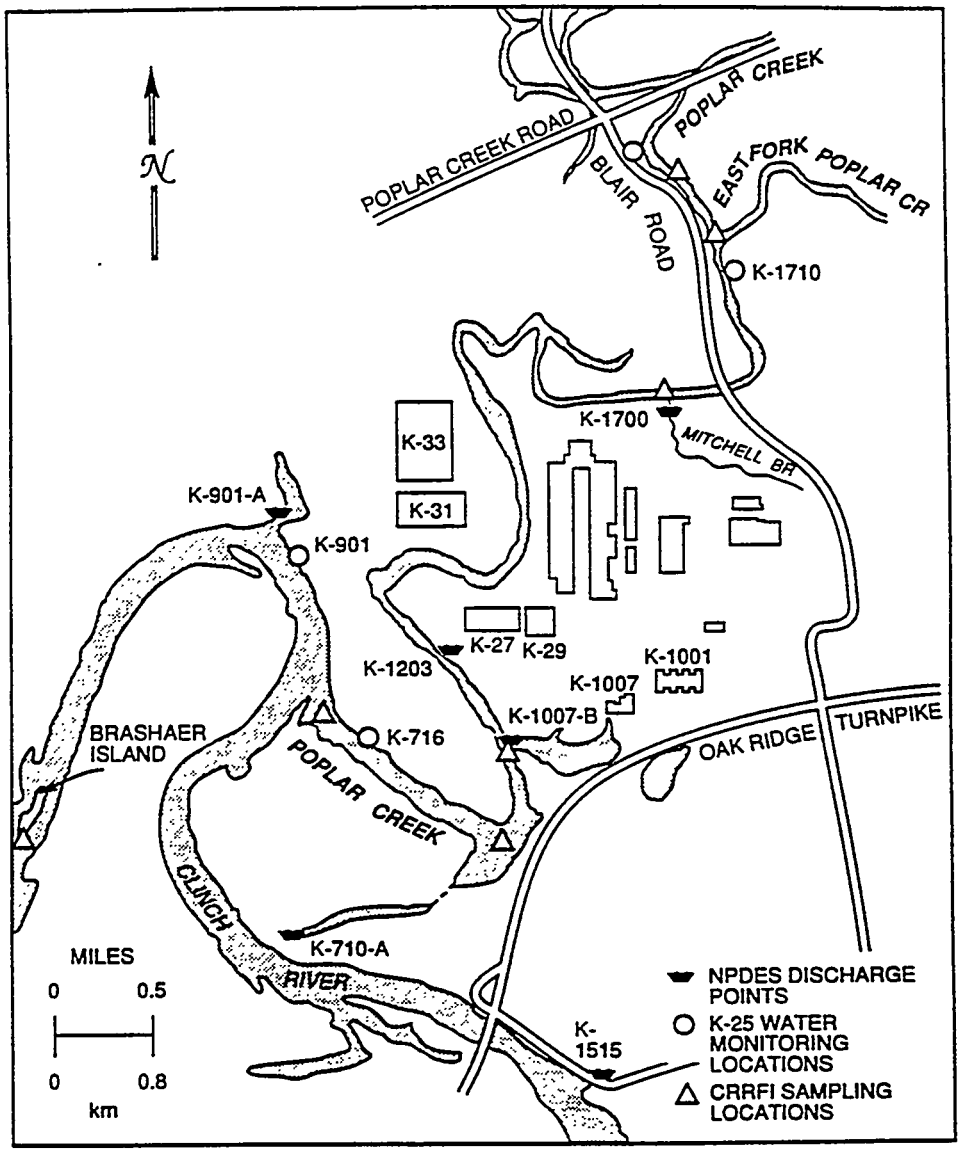

Fig. 4.3. ORGDP (K-25) surface water monitoring locations and Clinch River RFI sampling stations.

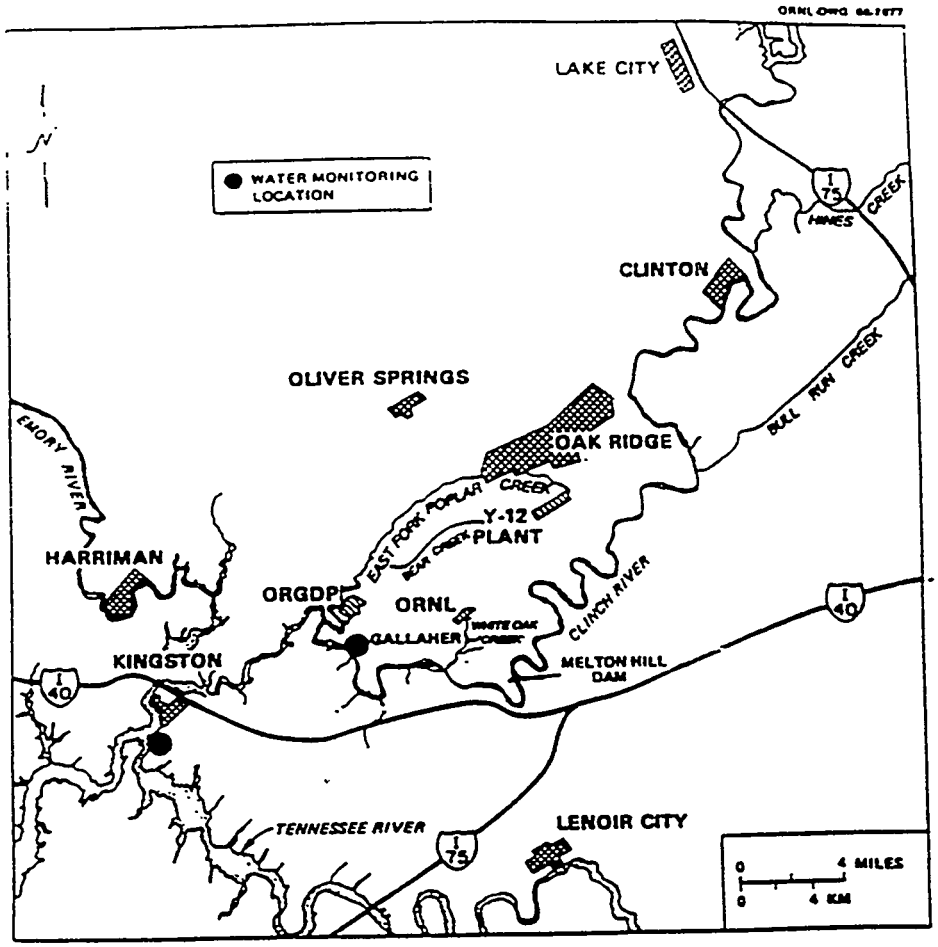

Fig. 4.4. Locations of the Gallaher (ORGDP) and Kingston potable water treatment plants on the Clinch River.

Concentrations of materials in surface waters on or around the ORR are compared with Tennessee's in-stream allowable concentrations, which are based on the long-term protection of domestic water supply, fish and aquatic life, and recreation classifications and recommendations made by the TDHE to DOE-Oak Ridge Operations (ORO). Similarly, concentrations of materials in the Clinch River outlet for the ORGDP sanitary water plant are compared with Tennessee water quality criteria for domestic water supplies. Detailed information on specific monitoring procedures, station locations, and recent water quality trends are provided in the quarterly and annual Environmental Surveillance Reports (Rogers et al. 1988). Data provided by these ongoing surface-water monitoring programs on the ORR, as well as other ongoing programs on the Clinch River-Watts Bar Reservoir system, will be used in the Clinch River RFI to help in characterization of contaminant sources, releases to surface waters, and contaminants of concern.

Surface Water Monitoring at ORNL. The ORNL site is drained by two main streams, White Oak Creek (WOC) and Melton Branch (see Fig. 4.2), and ORNL effluents discharge primarily to these two streams or their tributaries. WOC flows through Bethel Valley, where Fifth Creek, First Creek, and Northwest Tributary enter. WOC flows through a gap in Haw Ridge into Melton Valley, where it is joined by Melton Branch. WOC and Melton Branch drain into White Oak Lake (WOL), which is controlled by White Oak Dam (WOD) and is the last monitoring/sampling point before effluents leave the ORR and enter the Clinch River. Below WOD, the WOC embayment is affected by water levels in the Clinch River that are controlled by releases from the Melton Hill Dam (see Fig. 4.3). Additionally, two small discharges flow from the 7600 area directly to Melton Hill Reservoir, and Raccoon Creek, which receives ^{90}Sr from SWSA-3, discharges directly to the Clinch River.

To monitor discharges of radionuclides from ORNL processes, stream flow is recorded and concentrations are measured in water samples collected regularly from the following stations: 1500 area, 190 ponds, First Creek, 2000 area, acid neutralization facility (3518), PWTP (3544), Fifth Creek, 7500 bridge, Melton Branch 1 (MB1), Melton Branch 2 (MB2), Melton Hill Dam, Northwest Tributary (NWT), Raccoon Creek, STP, transuranic

process plant (TPP) ponds, HFIR, WOC, WOC headwaters, and WOD. Real-time monitoring of pH, dissolved oxygen, turbidity, conductivity, temperature, flow, and gross beta and gamma activity (in cpm) is performed at Melton Branch, WOC, and WOD; a gamma spectrum is also monitored at WOD. The samples collected and analyzed daily at the 7500 bridge are used as an early warning of radioactive discharges from ORNL processes (see Fig. 4.2). Radiological monitoring at stations in the 1500 area, 190 ponds, 3518, and 3544 was initiated in February 1987.

Annual discharges of radioactivity past White Oak Dam (WOD) into the Clinch River are summarized in Table 4.8. These discharges are calculated by (1) analyzing radionuclide concentrations in weekly flow-proportional samples (2) multiplying this concentration by the total weekly flow, and (3) integrating these weekly samples for a year. Approximately 665 Curies (2.5×10^{13} Bq) of ^{137}Cs have been released from White Oak Lake into the Clinch River system. Because most of this release occurred between 1954 and 1959 (Table 4.8), and because the half-life of ^{137}Cs for radioactive decay is 30 y, the total decay-corrected amount of 137Cs discharged as of June 1986 is approximately 335 Curies. Radioactive discharges into the on-site creeks and later into the Clinch River are affected not only by the concentrations in the streams, but also by rainfall, surface runoff, subsurface inflow to streams, and stream flows.

Annual minimum, maximum, and average radionuclide concentrations in water at WOD and at several off-site stream monitoring locations are given in Table 4.9. The maximum concentration is given as a percentage of the derived concentration guide (DCG) in the last column of this table. Although the data are limited ($n = 4$), none of the percentages were above 0.1%. The Kingston and Gallaher (ORGDP) water samples are collected weekly from potable water treatment plant intakes and are analyzed quarterly for radionuclides (see Fig. 4.3). For comparison, samples were collected daily from the ORNL potable water system (tap water) in Building 4500S and analyzed quarterly for radionuclides. ORNL and the City of Oak Ridge obtain tapwater from Melton Hill Lake. In addition, flow proportional samples are collected weekly from Melton Hill Dam and analyzed quarterly for radionuclides. Melton Hill Dam is located on the Clinch River, upstream of ORNL's discharge point to the Clinch River, and these

Table 4.8. Annual Discharges of Radionuclides from White Oak Creek to the Clinch River, 1944 to 1984[a] (Curies).

Year	Beta	^{137}Cs	^{106}Ru	^{89}Sr	^{90}Sr	TRE(-Ce)[b]	^{144}Ce	^{95}Zr	^{95}Nb	^{131}I	^{60}Co	^{3}H	TRU
1944[c]	600												
1945[c]	500												
1946[c]	900												
1947[c]	200												
1948[c]	494												
1949		77	110		150	77	18	180	22	77		NA[d]	
0.04[d]													
1950		19	23		38	30	NA	15	42	19			0.04
1951		20	18		29	11	NA	5	2	18			0.08
1952		10	15		72	26	23	19	18	20			0.03
1953		6	26		130	110	7	8	4	2			0.08
1954		22	11		140	160	24	14	9	4	NA		0.07
1955		63	31		93	150	85	5	6	7	7		0.25
1956		170	29		100	140	59	12	15	4	46		0.28
1957		89	60		83	110	13	23	7	1	5		0.15
1958		55	42	NA	150	240	30	6	6	8	9		0.08
1959		76	520	0.3	60	94	48	27	30	1	77		0.68
1960		31	1900	1.9	28	48	27	38	45	5	72		0.19
1961		15	2000	2.0	22	24	4	20	70	4	31		0.07
1962		6	1400	1.7	9	11	1	2	8	0.4	14		0.06
1963		4	430	1.0	8	9	2	0.3	0.7	0.4	14		0.17
1964		6	190	0.8	7	13	0.3	0.2	0.1	0.3	15	1,900	0.08
1965		2	69	0.6	3	6	0.1	0.3	0.3	0.2	12	1,200	0.50
1966		2	29	0.9	3	5	0.1	0.7	0.7	0.2	7	3,100	0.16
1967		3	17	0.7	5	9	0.2	0.5	0.5	0.9	3	13,300	1.03
1968		1	5	0.6	3	4	0.03	0.3	0.3	0.3	1	9,700	0.04
1969		1	2	0.3	3	5	0.02	0.2	0.2	0.5	1	12,200	0.20
1970		2	1	0.3	4	5	0.06	0.02	0.02	0.3	1	9,500	0.40
1971		1	0.5	0.2	3	3	0.05	0.01	0.01	0.2	1	8,900	0.05
1972		2	0.5	NA	6	5	0.03	0.01	0.01	0.3	1	10,600	0.07
1973		2	0.7		7	NA	0.02	0.05	0.05	0.5	1	15,000	0.08
1974		1	0.2		6		0.02	0.02	0.02	0.2	0.6	8,600	0.02
1975		0.6	0.3		7		NA	NA	NA	0.3	0.5	11,000	0.02
1976		0.2	0.2		5					0.03	0.9	7,400	0.01
1977		0.2	0.2		3					0.03	0.4	6,200	0.03
1978		0.3	0.2		2					0.04	0.4	6,300	0.03
1979		0.2	0.1		2.4					0.04	0.4	7,700	0.03
1980		0.6	0		1.5					0.04	0.4	4,600	0.04
1981		0.2	0.1		1.5					0.04	0.7	2,900	0.04
1982		1.5	0.2		2.7					0.06	1.0	5,400	0.03
1983		1.2	0.2		2.1					0.004	0.3	5,600	0.05
1984		0.6	0.2		2.6					0.05	0.2	6,400	0.03

[a]Data from Ohnesorge (1986).
[b]Total rare earths minus cerium.
[c]Individual radionuclide data not available.
[d]No analysis performed
[e]Transuranic

Table 4.9. Radionuclide concentrations in off-site surface waters in the vicinity of the Oak Ridge National Laboratory, 1987. Source: Rogers et al. (1988).

Radionuclide	Number of samples	Concentration (pCi/L)				
		Max	Min	Av	95% cc[a]	Percent of DCG[b]
			Gallaher[c]			
^{60}Co	4	<2.4	<2.5	<2.5	0.0	<0.046
^{137}Cs	4	<2.5	<2.5	<2.5	0.0	<0.093
Gross Alpha	4	3.5	1.1	2.6	1.1	NA
Gross Beta	4	7.0	4.6	5.6	1.1	NA
Total Pu	4	0.050	0.050	0.050	0.0	0.0019
Total Sr	4	4.6	2.0	3.3	1.2	0.43
Tritium	4	2500	1500	1700	480	0.11
^{234}U	4	0.10	0.050	0.079	0.026	0.019
^{235}U	4	0.050	0.050	0.050	0.0	0.0093
^{236}U	4	0.00035	<0.000032	<0.00014	0.00015	0.0010
^{238}U	4	0.068	0.050	0.056	0.0084	0.013
			Kingston[c]			
^{60}Co	4	<2.5	<2.5	<2.5	0.0	<0.046
^{137}Cs	4	<2.5	<2.5	<2.5	0.0	<0.093
Gross Alpha	4	1.8	1.0	1.3	0.37	NA
Gross Beta	4	4.0	4.0	4.0	0.0	NA
Total Pu	4	0.050	0.050	0.050	0.0	0.0019
Total Sr	4	4.3	2.0	3.0	1.2	0.40
Tritium	4	1500	1500	1500	0.0	0.069
^{234}U	4	0.10	0.062	0.079	0.021	0.019
^{235}U	4	0.050	0.050	0.050	0.0	0.0093
^{238}U	4	0.00059	<0.000099	<0.00029	0.00021	0.0010
^{238}U	4	0.061	0.050	0.053	0.0054	0.011
			Melton Hill[c]			
^{60}Co	4	<2.5	<2.5	<2.5	0.0	<0.046
^{137}Cs	4	2.5	<2.5	<2.5	0.0	0.093
Gross Alpha	4	2.2	<1.0	<1.3	0.57	NA
Gross Beta	4	7.0	4.3	5.7	1.2	NA
Total Pu	4	0.050	0.050	0.050	0.0	0.0019
Total Sr[e]	4	3.8	2.0	2.5	0.85	0.35
^{234}U	4	0.14	0.091	0.12	0.025	0.026
^{236}U	4	0.00017	<0.000037	<0.00012	0.000066	0.0010
^{234}U	4	0.090	0.055	0.074	0.017	0.017
			ORNL Tap Water			
^{60}Co	4	<2.5	<2.5	<2.5	0.0	<0.046
^{137}Cs	4	<2.5	<2.5	<2.5	0.0	<0.093
Gross Alpha	4	2.2	1.0	1.4	0.51	NA[d]
Gross Beta	4	6.8	<4.0	<4.7	1.4	NA[d]
Total Pu	4	0.050	0.050	0.050	0.0	0.0019
Total Sr[e]	4	5.1	2.0	3.0	1.5	0.48
^{234}U	4	0.087	0.050	0.059	0.018	0.016
^{235}U	4	0.050	0.050	0.50	0.0	0.0093
^{236}U	4	0.000040	<0.000013	<0.000023	0.000012	0.0010
^{238}U	4	0.052	0.050	0.00075	0.0095	

[a]95% confidence coefficient about the average.
[b]Percent of DCG = maximum x 100/derived concentration guide (DCG).
[c]See Fig. 2.2.
[d]Not applicable.
[e]Total Sr = total radioactive strontium (^{89}Sr + ^{90}Sr).

samples serve as a local background or reference station. There were no significant statistical differences (P = 0.05) in the total radioactive strontium, total plutonium, or ^{235}U measured among the four off-site locations in Table 4.9. ORNL tap water concentrations of uranium isotopes were at least as low as in the off-site streams. Table 4.10 lists the annual sample results for the NPDES discharge point at White Oak Dam.

Surface Water Monitoring at ORGDP. Surface water samples are collected as part of the Clean Water Act (CWA) requirements and DOE orders. Both NPDES and perimeter ambient water sampling locations under ORGDP responsibility are shown in Fig. 4.4. Water quality and radionuclide data for perimeter ambient water are presented to document ORGDP's impact on the surrounding streams and to differentiate this impact from that of other sites. During 1987, grab samples were collected once a week at all locations, with the exception of K-1513, and composited into monthly samples. At K-1513, 24-h composite samples were collected each week and composited into a monthly sample. All monthly samples were analyzed for radiological and nonradiological parameters. Mitchell Branch, located on the northeast side of the plant site, is shown in Fig. 4.3. The branch is sampled for both radiological and non-radiological parameters at three locations: near the headwaters, upstream, and downstream of a spring flowing into the branch.

Table 4.11 presents radiological data for the ambient surface water surrounding ORGDP. Fig. 4.3 gives the sampling locations. Only uranium exceeded the detection limit in Poplar Creek and the Clinch River. The uranium determination was conducted by wet chemistry methods and reduced for presentation as pCi/L. Results indicate that uranium values were elevated in Poplar Creek both above and below ORGDP, but that uranium values in the west fork of Poplar Creek (which does not receive discharges from either ORGDP or Y-12) were not elevated. The data in Table 4.11 also indicate that both gross alpha and gross beta are elevated in Mitchell Branch.

Tables 4.12 to 4.18 present 1987 water quality data for the ambient surface water surrounding ORGDP. Figure 4.3 depicts the sampling locations. When compared to

Table 4.10. ORNL liquid releases and radionuclide concentrations for White Oak Creek, White Oak Dam, and Melton Branch 1987. Source: Rogers et al. 1988.

Radionuclide	Emission source release (Ci)	Derived concentration Guide (DCG) (pCi/L)	Average flow-weighted concentration (pCi/L)	Percent of DCG[a]
		White Oak Creek		
^{60}Co	0.046	5400	<6.8	<0.13
^{137}Cs	0.47	2700	68	2.5
Total Sr	0.71	1100	100	9.7
Tritium	380	2,200,000	56,000	2.6
		White Oak Dam		
^{241}Am	0.0012	110	<0.14	<0.13
^{244}Cm	0.0028	1600	<0.34	<0.021
^{60}Co	0.12	5400	<15	<0.27
^{137}Cs	0.57	2700	69	2.5
Gross Beta	3.3	NA	390	NA
^{238}Pu	0.00049	2700	<0.058	<0.0022
^{239}Pu	0.0014	2700	<0.16	<0.0060
Total Sr	1.2	1100	140	13
Tritium	2500	2,200,000	300,000	14
		Melton Branch I		
^{60}Co	0.075	5400	49	0.90
^{137}Cs	0.0073	2700	<4.8	<0.18
Total Sr	0.44	1100	280	26
Tritium	3200	2,200,00	2,100,000	95

[a]Percent of DCG = average flow-weighted concentration X 100/DCG.

Table 4.11. Radionuclide concentrations in surface waters in and around the Oak Ridge Gaseous Diffusion Plant, 1987. See Fig. 4.4 for sampling locations. Source: Rogers et al. (1988).

Radionuclide	No. of samples	Concentration (mg/L)			Percent of DCG[a]
		Max	Min	Av	
		West Fork Poplar Creek			
Np	11	<1	<1	<1	NA[b]
Pu	11	<2	<1	<1	NA
Tc	11	<224	<105	<164	NA
Cs	11	<100	<100	<100	NA
U[c]	11	2.0	<0.7	<0.7	0.14
U (mg/L)	11	0.003	<0.001	<0.001	
		K-1710			
Np	11	<2	<1	<1	NA
Pu	11	<3	<1	<1	NA
Tc	11	<222	<109	<164	NA
Cs	11	<100	<100	<100	NA
U	11	10	<0.7	<5.4	1.08
U (mg/L)	11	0.015	<0.001	<0.008	
		K-716			
Np	11	<2	<1	<1	NA
Pu	11	<3	<1	<1	NA
Tc	11	<222	<109	<165	NA
Cs	11	<100	<100	<100	NA
U	11	8.7	<0.7	<2.7	0.54
U (mg/L)	11	0.013	<0.001	<0.004	
		K-1513			
Np	11	<2	<1	<1	NA
Pu	11	<3	<1	<1	NA
Tc	11	<222	<109	<165	NA
Cs	11	<100	<100	<100	NA
U	11	4.0	<0.7	<2.0	0.4
U (mg/L)	11	0.006	<0.001	<0.003	
		K-901@ 892			
Np	11	<2	<1	<1	NA
Pu	11	<3	<1	<1	NA
Tc	11	<222	<109	<164	NA
Cs	11	<100	<100	<100	NA
U	11	2.7	<0.7	<1.3	<0.26
U (mg/L)	11	0.004	<0.001	<0.002	
		Clinch River			
Np	10	<1	<1	<1	NA
Pu	10	<2	<1	<1	NA
Tc	10	<224	<105	<164	NA
Cs	10	<100	<100	<100	NA
U	10	1.3	<0.7	<0.7	0.14
U (mg/L)	10	0.002	<0.001	<0.001	
		Mitchell Branch			
		Source			
Alpha	12	11.7	<2	<3.6	
Beta	12	97.5	<2	<15.1	
Gamma	3	<100	<100	<100	

Table 4.11 (continued)

Radionuclide	No. of samples	Concentration (mg/L)			Percent of DCG[a]
		Max	Min	Av	
			Upstream		
Alpha	12	29.2	<2	<14.3	
Beta	12	38.6	<2	<17.8	
Gamma	3	<100	<100	<100	
			Downstream		
Alpha	12	21.8	<2	<8.6	
Beta	12	57.8	21	35.5	
Gamma	3	<100	<100	<100	

[a]Maximum concentration as a percentage of the derived concentration guide (DCG) from Draft Order 5480.xx.
[b]Not applicable.
[c]The specific activity for natural uranium of 1.49 (10^6) g/Ci was used to determine pCi/L.

Table 4.12. Water quality variables and metals concentrations at K-1710, ORGDP, 1987. Source: Rogers et al. (1988).

Parameter	Concentration (mg/L)		
	Max	Min	Av
Arsenic	<0.005	<0.005	<0.005
Mercury	0.0004	<0.0002	0.0002
COD	11	<5	<7
Suspended solids	17	4	11
Dissolved solids	310	132	215
pH (units)	8.0	7.7	
Cyanide	0.017	<0.002	<0.006
Ammonia nitrogen	0.2	<0.2	<0.2
Fluoride	0.70	<0.10	<0.44
Nitrate nitrogen	10	0.68	2.0
Sulfate	49	32	40
Chromium	0.041	<0.010	<0.013
Copper	0.050	<0.0040	<0.008
Manganese	0.250	0.022	0.114
Nickel	<0.050	<0.050	<0.050
Sodium	15.0	4.0	10.0
Zinc	0.13	<0.02	<0.03
Cadmium	<0.002	<0.002	<0.002
Lead	0.007	<0.004	<0.004

Table 4.13. Water quality variables and metals concentrations at K-716, ORGDP, 1987. Source: Rogers et al. (1988).

Parameter	Concentration (mg/L)		
	Max	Min	Av
Arsenic	<0.005	<0.005	<0.005
Mercury	0.0005	<0.0002	0.0002
COD	14.5	<5	<7.1
Suspended solids	22	5	14
Dissolved solids	214	136	177
pH (units)	8.5	7.6	
Cyanide	0.14	<0.002	<0.005
Ammonia nitrogen	0.2	<0.2	<0.2
Fluoride	0.6	<0.1	<0.2
Nitrate nitrogen	33.6	0.24	3.38
Sulfate	40	23	30
Chromium	<0.01	<0.01	<0.01
Copper	0.054	<0.004	<0.009
Manganese	1.5	<0.01	<0.08
Nickel	<0.050	<0.050	<0.050
Sodium	8.6	4.0	6.7
Zinc	0.054	<0.020	<0.023
Cadmium	<0.002	<0.002	<0.002
Lead	0.005	<0.004	<0.004

Table 4.14. Water quality variables and metals concentrations at K-1513. ORGDP, 1987. Source: Rogers et al. (1988).

Parameter	Concentration (mg/L)		
	Max	Min	Av
Arsenic	0.005	<0.005	<0.005
Mercury	0.0004	<0.0002	<0.0002
COD	7.5	<5	<5.2
Suspended solids	19	<4	<6
Dissolved solids	230	122	171
pH (units)	8.2	7.8	
Cyanide	0.006	<0.002	<0.003
Ammonia nitrogen	<0.2	<0.2	<0.2
Fluoride	0.19	<0.10	<0.11
Nitrate nitrogen	8.37	0.19	1.10
Sulfate	27	19	22
Chromium	<0.010	<0.010	<0.010
Copper	0.085	<0.004	<0.013
Manganese	0.084	<0.010	0.025
Nickel	<0.050	<0.050	<0.050
Sodium	5.9	3.6	4.7
Zinc	0.064	<0.02	<0.03
Cadmium	<0.002	<0.002	<0.002
Lead	0.005	<0.004	<0.004

Table 4.15. Water quality variables and metals concentrations at K-901, ORGDP, 1987. Source: Rogers et al. (1988).

Parameter	Concentration (mg/L)		
	Max	Min	Av
Arsenic	<0.005	<0.005	<0.005
Mercury	0.0006	<0.0002	<0.0002
COD	18	<5	<6
Suspended solids	7	2	4
Dissolved solids	208	156	161
pH (units)	8.3	7.6	
Cyanide	0.005	<0.002	<0.003
Ammonia nitrogen	<0.2	<0.2	<0.2
Fluoride	0.19	<0.10	<0.10
Nitrate nitrogen	16.7	0.42	1.80
Sulfate	28	20	20
Chromium	<0.010	<0.010	<0.010
Copper	0.0300	<0.0040	<0.0063
Manganese	0.056	<0.010	<0.032
Nickel	<0.050	<0.050	<0.050
Sodium	6.6	3.9	4.8
Zinc	0.059	<0.020	<0.033
Cadmium	0.003	<0.002	<0.002
Lead	0.004	<0.004	<0.004

Table 4.16. Water quality variables and metals concentrations at Clinch River kilometer 18 (Brashaer Island), 1 km downstream of the ORGDP, 1987. See Fig. 4.4 for station location. Source: Rogers et al. (1988).

Parameter	Concentration (mg/L)		
	Max	Min	Av
Arsenic	<0.005	<0.005	<0.005
Mercury	<0.0002	<0.0002	<0.0002
COD	28	<5	<9
Suspended solids	13	<4	<8
Dissolved solids	216	138	165
pH (units)	8.4	7.6	
Cyanide	0.003	<0.002	<0.002
Ammonia nitrogen	<0.2	<0.2	<0.2
Fluoride	0.5	<0.1	<0.1
Nitrate nitrogen	0.61	0.17	0.40
Sulfate	25	14	21
Chromium	<0.01	<0.01	<0.01
Copper	<0.004	<0.004	<0.004
Manganese	0.074	<0.01	<0.02
Nickel	<0.050	<0.050	<0.050
Sodium	5.6	2.6	4.7
Zinc	0.24	<0.02	<0.02
Cadmium	0.003	<0.002	<0.002
Lead	0.025	<0.004	<0.007

Table 4.17. Chemical oxygen demand (COD) levels in Mitchell Branch, ORGDP, 1987. Source: Rogers et al. (1988).

Location	Concentration (mg/L)		
	Max	Min	Av
Source	44	<5	<16.2
Upstream	17	<5	<7.4
Downstream	25	<5	<7.1

Table 4.18. Water quality variables and metals concentrations at West Fork Poplar Creek monitoring station, located just upstream of the ORGDP, 1987. See Fig. 4.4 for station location. Source: Rogers et al. (1988).

Parameter	Concentration (mg/L)		
	Max	Min	Av
Arsenic	<0.005	<0.005	<0.005
Mercury	<0.0002	<0.0002	<0.0002
COD	11	<5	<7
Suspended solids	29	1	12
Dissolved solids	252	116	186
pH (units)	8.0	7.3	
Cyanide	0.01	<0.002	<0.003
Ammonia nitrogen	<0.2	<0.2	<0.2
Fluoride	0.3	<0.1	<0.2
Nitrate nitrogen	1.3	<0.11	<0.35
Sulfate	80	27	44
Chromium	<0.01	<0.01	<0.01
Copper	<0.004	<0.004	<0.004
Manganese	0.38	<0.010	<0.102
Nickel	<0.050	<0.050	<0.050
Sodium	7.3	2.4	5.2
Zinc	0.054	<0.020	<0.023
Cadmium	<0.002	<0.002	<0.002
Lead	0.014	<0.004	<0.005

the primary and secondary national drinking water standards, two parameters show excesses: manganese and nitrate. The source of the manganese is upstream of the ORGDP because average values exceed drinking water standards upstream of the plant. On the Clinch River, only maximum values periodically exceed drinking water standards. The average nitrate-nitrogen concentration increases from 20% of the primary drinking water standard to 30% of the standard from K-1710 (upstream) to K-716 (downstream). In West Fork Poplar Creek, the average value is only 3% of the drinking water standard. At K-901-A and in the Clinch River, the average values are 18% and 4% of the standard, respectively. It appears that ORGDP slightly elevates the nitrate-nitrogen concentration in the waters of Poplar Creek. No additional effects on drinking water parameters were indicated by the comparison of upstream and downstream data. At K-1700, locally known as Mitchell Branch, elevated chemical oxygen demand (COD) values were recorded. A potential source is naturally occurring decomposition products. No drinking water standard exists for COD.

Surface Water Monitoring at Y-12. The Y-12 Plant sanitary sewage system discharges to the city of Oak Ridge west end sewage treatment facility. These discharges are monitored for radiological and nonradiological parameters as required in the industrial users' permit No. 001
issued to the Y-12 Plant in final form on December 16, 1987. Before issuance of this permit, monitoring was conducted in accordance with a draft permit issued in February 1986. These data are summarized in Tables 4.19 and 4.20.

At the Y-12 Plant, surface water is also monitored routinely at two locations that are not required by NPDES permit No. TN0002968. At each of these locations, samples are also collected for both radiological and nonradiological parameters. The first location is at kilometer 12.4 on upper Bear Creek near the S-3 ponds area and the southwest end of the Y-12 Plant. See the drainage map, Fig. 3.9 in Section 3, for locations of streams in the Oak Ridge area. As required by the 1983 complaint order issued by TDHE to the Y-12 Plant, grab samples are collected weekly at this location. Analytical data are reported quarterly to the TDHE as an attachment to the Discharge Monitoring Report (DMR). A summary of these data is presented in Table 4.21.

Table 4.19. Annual summary for Y-12 Plant discharges to the City of Oak Ridge west-end sewage treatment facility, 1987. Source: Rogers et al. (1988).

Parameter	Concentration[b]		
	Max	Min	Av
Mercury	0.0250	0.0003	0.0054
Alpha (pCi/L)	65.0	<1.0	<30.2
Beta (pCi/L)	126.0	<4.0	<32.1
^{238}Pu (pCi/L)	<0.91	<0.10	<0.42
^{235}U (pCi/L)	9.20	0.36	<1.93
^{235}U (%)	3.22	0.63	1.55
Uranium	0.026	0.002	0.011
CN	0.010	0.002	0.017
NO_3-N	11	0.1	<2.5
pH (units)	7.9	7.4	NA[c]
Kjeldahl nitrogen	28	0.5	17
TSS	220	<5	<51
PCB	0.0020	<0.0005	<0.0007
BOD	58	<5	<29
Aluminum	4.51	0.02	0.73
Arsenic	<0.04	<0.04	<0.04
Barium	0.1480	0.0387	0.0809
Beryllium	0.0005	<0.0001	<0.0002
Boron	0.0690	0.0140	0.0330
Cadmium	0.010	<0.003	<0.004
Calcium	58.8	36.9	47.7
Cerium	<0.02	<0.02	<0.02
Chromium	0.007	<0.006	<0.006
Cobalt	0.004	<0.002	<0.002
Copper	0.077	<0.002	<0.024
Gallium	<0.01	<0.01	<0.01
Iron	4.22	0.07	1.07
Lanthanum	<0.003	<0.003	<0.003
Lead	<0.02	<0.02	<0.02
Lithium	0.015	0.001	0.007
Magnesium	13.6	6.54	10.64
Manganese	0.370	0.034	0.166
Molybdenum	0.026	<0.006	<0.008
Nickel	0.027	<0.007	<0.011
Niobium	<0.01	<0.01	<0.01
Phosphorus	7.64	0.12	2.97
Potassium	14.4	2.3	7.3
Scandium	<0.0004	<0.0004	<0.0004
Silver	<0.004	<0.004	<0.004
Sodium	42.2	12.5	21.2
Strontium	0.168	0.083	0.129
Thorium	<0.01	<0.01	<0.01
Titanium	0.062	<0.002	<0.012
Vanadium	<0.004	<0.004	<0.004
Zinc	0.567	0.015	0.190
Zirconium	<0.002	<0.002	<0.002

[a]All samples collected in accordance with the Oak Ridge Sewer Use Ordinance were within the limits set in the permit with the exception of one cyanide result. The single cyanide value above the limit specified in the permit was investigated, but the cause has not been determined. Follow-up sampling indicated the cyanide excursion was of short duration and that samples have returned to normal values.
[b]Units are in mg/L unless noted otherwise.
[c]Not applicable.

Table 4.20. Annual summary for Y-12 Plant discharges to the City of Oak Ridge east-end sewage treatment facility, 1987. Source: Rogers et al. (1988).

Parameter	Concentration[a]		
	Max	Min	Av
Mercury	0.0080	0.0003	0.0024
Alpha (pCi/L)	150.0	<1.0	<36.6
Beta (pCi/L)	85.0	<4.0	<27.9
^{238}Pu (pCi/L)	<2.30	<0.17	<0.53
^{235}U (pCi/L)	12.00	<0.12	<1.71
^{235}U (%)	2.08	0.31	1.16
Uranium	0.190	0.002	0.024
CN	0.011	<0.002	<0.005
NO_3-N	4.5	0.2	1.1
pH (units)	8.1	7.6	NA[b]
Kjeldahl nitrogen	22	6.0	13
TSS	210	<5.0	<35
PCB	<0.0005	<0.0005	<0.0005
BOD	86	<5	<29
Aluminum	0.92	0.05	0.23
Arsenic	<0.04	<0.04	<0.04
Barium	0.0750	0.0346	0.0472
Beryllium	<0.0001	<0.0001	<0.0001
Boron	0.0600	0.0160	0.0260
Cadmium	<0.003	<0.003	<0.003
Calcium	53.3	37.9	42.7
Cerium	<0.02	<0.02	<0.02
Chromium	<0.006	<0.006	<0.006
Cobalt	<0.002	<0.002	<0.002
Copper	0.024	0.005	0.014
Gallium	<0.01	<0.01	<0.01
Iron	0.91	0.16	0.36
Lanthanum	<0.003	<0.003	<0.003
Lead	<0.02	<0.02	<0.02
Lithium	0.064	0.004	0.018
Magnesium	12.2	0.05	9.57
Manganese	0.167	0.043	0.084
Molybdenum	0.154	0.010	0.043
Nickel	0.010	<0.007	<0.007
Niobium	<0.01	<0.01	<0.01
Phosphorus	3.60	0.89	2.14
Potassium	10.3	3.6	5.8
Scandium	<0.0004	<0.0004	<0.0004
Silver	0.046	<0.004	<0.012
Sodium	17.7	8.4	13.6
Strontium	0.144	0.102	0.118
Thorium	<0.01	<0.01	<0.01
Titanium	0.007	<0.002	<0.003
Vanadium	0.005	<0.004	<0.004
Zinc	0.222	0.059	0.122
Zirconium	<0.002	<0.002	<0.002

[a]All units are in mg/L unless noted otherwise.
[b]Not applicable.

Table 4.21. Surface water quality monitoring data for Upper Bear Creek, Y-12 Plant, 1987. Source: Rogers et al. (1988)

Parameter	Concentration[a]		
	Max	Min	Av
Hg	0.0020	<0.0002	<0.0004
Alpha (pCi/L)	1000.0	6.7	496.5
^{241}Am (pCi/L)	<6.80	<0.10	<1.53
Beta (pCi/L	2000.0	9.3	776.1
^{237}Np (pCi/L)	18.00	0.23	<2.43
^{238}Pu (pCi/L)	<2.70	<0.03	<0.70
$^{239/240}$Pu (pCi/L)	<1.80	<0.03	<0.30
^{99}Tc (pCi/mL)	<40.00	<0.03	<1.50
^{235}U (pCi/L)	40.00	<0.58	<11.17
^{235}U (%)	5.44	0.21	0.50
U	1.690	0.019	0.969
CN	0.120	<0.002	<0.013
F	1.1	0.5	0.8
Nitrate-nitrogen	600.0	6.6	198.0
Dissolved oxygen	12.0	2.8	6.8
pH (units)	7.5	6.8	7.2
Phenols	0.140	<0.001	<0.004
TDS	4100	290	2003
TSS	100	0.5	<10
Chloroform (μg/L)	80	<10	<10
Methylene chloride (μg/L)	48	<10	<10
Perchloroethylene (μg/L)	<10	<10	<10
Trichloroethane (μg/L)	<10	<10	<10
Trichloroethylene (μg/L)	<10	<10	<10
PCB	0.0006	<0.0005	<0.0005
Aluminum	20.60	<0.01	<1.01
Arsenic	<0.04	<0.04	<0.04
Barium	0.1950	0.0275	0.0764
Beryllium	0.0010	<0.0001	<0.0002
Boron	0.1700	0.0350	0.1088
Cadmium	0.017	<0.003	<0.006
Calcium	680.0	59.8	352.4
Cerium	0.03	<0.02	<0.02
Chromium	0.014	<0.006	<0.006
Cobalt	0.008	<0.002	<0.002
Copper	0.025	<0.002	<0.004
Gallium	<0.02	<0.01	<0.01
Iron	11.70	<0.02	<0.57
Lanthanum	0.003	<0.003	<0.003
Lead	0.02	<0.02	<0.02
Lithium	0.060	0.011	0.021
Magnesium	130.0	8.2	60.8
Manganese	5.400	0.139	1.918
Molybdenum	<0.006	<0.006	<0.006
Nickel	0.029	<0.007	<0.008
Niobium	<0.06	<0.01	<0.01
Phosphorus	0.30	<0.06	<0.07
Potassium	21.2	3.6	9.2
Scandium	0.0033	<0.0004	<0.0005
Silver	0.006	<0.004	<0.004
Sodium	179.0	29.2	82.5
Strontium	1.570	0.148	0.886
Thorium	<0.01	<0.01	<0.01
Titanium	0.119	<0.002	<0.009
Vanadium	<0.018	<0.004	<0.004
Zinc	0.097	<0.001	<0.009
Zirconium	0.006	<0.002	<0.002

[a]All units are in mg/L unless noted otherwise.

Monitoring has also been conducted at the influent to New Hope Pond which is located near the south corner of the east end of the Y-12 Plant. Most of the samples collected at this location are time-proportional, 24-h composites. Both radiological and nonradiological parameters are analyzed at this location, and data collected are used for a variety of purposes. Samples at the influent to New Hope Pond are collected at the same time as samples from the effluent of the pond to help determine the effectiveness of the pond in improving the quality of water in East Fork Poplar Creek as well as monitoring the effectiveness of Y-12 Plant's area source control activities. Summaries of the 1987 influent data are presented in Tables 4.22 and 4.23. These data indicate that New Hope Pond acted as an efficient sink for contaminants leaving the Y-12 site. New Hope Pond has recently been closed and replaced by Lake Reality, a larger, lined retention-settling basin that drains to EFPC.

Surface Water Monitoring on the Clinch River by Other Institutions. Both TVA and the U.S. Geological Survey (USGS) monitor water quality just below Melton Hill Dam. The Tennessee Department of Health and Environment (TDHE) maintains a monitoring station at 3.2 km below the mouth of Poplar Creek and the Oak Ridge Gaseous Diffusion Plant (ORGDP). Data provided by these ongoing surface-water monitoring programs on the Clinch River-Watts Bar Reservoir system will be used in this RFI with data from the surface-water monitoring programs at the three DOE facilities to help characterize contaminant sources, quantify contaminant releases, document contaminant transport patterns, and identify contaminants of concern with regard to potential environmental and human health risks.

Table 4.22. Annual summary for New Hope Pond influent radiological data, Y-12 Plant, 1987. Source: Rogers et al. (1988).

Parameter	Concentration[a]		
	Max	Min	Av
^{241}Am	4.3	<0.27	<1.01
^{137}Cs	<23	<5.4	<11
^{60}Co	<21	<5.6	<12
^{237}Np	<1.6	<0.4	<0.8
^{95}Nb	<24	<6.8	<11
^{238}Pu	<0.97	<0.04	<0.38
$^{239/240}Pu$	<0.22	<0.04	<0.12
^{226}Ra	6.1	<0.4	<1.6
^{106}Ru	<135	<39	<87
^{90}Sr	<9.1	<6.0	<7.0
^{99}Tc (pCi/mL)	<40	<0.02	<3.6
^{228}Th	4.1	0.15	0.97
^{230}Th	<1.6	<0.3	<0.73
^{232}Th	<1.6	<0.09	<0.4
Thorium, total (mg/L)	0.189	<0.003	<0.024
Tritium	<1300	<10	<763.6
^{234}U	19	<0.85	<10
^{235}U activity	19	<0.34	<2.3
^{235}U (%)	1.22	<0.52	<0.83
^{238}U	10	0.3	<5.5
Uranium, total (mg/L)	0.029	0.007	0.017
^{95}Zr	<53	<14	<22

[a]Units are in pCi/L unless noted otherwise.

Table 4.23. Annual summary for New Hope Pond influent nonradiological data, Y-12 Plant, 1987. Source: Rogers et al. (1988).

Parameter	Concentration (mg/L)		
	Max	Min	Av
Mercury	0.22	0.0005	0.0082
Selenium	<0.002	<0.002	0.002
Ammonia	2.1	<0.4	<0.5
BOD	9	<5	<5
COD	35	4.6	<11
Chloride	300	<2	<23
Cyanide	0.113	<0.002	<0.025
Fluoride	11	0.7	1.0
Nitrate	8	1.8	3.1
TOC	250	<2	<6
TDS	670	120	250
TSS	170	<5	<9
Sulfate	110	21	55
Aluminum	4.64	0.09	0.59
Arsenic	<0.04	<0.04	<0.04
Barium	0.468	0.039	0.053
Beryllium	0.0002	<0.0001	<0.0001
Boron	0.067	<0.015	<0.022
Cadmium	<0.003	<0.003	<0.003
Calcium	64.1	38.9	48.0
Cerium	<0.02	<0.02	<0.02
Chromium	0.026	<0.006	<0.007
Cobalt	0.004	<0.002	<0.002
Copper	0.029	0.005	0.012
Gallium	<0.01	<0.01	<0.01
Iron	8.18	0.07	0.77
Lanthanum	<0.003	<0.003	<0.003
Lead	0.02	<0.02	<0.02
Lithium	0.392	0.007	0.025
Magnesium	15.1	9.02	11.6
Manganese	0.229	0.032	0.080
Molybdenum	0.338	0.055	0.162
Nickel	0.36	<0.007	<0.009
Niobium	<0.01	<0.01	<0.01
Phosphorus	0.74	0.2	0.41
Potassium	3.4	1.4	2.1
Scandium	0.0011	<0.0004	<0.0004
Silver	<0.004	<0.004	<0.004
Sodium	148	7	17
Strontium	0.259	0.107	0.131
Thorium	<0.01	<0.01	<0.01
Titanium	0.058	<0.002	<0.006
Vanadium	0.011	<0.004	<0.005
Zinc	0.246	0.043	0.094
Zirconium	0.004	<0.002	<0.002

5. PREVIOUS INVESTIGATIONS OF CONTAMINATION IN OFF-SITE SURFACE WATERS

Past studies have focused primarily on releases of radioactive materials from the Oak Ridge facilities (summarized in the previous section) and on the transport and fate of radionuclides in the Clinch River downstream from the ORR. Much less information exists on releases of metals and organic contaminants. Relatively little effort has been made to characterize the contamination in the Tennessee River-reservoir system downstream of the Clinch River confluence.

5.1 GAMMA-RADIATION SURVEY

The first major program to investigate the spatial distribution of radionuclides released to the Clinch River from the Oak Ridge facilities was a 5-year gamma-radiation survey of surface sediments downstream from the ORR (Cottrell 1959). Annual surveys of the gamma activity associated with the sediment surface were performed for five consecutive years (1954 - 1958) by towing a submersible Geiger-Muller gamma counter along the sediment surface at selected stations between CRM 28 (now upstream of Melton Hill Dam) and the Chickamauga Dam (at TRM 471). Results showed that most of the gamma radioactivity (primarily from ^{137}Cs, ^{60}Co, rare-earth isotopes, and short-lived ^{103}Ru) was associated with sediments in the Clinch River and in Watts Bar Reservoir. However, gamma activity was readily detectable farther downstream in Chickamauga Reservoir and beyond (Fig. 5.1).

5.2 COMPREHENSIVE CLINCH RIVER STUDY

During the 1960-1964 "Clinch River Study", a comprehensive physical, chemical, biological, and sedimentological investigation was conducted to determine the environmental fate, ecological effects, and impact on man of radionuclides released to the Clinch River from ORNL (Struxness et al. 1967). However, this intensive study was restricted primarily to the Clinch River itself. Only a limited number of samples were collected for Watts Bar Reservoir (e.g., Churchill et al. 1965). Results of the Clinch

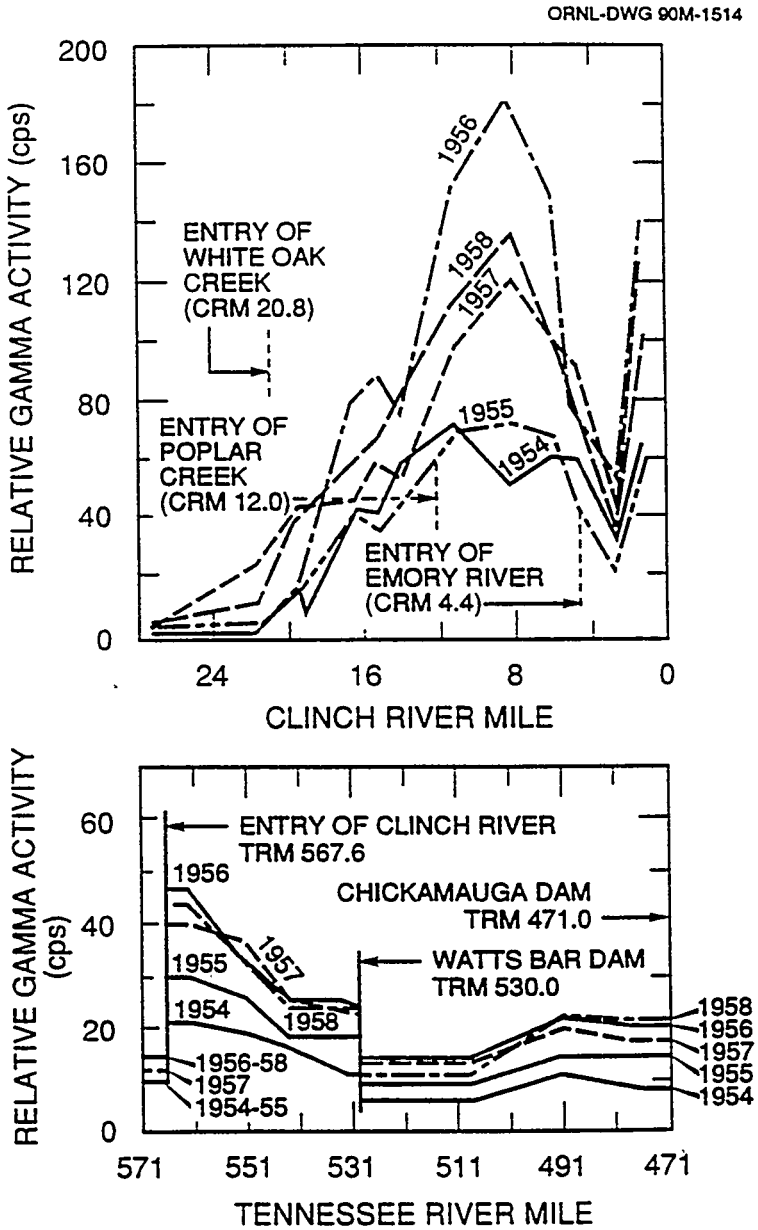

Fig. 5.1. Gamma radiation (expressed in counts per second) along the longitudinal axis of the Clinch River (from the Oak Ridge Reservation to the Clinch River mouth at Kingston, upper panel) and the Tennessee River (throughout Watts Bar and Chickamauga reservoirs, lower panel). Gamma activity was measured by Cottrell (1959) in 1954-1958 by towing a submersible gamma detector along the sediment surface. Note change in the gamma-activity scale in the upper and lower panels.

River Study indicated that soluble contaminants (e.g., ^{3}H, ^{90}Sr) released from White Oak Lake were rapidly diluted in the Clinch River and were flushed downstream without accumulating to any great extent (Nelson 1962; Cowser et al. 1966). Results from ^{90}Sr analysis of water samples and the valves (shells) of freshwater clams showed that concentrations of ^{90}Sr were detectable in the Tennessee River up to 500 miles downstream from the release point (WOD) and could be accurately predicted on the basis of dilution (Churchill et al. 1965, Nelson 1967, 1969).

Only about 21% of the ^{137}Cs, 9% of the ^{60}Co, and less than 1% of the ^{90}Sr previously released from White Oak Lake had accumulated in the sediments of the Clinch River (Pickering et al. 1966; Struxness et al. 1967). Parker et al. (1966) concluded that very little of the radioactive material introduced into the Clinch River was retained in either the bottom sediments or in the biota. Struxness et al. (1967) concluded that, with regard to radionuclide transport, the Clinch River functioned much like a pipeline by transporting both soluble and particle-reactive materials downstream.

5.3 CLINCH RIVER BREEDER REACTOR SITE STUDY

A third set of studies of the Clinch River sediments was conducted in the 1970's to reevaluate the distribution of ^{137}Cs and to document levels of plutonium in the Clinch River sediments near the site proposed for the Clinch River Breeder Reactor (Project Management Corp. 1975, Oakes et al. 1982, TVA 1981, 1983, 1984). Those results indicated that much of the ^{137}Cs previously deposited in the Clinch River had been eroded from the river sediments and transported downstream. Oakes et al. (1982) reported that $^{239,240}Pu$ activities in the sediment were as high as 2 pCi/g (75 mBq/g) in some areas of the Clinch River.

5.4 ORGDP SEDIMENT SURVEY

During 1985, approximately 180 surface sediment samples and three sediment cores were collected from Poplar Creek and the Clinch River in the vicinity of the ORGDP to document levels of contamination and identify contaminant source areas (Ashwood et al.

1986). Poplar Creek sediments were found to contain above-background levels of several trace metals (Ag, Cd, Cr, Hg, Se, and Zn), PCBs, and radionuclides (^{238}U, ^{60}Co, ^{99}Tc, and ^{137}Cs). Except for mercury, the highest levels of trace metal contamination occurred in the sediments of the K1700 stream and the K901A chromate pond (refer back to Fig. 4.3). The highest mercury levels occurred in the sediments of Poplar Creek, as a result of discharges from Y-12 via East Fork Poplar Creek (EFPC). Poplar Creek sediments upstream of the ORGDP facility were contaminated with uranium. This result is consistent with the surface water monitoring data for uranium and suggests that Y-12 may be a significant source for uranium in the Poplar Creek and Clinch River system. Although some ^{137}Cs and ^{60}Co may have entered Poplar Creek from EFPC, most has apparently entered from the Clinch River during periods of backflow into Poplar Creek. PCB concentrations were as high as 13 $\mu g/g$ in the sediments of Pond K1007B, but were less than 1 $\mu g/g$ in Poplar Creek sediments downstream from the pond discharge site.

5.5 BIOTIC SURVEYS OF POPLAR CREEK, WHITE OAK CREEK, AND ADJACENT PORTIONS OF THE CLINCH RIVER

The Project Management Corporation (1975) conducted a one-year (1974-1975) physical, chemical, and biological survey of the Clinch River just upstream of the ORGDP as part of the preconstruction environmental assessment associated with the Clinch River Breeder Reactor Project. An additional one-year survey (1975-1976) provided preoperational baseline data necessary to assess the potential environmental impacts of the Exxon Nuclear Fuel Recovery and Recycling Center (NFRRC) (Exxon Nuclear Company, Inc. 1976). These data were summarized and supplemented by Loar et al. (1981) and Loar (1981) in their investigations of the biotic communities of White Oak Creek, Poplar Creek, and the Clinch River. Loar and co-workers also summarized and compared earlier surveys of the White Oak Lake, WOC embayment, and Clinch River fish communities to the results of their investigations.

Samples of the aquatic communities near the ORGDP were collected from April 1977 through September 1978 (Loar 1981). Sampling of the White Oak Creek watershed,

White Oak Lake, WOC embayment, and the Clinch River near the mouth of WOC (Loar et al. 1981) occurred from March 1979 through June 1980. In both studies, the taxonomic composition, abundance, and temporal distributions of the major biotic communities (phytoplankton, zooplankton, ichthyoplankton, periphyton, benthic macroinvertebrate, and fish) were characterized. Samples of benthic macroinvertebrates and fish tissue were also analyzed for heavy metals.

Loar et al. (1981) reported that the Clinch River immediately below Melton Hill Dam is characterized by low densities of phytoplankton, but relatively high periphyton biomass. The distribution of macrobenthos populations are affected to some extent by the peaking-power operation of Melton Hill Dam, although macroinvertebrate densities in this region of the river were generally similar to those found 2 to 10 km downstream. Ichthyoplankton (primarily clupeid larvae) densities were also low immediately downstream from the dam, but significant increases in the numbers of fish larvae occurred in the Clinch River below the mouth of Poplar Creek.

Large numbers of sauger migrate from Watts Bar Reservoir up the Clinch River to Melton Hill Dam in late winter and return to the reservoir in early summer. This migration supports a popular sport fishery at this time of the year. Similarly, in early summer, striped bass move from the main body of Watts Bar Reservoir into the cooler waters of the Clinch River arm of the reservoir. White bass, gizzard shad, and threadfin shad also exhibit seasonal migrations from the reservoir, up the Clinch River, and into the mouths of creeks and embayments for spawning. Loar (1981) concluded that Poplar Creek and its embayment are fertile, important spawning sites for gizzard shad and white bass.

Loar (1981) reported that mercury concentrations in the sediments of lower Poplar Creek (between PCM 5.5 and 0.5) were very high in certain areas. The nonuniform distribution of mercury in lower Poplar Creek suggested a large, local, but unknown source. It later became known that large quantities of mercury had been released from the Y-12 Plant into East Fork Poplar Creek during 1950-1963 (see Section 4.3.3, above

and Section 5.5, below). Elevated levels of mercury and PCBs were also found in game fish collected from lower Poplar Creek and the Clinch River.

The species composition and abundance of fishes observed during the 1974-1975 survey (Project Management Corporation 1975) was similar to those reported by Loar (1981) and Loar et al. (1981) for the Clinch River in the vicinity of the ORR. No species were collected that are listed as threatened or endangered by the State of Tennessee (Tennessee Wildlife Resources Commission 1975) or by the U.S. Department of the Interior (1980).

5.6 OAK RIDGE TASK FORCE STUDIES

Declassification of information (in 1983) on mercury discharged and unaccounted for from the Y-12 Plant (Wilcox 1983, Marshall 1983) led to increased examination of downstream areas for mercury contamination (Elwood 1984; Van Winkle et al. 1984) and to the organization of the interagency Oak Ridge Task Force (ORTF). The Task Force evaluated associated threats of off-site contamination to human health, fish, and wildlife. Most of the ORTF investigation focused specifically on the mercury contamination of East Fork Poplar Creek and its floodplain. Several studies relevant to the Clinch River RFI were supported by the ORTF including (1) instream contaminant surveys by the Tennessee Valley Authority (TVA 1986), (2) an investigation of contaminant uptake by floodplain plants (Gist 1987), (3) a preliminary investigation of the extent of mercury contamination of off-site surface waters (Turner et al. 1984), and (4) a preliminary contaminant screening studies for assessing risks to human health (Hoffman et al. 1984, Travis et al. 1986, 1989).

5.6.1 TVA Instream Contaminant Study

A total of 1,526 water, sediment, and aquatic biota samples were collected by the Tennessee Valley Authority to assess off-site mercury contamination derived from the Y-12 releases (TVA 1985a,b,c,d,e; 1986). This ORTF-supported study focused primarily on EFPC. It was estimated that of the ≈150 metric tons of mercury discharged from Y-12,

about 77 metric tons of mercury had accumulated in the EFPC floodplain and that 0.2 metric tons were exported annually from the EFPC.

5.6.2 Preliminary Contaminant Screening Analysis

In addition to mercury, various other contaminants were analyzed in selected sediment and fish tissue samples. These data were summarized by Hoffman et al. (1984), who conducted a preliminary (screening-level) human-health risk assessment for the purpose of identifying contaminants warranting further study. The screening analysis used reported concentrations of more than 130 contaminants (including radionuclides, metals, and organic compounds) in sediment samples collected from EFPC and the Clinch River in the vicinity of the ORR. The contaminants listed in Table 5.1 were found to warrant further investigation as potential human health risks, because they had screening level intake (SLI) to allowable daily intake (ADI) ratios that were equal to or greater than 1 and concentration values that were greater than those in reference station samples. Travis et al. (1986, 1989) conducted a similar screening-level risk assessment based on contaminant concentrations in fish tissue which yielded similar conclusions.

5.6.3 Mercury Contamination of Off-site Surface Waters

Turner et al. (1985) collected seven sediment cores from Watts Bar and Chickamauga Reservoirs (Fig. 5.2) to determine the downstream extent of the mercury contamination. Concentrations of Hg and ^{137}Cs were strongly correlated in sediment cores collected in Watts Bar Reservoir, both exhibiting peak concentration at sediment depths ranging from about 40 cm to 100 cm (Fig. 5.3). Comparison of the aquatic discharge histories of inorganic Hg from the Y-12 Plant and of ^{137}Cs from ORNL's White Oak Lake (Fig. 5.4) shows the near-coincidence of the peak release of ^{137}Cs in 1956 with that of Hg in 1957-58, and sharp declines in both releases after 1959.

Of the cores collected in 1983 from the Clinch River, Watts Bar Reservoir, and Chickamauga Reservoir, the highest concentrations of Hg (37 μg/g) and of Cs-137 (152 pCi/g) were found in the core obtained at CRM 1 (just upstream from the Clinch River

Table 5.1. Contaminants whose concentrations in sediment at any sampling location exceed sediment concentrations at either control locations PC-3 or CRM-24. Source: Hoffman et al. (1984).

ORGANICS
Acenaphthalene
Anthracene
Benzo(a)pyrene
Benzo(a)fluoranthene
Chrysene
Fluoranthene
Methylene chloride
Phenanthrene
Pyrene
Tetrachloroethylene
3,4-Benzofluoranthene
METALS AND CYANIDE
Arsenic
Beryllium
Cadmium
Chromium
Copper
Lead
Mercury
Nickel
Selenium
Silver
Zinc
RADIONUCLIDES
Cs-137
NP-237
TC-99
U-238

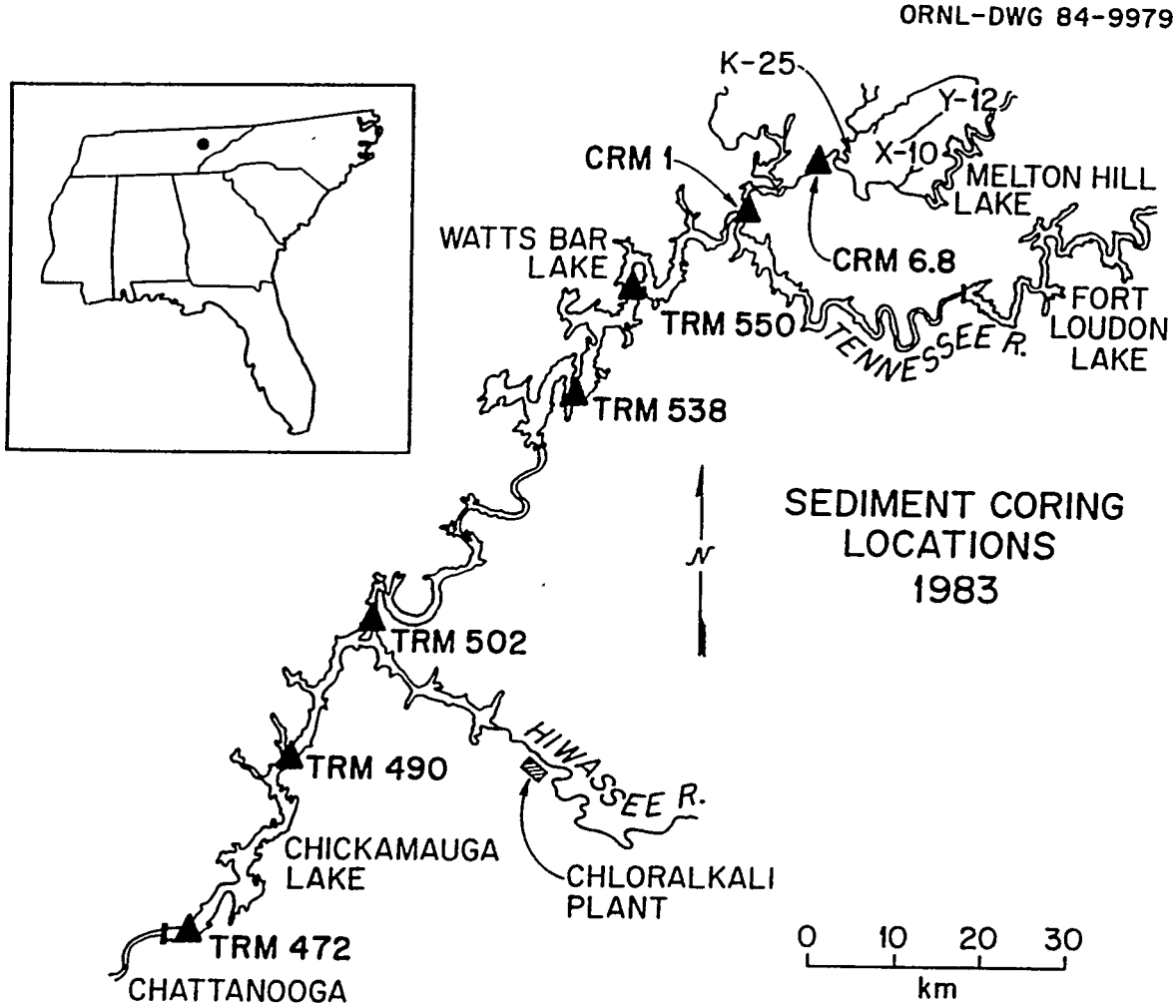

Fig. 5.2. Sediment coring sites in Watts Bar and Chickamauga reservoirs sampled by Turner et al. (1985) to determine the downstream extent of mercury contamination derived from Y-12 releases. CRM is Clinch River Mile, TRM is Tennessee River Mile.

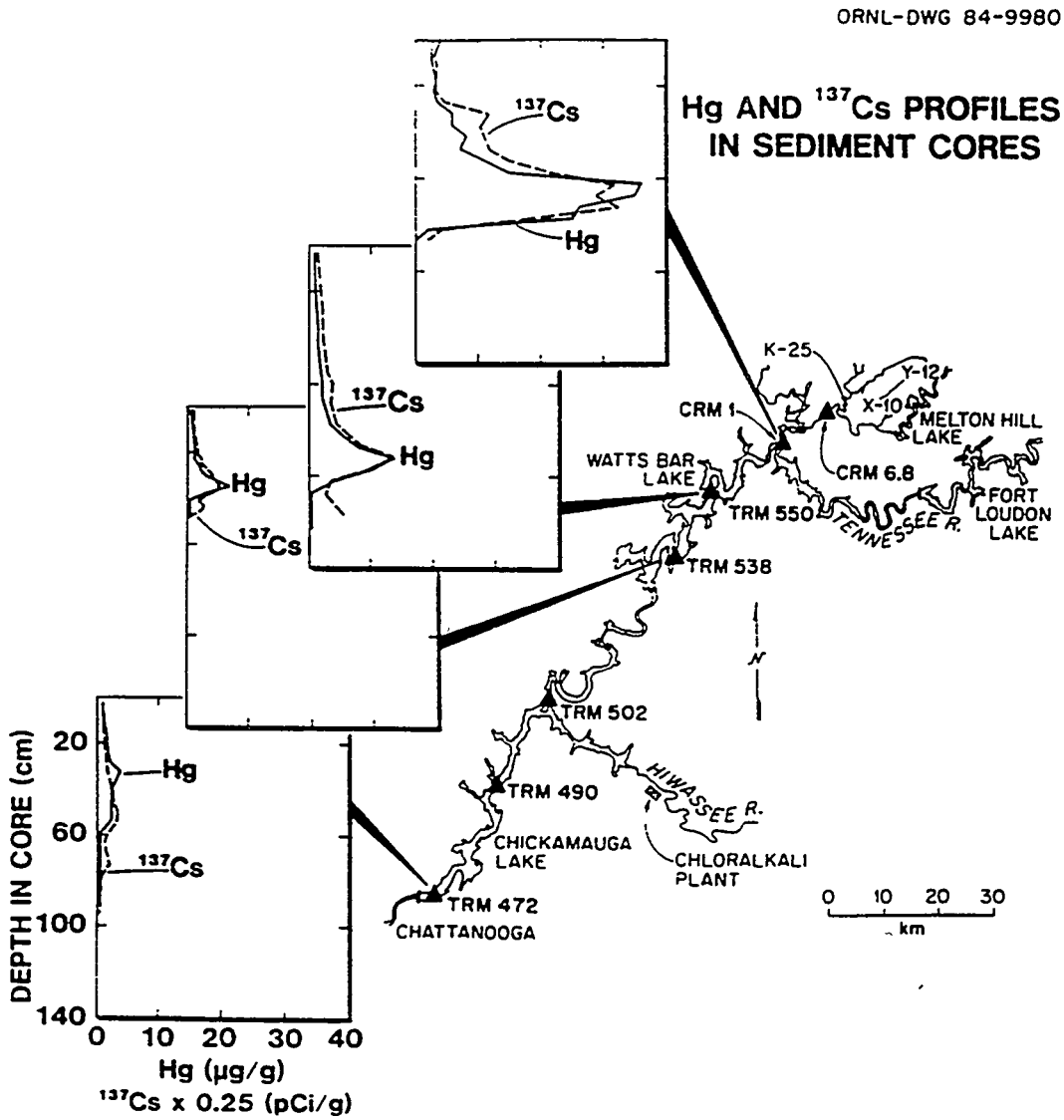

Fig. 5.3. The vertical distributions of mercury (Hg) and cesium-137 ^{137}Cs) in selected sediment cores obtained from Watts Bar and Chickamauga reservoirs by Turner et al. (1985). All profiles are plotted using the same sediment-depth, Hg-concentration, and ^{137}Cs-activity scales.

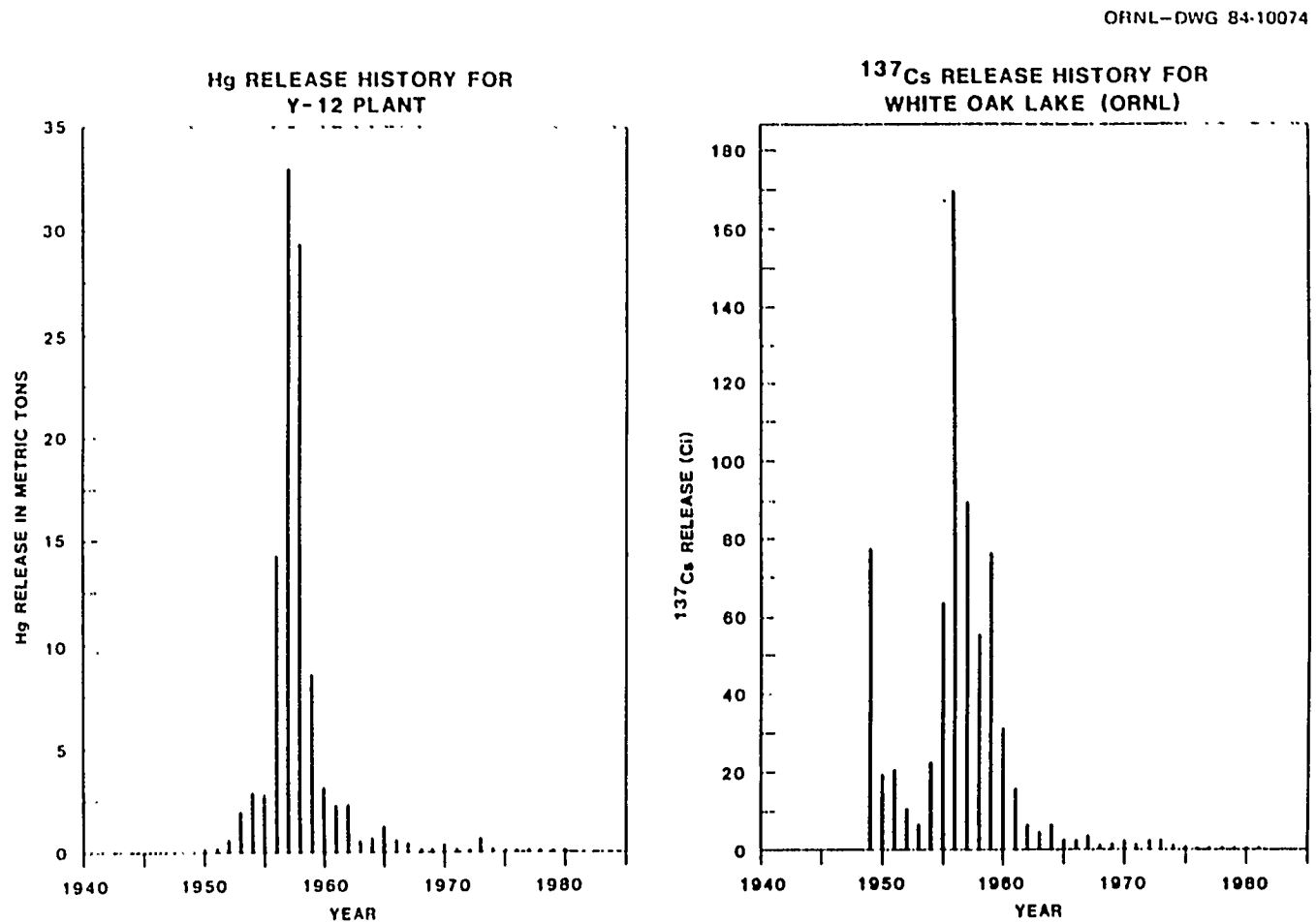

Fig. 5.4. The release histories (aquatic discharges) of Hg from the Y-12 Plant and of ^{137}Cs from the ORNL (Turner et al. 1985).

mouth) near Kingston, Tennessee (Table 5.2). Sediment cores collected from lower Chickamauga Reservoir, however, contained more complex Hg profiles (in part, a result of additional Hg inputs to the reservoir from a chloralkali plant located on the Hiwassee River), but very similar ^{137}Cs profiles to those in Watts Bar Reservoir (Turner et al. 1984).

5.7 RECENT STUDIES TO DETERMINE THE EXTENT OF CLINCH RIVER AND WATTS BAR RESERVOIR CONTAMINATION

5.7.1 ^{137}Cs and Hg in Watts Bar Reservoir Sediments

Olsen and Kimmel (1987, 1988) have recently measured the vertical distribution of ^{137}Cs in over 60 sediment cores and the ^{137}Cs activity in 187 surface-sediment samples collected from Watts Bar Reservoir. Surface sediment samples were used to develop a map of sediment characteristics and to identify sites best suited for sediment coring. Radiocesium was chosen because: (1) its primary source is ORNL, (2) its history of release from WOL is well documented, (3) it is rapidly sorbed to riverborne suspended matter and, therefore, serves as an excellent tracer for the transport and accumulation patterns of a wide variety of other particle-reactive contaminants (e.g., Hg, Pu, PCBs), and (4) it is accurately measured by gamma spectrometry. The objectives of this preliminary scoping study were to (1) use ^{137}Cs to evaluate the extent of contaminant accumulation in the reservoir sediments, (2) preliminarily identify highly contaminated off-site areas that could constitute potential risks to human-health or the environment, and (3) estimate the retention efficiency of the reservoir for ^{137}Cs and, thereby, for other particle-associated contaminants.

The results of this scoping study confirmed the earlier ORTF conclusions that the vertical distribution of ^{137}Cs in the Watts Bar Reservoir sediment is strongly correlated with the historical record of ^{137}Cs discharges from ORNL, exhibiting a large subsurface peak coincident with the draining of WOL in the mid-1950s. The sediment depth of the subsurface peak and the thickness of the ^{137}Cs-contaminated sediment vary with the rate of sediment accumulation and the location within the reservoir. In areas of rapid

Table 5.2. Levels of Hg and ^{137}Cs in surface (0-2 cm) sediments and subsurface peaks in core collected in 1983 from the Clinch River, Watts Bar Reservoir, and Chickamauga Reservoir. Source: Turner et al. (1984).

	Surface		Subsurface Peak	
	Hg (μg/g)	^{137}Cs (pCi/g)	Hg (μg/g)	^{137}Cs (pCi/g)
	Clinch River			
CRM 6.8	3.8	-[a]	13	-[a]
CRM 1	3.0	15	37	152
	Watts Bar Lake			
TRM 550	0.82	4.2	14	54
TRM 538	0.68	3.9	6.9	21
	Chickamauga Lake			
TRM 502[b]	0.37	-[a]	0.54	-[a]
TRM 490	0.73	-[a]	2.6	0
TRM 472	0.78	2.2	3.5	12

[a]Not determined.
[b]Multiple sand layers in core; period of deposition uncertain.

sediment accumulation, such as in the upper portion of the reservoir and along the old river channel, the highest ^{137}Cs concentrations occur at sediment depths as great as 80-90 cm. In areas of slower sediment accumulation and in off-channel areas, maximum levels of ^{137}Cs occur nearer the sediment surface. The ^{137}Cs inventory of most sediment cores from Watts Bar Reservoir far exceeds the background (fallout) inventory for 1950-1987 (Table 5.3).

The vertical distributions of ^{137}Cs in a sediment core from upper Watts Bar Reservoir (Fig. 5.5) and from an uncontaminated reference site (Norris Reservoir, located on the Clinch River upstream from the Oak Ridge facilities) (Fig. 5.6), illustrate that:

(1) peak ^{137}Cs levels in Watts Bar Reservoir sediments far exceed and predate the 1963 peak in ^{137}Cs fallout derived from atmospheric bomb testing,

(2) the ^{137}Cs activity peak in Watts Bar Reservoir sediments corresponds to the mid-1950's peak in ^{137}Cs discharges coincident with the draining of White Oak Lake, and

(3) present-day levels of ^{137}Cs in near-surface Watts Bar Reservoir sediments exceed average background fallout levels by a factor of 10 and exceed the 1963 fallout peak level in Norris Reservoir sediments by a factor of 2.

The total accumulation of ^{137}Cs in Watts Bar Reservoir sediments was estimated by measuring the inventory of ^{137}Cs in each sediment core (Fig. 5.7) and extrapolating these data spatially over areas of similar sedimentary characteristics. A Geographic Information System (GIS) and ARC:INFO software were employed in making these spatial extrapolations of the ^{137}Cs inventory data. The reservoir surface area (from the city of Kingston to Watts Bar Dam) was subdivided into polygons on the basis of (1) proximity to the Clinch River mouth, (2) sediment characteristics, and (3) the ^{137}Cs concentration in surface-sediment samples. A ^{137}Cs inventory was then calculated for each polygon. In areas where no sediment cores were collected, the ^{137}Cs inventory was estimated as an average calculated from inventories for sediment cores collected within the same vicinity and having the same sediment characteristics.

Table 5.3. Radionuclide inventories in Watts Bar Reservoir sediment.

Location	Water depth	Sediment type	Cs-137 inventory (mBq/CM2)	BE-7 inventory (mBq/cm2)
KCP-A	11 m	Soft mud	58719	46
TN 567.5	15 m	Soft mud	36488	48
GC SLEW	3 m	Soft mud	2193	28
7th GREEN	3 m	Clay mud	5486	16
C5-4-5	6 m	Soft mud	30525	47
C5-4-2	3 m	Sandy mud	558	1
C6-1-6	4 m	Soft mud	15059	13
C6-2-1	6 m	Soft mud	26492	30
C6-2-2	11 m	Soil sed	>6882	59
C6-2-4	9 m	Soft mud	>8066	59
CC #1	7 m	Sandy mud	3367	38
CC #3	7 m	Sandy mud	4107	40
C6-3-1	10 m	Sandy mud	11618	9
C6-3-2	13 m	Soft mud	>17538	48
C6-3-3	5 m	Soft mud	20054	17
C6-4-4	8 m	Soft mud	20128	78
C6-4-M	9 m	Soft mud	>14948	66
C6-4-9	8 m	Soil sed	3853	7
C7-1-1	10 m	Soft mud	11470	31
C7-1-5	15 m	Soft mud	11507	31
ROCK LD	5 m	Soil sed	3139	13
NEW HOPE	4 m	Sand & grav	144	10
C7-2-2	17 m	Soft mud	>16132	37
C7-2-5	12 m	Soft mud	>18796	37
C7-2-7	16 m	Clay mud	>7585	37
C7-3-4	16 m	Soft mud	>23458	52
C7-3-5	7 m	Soft mud	16280	20
C8-1-2	11 m	Clay mud	5846	22
C8-1-4	17 m	Soft mud	>23199	36
C8-1-5	10 m	Clay mud	6031	7
C8-1-7	17 m	Soft mud	6660	67
C8-2-3	22 m	Soft mud	12691	67
C8-2-4	11 n	Sandy mud	427	35
C7A-1-10	15 m	Soft mud	4588	34
C7A-2-2	8 m	Soft mud	>5661	43
C8-3-1	20 m	Soft mud	>10027	10
C8-3-3	7 m	Soil sed	4958	26
C9-1-1	8 M	Sandy mud	9842	4
C9-1-2	16 m	Soft mud	>18685	71

Table 5.3. (continued)

Location	Water depth	Sediment type	Cs-137 inventory (mBq/CM2)	BE-7 inventory (mBq/cm2)
C9-1-3A	3 m	Soil sed	236	26
C9-2-4	13 m	Soil sed	52	0
C9-2-6	12 m	Soft mud	>15947	48
C9-2-7	15 m	Soft mud	11026	0
C9-2-8	13 m	Soft mud	8880	41
C9-2-11	21 m	Sand & grav	200	0
C9-3-4	23 m	Soft mud	>12617	45
C9-3-7	12 m	Soft mud	12543	111
C9-4-3	16 m	Soft mud	20572	34
C9-4-5	25 m	Soft mud	>4514	46
C10-1-2	10 m	Soft mud	3996	32
C10-2-A	10 m	Soft mud	781	39
C10-3-2	8 m	Sandy mud	345	43
C10-5-3	12 m	Soft mud	822	37
C11-1-3	15 m	Soft mud	9250	63
C11-1-9	17 m	Soft mud	10693	38
C11-2-1	25 m	Soft mud	14689	96
C11-2-5	11 m	Soft mud	11322	51
FALLOUT CS-137 INVENTORY (1950-1987)			333	

ORNL-DWG 89M-13949

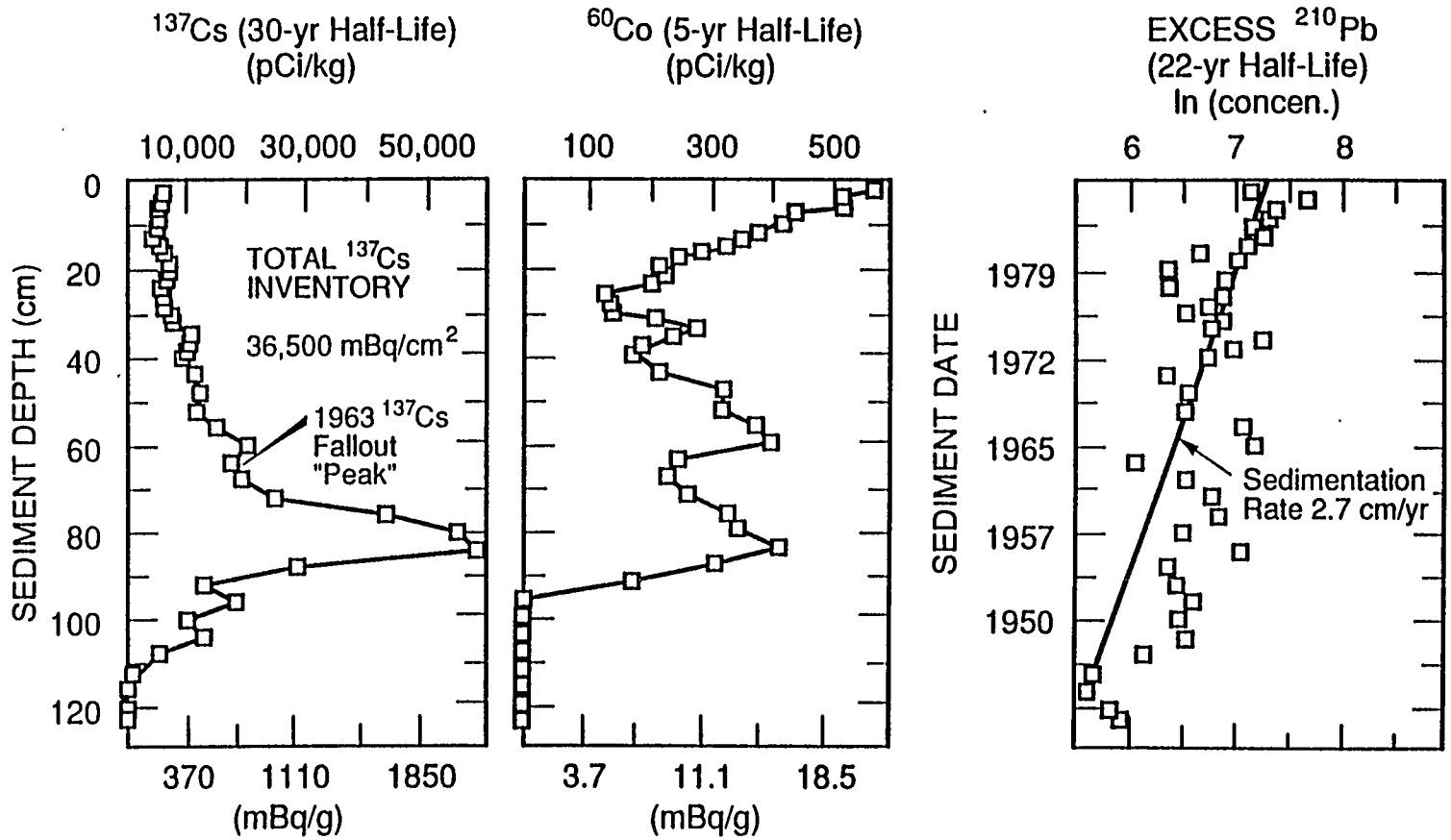

Fig. 5.5. Vertical distributions of ^{137}Cs, ^{60}Co, and excess ^{210}Pb in a sediment core obtained from the Clinch River mouth (TRM 567.5) in upper Watts Bar Reservoir near Kingston, Tennessee.

ORNL-DWG 89M-13948

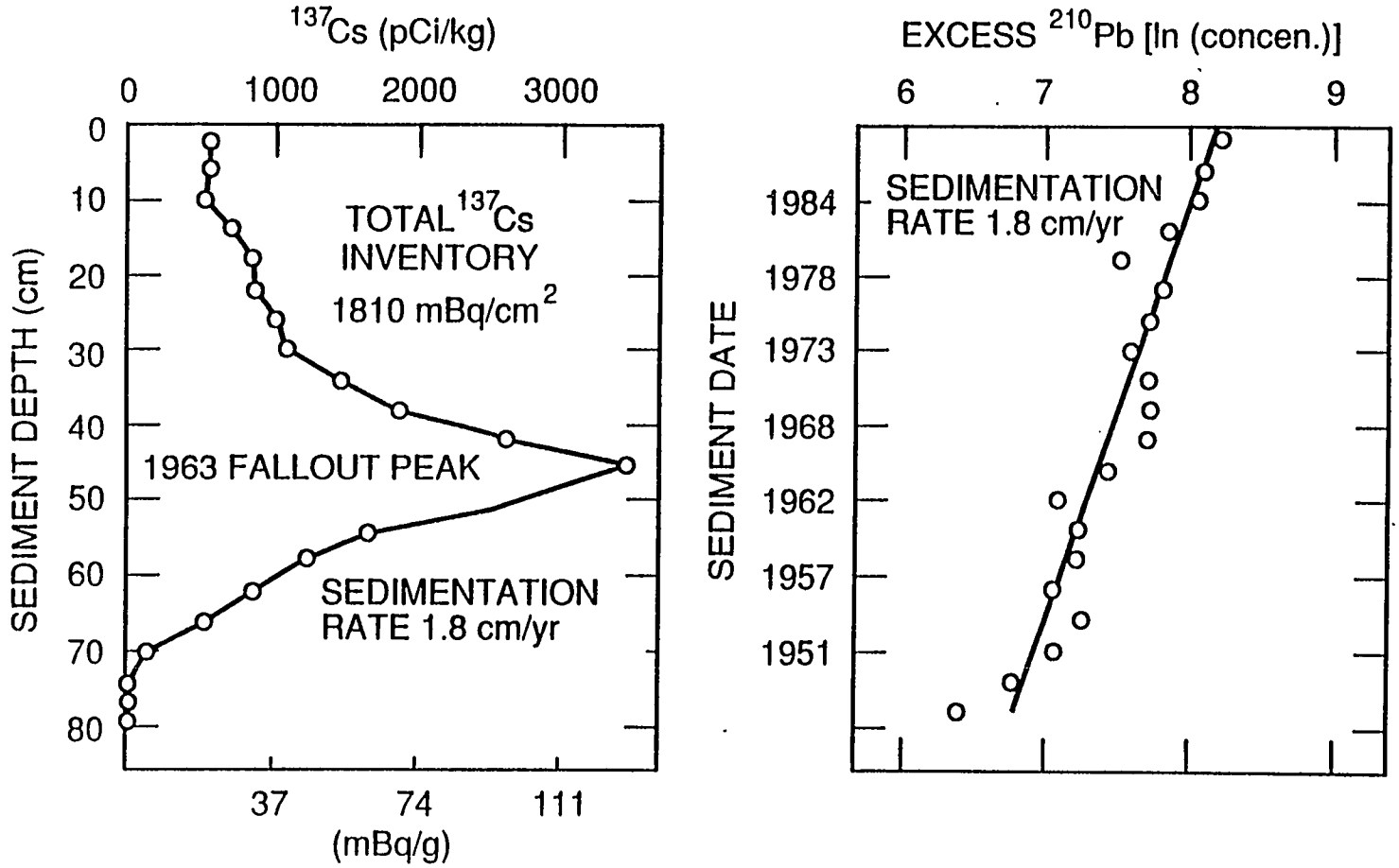

Fig. 5.6. Vertical distributions of ^{137}Cs and excess ^{210}Pb in a sediment core obtained from Norris Reservoir, located on the Clinch River upstream from the U.S. DOE Oak Ridge Reservation (see Fig. 2.6 for location of Norris Reservoir).

ORNL DWG 89M-13941

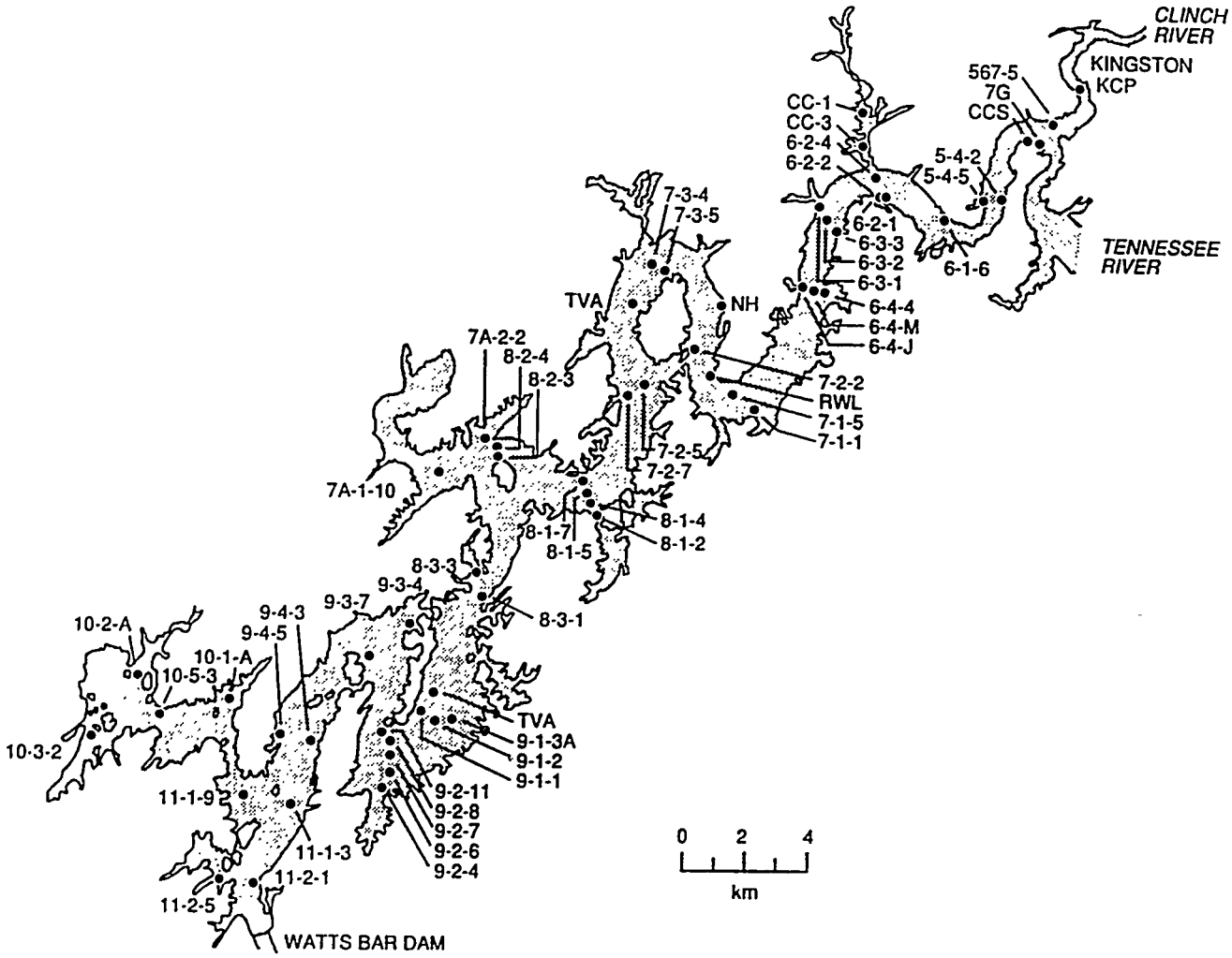

Fig. 5.7. Sediment-coring sites in Watts Bar Reservoir sampled during the recent ^{137}Cs scoping study of the reservoir sediments.

It is estimated that about 1.07 x 10^{13} Bq (290 Ci) of ^{137}Cs now reside in the sediments of Watts Bar Reservoir (Table 5.4). Approximately 89% of this ^{137}Cs activity resides in "deep" sediments, rather than in marginal sediment areas. A decay-corrected total of 1.24 x 10^{13} Bq (335 Ci) of ^{137}Cs has been estimated to have been released from WOL into the Clinch River since 1949, which suggests that about 85% of the total ^{137}Cs released has been retained in the sediments of Watts Bar Reservoir. The remaining 15% of the total ^{137}Cs released may reflect error in the estimate, uncertainty in the ^{137}Cs release history, or may indicate the relative amount of ^{137}Cs retained in floodplain areas or transported downstream past Watts Bar Dam.

The ^{137}Cs inventory for Watts Bar Reservoir sediments and the strong correlation between concentrations of Hg and ^{137}Cs in Watts Bar Reservoir sediment cores allow a preliminary estimate of a Hg inventory for Watts Bar Reservoir sediments. The strong correlation between Hg and ^{137}Cs (Fig. 5.8) results from their nearly coincident discharge histories and from their strong tendencies to associate with particles in aquatic systems. As a result, both Hg and ^{137}Cs tend to accumulate in the same particle deposition areas, and their vertical distributions in sediment cores are nearly identical.

Using ^{137}Cs activity as an indicator of Hg concentration in the sediments, it is estimated that approximately 73 metric tons of Hg has accumulated in the Watts Bar Reservoir sediments between Kingston and the dam (Table 5.4). Because the relationship between Hg and ^{137}Cs in Watts Bar Reservoir sediments was estimated from the vertical profile data in only a limited number of sediment cores, this estimate must be considered preliminary. Further sampling and analysis are planned to more accurately define this relationship.

5.7.2 Contaminants in Fish

Fish from Melton Hill, Watts Bar, and other reservoirs in the upper Tennessee River valley have been collected and analyzed for PCBs as part of a large-scale, ongoing, collaborative sampling effort by the TVA, TDHE, TWRA, and ORNL to determine the extent of PCB contamination of fish in TVA surface-water impoundments. Fish from

Table 5.4. ^{137}Cs and Hg inventories in Watts Bar Reservoir sediments.

Sediment Type	Surface Area (km^2)	^{137}Cs Inventory (10^{12} Bq)	Hg Inventory (mtons)
Soft Mud	58.3	9.0	61
Clay Mud	4.8	0.3	2
Sandy Mud	6.3	0.2	<1
Sand/Gravel	9.8	<0.1	1
Margin Soil	36.6	1.2	8
TOTAL	116. km^2	10.8×10^{12} Bq (290 Curies)	73 TONS

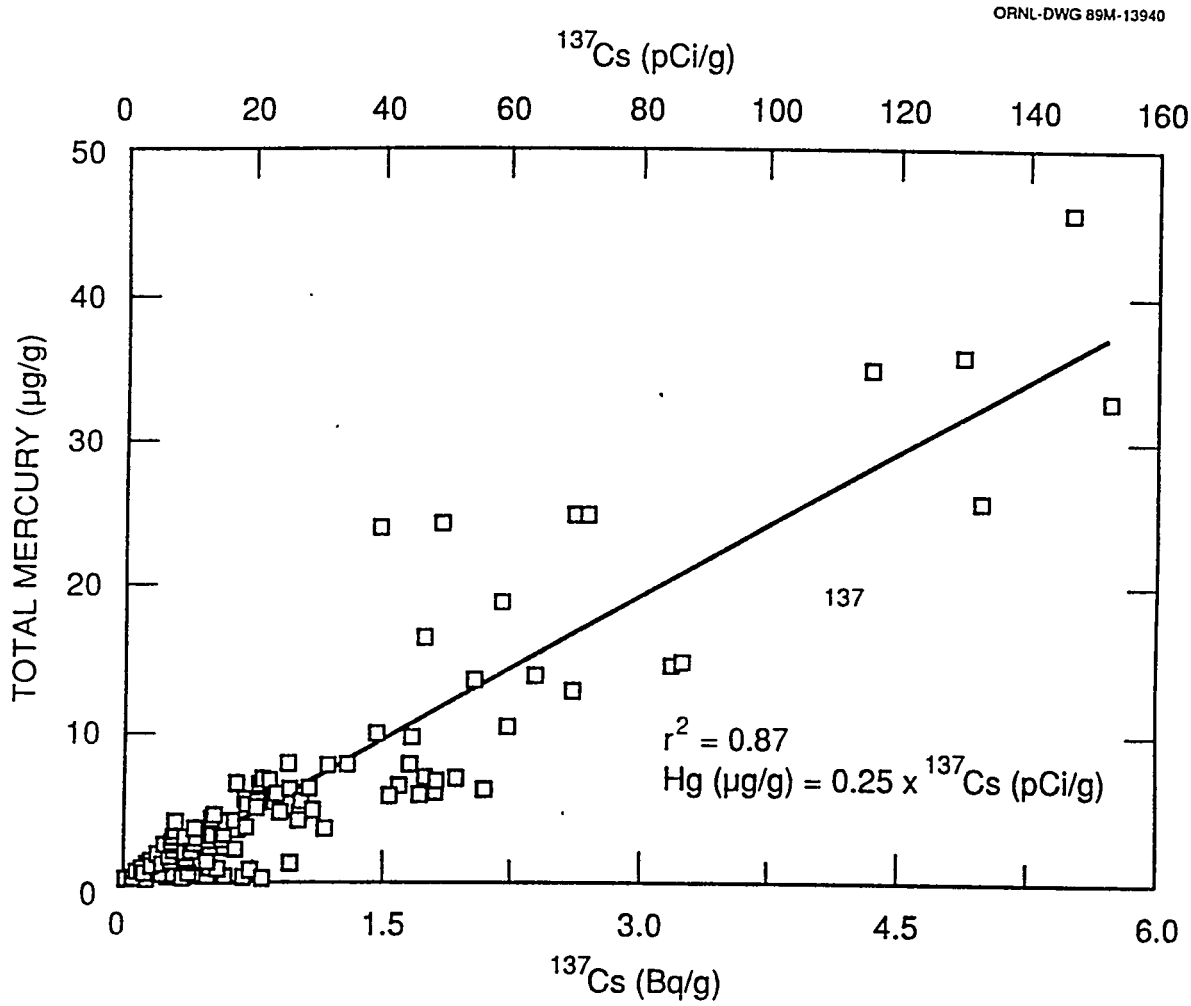

Fig. 5.8. Relationship between total mercury concentration and ^{137}Cs activity in sediment samples from Watts Bar Reservoir.

White Oak Creek, White Oak Lake, WOC embayment, Poplar Creek, Melton Hill Reservoir, and reaches of the Clinch River adjacent to the ORR have been collected and analyzed for PCBs, as part of the ORNL Biological Monitoring and Abatement Program (BMAP). Results of these sampling efforts indicate that PCB contamination of fish in Eastern Tennessee reservoirs is widespread and occurs at levels that commonly exceed the FDA tolerance limit of 2 $\mu g/g$ (Tables 5.5 and 5.6). The Tennessee Department of Health and Environment (TDHE) has recently issued advisories related to consumption of fish from water in the Tennessee River system that may be contaminated with organics. In addition, consumption of catfish from Melton Hill Reservoir is prohibited, and consumption of all fish from East Fork Poplar Creek is banned.

The ORNL BMAP sampling of fish in WOC embayment and the Clinch River and analysis for both PCBs and ^{90}Sr indicates that, although ORNL via White Oak Creek is a source of PCBs to the Clinch River, it is not a unique source (Loar 1988a, 1989). PCB contamination was evident in channel catfish (Tables 5.7 and 5.8) from WOL, WOC embayment, Poplar Creek, the Clinch River, and from Melton Hill Reservoir (upstream from WOC inputs). Additionally, high PCB levels were found in gizzard shad collected from WOL, WOC embayment, and Poplar Creek (Table 5.9). Based on the relationship between the levels of PCBs and ^{90}Sr in the fish collected near the ORR, it has been estimated that ORNL inputs via White Oak Creek may be responsible for a substantial fraction (up to about 85%) of the PCB burden of channel catfish and gizzard shad in the Clinch River near the ORR (Loar 1989). However, the presence of PCBs in fish from Melton Hill Reservoir and from Poplar Creek show clearly that other PCB sources also contribute to the contamination problem.

Concentrations of metals in sediments and periphyton at NPDES monitoring sites near the Y-12 Plant, ORGDP, and ORNL clearly indicate that fish at some of these sites are likely to be exposed to relatively high concentrations of metals (Ashwood et al. 1986, Loar 1988a). Fish at these sites were collected and analyzed for trace metal content as part of the DOE facilities BMAPs (Loar 1988a,b; Smith et al. 1988; Loar 1989). Mean concentrations of metals in water and sunfish at NPDES sites in WOC, WOL, Melton

Table 5.5. Summary of PCB concentrations in fish collected from Fort Loudoun, Watts Bar, Tellico, and Chilhowee Reservoirs in Autumn 1987. Source: D. Dycus, TVA Chattanooga, unpublished data. Units are micrograms PCB per gram wet weight.

Location[a]		Species	Composite/ Individual	(No.)	PCB Concentration Mean	Range
Loudoun	TRM 640	Whitebass	Composite	(1)	<0.1	-
	LRM 3.0	Channel catfish	Individual	(10)	2.4	0.2-5.3
		Largemouth bass	Individual	(10)	2.5	<0.1-6.1
	TRM 628	Channel catfish	Individual	(10)	2.2	<0.1-4.5
		Largemouth bass	Individual	(10)	0.3	<0.1-1.3
		Whitebass	Composite	(1)	<0.1	-
Watts Bar	TRM 598-602	Channel catfish	Individual	(10)	1.5	0.4-3.1
		Striped bass	Individual	(10)	1.5	0.3-4.8
		Largemouth bass	Composite	(1)	1.4	-
		Crappie	Composite	(1)	0.6	-
		Carp	Composite	(1)	2.7	-
	TRM 585-587	Catfish[b]	Individual	(10)	1.6	0.3-3.2
		Largemouth bass	Composite	(1)	0.3	-
		Crappie	Composite	(1)	0.1	-
		Whitebass	Composite	(1)	0.9	-
	TRM 571-572	Catfish[b]	Individual	(10)	2.1	0.9-3.0
		Striped/Hybrid	Individual	(7)	2.9	1.4-4.9
		Largemouth bass	Composite	(1)	0.7	-
		Crappie	Composite	(1)	<0.1	-
		Whitebass	Composite	(1)	0.8	-
		Smallmouth buffalo	Composite	(1)	3.1	-
	TRM 565	Channel catfish	Individual	(6)	1.4	0.1-4.4
Tellico	LTRM 1.0	Channel catfish	Individual	(10)	0.9	0.2-2.9
	LTRM 11.0	Channel catfish	Individual	(10)	1.0	0.2-2.2
Chilhowee	LTRM 34.0	Rainbow trout	Individual	(10)	<0.1	-
		Whitebass	Composite	(1)	<0.1	-
		Smallmouth bass	Composite	(1)	<0.1	-

[a]TRM = Tennessee River Mile
LRM = Little River Mile
LTRM = Little Tennessee River Mile
[b]Both channel and blue catfish included

Table 5.6. Summary of PCB concentrations in fish collected from Fort Loudoun, Tellico, and Watts Bar Reservoirs - collected Autumn 1988. Source: D. Dycus, TVA Chattanooga, unpublished data. Micrograms per gram wet weight.

Location*		Species	Composite/ Individual	(No.)	PCB Concentration Mean	Range	No. ≥2.0
Loudoun	LRM 3	Channel catfish	Individual	10	3.5	1.8-7.1	8
		Largemouth bass	Individual	10	1.35	0.2-4.8	3
	TRM 628	Channel catfish	Individual	10	1.1	0.2-4.4	1
		Largemouth bass	Individual	10	0.5	<0.1-1.0	0
Tellico	LTRM 1	Channel catfish	Individual	10	1.6	0.3-4.2	3
		Walleye	Individual	2	0.3	0.2-0.3	0
	LTRM 11	Channel catfish	Individual	10	1.2	0.7-2.2	2
Watts Bar	TRM 532	Channel catfish	Individual	10	1.4	<0.1-4.3	4
		Striped bass	Individual	10	2.0	0.2-4.8	3
		Smallmouth buffalo	Individual	1	0.4	-	0
		Largemouth bass	Composite	1	0.1	-	-
		Black crappie	Composite	1	<0.1	-	-
	TRM 562	Channel catfish	Individual	10	2.7	1.3-7.5	6
	TRM 570	Channel catfish	Individual	10	2.1	0.1-7.4	4
		Smallmouth buffalo	Individual	10	0.8	0.2-14.	0
		Largemouth bass	Composite	1	0.6	-	-
		White crappie	Composite	1	<0.1	-	-
	TRM 600	Channel catfish	Individual	10	2.4	0.8-4.4	5
		Largemouth bass	Composite	1	0.5	-	-
	CRM 2*	Channel catfish	Individual	8	2.2	<0.1 - 4.6	4
		Largemouth bass	Composite	1	0.6		
		Sauger	Composite	1	1.7		
	CRM 19*	Channel catfish	Individual	8	0.6	0.2 - 2.4	1
	CRM 24*	Channel catfish	Individual	10	0.5	<0.1 - 1.6	0
	CRM 39*	Channel catfish	Individual	8	0.6	<0.1 - 1.5	0
		Largemouth bass	Composite	1	<0.1		
	CRM 50*	Channel catfish	Individual	8	0.3	<0.1 - 1.0	0
		Largemouth bass	Composite	1	0.2		

*All Clinch River locations are part of an interlaboratory split-sample study including laboratories at TVA, ORNL, and State of Tennessee. Results from all laboratories are not available at this time.

Table 5.7. Levels of PCBs (μg/g wet wt.) and ^{90}Sr (Bq/kg, dry wt. bone) in White Oak Creek/Clinch River channel catfish (Ictalurus punctatus) from lower White Oak Creek (WCK), White Oak Lake (WOL), Clinch River (CRK) and other local sites. Values are mean ± 1 s.d., range, and number of samples (in parentheses). Source: Loar (1989).

Site	Location	PCB-total	PCB-1254	PCB-1260	^{90}Sr
1	WOL	1.00 ± 0.86 0.41 - 2.50 (5)	0.30 ± 0.30 0.06 - 0.80 (5)	0.70 ± 0.57 0.35 - 1.70 (5)	4800 ± 1107 3700 - 6600 (5)
2	WCK 0.3	1.59 ± 0.87 0.57 - 3.28 (8)	0.52 ± 0.50 0.03 - 1.40 (8)	1.07 ± 0.78 0.43 - 2.6 (8)	351 ± 326 24 - 1100 (8)
3	CRK 34.8	1.69 ± 1.16 0.83 - 3.0 (3)	0.61 ± 0.49 0.13 - 1.10 (3)	1.08 ± 0.84 0.23 - 1.9 (3)	359 ± 372 47 - 770 (3)
4	CRK 32.2	1.61 ± 1.55 0.51 - 4.7 (8)	0.46 ± 0.60 0.01 - 1.9 (8)	1.15 ± 1.22 0.26 - 3.4 (8)	158 ± 270 13 - 800 (8)
MHR	Melton Hill Reservoir	0.81 ± 0.61 0.23 - 2.0 (7)	0.37 ± 0.34 0.01 - 1.0 (7)	0.43 ± 0.28 0.19 - 1.0 (7)	11 ± 10 1 - 27 (6)

Table 5.8. Concentrations of PCBs (μg/g, wet wt) and ^{90}Sr (Bq/kg, dry wt bone) in channel catfish (Ictalurus punctatus) from sites in the Clinch River arm of Watts Bar Reservoir in the vicinity of DOE facilities. Sampling sites were located in lower White Oak Creek embayment (WCK 0.3), the Clinch River (CRK), lower Poplar Creek (PCK), and Melton Hill Reservoir (MHR). Values are mean ± 1 SD, range, and number of samples (in parentheses). Source: Loar (1989).

Location	PCB-total	PCB-1254	PCB-1260	^{90}Sr
WCK 0.3	0.96 ± 0.80 0.15 - 2.27 (8)	0.45 ± 0.45 0.08 - 1.30 (8)	0.51 ± 0.38 0.07 - 1.00 (8)	600 ± 677 405 - 1425 (8)
CRK 32.2	0.58 ± 0.75 0.20 - 2.40 (8)	0.27 ± 0.42 0.06 - 1.30 (8)	0.31 ± 0.33 0.11 - 1.10 (8)	732 ± 1125 14 - 3200 (8)
PCK 6.9	0.71 ± 0.37 0.28 - 1.31 (8)	0.10 ± 0.09 0.01 - 0.28 (8)	0.61 ± 0.39 0.21 - 1.30 (8)	33 ± 35 3 - 110 (8)
CRK 15.0	0.50 ± 0.21 0.15 - 0.90 (9)	0.08 ± 0.08 <0.01 - 0.23 (9)	0.42 ± 0.17 0.12 - 0.67 (9)	217 ± 399 19 - 1200 (9)
MHR	0.52 ± 0.49 0.07 - 1.61 (10)	0.04 ± 0.08 <0.01 - 0.27 (10)	0.48 ± 0.47 0.05 - 1.60 (10)	58 ± 95 0 - 250 (10)

Table 5.9. Concentrations of PCBs (μg/g, wet wt) and ^{90}Sr (Bq/kg, dry wt bone) in gizzard shad (Dorosoma cepedianum) from White Oak Lake (WOL), lower White Oak Creek embayment (WCK 0.3), the Clinch River (CRK), lower Poplar Creek (PCK), and Melton Hill Reservoir (MHR). Values are mean ± 1 SD and range of three composites of five fish each. Source: Loar (1989).

Site	PCB-total	PCB-1254	PCB-1260	^{90}Sr
WOL	6.0 ± 0.55 5.40 - 6.39	1.73 ± 1.65 0.49 - 3.60	4.30 ± 1.60 2.70 - 5.90	2967 ± 833 2300 - 3900
WCK 0.3	2.98 ± 2.33 0.91 - 5.50	1.38 ± 1.26 0.41 - 2.80	1.60 ± 1.10 0.50 - 2.70	718 ± 561 74 - 1100
CRK 32.2	0.98 ± 0.66 0.58 - 1.74	0.40 ± 0.37 0.17 - 0.83	0.58 ± 0.29 0.38 - 0.91	106 ± 60 37 - 150
CRK 15.0	0.82 ± 0.21 0.58 - 0.94	0.24 ± 0.05 0.21 - 0.30	0.58 ± 0.18 0.37 - 0.7	149 ± 201 218 - 380
PCK 6.9	2.98 ± 1.31 1.76 - 4.37	0.61 ± 0.47 0.17 - 1.10	2.37 ± 1.61 1.20 - 4.20	18 ± 18 0 - 35
MHR	0.40 ± 0.05 0.35 - 0.44	0.13 ± 0.04 0.08 - 0.16	0.27 ± 0.06 0.21 - 0.33	8 ± 6 0.7 - 13

Branch, Mitchell Branch, and EFPC are presented in Table 5.10. Except for mercury, no metals occurred at consistently higher concentration in water at some sites than at others. Concentrations of mercury in fish and water differed among sites, reflecting the bioaccumulation of mercury in fish tissue. For other metals, mean annual concentrations or detection limits of all metals in water were well below EPA water quality criteria for protection of human health.

Both the White Oak Creek and Poplar Creek embayments are fertile nursery areas for several forage- and game-fish species in the Clinch River and Watts Bar Reservoir (Loar 1981, Loar et al. 1981; Sherwood and Loar 1987). Both embayments have been compared to tidal estuaries in regard to their fluctuating hydrodynamic regimes and water levels (resulting from hydropower operations), their high biological productivity, and their importance to the fishery as spawning habitat (Loar 1981, Loar et al. 1987). Relatively high contamination levels in the embayment water and sediments, high levels of PCB contamination in channel catfish and gizzard shad, and the known high mobility and importance of the gizzard shad as a key forage species in Watts Bar Reservoir, all suggest that the movements of contaminated fish may provide a mechanism whereby localized sources of contaminants can result in a widespread contamination of the reservoir food web.

5.7.3 Contaminants in Waterfowl

Waterfowl (geese, ducks, coots) frequent ponds and settling basins on the Oak Ridge Reservation (ORR). Waterfowl nesting on or feeding in ORR waste disposal ponds and settling basins can potentially accumulate contaminants (radionuclides, metals, organics), and migrate off the ORR to off-site surface-water environments where they may be harvested and consumed by hunters. Thus, the movement of waterfowl from the ORR to off-site aquatic habitats constitutes a potential pathway of off-site contaminant transport and of contaminant exposure to humans.

A study was initiated in 1987 to census waterfowl on the lakes, ponds, and streams associated with ORNL (see Loar 1988a). The purpose of this study is to determine the

Table 5.10. Comparison of mean annual metal concentrations in water[a] (mg/L) and mean metal concentrations in fish (Lepomis macrochirus and L. auritus), µg/g, wet wt.) from White Oak Creek (WCK), Melton Branch (MEK), White Oak Lake (WOL), Mitchell Branch (MIK), and East Fork Poplar Creek (EFK). Water quality and fish samples were collected in 1987, with the exception of Melton Branch fish (collected January 1988) and 4 of 12 fish from East Fork Poplar creek (collected May 1988). N = 6 except where noted. Water quality values include the range (in parentheses); fish values are the mean ± 1 SE. ND = No data available. Source: Loar (1989).

Metal	SITE WCK 2.9		MEK 0.2		WOL		MIK		EFK 23.4	
	Water	Fish[b]	Water	Fish	Water	Fish	Water	Fish	Water	Fish[c]
Ag	<0.005	<0.04	<0.005	<0.04	<0.005	<0.04	<0.01	<0.05	ND	<0.1
As	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	ND	<0.1	ND	<0.05
Be	ND	<0.02	ND	<0.02	ND	<0.02	<0.001	<0.05	0.0001 (<0.0001-0.0003)	<0.05
Cd	<0.002	0.008 ± 0.001	<0.002	0.006 ±0.002	<0.005	0.007 ±0.003	0.0022 (<0.002-0.012)	0.05 ± 0.01	<0.003	0.011 ± 0.05
Cr	0.062 (<0.024-0.48)	<0.1	<0.024	<0.1	0.034 (<0.024-0.093)	<0.1	0.011 (<0.01-0.023)	<0.1	0.006 (<0.006-0.011)	<0.1
Cu	0.012 (<0.012-0.014)	0.27 ± 0.05	0.012 (<0.012-0.017)	0.15 ± 0.05	0.015 (<0.012-0.032)	0.18 ± 0.06	ND	0.68 ± 0.14	0.0078 (0.003-0.011)	0.37 ± 0.04
Hg[d]	0.00008 (<0.00005-0.00011)	0.38 ± 0.29	0.00005 (<0.00005-0.00010)	0.006 ± 0.01	0.00008 (<0.00005-0.00020)	0.26 ± 0.041	0.0003 (<0.0002-0.0008)	0.17 ± 0.068	0.0028 (<0.002-0.037)	1.23 ± 0.31
Li	ND	<0.4	ND	<0.4	ND	<0.4	ND	<0.5	0.023 (0.009-0.318)	<0.5
Ni	0.047 (<0.036-0.17)	<0.6	0.036	<0.6	<0.038	<0.6	ND	<1	0.009 (<0.007-0.204)	<1
Pb	0.0047 (<0.004-0.012)	0.04[e]	<0.004	<0.02	0.0065 (<0.004-0.018)	<0.03[e]	0.009 (<0.004-0.036)	0.08 ± 0.05	<0.02	0.03 ± 0.003[f]
Se	ND	0.40 ± 0.03	ND	0.23 ± 0.03	ND	0.24 ± 0.02	<0.005	0.50 ± 0.10	ND	0.48 ± 0.04
Zn	0.035 (0.022-0.072)	6.5 ± 0.5	0.030 (<0.012-0.099)	6.8 ± 0.6	0.042 (<0.012-0.18)	9.5 ± 1.3	0.036 (<0.02-0.32)	5.5 ± 0.3	0.053 (0.19-0.151)	6.6 ± 0.6

[a]Values are the annual average of 24-h composite samples collected monthly (Rogers et al. 1988b).
[b]n = 13
[c]n = 12
[d]Mean Mg values calculated using n = 15 for WCK 2.9, n = 8 for MEK 0.2 and WOL, and n = 16 for EFK 23.4.
[e]Only one of six samples exceeded detection limit.
[f]Eight values below detection limit of 0.2 were included as 0.2 in calculating mean (n = 12).

resident and transient populations of waterfowl that inhabit ORR aquatic habitats and to determine the potential contaminant exposure to humans associated with consuming contaminated waterfowl. Data obtained from this ongoing study, which is now being expanded to include aquatic environments throughout the ORR, will be used in the CRRFI to assess the environmental and human-health risks associated with the off-site movement of contaminated waterfowl.

5.8 SUMMARY OF PREVIOUS SCREENING ANALYSES

The purpose of a screening analysis is to preliminarily identify contaminants that warrant detailed site-specific evaluation in terms of their potential risk to the environment or human health. Screening is accomplished by using simplifying assumptions and intentionally biased calculational approaches that require a minimum of site-specific information to identify contaminants that are clearly (1) not of concern or (2) in need of immediate remedial action. All other contaminants, identified as being below upper limits of action and above lower limits of concern, are designated for additional investigation and analysis to improve the accuracy of estimating their potential impact.

In past screening-level studies (Hoffman et al. 1984; Travis et al. 1986, 1989; Loar et al. 1987; 1988), conservatively biased calculational procedures were employed that were not likely to underestimate the acute exposure of humans to a given contaminant. Individual contaminants were screened out and given a low priority for further consideration if calculated exposures did not approach or exceed specific lower limits of concern. Individual contaminants that were estimated to approach or exceed these limits were designated as pollutants warranting further analysis and investigation. In the screening analysis by Hoffman et al. (1984), the contaminants that were present in concentrations above the limits of detection and that were not screened out at "off-site" locations are listed in Table 5.11.

The Tennessee Valley Authority analyzed fish from the Clinch River and Poplar Creek for radionuclides and other contaminants (TVA 1985e). The radionuclides, metals, and organic pollutants found in fish at levels above detection limits are also shown in

Table 5.11. Environmental contaminants identified for additional study by a screening analysis of either contaminated fish or sediment.

Hoffman et al. 1984	TVA 1985 ORNL 1985*	Travis et al. 1986	Loar et al. 1987, 1988
	RADIONUCLIDES		
Co-60			Co-60
Cs-137		Cs-137	Cs-137
			H-3
	Pu-238		
	Pu-239		
	Sr-90		Sr-90
Tc-99			
	U-234		
	U-235		
U-238	U-238	U-238	
	METALS		
	Antimony		
Arsenic	Arsenic	Arsenic	Arsenic
Beryllium	Beryllium	Beryllium	Beryllium
Cadmium	Cadmium		
Chronium	Chronium		
Copper	Copper		
Lead	Lead		Lead
Mercury	Mercury	Mercury	
Nickel			
Selenium	Selenium		Selenium
Silver	Silver		Silver
	Thallium	Thallium	
Zinc	Zinc		
	ORGANICS		
Acenaphthalene			
Anthracene			
Benzo(a)anthracene			
Benzo(a)pyrene			
Benzo(a)fluoranthene			
Chrysene			
Fluoranthene			
Methylene Chloride			
Phenanthrene			
Pyrene			
Tetrachloroethylene			
3,4,-Benzofluoranthene			
	4,4 DDD		
	4,4 DDE		
	Aldrin	Aldrin	
	Bis (2-ethyl-hexy 1) Phthalate		
	Chloroform		
	Di-n-butyl phthalate		
	PCBs	PCBs	PCBs

*Analysis of radionuclides only

Table 5.11. Travis et al. (1986, 1989) used the screening limits developed by Hoffman et al. (1984) to analyze the concentrations of contaminants detected in fish by TVA (1985e). Contaminants that exceeded the screening limits in this analysis are also presented in Table 5.11.

Department of Energy document OR-890 (DOE 1988) reports historical releases of radionuclides from current DOE Oak Ridge Operations facilities, and estimates population doses to the public from past releases. Estimated historical doses were much lower than the doses received from natural and man-enhanced radioactivity. The environmental surveillance report for 1987 (Rogers et al. 1988) also contains a section on radiation doses as a result of current releases of radionuclides from the Oak Ridge facilities. In addition, the calculated daily intake for some of the nonradioactive pollutants released at discharge points from the Oak Ridge facilities were compared with the acceptable daily intake.

The results of these previous screening-level risk analyses (Table 5.11) and of an additional screening analysis based on an integration of existing data on contaminants in off-site surface waters (Blaylock et al. in preparation) have been used to preliminarily identify potential contaminants of concern to be examined in the CRRFI analysis of off-site surface water contamination (Table 5.12). Additional risk analyses will be more site-specific, will have more extensive data requirements than initial screening analyses, and will include the distinction between "upper limits for action", for which non-conservative exposure scenarios will be constructed, and "lower limits of concern", for which conservative screening approaches will be taken (see Section 7.3). Additionally, CRRFI risk analyses will include a formal analysis of uncertainty in the calculation of dose and risk.

Table 5.12. List of contaminants of concern for phase one of CRRFI sampling plan.

Inorganic Chemicals	Organic Chemicals	Radionuclides
Arsenic	Anthracene	^{90}Sr
Antimony	Benzo(A)anthracene	^{137}Cs
Barium	Beta BHC	^{3}H
Beryllium	Bis(2-ethylhexyl)phthalate	^{60}Co
Boron	Carbon tetrachloride	^{241}Am
Cadmium	Chlordane	^{239}Pu
Chromium	Chrysene	^{234}Pa
Copper	Fluoranthene	^{244}Cm
Lead	Methyl chloride	^{238}U
Mercury	PCB-1254	
Nickel	PCB-1260	
Selenium	Phenanthrene	
Silver	Pyrene	
Thallium	Trans-1,2-dichloroethane	
Tin	Trans-1,3-dichloropropene	
Uranium	Vinyl chloride	
Vanadium		
Zinc		

6. IDENTIFICATION OF ENVIRONMENTAL PATHWAYS, POTENTIAL RECEPTORS, AND ARARs

6.1 OVERVIEW

Risk assessment is a quantitative procedure conducted to characterize the nature and magnitude of potential risks to public health and welfare and to the environment resulting from exposure to hazardous substances, pollutants, or contaminants released from specific sites (EPA 1986). Human-health and environmental risk assessments are key components of the CRRFI and will be conducted on an iterative basis, as relevant data become available, to (1) determine if interim corrective measures are needed immediately to protect public health, welfare, or the environment, (2) evaluate the need for and advisability of long-term remedial actions, and (3) evaluate the No-Action Alternative. Existing data and data collected during Phase-1 sampling and analysis and the site-characterization phases of the CRRFI will be used to estimate the extent to which off-site contamination may pose a threat to human health and/or to the environment. Concomitantly, these data and those data resulting from Phase-2 sampling efforts will be used to identify and to preliminarily evaluate potentially appropriate remedial-action alternatives. Finally, risk assessment will employed throughout the CRRFI as a tool for focusing data collection efforts and for decision making.

6.2 CONCEPTUAL SITE MODEL: CONTAMINANT SOURCES, PATHWAYS, AND RECEPTORS

Prerequisite to risk assessment analyses is the identification of contaminant sources, contaminants of concern, potential environmental pathways of exposure, and potential receptors. Contaminant sources, releases, and likely contaminants of concern for the off-site surface water environment have been reviewed and identified in Sections 4 and 5. The objective of the conceptual site model is to identify and summarize current knowledge of contaminant sources, the potential environmental pathways of exposure (including transport media and exposure routes), and the potential receptors for contaminants released from the ORR to downstream surface waters.

Contaminant sources and transport/exposure pathways relevant to off-site surface-water contamination derived from the Oak Ridge facilities and the potential human and non-human receptors are indicated diagrammatically in Fig. 6.1. Details of the conceptual site model are described in the following sections.

6.3 ENVIRONMENTAL PATHWAYS OF CONTAMINANT TRANSPORT AND EXPOSURE

6.3.1 Contaminant Transport Media

For the CRRFI, the contaminants identified at off-site locations will have been transported from the point of release (i.e., the ORR) to the location being investigated via surface water transport. Therefore, the media of concern in the CRRFI will be those associated with the surface-water environment downstream from the ORR: the water itself, suspended particles/sediments, deposited sediments, and aquatic organisms.

Secondary modes of contaminant transport (e.g., resuspension/redistribution of contaminated sediments by unusual storm events or by dredging activities, remobilization of contaminants from bottom sediments to the water column, biological uptake of contaminants from sediments by bottom-dwelling (benthic) organisms and transfer up the food chain, contaminant transfer from the aquatic environment to the terrestrial environment by dredging and land disposal of contaminated sediments) will also be examined in association with the identification and preliminary evaluation of potential remediation alternatives.

6.3.2 Point of Contact with the Contaminated Medium

To estimate the potential risk associated with off-site contamination of surface waters, the likely points of highest potential exposure for various contaminant - transport media combinations will be identified, along with the contaminant concentration(s) at that point.

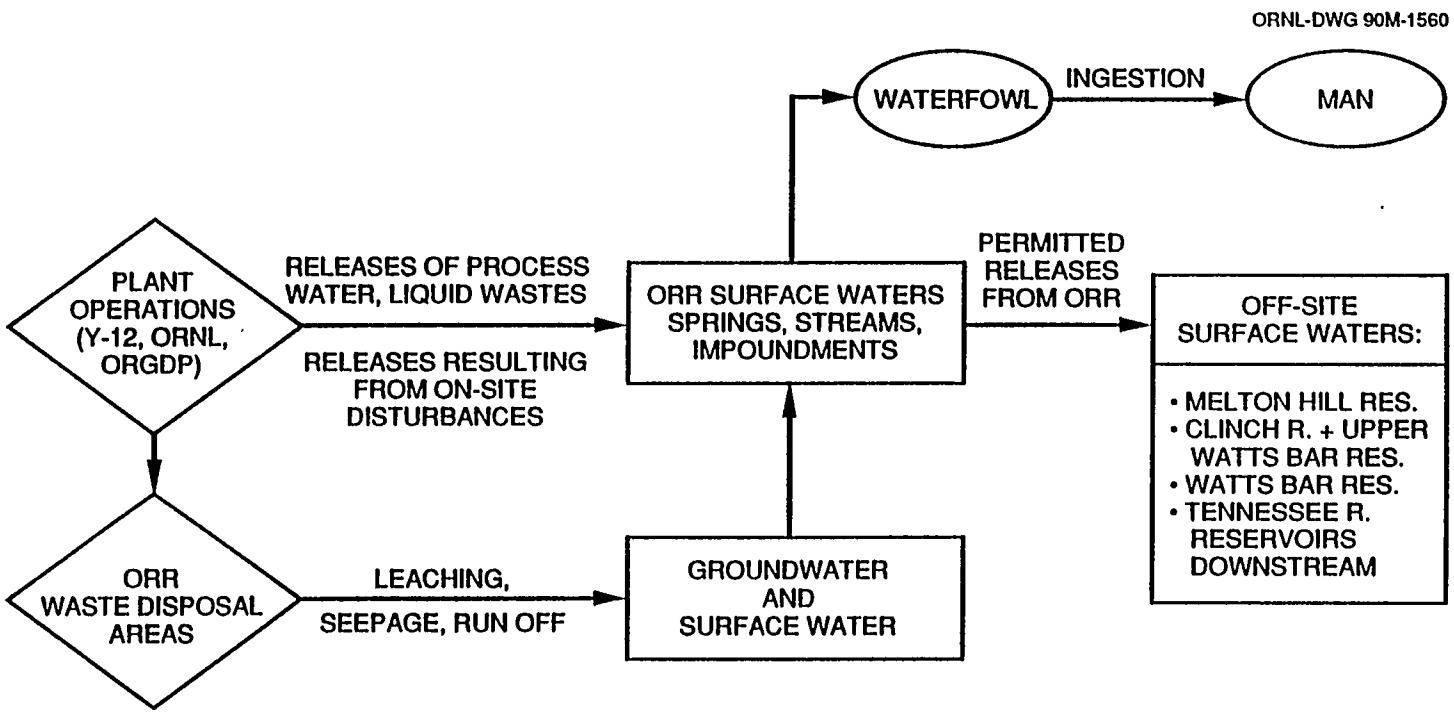

Fig. 6.1.A. The Conceptual Site Model. This flow-chart represents the contaminant sources, potential transport and exposure pathways, and potential human and non-human receptors for contaminants released from the U.S. DOE Oak Ridge Reservation into the off-site aquatic environment.

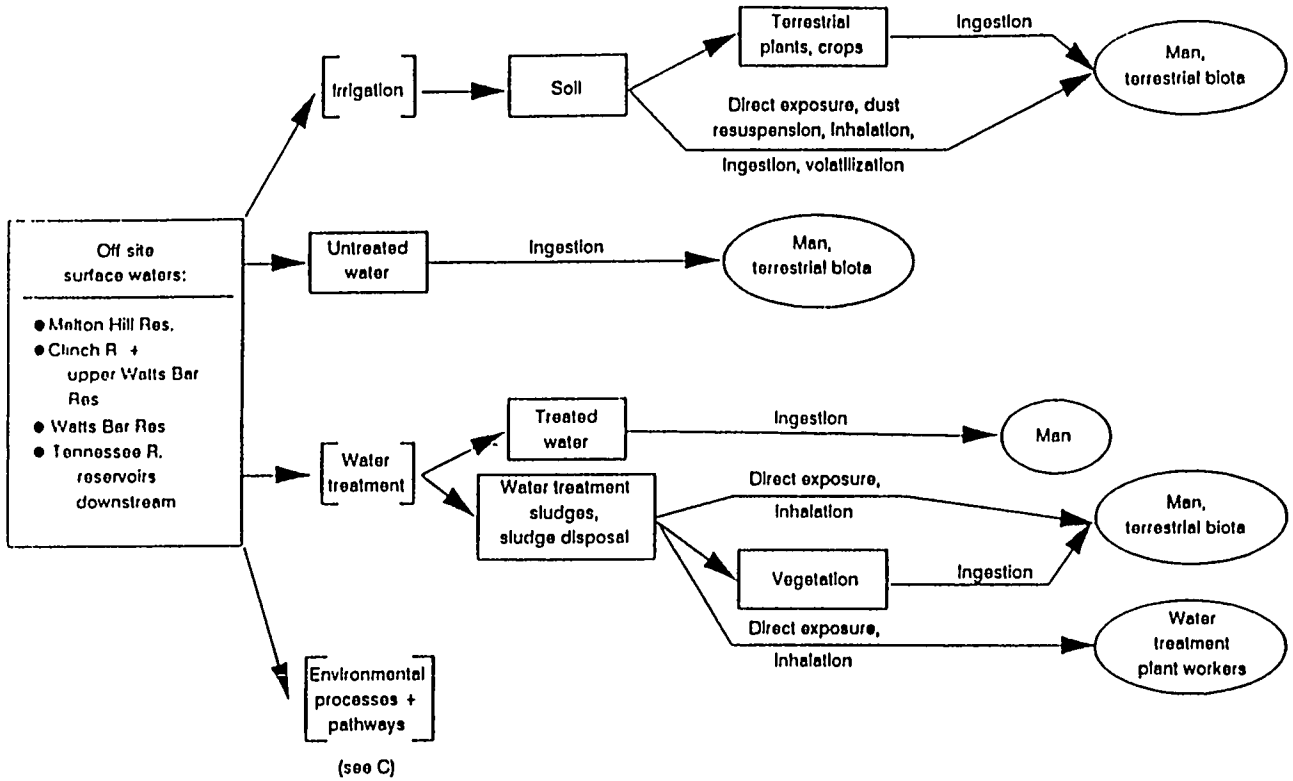

Fig. 6.1.B. The Conceptual Site Model, continued.

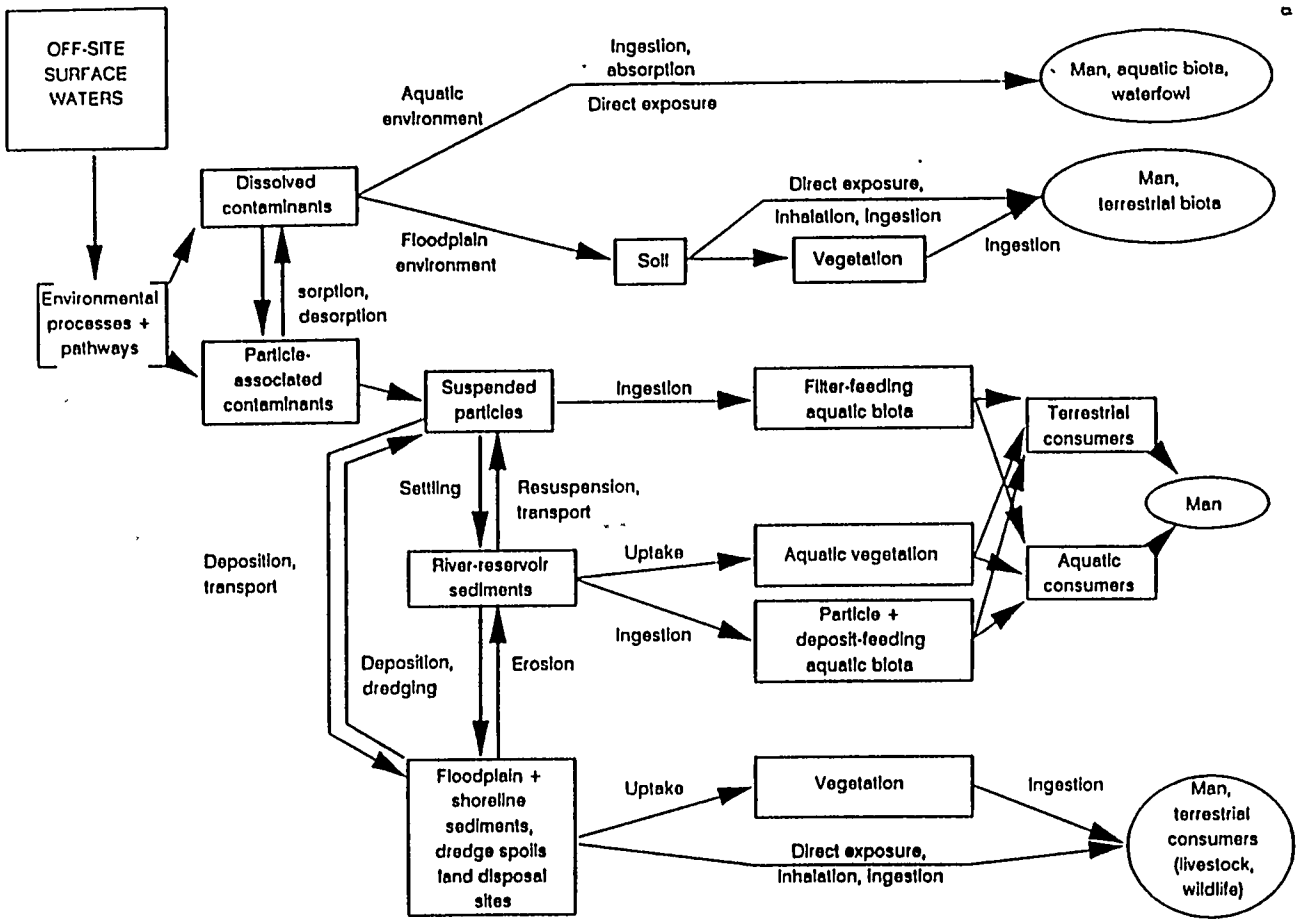

Fig. 6.1.C. The Conceptual Site Model, continued.

Dissolved Contaminants

For the CRRFI, the highest potential exposure to dissolved contaminants should occur at the ORR boundary; i.e., at the points of surface water flow from the reservation to the public domain. These points include the mouths of White Oak Creek and Poplar Creek, points of direct effluent releases to the Clinch River from the ORGDP (e.g., from the chromate pond weir), and points of release from Y-12 into Melton Hill Reservoir via tributaries of McCoy Branch embayment (from Rogers Quarry), Scarboro embayment (from Kerr Hollow Quarry), and Walker Branch embayment (from waste disposal areas adjacent to the east fork of Walker Branch). Because Poplar Creek within the confines of the ORGDP is included in the CRRFI, it will also represent a potential point of high exposure to soluble contaminants.

Particle-Associated Contaminants

Points of high potential exposure to hydrophobic (particle-associated) contaminants, however, will not occur at effluent release points, but are most likely to occur at points of sediment deposition and accumulation. The distribution of ^{137}Cs in the river, reservoir, and floodplain sediments provides an excellent and readily detectable tracer for locating and identifying deposition-accumulation zones for particle-associated contaminants.

Exposure points with lower predicted chemical concentrations, but larger potentially exposed receptor populations, will also be evaluated. These include primarily the locations of municipal water-supply intakes.

6.3.3 Mode of Exposure at Contact Points

Exposure routes describe the ways in which a receptor can come into contact with contaminants in a specific environmental medium. Environmental media to be considered for off-site surface water contamination include water, sediment, and food. The primary exposure routes for the environment (i.e., for the aquatic biota) are: direct

uptake and metabolism of dissolved contaminants, direct contact or exposure, absorption, and ingestion of contaminated food organisms or particulate matter. The primary exposure routes of greatest potential risk to human health are: ingestion of contaminated food (e.g., fish, clams, waterfowl, or vegetables grown on contaminated sediment/soil), ingestion of contaminated drinking water, direct ingestion of contaminated sediment/soil (e.g., by small children), and direct exposure (e.g., to contaminated sediment/soil). Dermal absorption and inhalation will be considered for certain contaminants. Procedures for estimating rates of exposure are described in detail by EPA (1989a,b).

6.4 POTENTIAL RECEPTORS

6.4.1 Human Health and Welfare

Regional Demography

Based on 1980 census data, except for the City of Oak Ridge (ca. 28,000 population), the land within 8 km of the ORR is predominantly rural, and is used largely for residences, small farms, and pasture land. The ORR, itself, is within the Oak Ridge city limits.

Figure 6.2 shows the location of population centers in the vicinity of the ORR. The approximate (1980) populations of cities and towns within an 80-km radius of the ORR are listed in Table 6.1, and directional population-distribution maps are shown in Figs. 6.3 and 6.4. Fewer than 5,000 persons live within a 10-km radius of the center of the ORR; however, it should be noted that most of the area within a 10-km radius is encompassed by the 14,260-ha ORR.

Knoxville, the largest metropolitan center near Oak Ridge, is located about 40 km to the east and has a population of about 183,000 (Petrick et al. 1984, Baumgardner and Chance 1984). Knoxville draws its water supply from the Tennessee River upstream from Watts Bar Reservoir. A number of small towns are located near the ORR; their

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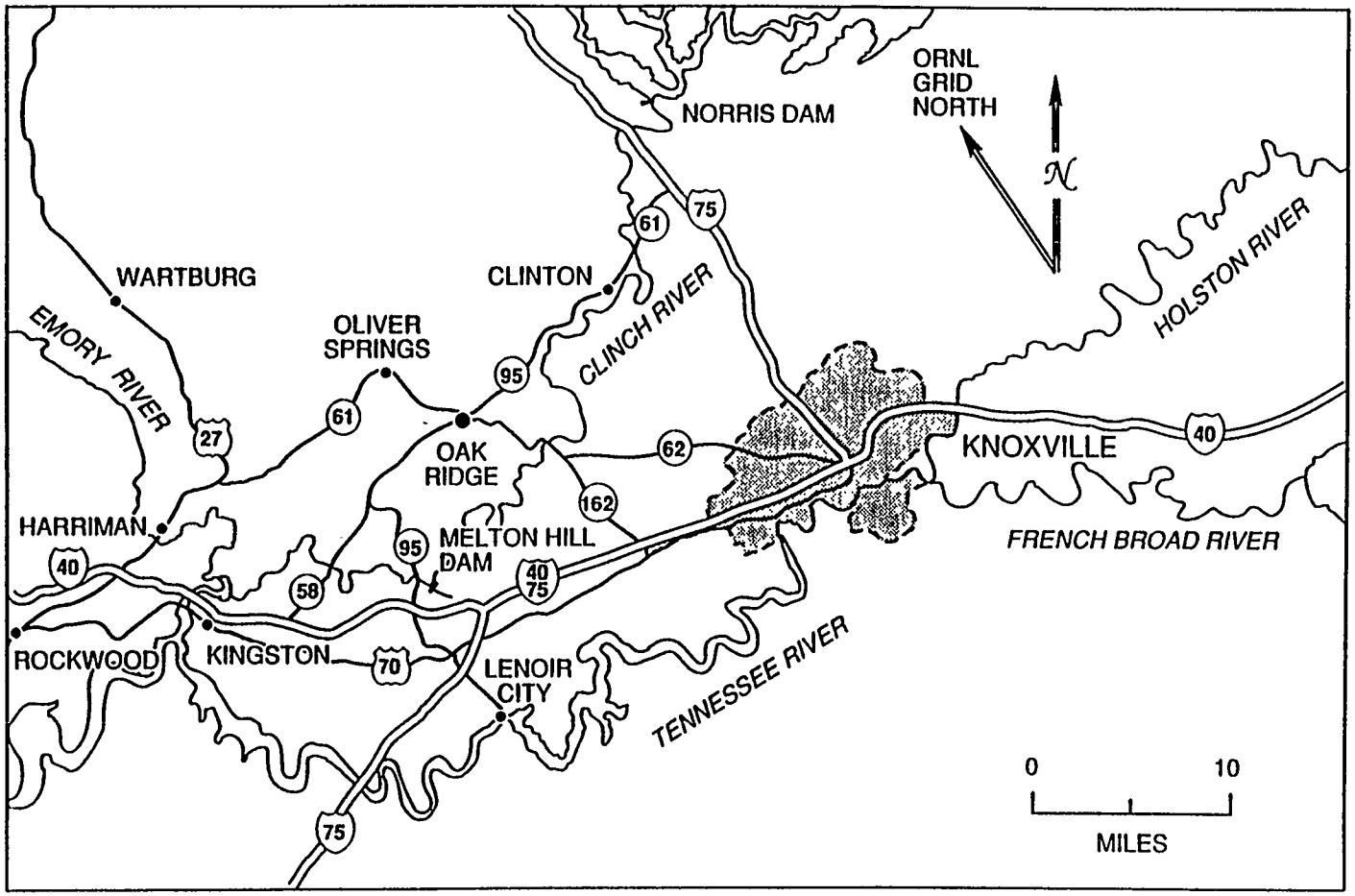

Fig. 6.2. Human population centers and major surface-water features in the vicinity of the U.S. DOE Oak Ridge Reservation, eastern Tennessee.

Table 6.1. Populations of central East Tennessee towns. Source: MMES (1986).

Town/city	Population
Anderson County	
Clinton	5,245
Lake City	2,335
Norris	1,374
Oak Ridge	27,662
Oliver Springs	3,600
Blount County	
Friendsville	694
Alcoa	6,870
Maryville	17,478
Knox county	
Knoxville	183,139
Loudon County	
Greenback	546
Lenior City	5,446
Loudon	3,940
Morgan County	
Wartburg	761
Roane County	
Harriman	8,303
Kingston	4,441
Rockwood	5,767
Sevier County	
Sevierville	4,566
Union County	
Luttrell	962
Maynardville	924
Campbell County	
Caryville	2,039
Jellico	2,769
Jacksboro	1,620
LaFollette	8,176

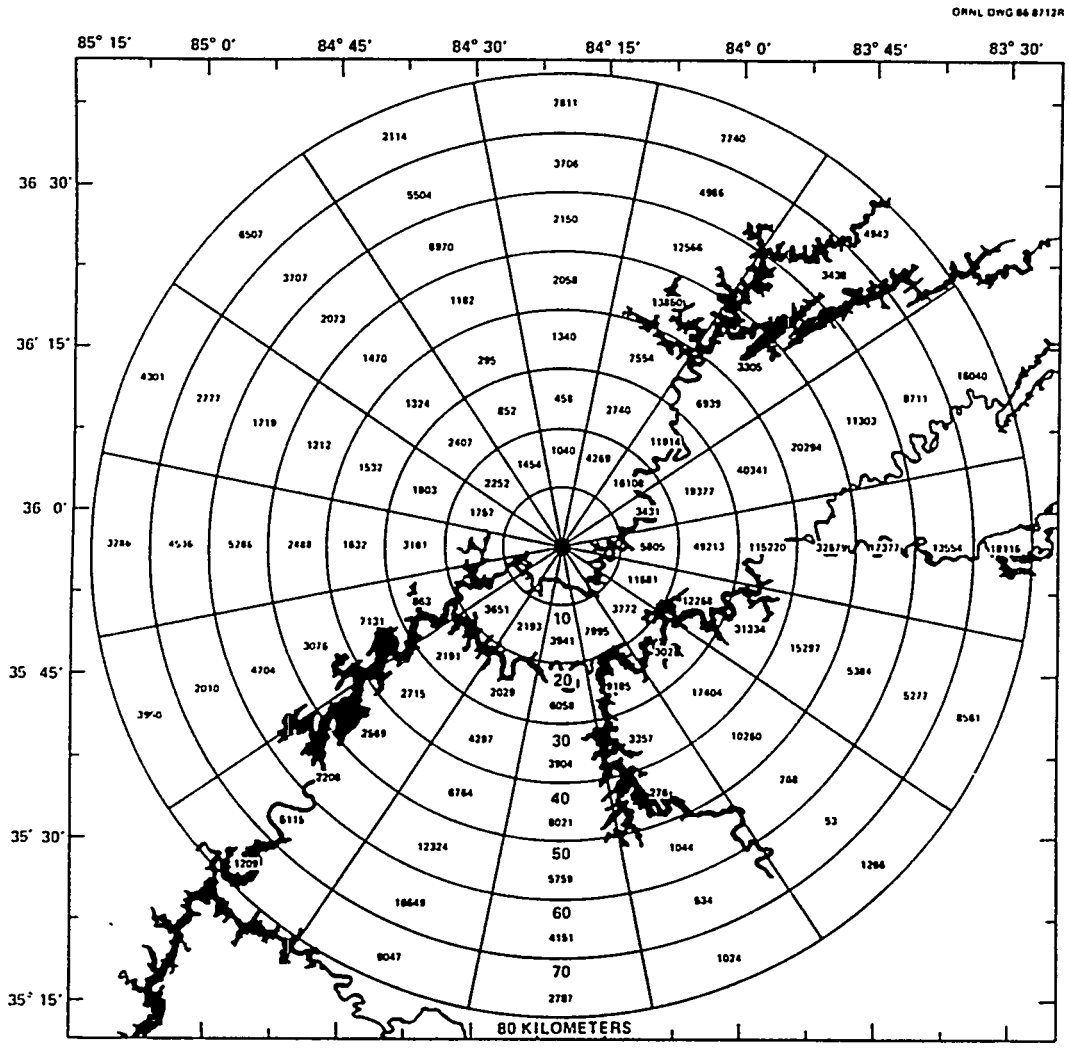

Fig. 6.3. Human population density indicated by sector from the center of the U.S. DOE Oak Ridge Reservation and in relation to major surface-water features. Population estimates based on 1980 census data.

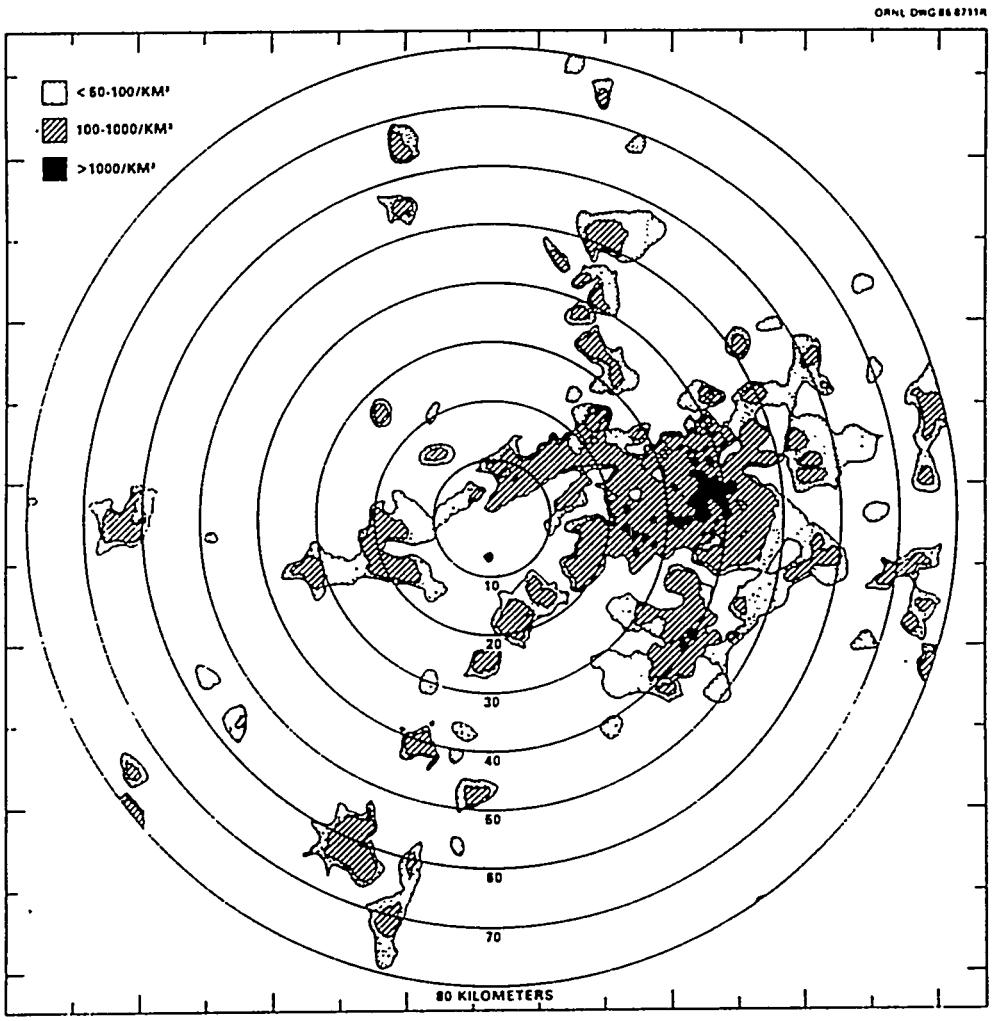

Fig. 6.4. Human population density mapped from the center of the U.S. DOE Oak Ridge Reservation. Fewer than 5,000 persons live within a 10-km radius of the center of the ORR. Population estimates based on 1980 census data.

approximate populations and distances from the ORR are: Oliver Springs (pop. 3600), 11 km to the northwest; Clinton (pop. 5300), 16 km to the northeast; Lenoir City (pop. 5400), 11 km to the southeast; Kingston (pop. 4400), 11 km to the southwest; and Harriman (pop. 8300), 13 km to the west.

Water Use

Water-Use Classifications

Streams in the Clinch River basin are classified by use by the Tennessee Department of Public Health (TDPH 1978) based on water quality. Water-use classifications for streams on or near the ORR are presented in Table 6.2. Surface waters in the Clinch and Tennessee Rivers are used for multiple purposes, including domestic water supply, industrial processes, fishing and other water-based recreation, irrigation, hydroelectric power generation, and navigation.

Municipal Water Supplies

The City of Oak Ridge, ORNL, and the Y-12 Plant draw their water supplies from Melton Hill Reservoir, which may be affected by contaminant releases from the Y-12 Plant, the Bull Run Steam Plant, and the cities of Oak Ridge and Clinton. Twelve additional water supplies, serving an estimated population of 200,000 persons, use water potentially influenced by materials released to the Clinch River via White Oak Creek and Poplar Creek. Principal domestic water-supply users are the ORGDP and the TVA Kingston Steam Plant on the Clinch River, and the communities of Kingston, Rockwood, Spring City, Soddy-Daisy, Falling, Waldens Ridge, Chattanooga, and South Pittsburg, Tennessee, on the Tennessee River. Additionally, stratified conditions in the upper portion of Watts Bar Reservoir during the summer months create the possibility that the cooler Clinch River water released during hydropower generation cycles at Melton Hill Dam may underflow upstream in the Emory River to water-supply intakes at Harriman.

Table 6.2. Use classifications for the Clinch River and its tributaries on the ORR[a]

Stream	Description	DOM[b]	IND[c]	FISH[d]	REC[e]	IRR[f]	LW&W[g]	NAV[h]
Clinch River	km 7.0-19.2 (Poplar Creek)	X	X	X	X	X	X	X
Poplar Creek	km 0.8-0.8		X	X	X	X	X	
Poplar Creek	km 0.8-2.1			X		X	X	
Poplar Creek	km 2.1-8.8			X	X	X	X	
East Fork Poplar Creek	km 0.0-7.7			X	X	X	X	
Bear Creek	km 0.0-origin			X	X	X	X	
East Fork Poplar Creek	km 7.7-13.3			X		X	X	
East Fork Poplar Creek	km 13.3-dam at Y-12 Plant			X	X	X	X	
Poplar Creek	km 8.8-19.8			X	X	X	X	
Poplar Creek	km 19.8-23.0			X		X	X	
Indian Creek	At Poplar Creek (km 22.9); km 0.0-origin			X	X	X	X	
Poplar Creek	km 23.0-origin			X	X	X	X	
Clinch River	km 19.2-32.0	X	X	X	X	X	X	
White Oak Creek	km 0.0-origin			X			X	
Melton Branch	km 0.0-origin			X			X	
Clinch River	km 32.0-63.4	X	X	X	X	X	X	X
Clinch River	km 63.4-65.8	X	X	X	X	X	X	X
Scarboro Creek	km 0.0-1.6			X	X	X	X	
Scarboro Creek	km 1.6-2.1			X		X	X	
Scarboro Creek	km 2.1-origin			X	X	X	X	
Clinch River	km 65.8-74.7	X	X	X	X	X	X	X

[a]Source: Tennessee Department of Public health, 1978. Water Management Plant - Clinch River Basin.
[b]DOM = Domestic water supply.
[c]IND = Industrial water supply.
[d]FISH = Fish and aquatic life.
[e]REC = Recreation.
[f]IRR = Irrigation.
[g]LW&W = Livestock watering and wildlife.
[h]NAV = Navigation.

Industrial Water Supplies

Industrial water withdrawals from the Clinch-Tennessee River system in the vicinity of the ORR are listed in Table 6.3. All point discharges are described in detail by the Tennessee Department of Public Health (TDPH 1978).

Recreational Use of Surface Waters

The surface waters adjacent to and downstream from the ORR (i.e., Melton Hill Reservoir, the lower Clinch River, and Watts Bar Reservoir) are popular, heavily used areas for water-based recreational activities (including fishing, waterfowl hunting, boating, water skiing, swimming, and sunbathing).

Sport fishing for game fish such as striped bass, largemouth bass, white bass, sauger, walleye, crappie, and catfish is particularly popular in Melton Hill and Watts Bar reservoirs, both of which are locations of choice for fishing tournaments. Cool-water game species (e.g., muskellunge and northern pike) have been stocked in Melton Hill Reservoir, and are becoming increasingly popular with the sport fishermen.

Some fish collected from Melton Hill Reservoir, White Oak Creek embayment, and the Clinch River and Tennessee River arms of Watts Bar Reservoir have been determined to contain tissue concentrations of PCBs that exceed the FDA tolerance limit of 2 ppm (see Section 5.7.2.). Accordingly, the Tennessee Department of Health and Environment has recently issued public advisories related to the consumption of fish taken from surface waters in the Tennessee River system that may be contaminated. In the Tennessee River arm of Watts Bar Reservoir (Kingston to Lenoir City), catfish, striped bass, and striped bass x white bass hybrids are banned from human consumption. Also, consumption of largemouth bass, white bass, sauger, carp, and smallmouth buffalo has been limited to no more than 545 grams per month from this area. In the Clinch River arm of Watts Bar Reservoir (Kingston to Melton Hill Dam), catfish consumption is limited to no more than 545 grams per month. In addition, consumption of catfish

Table 6.3. Industrial water withdrawals from the Clinch-Tennessee River System

Industrial water use	Average withdrawal rate (m^3/s)	Withdrawal source and location		River distance from mouth of White Oak Creek (km)
Withdrawals above White Oak Creek (mouth of CRK[a] 33.5)				
Modine Manufacturing Co.	0.05	CRK	103.7	71.2
Tennessee Valley Authority, Bull Run Steam Plant	25	CRK	77.2	43.7
U.S. Department of Energy ORNL, Y-12, CARL, and city of Oak Ridge	0.96[b]	CRK	66.8	33.3
Withdrawals below White Oak Creek				
ORGDP	0.13[b]	CRK	23.3	10.2
ORGDP	0.54[c]	CRK	18.5	15.0
Withdrawal below Poplar Creek and White Oak Creek				
Tennessee Valley Authority, Kingston Steam Plant	61.3	ERK[d]	2.9	29.6
Watts Bar Hydro plant, lock, and steam plant	0.02	TRK[e]	851.5	94.5

Source: F. C. Fitzpatrick, Oak Ridge National Site Data for Safety Analysis Reports, ORNL/ENG/TM-19, Oak Ridge National Laboratory, Oak Ridge, TN, 1982, updated.
[a]CRK = Clinch River Kilometer.
[b]Process and potable water.
[c]Cooling water makeup only.
[d]Emory River Kilometer.
[e]Tennessee River Kilometer.

from melton Hill Reservoir is prohibited, and consumption of all fish from East Fork Poplar Creek is banned.

6.4.2 The Off-Site Aquatic Environment

The Clinch River forms the southern and western boundary of the ORR for a distance of approximately 63 km, extending from CRM 49 on Melton Hill Reservoir to CRM 10, approximately 3.2 km downstream from the mouth of Poplar Creek. The surface water environments potentially affected by contaminant releases from the ORR include Melton Hill Reservoir, the lower Clinch River between Melton Hill Dam and Kingston (where the Clinch River enters the Tennessee River), and Watts Bar Reservoir. Although some contamination may pass through the Watts Bar Dam and be transported farther downstream, the existing data indicate that a high percentage of the particle-associated contaminants are retained within the Watts Bar Reservoir sediments (see Section 5 of this document).

The sediments, limnology, and the biotic communities of the lower Clinch River have been surveyed extensively over the years in connection with contaminant releases from the ORR (e.g., see Section 5 of this document and Loar 1981, Loar et al. 1981, Loar 1984) and development of additional proposed facilities (Project Management Corp. 1975, Exxon Nuclear Co., Inc. 1976). The planktonic, benthic, and fish communities of the river-reservoir system are diverse and productive, as is typical of upper Tennessee Valley reservoirs.

Both Melton Hill and Watts Bar reservoirs are short water-residence time, phosphorus-limited, but moderately productive systems (Elser and Kimmel 1984, 1985). Because Watts Bar Reservoir receives inflow from both the Clinch River and Tennessee River drainages and is more thoroughly mixed vertically, it is considerably more productive (i.e., with regard to phytoplankton photosynthetic production of organic matter) than Melton Hill Reservoir (Elser and Kimmel 1984, 1985). Both reservoirs support a large standing crop and a high diversity of native and introduced fish species.

The fisheries in both reservoirs are classified as cool-warmwater communities, since species of both water types are present. A total of 53 species and two hybrids represented by 14 families has been reported. Of these species, 16 species and the two hybrids (walleye/sauger and white bass/striped bass) are considered game fish, 16 species are forage fish, and 21 species are considered rough or commercial fish. The principal predators and most prized game fish are largemouth bass (Micropterus salmoides), striped bass (Morone saxatilis), white bass (Morone chrysops), sauger (Stizostedion canadense), and channel catfish (Ictalurus punctatus). Muskelluge and northern pike have recently been introduced to Melton Hill Reservoir.

Threadfin shad (Dorosoma petenense) and gizzard shad (D. cepedianum) are the dominant forage-fish species, and they play a pivotal role in linking lower trophic-level production to the higher consumers (Fig. 6.5). The threadfin shad populations undergo dramatic seasonal fluctuations in abundance as a result of naturally occurring cold-shock mortality in the winter (McLean et al. 1980).

Many of these fish species, including those taken by sport fishermen, do not have well-defined home ranges. These fish often move into embayments and creeks seasonally to spawn or to use these highly fertile areas as feeding and nursery grounds. Based primarily on observations of high densities of ichthyoplankton and larval fish, Loar (1981) and Loar et al. (1981) noted the ecological importance of both the White Oak Creek and the Poplar Creek embayments as productive nurseries for the Clinch River - Watts Bar Reservoir fish community. As noted in Sections 4 and 5, these embayments are the primary discharge points for the release of contaminants from the ORR to the Clinch River.

Several species have been shown to migrate between contaminated and uncontaminated areas within the Clinch River system. Sauger enter the tailwaters below Melton Hill Dam in late winter and spring, respectively, and return to Watts Bar Reservoir in early summer (Loar et al. 1981). In early summer, striped bass (Morone saxatilis) move from the main body of Watts Bar Reservoir to the cooler waters of the Clinch River arm of the reservoir (Cheek et al. 1983). Early in the summer of 1988, two striped bass were

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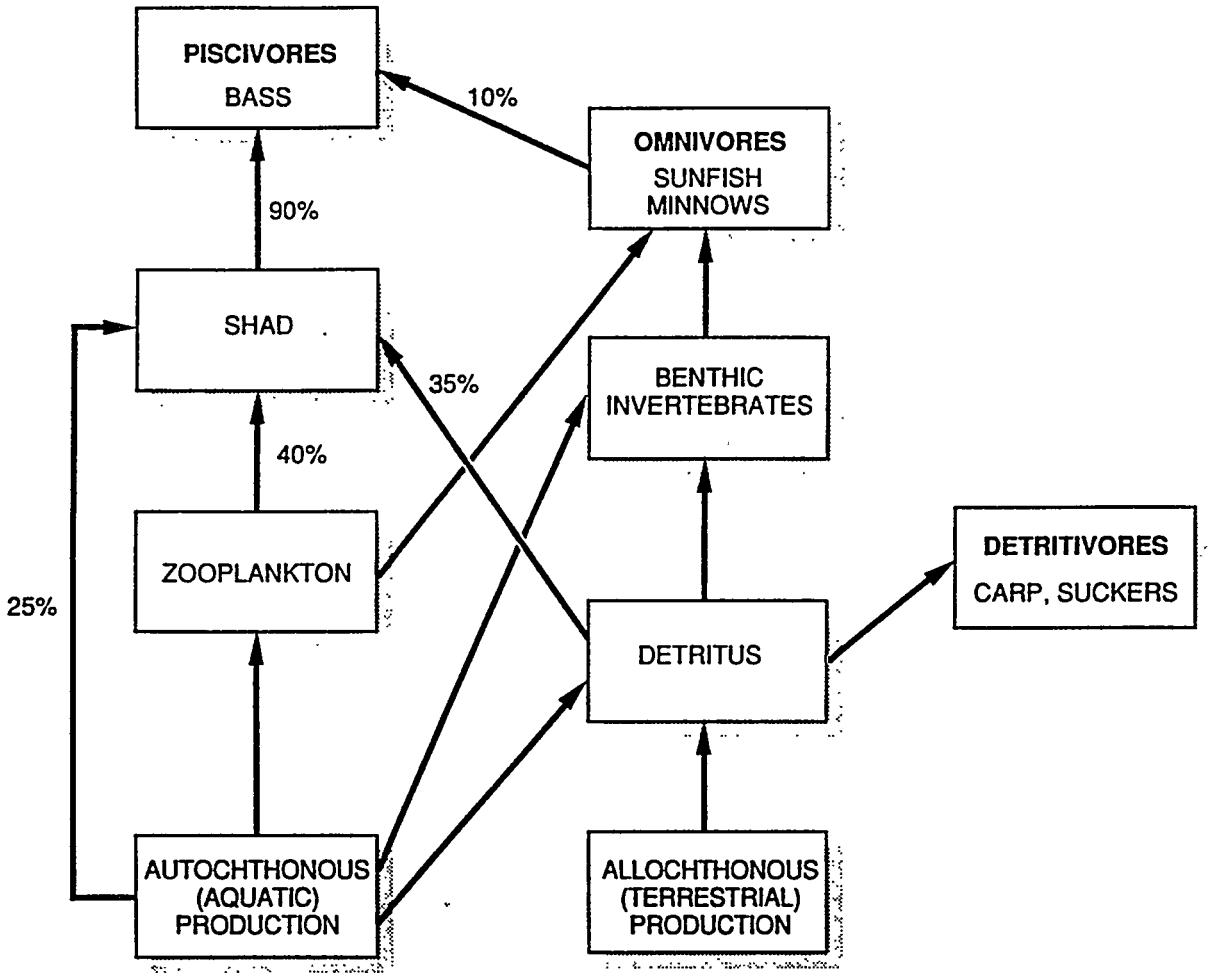

Fig. 6.5. Generalized food-web diagram for the fish community of Watts Bar Reservoir, eastern Tennessee. The percentage values shown represent the relative importance of various food resources to components of the fish community. Typically, in southeastern U.S. mainstem impoundments, the shad populations occupy a critical food-web link between the lower trophic levels and the top piscivores (i.e., game fishes, such as striped bass and largemouth bass).

electroshocked from the lower reaches of East Fork Poplar Creek (km 1.0) during a routine fisheries survey (S. M. Adams, ORNL Environmental Sciences Division, personal communication, 1989). Another important game fish, the white bass (Morone chrysops), has been observed to use Poplar Creek above the ORGDP as a major spawning area (Loar 1981).

The two most important forage fishes in the river-reservoir system, the gizzard shad and the threadfin shad, also exhibit seasonal migration into the mouths of creeks and embayments. The great winter abundance of threadfin shad in White Oak Creek embayment suggests that this species, which is stressed by low temperatures (Griffith 1978, McLean et al. 1980), moves into the warmer waters found near the mouths of creeks in late winter (Loar 1981).

The smallmouth buffalo (Ictiobus bubalus), a rough/commercial fish, has been shown to migrate extensively in and out of contaminated areas (Martin et al. 1964). Conventional tagging methods showed that individuals of this species are quite mobile, with one recapture occurring 450 miles downstream from the Clinch River tagging site. Autoradiographic analysis of ^{90}Sr deposited in the fish scales demonstrated that smallmouth buffalo move between White Oak Creek embayment (an area of significant contamination and ^{90}Sr exposure) and uncontaminated areas. An individual fish, known to have resided in the White Oak Creek embayment, was recaptured 47 miles downstream in Watts Bar Reservoir. Even though the area of White Oak Creek embayment is relatively small, 8 percent of all smallmouth buffalo captured in Watts Bar Reservoir had detectable ^{90}Sr in their scales, and thus showed autoradiographic evidence of some period of residency in the embayment.

Mobile fish species not only concentrate and accumulate toxic substances from their environment, but also provide a pathway for the transfer of toxic or radioactive substances from areas of contamination to uncontaminated areas. Because several highly mobile game fish species (i.e., striped bass, sauger, white bass) are frequently taken for human consumption, they constitute a potential avenue of contaminant transport and exposure.

6.5 ESTIMATES OF EXPOSURE AND RISK AND IDENTIFICATION OF ARARS

The final step in the exposure assessment is to integrate the information available and develop a quantitative estimate of the expected exposure level(s) resulting from the actual or potential release of contaminants from the site or from a resuspension/redistribution of contaminants in an off-site location. The risk assessment will involve the development of a variety of exposure scenarios which for the CRRFI will include the potential risk to human health and to the environment associated with (1) ingestion of contaminated food, water, sediment, or soil, (2) direct exposure to contaminated media, (3) disturbance of deeply buried contaminant deposits, (4) bulk removal and land disposal of contaminated sediments, and (5) potential releases resulting from on-site and/or off-site remedial-action activities.

Section 121 of CERCLA requires that, subject to specified exceptions, remedial actions be undertaken in compliance with applicable or relevant and appropriate environmental laws, both State and Federal. These standards, requirements, criteria, or limitations are called ARARs ("Applicable or Relevant and Appropriate Requirements") and TBC ("To Be Considered" advisories, criteria, or guidelines). A comparison of acceptable levels of contamination with actual levels identified during the exposure assessment must be made. Contaminant-specific ARARs, when available, should be used to determine acceptable levels. When ARARs are not available, acceptable levels will be based on concentration levels that would yield exposures less than or equal to reference doses for non-carcinogens and specified risk levels based on potency factors for carcinogens.

Other criteria advisories and guidance, referred to as TBCs are non-promulgated advisories or guidance issued by Federal or State governments that are not legally binding and are not ARARs. This material may be considered along with ARARs to address a particular situation or if no ARARs ensure protectiveness, TBC advisories, criteria, or guidelines should be used.

There are several different types of requirements with which actions may have to comply. These are separated into the following three groups of ARARs.

- Chemical- and radionuclide-specific requirements are usually health- or risk-based numerical values or methodologies resulting in establishment of numerical values. These values establish the acceptable amount or concentration of a contaminant that may be found in, or discharged to, the ambient environment.

- Location-specific requirements are restrictions placed on the concentration of hazardous substances or the conduct of activities solely because they occur in special locations.

- Action-specific requirements are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous waste.

The development of ARARs is an ongoing process throughout the remedial investigation process. During the risk assessment, contaminant-specific and location-specific ARARs are developed. Action-specific ARARs are developed during the analysis of alternatives. DOE, EPA, and the Tennessee Department of Health and Environment (TDHE) have drafted a proposed Federal Facility Agreement (FFA) for the environmental restoration of the ORR. Section XXI(F) of the FFA specifies that all ARAR determinations be submitted to EPA/TDHE for approval prior to incorporation into any draft primary document. Therefore, a preliminary list of available federal and state ARARs will be compiled and submitted to EPA/TDHE as a draft report under separate cover.

In the absence of federal or state-promulgated ARARs, or in the case where ARARs are not adequately protective, other federal or state criteria, advisories, or guidance will be considered and submitted to EPA/TDHE for approval. These will include EPA Office of Drinking Water Health Advisories (HAs), EPA Reference Doses (RfDs) and carcinogen potency factors (CPFs), state guidance values, etc. Current RfDs and CPFs available from the IRIS database (EPA 1989b) and the EPA Health Effects Assessment Summary Tables (EPA 1989d) have been supplied for the preliminary screening level

study contingent on fianl approval from EPA/TDHE. These values will be submitted to EPA/TDHE in the ARAR report.

The EPA Office of Radiation Programs have derived slope factors for radionuclides of concern at remedial sites for each of four major exposure pathways (inhalation, ingestion, air immersion, and ground and surface irradiation). If approved by EPA/TDHE, these factors will be employed in the baseline risk assessment. These are currently undergoing internal review and are expected to be available in early 1990 (Reisman 1989).

7. WORK PLAN

7.1 BACKGROUND AND OBJECTIVES OF THE CLINCH RIVER RFI

The Clinch River RFI (CRRFI) focuses on portions of the Clinch and Tennessee Rivers that may have been adversely affected by contaminants released from the Department of Energy facilities at Oak Ridge, Tennessee, from the early 1940s to present. The contaminants originate from research, industrial, and waste disposal activities conducted at:

- the ORNL, an energy research and development laboratory;
- the ORGDP, a uranium-enrichment facility until its closure in 1986; and
- the Y-12 Plant, a facility for producing nuclear-weapons components.

The contaminants of potential concern include a variety of radionuclides, metals, and organic compounds. Some liquid wastes are discharged to streams on the ORR (see Fig. 3.9), which drain into the impounded Clinch River (Melton Hill Reservoir, Watts Bar Reservoir; see Fig. 2.6); however, much of the water-borne contamination is derived from seepage into the shallow groundwater from old waste storage pits and trenches. The contaminated groundwater drains into ORR streams and ultimately into the Clinch River.

The Clinch River enters the Tennessee River system of multiple-purpose impoundments near Kingston, Tennessee, 34 km downstream from the Oak Ridge complex. Watts Bar Reservoir is located on the Tennessee River just below its confluence with the Clinch River, and is the first impoundment downstream of the ORR (Fig. 2.6). Watts Bar Reservoir was impounded in 1942, just prior to the development of the Oak Ridge complex, and therefore, retains in its sediments a long-term accumulation of contaminants derived from the Oak Ridge facilities. The CRRFI will evaluate the potential risks to human health, human welfare, and to the environment that are associated with (1) current and recent contaminant releases to the Clinch River from the

Oak Ridge facilities, and (2) long-term contaminant accumulations in the river and reservoir sediments downstream from the ORR.

Primary objectives of the CRRFI are to:

- define the nature and extent of off-site contamination of the aquatic environment,
- quantify potential risks to human health, human welfare, and to the environment resulting from the existing off-site contamination,
- obtain data applicable to the identification and evaluation of appropriate remediation alternatives.

The CRRFI will be coordinated with ongoing environmental monitoring and environmental restoration programs at ORNL, ORGDP, and Y-12 in compliance with the provisions of RCRA, CERCLA, NEPA, and Tennessee hazardous waste management regulations and environmental standards. On-site monitoring programs and remedial investigations will provide much data relevant to the identification of contaminants of concern, the determination of the nature and extent of off-site contamination, and the evaluation of potential human-health and environmental risks. Extant data on off-site contamination have been used in the design of the CRRFI Work Plan, described in this section.

Remediation of existing contamination problems is the ultimate goal of the RFI process. Data collected during the CRRFI will be used for site characterization, human-health and environmental risk assessment, and identification and evaluation of potential remedial-action alternatives. To ensure that the combination of existing data and new data to be collected will be adequate for these purposes, the potential pathways leading to human-health and environmental risks associated with off-site surface water contamination, potential off-site problem areas that could require remediation, and categories of corrective measures or remedial-action alternatives have been preliminarily identified (see Section 7.3, Task 4 description, below).

7.2 APPROACH AND ORGANIZATION OF THE CRRFI WORK PLAN

7.2.1 CRRFI APPROACH

The Clinch River RFI Plan has been developed in accordance with both the RCRA Facility Investigation (RFI) Guidance (OSWER Directive 9502.00-6C, July 1987) and the Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (EPA/540/G-89/004), OSWER Directive 9355.3-01, October 1988) issued by the U.S. Environmental Protection Agency (EPA 1987b and 1988, respectively).

A phased approach, relying heavily on risk analysis for estimating human-health and environmental risks associated with off-site contamination, will be employed throughout the CRRFI. This phased approach includes the following components:

1. Initial Review and Synthesis of Existing Information:

Review and synthesis of extant data coupled with an initial (screening-level) risk analysis to identify areas in which additional data are required for purposes of site characterization, risk assessment, and evaluation of remediation alternatives, and to preliminarily identify potential contaminants of concern.

2. Preliminary (Phase-1) Sampling and Analysis:

Sampling and analysis of water, sediments, and biota from selected sites that are representative of differing levels of contamination (including reference sites located upstream from the Oak Ridge DOE facilities) to determine the range of contaminant concentrations present in the off-site aquatic environment, to establish background (reference) concentrations for those contaminants, and to identify specific contaminants of concern by application of Phase-1 human-health and environmental risk analyses.

3. Focused (Phase-2) Sampling and Analysis:

Sampling and analysis efforts directed specifically toward site characterization and human-health and environmental risk assessments, with regard to specific contaminants, media, sites, and species of concern. Phase-2 data sampling and analysis will be

conducted in conjunction with iterative series of human-health and environmental risk analyses (see item 4, below) to provide direction and focus for the data collection efforts.

4. Iterative Risk Analyses:

Continual updating of risk assessments, as additional data become available, to better quantify estimates of potential risks to human health and to the environment, and to focus additional sampling efforts.

5. Identification and Preliminary Evaluation of Potential Corrective Measures / Remedial Action Alternatives

Identification and preliminary evaluation of potentially applicable remediation alternatives for off-site contamination problems. If needed, implementation of corrective measures/remedial actions will be accomplished through the RCRA Corrective Measures Study / Implementation process and the FS/ROD/RA components under CERCLA.

A logic diagram illustrating the decision pathway to be employed in the CRRFI phased approach is presented in Fig. 7.1.

7.2.2 CRRFI TASK STRUCTURE

The CRRFI Work Plan consists of four major tasks:

- Task 1 Site Characterization
- Task 2 Human-Health Risk Assessment
- Task 3 Environmental Risk Assessment
- Task 4 Identification and Preliminary Evaluation of Remedial Action Alternatives

These four major tasks, in conjunction with ongoing on-site remedial action activities, conform to EPA's recommended strategy for:

(1) characterization of contaminant sources and contaminant releases to surface waters (Task 1, also see Sections 4 and 5 of this document),

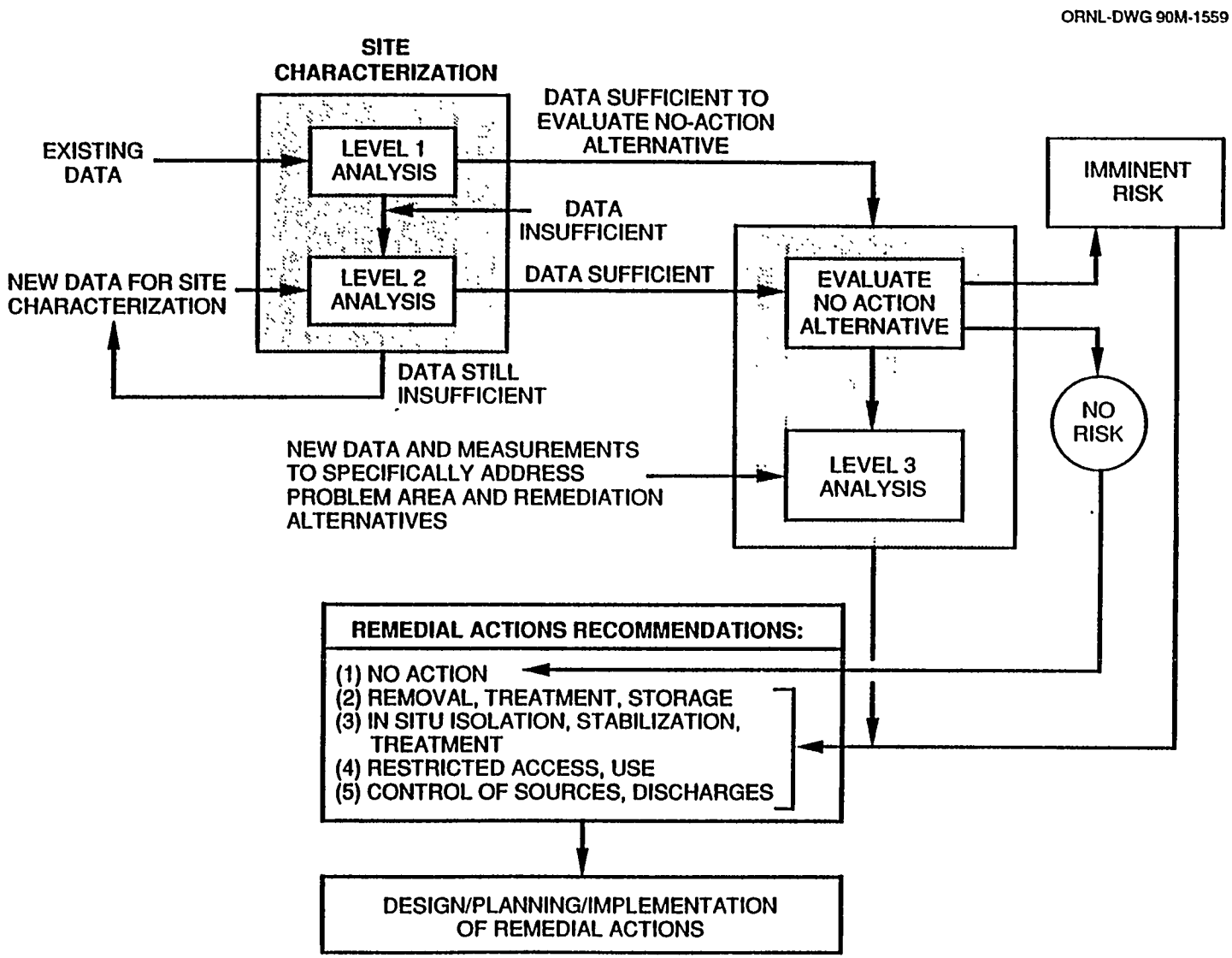

Fig. 7.1. Diagram of the risk-driven decision pathway that will be followed in the Clinch River RFI phased approach. The phased approach will allow the RFI activities to be progressively focused from site characterization efforts to problem identification (via iterative human-health and environmental risk analyses) to identification and preliminary evaluation of potential corrective-measure/remedial-action alternatives.

(2) characterization of the environmental setting and current conditions (Task 1, also see Sections 2, 3 and 4),

(3) identification of contaminants of concern and the extent of downstream migration of those contaminants (Task 1, also see Sections 4 and 5),

(4) identification of potential receptors and quantitative assessment of risks to the public health and welfare, and to the environment (Tasks 2 and 3, also see Section 6), and

(5) preliminary identification and evaluation of potential corrective measures/remedial action alternatives and, if necessary, implementation of interim corrective actions (Task 4).

The relationship of these tasks to each other, to the CRRFI phased approach, and to the final products of the CRRFI is shown in Fig. 7.2. The task structure of the RFI is summarized in Table 7.1, and the CRRFI subtasks are listed within the context of the phased approach in Table 7.2. Details of each task area and its relationship to the other major tasks are illustrated in individual figures that are included in the following Task Descriptions (Section 7.3).

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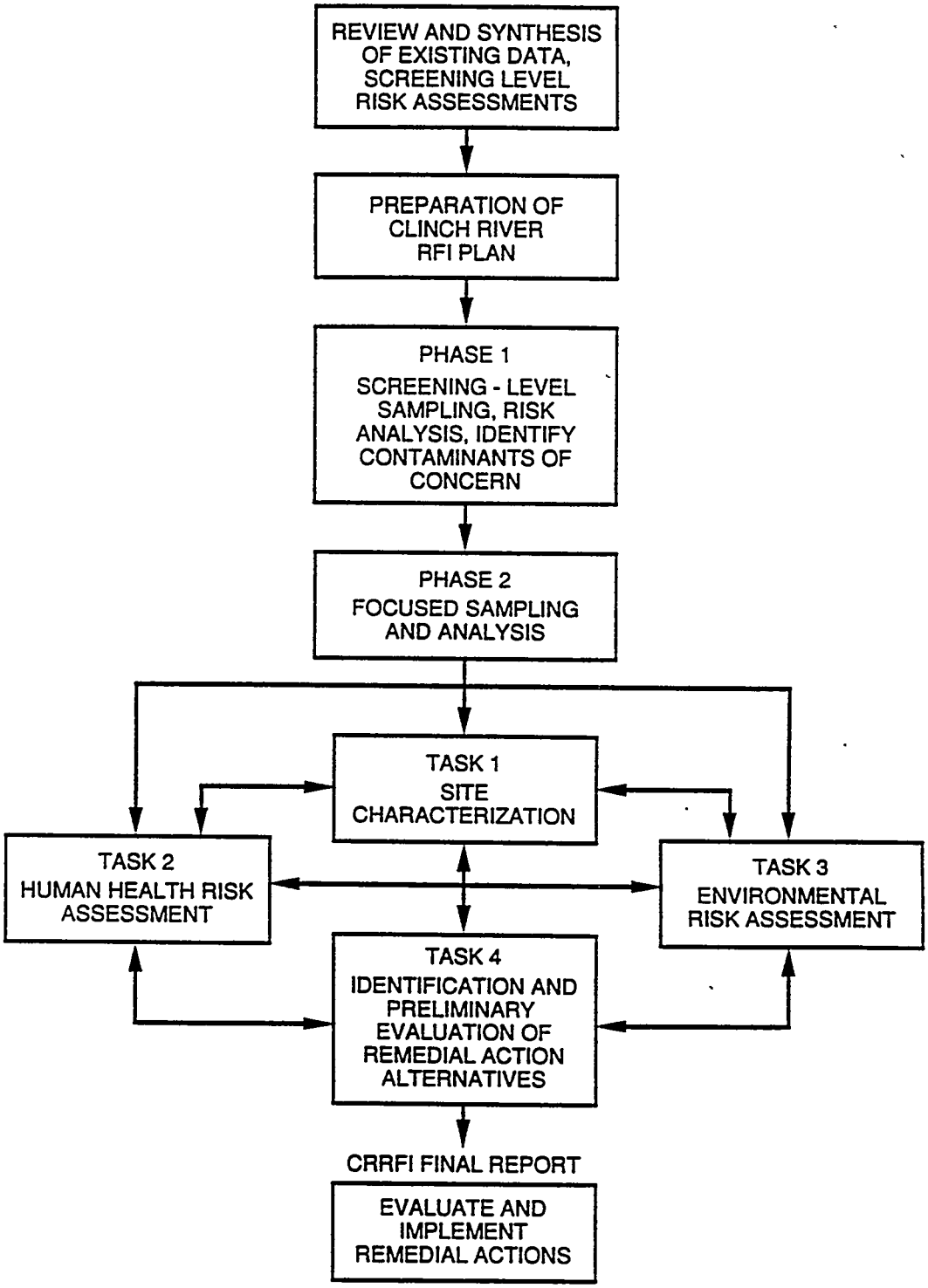

Fig. 7.2. Interrelationship of the CRRFI phased approach and the Work Plan task structure. See Tables 7.1 and 7.2 for additional detail.

Table 7.1. Summary of the Work Plan task structure of the Clinch River RCRA Facility Investigation.

Task 1 - Site Characterization

1.1 Review and synthesis of existing data
1.2 Preliminary ^{137}Cs scoping survey of Watts Bar Reservoir sediments (initiated as a component of the ORNL BMAP)
1.3 Phase-1 (screening-level) sampling and analysis for contaminants of concern
1.4 Phase-2 (focused) sampling for contaminants of concern
1.5 Distributions and inventories for contaminants of concern
1.6 Contaminant remobilization
1.7 Contaminant transport and fate assessment
1.8 Final site-characterization report

Task 2 - Human-Health Risk Assessment

2.1 Preliminary screening-level risk analysis based on existing data
2.2 Risk analysis based on Phase-1 sampling and analysis results
2.3 Focused (Phase-2) pathway-specific risk analyses conducted iteratively as additional data become available
2.4 Risk analysis for multiple pathways of exposure and identification of human subpopulations at risk
2.5. Final report on risk assessment for human-health and welfare

Task 3 - Environmental Risk Assessment

3.1 Initial screening-level environmental risk analysis based on existing data
3.2 Iterative risk assessments based on Phase-1 and Phase-2 sampling and analysis efforts
3.3 Biological indicators of stress in field populations
3.4 Pathway-specific sampling of selected species to quantify environmental risk
3.5 Final environmental risk assessment report

Task 4 - Preliminary Identification and Evaluation of Remedial Action Alternatives

4.1 Preliminary identification of potential problem areas
4.2 Preliminary identification of potential corrective measures/remedial action alternatives
4.3 Preliminary evaluation of potential corrective measures/remedial action alternatives
4.4. Final report on preliminary identification and evaluation of corrective measures / remedial action alternatives

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Table 7.2. CRRFI subtasks listed within the context of the phased approach to be employed throughout this investigation.

Preliminary Scoping

- Review and synthesis of existing data (Subtask 1.1)
- Screening-level human-health and environmental risk analyses (Subtasks 2.1 and 3.1)
- ^{137}Cs survey of Watts Bar Reservoir sediments (Subtask 1.2)

Phase 1

- Sampling and analysis of selected sites (Subtask 1.3)
- Phase-1 human-health and environmental risk analyses (Subtasks 2.2 and 3.2)
- Identification of specific contaminants, media, and pathways of concern

Phase 2

- Focused site-characterization activities:
  - Sampling and analysis focused on specific contaminants, media, and pathways of concern (Subtask 1.4)
  - Distributions and inventories for contaminants of concern (Subtask 1.5)
  - Contaminant remobilization and biological availability (Subtask 1.6)
  - Contaminant transport and fate assessment (Subtask 1.7)
- Focused human-health risk assessment activities:
  - Iterative risk analyses as additional data become available (Subtask 2.3)
  - Risk analysis for multiple pathways of exposure and identification of human subpopulations at risk (Subtask 2.4)
- Focused environmental risk assessment activities:
  - Iterative risk analyses as additional data become available (Subtask 3.2)
  - Biological indicators of stress in fish populations (Subtask 3.3)
  - Pathways-specific sampling of selected species (Subtask 3.4)

Phase 3

- Preliminary identification and evaluation of potential corrective measures (CMs) / remedial-action alternatives (CM/RAs)
  - Preliminary identification of potential problem areas (Subtask 4.1)
  - Preliminary identification of potential CMs/RAAs (Subtask 4.2)
  - Preliminary evaluation of potential CMs/RAAs (Subtask 4.3)

Phase 4

- Final reporting and recommendations

7.3 CRRFI WORK PLAN TASK DESCRIPTIONS

7.3.1 TASK 1: SITE CHARACTERIZATION

BACKGROUND AND OBJECTIVES

Soluble contaminants released from the Oak Ridge Reservation into off-site surface waters are rapidly diluted with Clinch River and Tennessee River water and are flushed downstream through the river-reservoir system without accumulating to any great extent (Nelson 1962, Cowser et al. 1966). For soluble materials (e.g., ^{3}H, ^{90}Sr, ^{99}Tc, ^{129}I), the extent of contamination of the system depends primarily on rates of dilution, water residence times, and the degree of contaminant uptake and retention by biota. In contrast, many less soluble (hydrophobic) contaminants become strongly associated with suspended particles as a result of (1) ion exchange, precipitation, or hydrophobic interactions with particle surfaces, (2) co-precipitation with iron and manganese hydrous oxide coatings, (3) complexation with organic detritus or organic materials sorbed to particles, and (4) uptake into aquatic organisms or incorporation into fecal material.

Sedimentation is the principal mechanism for the removal of particle-associated contaminants (e.g., PCBs, PAHs, Hg, Pb, Cu, Be, ^{60}Co, ^{137}Cs, $^{239,240}Pu$) from the water column, and the primary sink for particle-associated contaminants is their deposition and accumulation in bottom sediments. However, contaminants accumulated in the bottom sediments continue to be available for incorporation by biota via ingestion by benthic (bottom-dwelling) organisms or via sediment resuspension. Contaminants in sediments may eventually be isolated from the zone of biological activity by their burial by clean (uncontaminated) sediments.

River impoundments are efficient settling basins for river-borne suspended particles and particle-associated materials (Ritchie et al. 1975, Olsen et al. 1981, Kimmel and Groeger 1986). Watts Bar Reservoir functions as both (1) a dilution basin for soluble contaminants released from the ORR, and (2) a settling basin for particle-associated contaminants transported down the Clinch River from the ORR. Preliminary results of

the recent ^{137}Cs scoping study of the Watts Bar Reservoir sediments (conducted as part of the ORNL BMAP, see Loar 1988 and Section 5 of this document) indicate that about 85% of the total decay-corrected release of ^{137}Cs from the ORR since 1946 resides in the reservoir sediments. These results suggest that other particle-reactive contaminants of concern (e.g., ^{60}Co, Hg, PCBs) have likely been retained to a similar extent in the Watts Bar Reservoir sediments. While the particle-trapping efficiency of Watts Bar Reservoir effectively limits the downstream migration of particle-associated contaminants, it also results in the long-term accumulation of these contaminants in the reservoir sediments.

Thus, the primary objectives of the site characterization task are to:

(1) define the nature and extent of the contamination of the off-site surface water environment;

(2) quantify the migration, accumulation, and distribution patterns of contaminants of concern; and

(3) provide the data on contaminants of concern required for assessing the potential risks to human health and the environment, and identifying for evaluating potential remedial-action alternatives.

OVERVIEW OF SITE-CHARACTERIZATION SUBTASKS

To accomplish the objectives listed above, eight site-characterization subtasks (outlined in Figure 7.3) will be conducted.

Subtask 1.1 is a comprehensive review of extant data on contaminant releases from the ORR and on contaminant concentrations and distributions in the sediments, soils, and biota of off-site areas. This subtask has been largely completed in preparing the CRRFI Plan and this information is summarized in Sections 4 and 5. Extant data are being used to focus the screening-level human-health and environmental risk analyses for preliminarily identifying likely contaminants of concern, for identifying data needs, and for prioritizing additional work (see Subtasks 2.1 and 3.1).

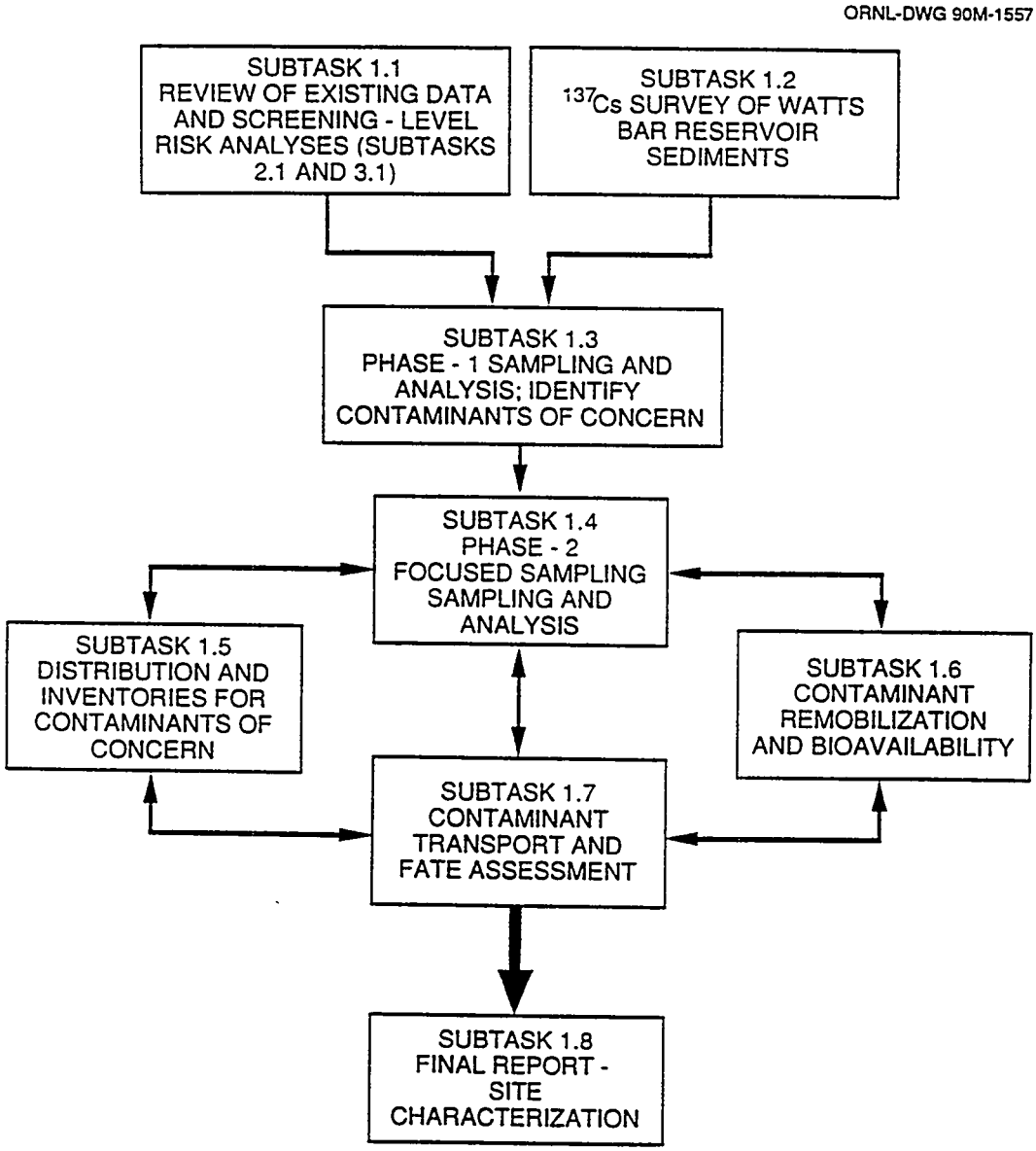

Fig. 7.3. Task 1: Site Characterization. Interrelationship of the Site Characterization subtasks.

Subtask 1.2 is a preliminary assessment of the sedimentary characteristics and of the ^{137}Cs distribution in Watts Bar Reservoir sediments. Most of the field work and analytical work on this subtask have been accomplished as a component of the ORNL BMAP (see Loar et al. 1987, Loar 1988a, and Section 5). The ^{137}Cs scoping of sediments will be extended to other off-site areas as a cost-effective method for identifying contaminant accumulation patterns and revealing potential "hot spots" or problem areas.

Subtask 1.3 is the Phase-1 sampling effort described in detail in the CRRFI Sampling and Analysis Plan. Samples of water, sediment, and biota will be collected from selected off-site areas representative of high-, intermediate-, and low-levels of contamination and will be analyzed for a variety of likely contaminants of concern as determined from existing data on contaminant releases, previous analytical results, and the results of previous screening analyses (see Section 5.8). Analytical results will be used to conduct an initial (screening-level) risk analysis for identifying specific contaminants of concern in human health and environmental risk assessments (see Subtasks 2.1 and 3.1). Depending on the results of the initial screening analyses, decisions will be made concerning contaminants, media, sites, and/or species for which focused (Phase 2) sampling and analyses will be necessary (Subtask 1.4).

In Subtask 1.5, contaminant concentrations and distributions will be mapped and contaminant inventories will be estimated to characterize the nature and extent of contaminant accumulation in the Clinch River and Watts Bar Reservoir sediments. Data obtained in Subtask 1.5 will be used to (1) link contaminant concentrations and inventories directly to human-health and environmental risk analyses (Subtasks 2 and 3), and (2) determine the need for a focused assessment of the mobility and biological availability of sediment-associated contaminants in off-site areas (Subtask 1.6).

If warranted, Subtask 1.6 will examine the potential for contaminant remobilization from the sediments and the availability of deeply buried contaminants to the biota. These results can then be used to estimate the effects of physical and biogeochemical processes (such as organic matter decomposition, chemical diagenesis, and sediment resuspension or relocation by major storm events, boat traffic, dredging, and other human activities)

on contaminant remobilization and bioavailability. This information will be important for determining whether remediation (other than by the natural isolation of contaminated sediments by burial under clean sediment layers) is necessary or advisable.

In Subtask 1.7, a contaminant transport and fate simulation model has already been developed for the Clinch River - Watts Bar Reservoir system (Loar et al. 1987, Loar 1988a). This model will be employed in the site characterization effort for data integration and for predicting the nature and extent of contaminant transport under a variety of flow and contaminant-release conditions. The application of such a model is necessary for integrating and interpreting data from such a hydrodynamically complex system. This two-dimensional simulation model was developed specifically for the Clinch River - Watts Bar Reservoir system by Dr. R.T. Brown of the Water Resources Research Center at Tennessee Technological University, as a component of the ORNL BMAP and the Y-12 Remedial Action Program (see Loar et al. 1987, Loar 1988a).]

The contaminant transport and fate simulation model will be implemented on an iterative basis to integrate and synthesize existing data, data collected in the CRRFI site-characterization efforts (Phase-1 and Phase-2 sampling) and in environmental surveillance monitoring programs conducted by ORNL, Y-12, and ORGDP, hydropower dam discharge data obtained from TVA Reservoir Operations, and contaminant release data. Furthermore, the model will be used to (1) examine the transport and plume concentrations of particle-reactive and water-soluble contaminants released from the ORR, (2) estimate contaminant dilution factors relevant to downstream receptors, (3) characterize water-mass movements and contaminant migration pathways associated with releases from the ORR; (4) link rates of contaminant removal from the water column to the location of contaminant deposition and accumulation zones; and (5) predict the consequences of off-site and on-site remedial action alternatives.

Subtask 1.8 will integrate all site-characterization data and results into a final, comprehensive report on the nature and extent of off-site, surface-water and sediment contamination.

DESCRIPTION OF SUBTASKS

Subtask 1.1. Review and Synthesis of Existing Data

Objectives. Operations and waste disposal activities on the ORR have introduced contaminants into local streams that ultimately drain into the Clinch River - Watts Bar Reservoir system. The purpose of this subtask is to review and integrate extant data on contaminant releases from the ORR and on contaminant concentrations in the water, sediments, soils, and biota associated with off-site aquatic environments. These data are being used to focus screening-level human-health and environmental risk analyses (Subtasks 2.1 and 3.1) toward (1) preliminary identification of likely contaminants of concern, (2) identification of additional data needs, and (3) prioritization and focusing of additional tasks.

Approach. This subtask is ongoing, and has largely been completed in preparation of the CRRFI Plan (see summaries in Sections 4, 5, and 6). Existing data on contaminant releases from the ORR, water quality and contaminant data on the Clinch River and Watts Bar Reservoir, environmental surveillance monitoring data, and data from ongoing studies are being incorporated into the CRRFI Records Control Data Base (see the CRRFI Data Management Plan) as they become available.

Applications. The results from review and integration of existing data will be used to conduct preliminary (screening-level) human-health and environmental risk assessments for identifying potential contaminants of concern and prioritizing data needs (Subtasks 2.1 and 3.1). Additionally, long-term water-quality data sets are being identified and used in calibration and verification of the contaminant transport and fate model described in Subtask 1.7. A thorough review of existing data helps avoid duplication of previous investigations and, therefore, results in a more focused and efficient site-characterization effort.

Subtask 1.2 ^{137}Cs Survey of Watts Bar Reservoir Sediments

Objectives. The objectives of this task are to (1) conduct a preliminary assessment of the sedimentary characteristics of Watts Bar Reservoir sediments, (2) use the distribution of ^{137}Cs to identify contaminant accumulation patterns and potential problem ("hot spot") areas and/or layers in the reservoir sediments, and (3) make a first-order estimate of the extent of ^{137}Cs contamination of the Watts Bar Reservoir sediments. Much of this subtask has already been accomplished as part of an off-site study supported by the ORNL and Y-12 Remedial Action Programs (see Section 5 of this document and Loar 1988a).

Approach. Most contaminants of concern are chemically and biologically reactive, and rapidly become associated with particles in freshwater systems. Consequently, uptake or sorption onto particles is the primary mechanism for removing chemically reactive contaminants from the water phase, and sedimentation is the principal mechanism for the accumulation of these contaminants in off-site areas over long time periods.

Radiocesium was chosen for this scoping effort because (1) it is the primary gamma-emitting radionuclide released from the Oak Ridge facilities, (2) its history of release into the Clinch River is well documented, (3) it is easy and inexpensive to measure non-destructively by gamma spectrometry, and (4) it sorbs rapidly to particulate matter and thus serves as a cost-effective tracer for identifying the transport and accumulation patterns of many other particle-associated contaminants. To date, the distribution of ^{137}Cs has been determined in 187 surface-sediment samples and 61 sediment cores collected from throughout Watts Bar Reservoir (see Section 5).

Applications. The ^{137}Cs scoping of Watts Bar Reservoir sediments has been completed as a component of the ORNL BMAP. The ^{137}Cs scoping technique will now be applied to other off-site areas, including off-channel embayments, tributary mouths, mudflats, island margins, dredge spoil or sludge disposal areas, and floodplain soils along the Clinch River. Off-site areas that contain elevated concentrations or inventories of ^{137}Cs

will be examined for other contaminants in the Phase-1 and Phase-2 sampling and analysis efforts (see Subtasks 1.3 and 1.4, Fig. 7.3).

Because ^{137}Cs behaves like many other chemically and biologically reactive contaminants by strongly associating with particles in river-reservoir systems, the ^{137}Cs distributions determined in Subtask 1.2 serve as a cost-effective method for identifying the accumulation patterns of other particle-associated contaminants. The non-destructive nature of gamma spectrometry and the minimal amount of time and effort required for ^{137}Cs measurements, make ^{137}Cs scoping an inexpensive method for screening samples prior to other, much more costly, chemical analyses for specific contaminants of concern.

Subtask 1.3. Phase-1 Sampling and Analysis for Contaminants of Concern

Objectives. The primary objective of this subtask is to provide contaminant concentration data from selected sites for conducting Phase-1 risk analyses. These initial human-health and environmental risk analyses (see Subtasks 2.1 and 3.1) will be directed at determining specific contaminants of concern to be investigated in the more focused, Phase-II sampling and analysis effort. Secondary objectives of this subtask are to (1) characterize concentration levels for a variety of probable contaminants of concern in the water, sediments, soils, and biota of selected off-site aquatic environments representative of high-, intermediate-, and low-levels of contamination, (2) determine background or reference levels of contaminants in selected sites upstream from ORR releases, (3) characterize the extent and history of contamination in these areas as revealed and recorded in dated sediment cores, (4) identify potential problem areas with regard to human-health or environmental risks, and (5) provide contaminant concentration data useful for evaluating potential remedial-action alternatives.

Task Description and Approach. Accomplishment of the above objectives will require: (1) collection of samples of water, sediment, soil, and biota from selected off-site locations (Fig. 7.4) representative of high-, intermediate-, low-, and background-levels of contamination, and (2) analysis of these samples for RCRA- and CERCLA-listed contaminants identified by the preliminary risk analyses (Subtasks 2.1 and 3.1) as being

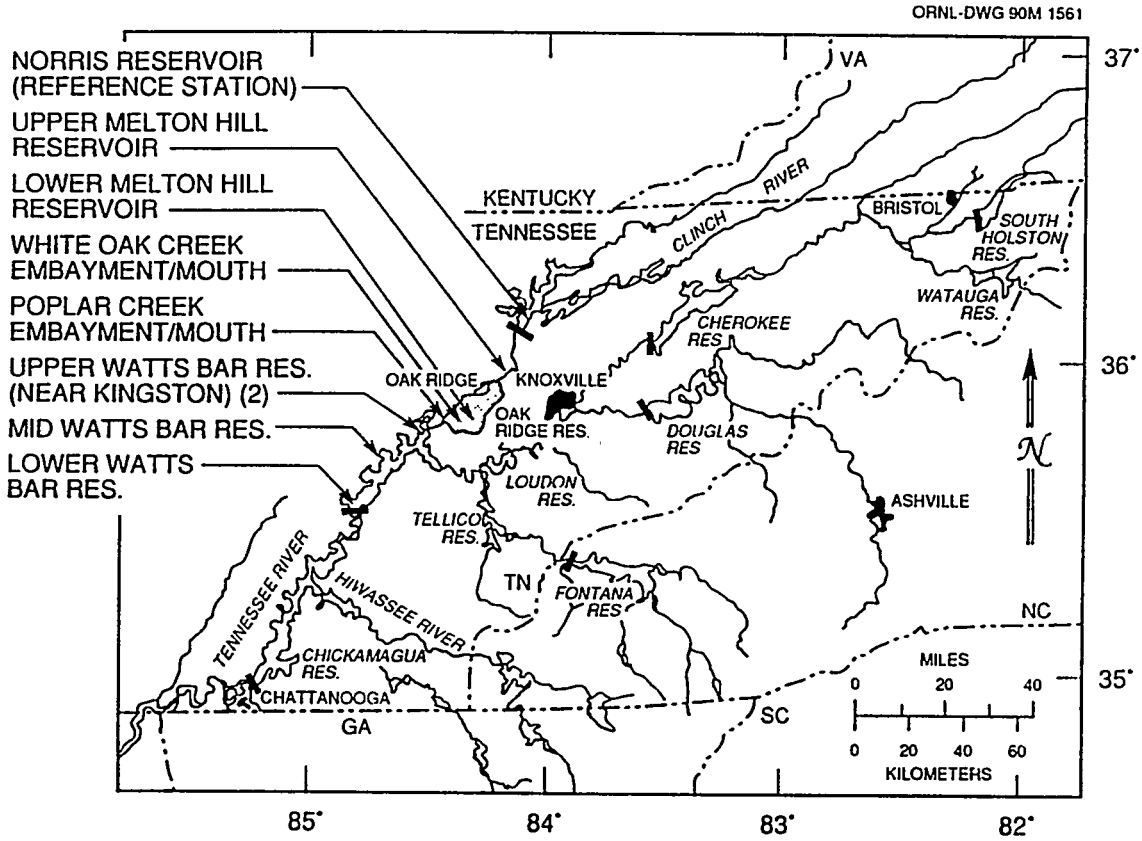

Fig. 7.4. Locations of sites selected for Phase-1 sampling and analysis efforts to identify specific contaminants of concern. The sampling sites were selected to be representative of high-, intermediate-, low-, and background-levels of contamination.

of potential concern (see Table 5.12). The Phase-I sampling effort is described in the CRRFI Sampling and Analysis Plan (see Section 9).

In brief, samples of surface water, sediment, and biota will be collected from each of the following categories of sites:

(1) Reference sites in the Clinch River drainage basins located upstream of the ORR (Norris and Fort Loudoun reservoirs).

(2) Up-lake and down-lake sites in Melton Hill Reservoir, located adjacent to the ORR.

(3) Points of ORR effluent inflow to the Clinch River (White Oak Creek mouth/embayment, lower Poplar Creek, Poplar Creek mouth/embayment, and points of direct discharge to the Clinch River.

(4) Downstream areas in the Clinch River and Watts Bar Reservoir that are representative of high and low sediment/contaminant accumulation as identified in the ^{137}Cs scoping effort (Subtask 1.2).

Analysis of these samples will provide data representative of a broad range of contaminant concentrations in water, sediments, and biota, and will permit the specific identification of contaminants-of-concern based on criteria of elevated concentrations and risk-assessment analyses.

Phase-1 (Screening-Level) Sampling and Analysis. Phase-1 of the CRRFI Sampling and Analysis Plan will be initiated in FY 1990 to expedite identification of specific contaminants of concern. Samples of water, sediment, and biota samples will be collected in each of the areas selected for the screening-level sampling. These samples will be analyzed for a variety of organic compounds, heavy metals, and radionuclides that have been determined to occur in the vicinity of the ORR at levels warranting further consideration (see Tables 5.11 and 5.12). Sampling operations and analyses will be

conducted according to documented environmental surveillance procedures (Kimbrough et al. 1988).

Phase-1 Risk Analysis. Data obtained from the above contaminant analyses will be used to conduct initial risk analyses to identify specific contaminants of concern (with regard to human health and environmental risk; see Subtasks 2.2 and 3.2) in off-site areas. In this way, contaminant concentration data obtained for site characterization will be linked directly to the human health and environmental risk analyses (Fig. 7.3).

Reference Levels and Other Contaminant Sources. A limited number of water, sediment, and biotic samples will be collected in impoundments upstream (Norris, Melton Hill, Fort Loudon) of Watts Bar Reservoir. Despite possible differences in watershed geology that can influence water chemistry, results from Norris, Melton Hill, and Fort Loudon reservoirs may be used to identify contaminant sources and to establish contaminant reference on background levels in sediments and other media at sites upstream from the Oak Ridge facilities. The downstream extent of the contamination originating from the Oak Ridge facilities will be assessed by limited sampling of the Tennessee River reservoirs downstream from Watts Bar Dam during the Phase-2 sampling and analysis effort focused on specific contaminants of concern.

Applications. Phase-1 sample collection will be initiated in FY 1990. The Phase-1 screening analysis and identification of specific contaminants of concern will be completed in FY 1991. The results from the screening-level sampling and analysis will provide the data required for risk analyses aimed at identifying contaminants of concern and providing initial estimates of human health and environmental risks. These results will be used to define contaminant concentrations and to help characterize contaminant sources and accumulation patterns. Depending on these results, decisions will be made concerning the need for additional sampling and contaminant analyses to document contaminant distributions, sediment inventories, and potential health and environmental risks.

Subtask 1.4. Phase-2 (Focused) Sampling for Contaminants of Concern

Depending on the results of the Phase-1 sampling and analysis (Task 1.3), a decision will be made concerning the need for additional sampling and contaminant analyses. This decision will be based on the approach illustrated in Figure 7.1. The approach for this task will be similar to that described in Subtask 1.3. The results will be used to document distributions and inventories for specific contaminants of concern, to make more reliable assessments of potential human health and environmental risks, and to preliminarily identify the most effective and cost-efficient corrective-action/remedial-action alternatives.

Subtask 1.5. Distributions and Inventories for Contaminants of Concern

Objectives . The objectives of this task are to (1) use maps, bathymetric charts, and sedimentological data to characterize the sediment contamination in off-site areas, and (2) quantify distributions and inventories for specific contaminants of concern in the Clinch River - Watts Bar Reservoir system. Meeting these objectives requires a capability of reliably extrapolating data from irregularly spaced samples to estimate the spatial distribution, concentrations, and total accumulation of various contaminants within the entire river/reservoir system.

Task Description and Approach. Knowledge of the off-site distribution of contaminants is required for (1) assessments of the associated risks to human health and to the environment, and (2) evaluation of potential corrective-action/remedial-action alternatives.

A Geographic Information System (GIS) was used in FY 1989 to combine the data on sediment characteristics with ^{137}Cs concentrations to produce a map describing the spatial distribution of ^{137}Cs in the Watts Bar Reservoir sediments and providing an integrated estimate of the total amount of ^{137}Cs retained within the reservoir sediments (Table 5.4).

In this subtask, GIS techniques will be employed to develop maps and estimates of the concentrations and spatial distributions of the contaminants of concern. These maps will be used to identify areas of high potential risk related either to human activities (swimming, boating, fishing, dredging) or to environmental processes such as sediment resuspension and contaminant remobilization. Spatial extrapolation of contaminant data from the sediment samples to the entire river-reservoir system will draw heavily on data obtained in Subtasks 1.2, 1.3, and 1.4 to develop relationships between the contaminants of concern, sediment characteristics, and ^{137}Cs distribution.

Estimates of the spatial distributions of contaminants of concern will be derived by a variety of techniques, including contouring and lattice estimation from the GIS software and kriging for the statistical summarization of the estimated surfaces. Kriging, a geostatistical technique, will be used to estimate both the spatial distribution of contaminants and the variance associated with contaminant distributions and to quantify the spatial correlation structure of contaminant concentrations in the reservoir. Maps will be produced from kriged estimates of contaminant concentrations and statistical confidence bounds throughout the reservoir system.

Kriged estimates will be integrated spatially to provide an overall estimate of contaminant concentrations and inventories for off-site areas of interest, with the associated confidence bounds. These spatially integrated estimates can then be improved, and their variances reduced, by adding auxiliary variables such as topography or water depth. If these variables are sufficiently correlated with the contaminant concentration, then cokriging will lead to better estimates. The parameters describing the contaminant can be used to simulate many possible "realizations" of concentrations with the same spatial correlation and mean. These values can then be used as stochastic input to the contaminant transport and fate simulation model to be employed in Subtask 1.7. The output from the simulation model will propagate the variation in the inputs. This process is called conditional simulation, and it produces a range of model outputs that can be summarized.

A sediment-resuspension index will be developed to identify areas having a high potential for sediment resuspension and contaminant exposure. Factors such as water depth, slope, fetch, lake-level fluctuations, and wave potential will be used to calculate this index. A spatial distribution map for the resuspension index will then be produced and overlain with maps of contaminant concentrations for use in risk analysis. Locations of public beaches, boat ramps, and other high public-use areas will also be mapped to aid in the risk assessment.

Applications. Products of this subtask will include distribution maps and tabulated inventories for contaminants of concern in the Clinch River and Watts Bar Reservoir sediments. Maps and inventories will reflect (1) total areal contaminant concentrations and inventories, and (2) location-specific and sediment-depth-specific contaminant distributions and inventories. In combination with spatial information on sediment resuspension potential and public use areas, location- and depth-specific information will be of particular importance for evaluating contaminant availability to biota, contaminant resuspension and/or remobilization, and the potential consequences of sediment disturbance resulting from natural causes (storm events) or human activities (boating activity, dredging, remedial-action efforts).

Subtask 1.6. Contaminant Remobilization

Objectives. Although burial by sedimentation isolates contaminants from human and biotic contact, contaminant burial may be disturbed in some areas by dredging activities, sediment resuspension, sediment mixing, or contaminant remobilization processes. If site characterization data indicate that contaminant concentrations in bottom sediments could constitute a significant human-health or environmental risk, then the potential consequences of contaminant remobilization from sediments will be evaluated in this subtask.

The primary objectives of Subtask 1.6 are to (1) estimate the mobility, migration, and bioavailability of identified contaminants of concern within specific problem areas, and (2) assess the relative toxicity of contaminated sediments and contaminants remobilized

from disturbed sediments to human and non-human biota. More specifically, Subtask 1.6 will (1) synthesize and assess the information obtained in Subtasks 1.1, 1.3, 1.4, and 1.5 with regard to the potential for contaminant remobilization from both undisturbed and disturbed sediments, (2) develop contaminant remobilization models to estimate the potential future extent of contaminant migration from accumulation zones, (3) identify information gaps on contaminant remobilization using the findings of the preceding subtasks and contaminant remobilization models, and if necessary, (4) conduct measurements to resolve critical information gaps.

Task Description and Approach. Recent work (described in Subtasks 1.1 and 1.2, and in Section 5 of this document) indicates that the sediments of Watts Bar Reservoir contain a large fraction of the ^{137}Cs, Hg, and other particle-associated contaminants released from the DOE Oak Ridge facilities during the past 45 years. Vertical profiles of contaminant distributions in sediment cores indicate that peak concentrations occur at various depths below the sediment-water interface depending on the history of contaminant releases from the DOE Reservation and on sediment-accumulation rates at particular reservoir locations (Fig. 5.3).

Burial by sedimentation helps to isolate these highly contaminated sediment layers from human contact and from availability to the aquatic food web; however, (1) contaminants can undergo migration/remobilization from undisturbed sediments, (2) buried contaminants may be disturbed by both natural processes and human-induced activities, and (3) contaminants in shallower, off-channel areas may occur in a surficial and near surface sediments. A thorough assessment of the potential for contaminant remobilization from surface sediments and from deeply buried layers of contaminated sediments in Watts Bar Reservoir (e.g., deep peaks of Hg and ^{137}Cs contamination, see Fig. 5.5) may be necessary to adequately estimate the human-health and environmental risks associated with (1) high deposition/contaminant accumulation sites, (2) natural sediment disturbances (e.g., sediment resuspension and transport during major storms), and (3) human-induced sediment disturbances (e.g., boating activity, barge traffic, dredging activities associated with maintenance of navigation channels, gravel dredging, or remediation efforts to remove contaminated sediments from the reservoir).

A phased approach will be used to evaluate contaminant remobilization from the Clinch River and Watts Bar Reservoir sediments. Information on contaminant concentrations and distributions obtained in Subtasks 1.1, 1.3, 1.4, and 1.5 will be used to estimate the potential extent of contaminant remobilization from sediments. Simple simulation models will be developed and used as tools to assess the mobility, migration, and bioavailability of sediment-associated contaminants. These time-variable models will be based on available literature values for the key processes occurring in the sediments (e.g., sorption, diffusion, sedimentation, bioturbation, and biogeochemical diagenesis) and will be used to assess the extent of potential contaminant remobilization at specific sites under a variety of sediment-disturbance scenarios.

The model will be employed initially to estimate the potential consequences of sediment resuspension and contaminant remobilization from surface and near-surface sediments and from the buried Hg- and ^{137}Cs-contaminated sediments in Watts Bar Reservoir. If critical information gaps are revealed, field and/or laboratory measurements will be focused on providing the data required to improve the contaminant remobilization/toxicity predictions. If sediment concentrations of other contaminants are found to constitute potential risks to human-health or to the environment (in Subtasks 2.3 and 3.2), the model will be employed to estimate their remobilization potential and toxicity.

Larger-scale effects of sediment resuspension and redistribution on contaminant remobilization will be estimated using the Clinch River - Watts Bar Reservoir contaminant transport and fate model described in Subtask 1.7. Assessments of the relative toxicity of contaminants remobilized from the sediments will be made in conjunction with the human health and environmental risk assessment tasks (Tasks 2 and 3).

Applications. In this task, the consequences of contaminant remobilization from sediments at specific sites will be estimated using site-characterization data on contaminant concentrations and distributions, a simple simulation model, and various

sediment-disturbance scenarios. The results obtained will be used for assessing the human-health and environmental risks associated with contaminant remobilization from (1) shallow contaminated sediments, (2) undisturbed, deeply buried layers of contaminated sediments, (3) disturbance and reexposure of contaminated sediments via storm events, dredging activities, etc. This information will be essential for evaluating remedial-action alternatives, including the no-action alternative of allowing contaminated sediment layers to remain undisturbed.

Subtask 1.7 Contaminant Transport and Fate Assessment

Objectives. The objective of this subtask is to apply a recently developed simulation model of contaminant transport and fate in Watts Bar Reservoir to (1) organize, integrate, and interpret the Clinch River RFI data, (2) characterize the transport and fate of contaminant releases from the ORR, and (3) evaluate the effectiveness and potential consequences of various off-site and on-site remedial action alternatives (Task 4).

Task Description and Approach. A working version of a branched, two-dimensional (longitudinal-vertical), laterally averaged simulation model of the Clinch River - Watts Bar Reservoir system was developed as a component of ongoing ORNL and Y-12 Remedial Action Programs (Loar et al. 1987, Loar 1988a). The river-reservoir transport and fate model is complementary to the Clinch River Dispersion Model and supplementary to ongoing Emergency Response System modeling efforts. Flood-control operations and hydroelectric-power generation at Norris and Melton Hill dams on the Clinch River, at Fort Loudon Dam on the Tennessee River, and at Watts Bar Dam result in a complex hydrodynamic regime in Watts Bar Reservoir, the lower Clinch River, Poplar Creek, and White Oak Creek embayment. Therefore, a two-dimensional transport model is essential for proper interpretation of the data obtained during various reservoir discharge and hydrologic transport conditions, and for short-term and long-term forecasting of contaminant transport, distribution, fate, and effects in the river-reservoir system.

In the working model, the reservoir is divided into 52 segments with up to 10 vertical layers per segment (Fig. 7.5) through which water is routed based on inflow and outflow rates, segment morphometry, and temperature-density relationships. The Tennessee and Emory Rivers are divided into three- to five-mile segments. The Clinch River is divided into one-mile segments to allow a more detailed simulation of the flow and mixing patterns immediately downstream of WOC and Poplar Creek. The working model includes the effects of wedge storage created on the Clinch River during peaking-power releases from Melton Hill Dam and the effects of the flushing of the WOC and Poplar Creek embayments as river elevation fluctuates during peaking-power cycles.

Inflow and outflow data reported in the 1961-1962 Clinch River Study have been used to parameterize the working model and to conduct model runs to assess the effects of different hydropower-operating conditions on the hydrodynamic transport of water-borne material (e.g., a contaminant release or "dye" in the model output, see Fig. 7.6). Results of these initial model runs indicate that the ability to integrate the effects of rapidly varying flow regimes, as provided by the transport model, is essential for interpreting contaminant transport and distribution patterns and for predicting contaminant concentrations downstream.

The overall structure of this model is well-suited for simulating the longitudinal aspects of contaminant transport and fate in a hydrodynamically complex, river-reservoir system. However, additional model verification using existing historical data sets and new field data is still needed. Parameters describing the contaminants of concern will be incorporated into the model following their identification in the screening-level (Phase-1) risk analyses (Subtasks 2.1 and 3.1). Specific capabilities of the model will be developed and incorporated as required in the phased progression of the CRRFI.

Applications. The development of the model structure and the initial model calibration and verification were accomplished as part of ongoing Remedial Action Programs at ORNL and Y-12 . Further modification, refinement, and application of the simulation model will be defined as the CRRFI progresses.

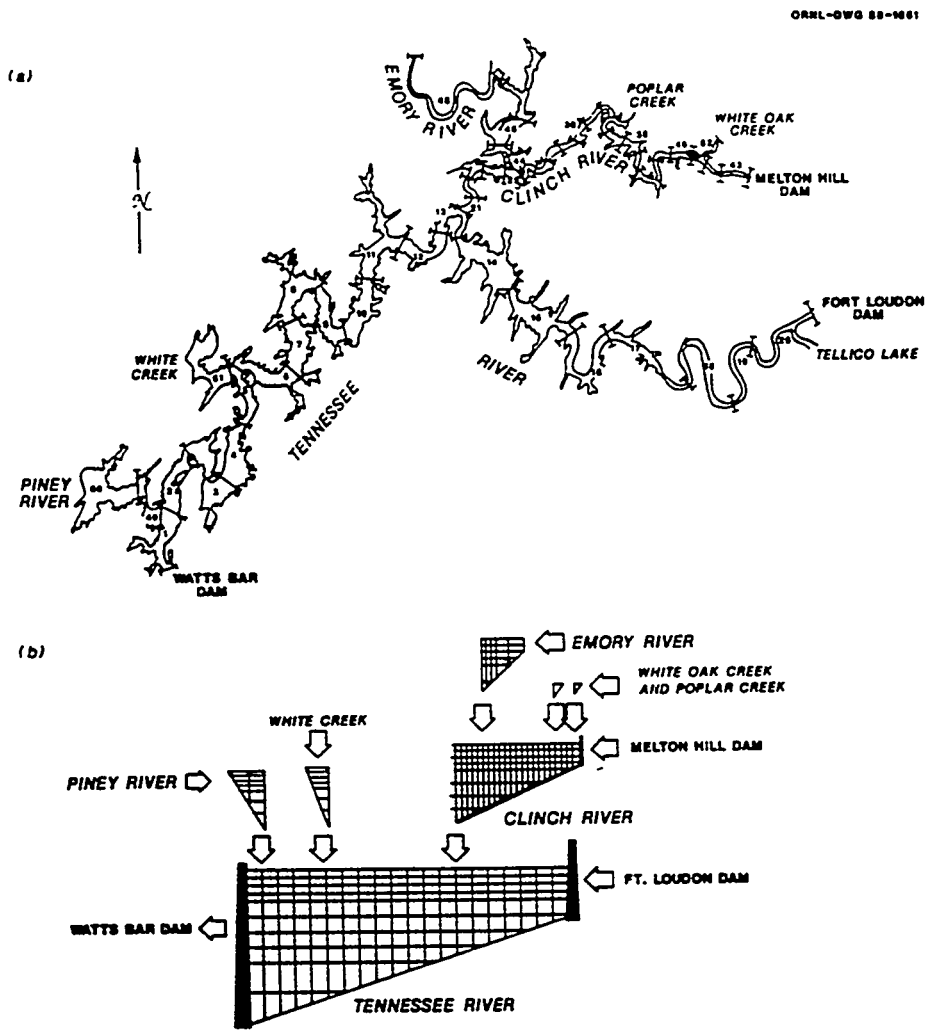

Fig. 7.5. Basic structure of the Clinch River and Watts Bar Reservoir contaminant transport and fate simulation model. The river-reservoir system is divided into 52 segments longitudinally (a), with up to 10 vertical layers per segment (b). Water and water-borne contaminants are routed through the model segments as dictated by inflow and outflow rates, segment morphometry, and water temperature - density relationships.

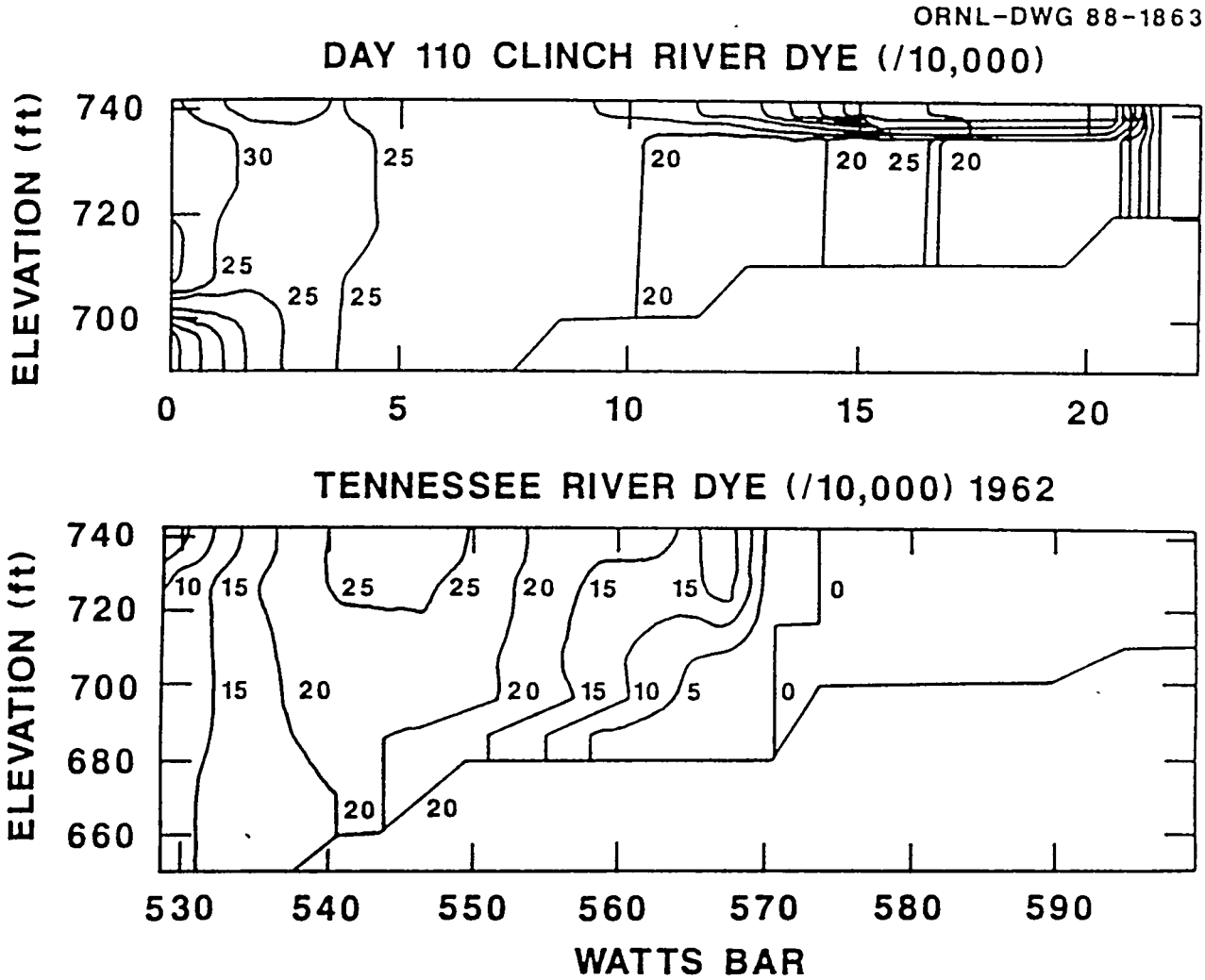

Fig. 7.6. Simulation model output of "dye" (or contaminant) concentrations in the Clinch River and in Watts Bar Reservoir displayed as longitudinal cross-sections of the river and the reservoir.

The contaminant transport and fate model will be employed immediately in site-characterization efforts for integrating data and for predicting the nature and extent of contaminant transport under a variety of flow and contaminant-release conditions. Such a capability is essential for intelligently planning a sampling/monitoring program, for integrating and interpreting data from a hydrodynamically complex system, and for performing human-health and environmental risk analyses based on a range of contaminant transport/release scenarios.

The model will be employed throughout the course of the CRRFI to:

(1) predict the extent of downstream migration and the plume concentrations of both particle-reactive and water-soluble contaminants released from the ORR,

(2) characterize water-mass movements and contaminant-migration pathways associated with contaminant releases,

(3) link rates of contaminant removal from the water column (e.g., by particle production, contaminant sorption, particle transport, and sedimentation) to the distribution of contaminants in the bottom sediment, and

(4) evaluate the effectiveness and potential consequences of off-site and on-site remedial action alternatives.

Subtask 1.8. Interim and Final Reports on Site Characterization

Interim information reports summarizing existing and measured data will be written on a annual basis. A final report on the site-characterization effort will also be written to provide a summary of the results and their implications. This final site characterization report will describe and quantify the nature and extent of contamination in off-site aquatic environments. It will also document contaminant migration pathways, transport and accumulation patterns, and remobilization processes. This information will be used to help decide whether any corrective actions are necessary and to provide recommendations for off-site monitoring strategies.

7.3.2 TASK 2. HUMAN-HEALTH RISK ASSESSMENT

BACKGROUND, OBJECTIVES, AND APPROACH

Risk assessment is a quantitative process conducted to help characterize the nature and magnitude of potential risks to public health and welfare resulting from exposure to hazardous substances, pollutants, or contaminants released from specific sites (EPA 1986, 1989). The baseline public health evaluation is a primary component of RCRA and CERCLA investigations and depends heavily on the quality of the site characterization data (Task 1). Both existing data and data collected during the CRRFI site characterization will be used to determine the extent to which off-site surface water contamination poses a threat to human health and to the environment. Concomitantly, site characterization data and the results of the human-health and environmental risk analyses (Tasks 2 and 3, respectively) will be used to develop and/or evaluate potential corrective-action/remedial-action alternatives (Task 4). These relationships are illustrated in Fig. 7.7.

The process of determining the risk to man is an iterative process. Data collection and analysis can be expensive at the level of detail needed to make a health risk determination. The initial stages of the analysis will use readily available information and broad sampling techniques to identify specific areas, media, organisms, and pathways that are of potential concern. As potential problems are identified, sampling strategies will be narrowed in focus and a more detailed risk assessments will be made.

The primary objective of this task is to determine if radioactive and non-radioactive contaminants released from the ORR into off-site surface waters constitute a threat to human health. This determination will be based on the application of a phased, risk-based approach for evaluating the level of human-health risk associated with contaminants of concern in the Clinch River - Watts Bar Reservoir system:

(1) An initial screening-level risk analysis based on extant data to <u>preliminarily</u> identify likely contaminants of concern (Subtask 2.1),

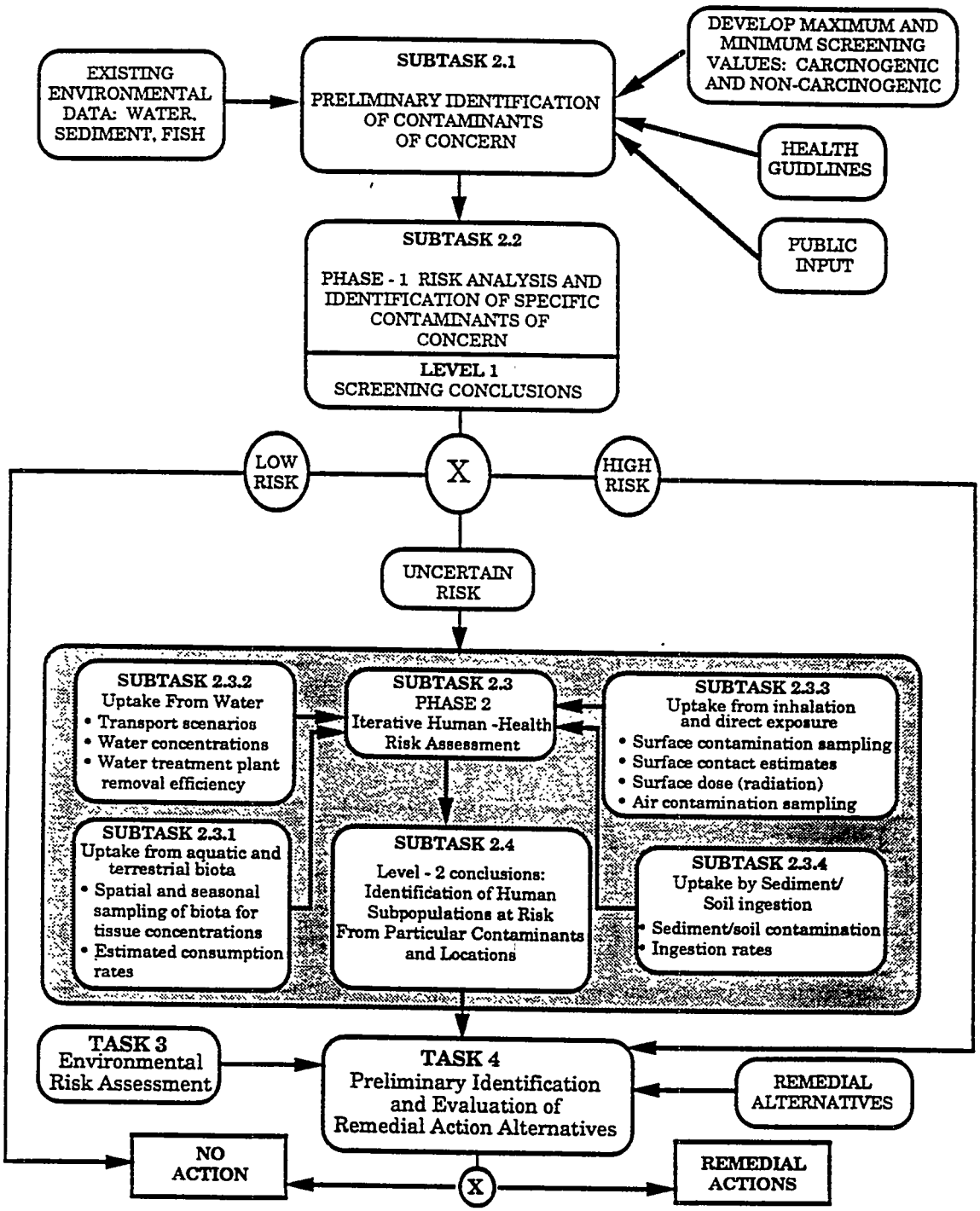

Fig. 7.7. Task 2: Human-Health Risk Assessment. Interrelationship of Task 2 subtasks to each other and to Tasks 1, 3, and 4.

(2) A preliminary risk analysis based on the results of Phase-1 sampling and analysis (see Section 9) to specifically identify contaminants of concern in the off-site surface water environment (Subtask 2.2),

(3) More detailed risk analyses focused on specific contaminants, media, problem areas, and environmental pathways, and based on the results of Phase-2 sampling and analysis to fill critical information gaps (Subtask 2.3). These risk analyses will be conducted on an iterative basis as additional pathway-specific data become available.

(4) Multiple-pathway risk analyses designed to identify particularly vulnerable human subpopulations and to estimate the risk to these subpopulations associated with off-site surface water contamination (Subtask 2.4)

DESCRIPTION OF SUBTASKS

Subtask 2.1. Screening-level risk analysis based on existing data

Preliminary screening analyses based on sediment concentrations have been conducted for radionuclides, metals, and organic contaminants for sites located on the Clinch River, Poplar Creek, and East Fork Poplar Creek (Hoffman et al. 1984; Travis et al. 1986, 1989). In addition, an on-site screening analysis of White Oak Lake and its environs has been conducted for radionuclides, metals, and some organic pollutants (Blaylock 1987, 1988). Results from these previous risk assessments (summarized in Table 5.11) and an initial screening-level risk analysis based on existing data on waste releases and off-site contaminant concentrations (Hoffman) et al., in preparation) have formed the basis for preliminarily identifying the potential contaminants of concern for the off-site surface water environment (Table 5.12).

The necessity for screening arises from the large number of contaminants that have been analyzed for in sediment, fish and water taken from the offsite-environmental prior to the initiation of this investigation. Therefore, the scope of the problem must be defined

to ensure that the sampling plan for the site characterization and the baseline risk assessment of the CRRFI focuses on only those contaminants and exposure media that plausibly contribute to a health or environmental risk. The screening analysis uses existing data to identify needs for additional data and to provide an appropriate focusing of the CRRFI sampling efforts.

For screening of potential contaminants of concern, two approaches are taken. The first uses conservatively biased calculations to identify contaminants and exposure pathways to be assigned a low priority for further study. Conservative calculations are designed to produce results that are highly unlikely to underestimate actual exposures. The second approach uses non-conservative calculations and assumptions to identify contaminants that should be assigned high priority for further investigation. Non-conservative calculations are designed to produce results that are highly unlikely to overestimate actual exposures.

Conservative Screening

The justification for this approach is that contaminants can be confidently assigned a low priority for further study is a conservative estimate of health and environmental risk is sufficiently small.

The conservative approach is based on the maximum reported concentration within a given reach of the off-site environment. This extreme value is selected in accordance with EPA risk assessment guidance (USEPA 1989). The conservative approach assumes that individuals may be exposed continuously to this maximum concentration for 70 years.

Unknown concentrations of contaminants are estimated using pathway models that employ conservative assumptions and transfer coefficients appropriate for screening. When the concentration of a contaminant in a specific environmental medium is below the limits of detection, models are used to conservatively estimate a concentration in that medium from concentrations reported in other media at the location. The models

and parameter values employed in this screening analysis were obtained primarily from Hoffman et al. (1984), Travis et al. (1989), IAEA (1981), NCRP (1984), and NCRP (in press). Where recommended screening procedures did not include values for a given contaminant, Baes et al. (1984), Baes et al. (1989), Lappenbush (1988), Lyman et al. (1982), site-specific data, and best professional judgement were used to provide a conservative estimate of potential exposure.

For contaminants of potential concern to human health, screening indices are calculated. The screening index for carcinogens is a conservative estimate of exposure via ingestion or inhalation of the contaminant multiplied by an EPA approved or suggested "slope factor" for non-radioactive substances (USEPA Integrated Risk Information system, IRIS, December 1989). The "slope factor" provides an estimate of the lifetime risk of additional cancer incidence per unit exposure. For radioactive materials, exposure is translated into units of effective dose equivalent by using factors of dose per unit intake or area deposition recommended for screening (NCRP, in press) and by multiplying by a weighted cancer incidence risk conversion factor (5.7×10^{-2} per Sievert) based on revisions derived from the 1988 report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR 1988; Stather et al., 1988; Clark 1988).

The screening index for non-carcinogens is a ratio that is composed of a conservatively biased estimate of ingestion or inhalation of the contaminant divided by a "reference dose factor" or RfD. An EPA approved exposure level below which adverse effects should not occur (USEPA Integrated Risk Information System, IRIS, December 1989).

To be consistent with EPA recommendations for human-health risk assessment (USEPA 1989a), screening indices for each contaminant are summed over all contaminants in a given pathway. For estimation of potential exposure to multiple pathways, screening indices are summed across pathways for each contaminant. Summation is conducted separately for carcinogens and non-carcinogens. Contaminants that are below the limits of detection in all samples taken from all environmental media at a given location are not included in these summations. In these special cases, the limits of detection are

evaluated according to the risk if the actual concentrations are equal to the detection limit.

Contaminants with non-carcinogen screening indices less than 0.1, or carcinogen screening indices less than 10^{-6}, are designated through conservative screening as definitely low priority substances. Contaminants with non-carcinogen screening indices greater than 1.0 or those with carcinogen screening indices greater than 10^{-3} are designated as potential high priority for further evaluation and potential corrective/remedial action.

For conservative screening, the exposure pathways that are considered are the ingestion of aquatic biota, water, and sediment. The ingestion of contaminated soil, vegetables, milk and meat are also considered as the result of either irrigation with contaminated water or dredging of contaminated sediment. Inhalation of contaminants in air from wind resuspension of surficially deposited dust particles is included. For radionuclides, the external exposure from gamma radiation emitted from radioactive deposits in sediment and surface soil are also evaluated.

The exposure pathways recommended by EPA for base-line risk assessment that have not been included in this conservative screening analysis are dermal contact with the contaminated medium and the inhalation of volatile organic compounds deposited either in sediment or soil (USEPA 1989b). Calculations for these pathways are still under development (USEPA 1989a,b). These pathways are not expected to be significant; however, a more detailed evaluation of these two exposure routes will be conducted during the first phase of the baseline risk assessment to ensure that a low priority of concern is not inadvertently assigned to a potentially high priority contaminant.

For screening analyses of multiple-pathway exposures, reasonable estimates of dietary habits and occupancy factors are used instead of absolute maximum values. Maximum estimates for the utilization of a specific pathway are not likely to apply to a single individual exposed to all pathways simultaneously.

Non-conservative Screening

The objective of non-conservative screening calculations is to rapidly identify contaminants and exposure pathways to be given the highest priority for remedial action consideration. Once a contaminant is assigned as a definite high priority, an immediate review by appropriate experts should be conducted of health advisory criteria established for these contaminants, including a review of the evidence used to establish EPA reference dose factors and slope factors. These reviews could establish the need for immediate implementation of interim corrective measures/remedial actions.

Because of the absence of conservative assumptions, exposures calculated using this approach could be reached or exceeded by some individuals living in the off-site environment. Average concentrations are used instead of maximum concentrations. The dietary habits and occupancy factors used are based on the assumption of causal use of the medium of concern during the lifetime of the individual. Simultaneous exposures to multiple pathways by the same individual are not considered; thus, calculated screening indices for carcinogens and non-carcinogens are not summed across pathways. Exposure pathways are limited to the ingestion fish, water, and sediment, and the external exposure from gamma radiation emitted from radioactive deposits in sediment.

The screening indices used for non-conservative screening are the same as those used for conservative screening. For carcinogens, a non-conservative estimate of exposure is multiplied by an established EPA slope factor to indicate the risk of excess concern incidence during a 70 year life-time. For non-carcinogens, a non-conservative estimate of exposure is divided by an EPA approved reference dose factors because of the possibility that the slope factors and reference dose factors may themselves reflect a large amount of conservatism, detailed reevaluation of these factors is warranted when non-conservative screening designates a contaminant as a definite high priority substance.

For non-conservative screening, contaminants which have non-carcinogen screening indices exceeding 1.0 or carcinogen screening indices exceeding 10^{-3} are designated as of definite high priority for further evaluation and possible interim corrective/remedial

action. Contaminants which have non-carcinogen screening interim corrective/remedial action. Contaminants which have non-carcinogen screening indices exceeding 0.1 or carcinogen screening indices exceeding 10^{-4} are assigned high priority for additional investigation. Because of the absence of conservative in the exposure calculations, contaminants are only designated as potentially low priority substances when non-carcinogen screening indices are less than 0.01 or carcinogen screening indices are less then 10^{-7}.

Subtask 2.2. Risk Analysis Based on Phase-1 Sampling and Analysis Results

A risk analysis based on Phase-1 sampling and analysis data will be conducted to further focus the CRRFI effort on those contaminants that represent a significant risk to human health. Identification of contaminants that, by virtue of their concentrations in the off-site environment and relative toxicity, are either highly likely or highly unlikely to cause a significant effect on human health or a violation of regulatory standards, will result in the most important contamination problems receiving highest priority for corrective/remedial action and/or further investigation (Fig. 7.8).

- Interim corrective/remedial measures will be implemented immediately to protect the public/environment from any contaminant found to be highly likely to result in a significant human-health or environmental risk.

- Contaminants found to be highly unlikely to represent a significant risk to human-health or to the environment will be assigned low priority for further investigation.

- Detailed, pathway-specific risk analyses will be undertaken on an iterative basis for those contaminants for which screening-level risk analyses indicate uncertainty with regard to potential human-health effects, environmental effects, or regulatory violations. Additional data collection may be required to adequately define the risk level associated with these contaminants.

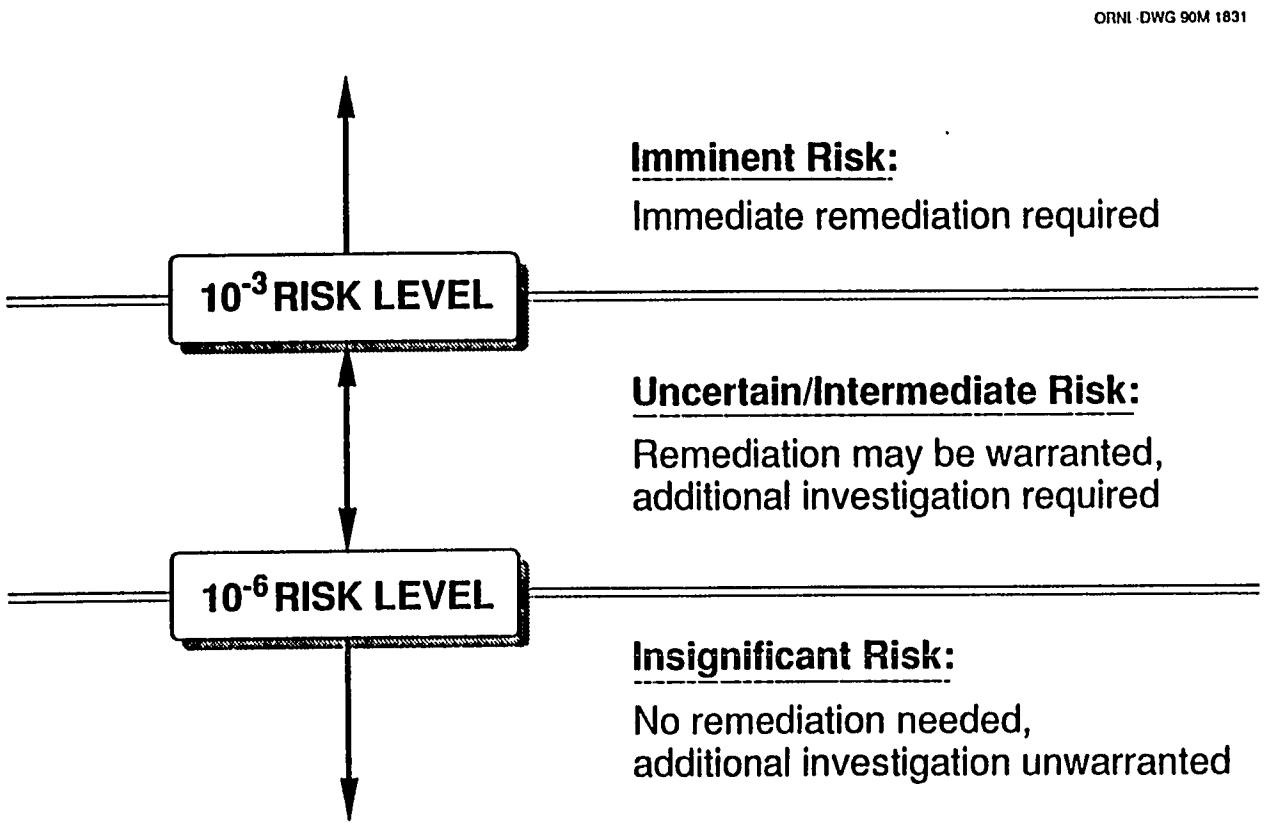

Fig. 7.8. Application of upper and lower risk levels as screening values to provide a consistent approach for identifying contamination problems that present potentially significant risks to human health or to the environment.

This preliminary analysis (Subtask 2.2) will be performed using existing and new data on concentrations of contaminants in water, sediment, and biota with pessimistic "worst case" and optimistic "best case" assumptions to estimate the highest and lowest conceivable exposures to humans. This technique will focus attention on the contaminants of highest importance to determine whether interim corrective/remedial actions should be initiated prior to the conclusion of more detailed investigations.

Subtask 2.3. Focused (Phase-2) Pathway-Specific Risk Analyses

The detailed human-health risk analysis will iteratively evaluate new information collected in Subtasks 2.1 and 2.2 and from the subtasks described below. The protocol will be similar to the initial screening analysis (Subtask 2.1) described above, although the data will be more extensive and more specific to particular contaminants, sites, media, organisms, and pathways of concern. Risk analyses will become more focused on specific environmental pathways (see Conceptual Site Model, Fig. 6.1) and more detailed as additional data become available and the critical problem areas become more apparent.

The more detailed risk analyses will estimate the human exposures and subsequent health risks to be expected from contaminants identified as potentially important as the result of:

- ingestion of aquatic and/or terrestrial foodstuffs,
- ingestion of drinking water,
- ingestion/inhalation of materials resuspended from sediment deposits,
- inadvertent ingestion of contaminants in water, sediment, soils, dredge spoils, and
- direct external exposure from radioactive substances in water, mudflats, sandbars, shoreline/floodplain soils, and sediments.

Subtask 2.3.1. Ingestion of Aquatic Biota by Man

Bioaccumulation of contaminants via the aquatic food chain is a potentially important pathway for the exposure of humans to contaminants released from the Oak Ridge facilities (Fig. 6.1), and is of particular interest in the CRRFI because of the heavy tourism and recreational use of the Clinch River and Watts Bar Reservoir as a sport fishery. Assessment of the risk to human health via this pathway will require data on concentrations of contaminants occurring in the biota that are potentially consumable by humans. Sampling of selected aquatic biota will be conducted at selected sites (see CRRFI Sampling and Analysis Plan, Section 9) to provide the information required for refining the initial screening-level risk analyses and for evaluating the risk to man associated with the ingestion of aquatic organisms taken from the Clinch River - Watts Bar Reservoir system.

A significant amount of monitoring data is available on off-site and on-site aquatic environments associated with the Oak Ridge facilities (see Sections 4 and 5). Data on contaminants in the Clinch River have been collected for more than two decades (e.g., Struxness et al. 1967). Currently, monitoring and abatement programs are being conducted on-site at all three of the Oak Ridge facilities and off-site at selected monitoring stations (e.g., see Rogers et al. 1988). Existing information from previous studies and from the environmental monitoring programs have been used to preliminarily identify potential contaminants of concern and potential environmental exposure pathways to humans to assess the risk to human health associated with contaminant releases from the ORR and to evaluate their effects on the environment (Subtasks 2.1 and 3.1).

Available data have been reviewed to initially assess the potential risk to humans and effects of contaminants on the environment. From the reviews and the preliminary risk analysis conducted in Task 2, potential contaminants of concern (radionuclides, metals, and organics) and exposure pathways that require additional data are being identified.

Preliminary sampling of aquatic biota will be conducted at selected sites identified in Tasks 2.2 and 2.3. Samples will be analyzed for contaminants of concern identified in Task 2.1 and the results will be used to refine the initial human-health risk assessment/screening analysis (Subtask 2.2) and to evaluate the potential risk to the environment (Subtask 3.2).

Sampling programs have been designed to take advantage of available data from monitoring programs and previous environmental studies. Fish, water, and sediment samples will be collected from previously identified sites, Subtasks 2.2 and 2.3. Sampling schedules and the extent of the sampling to be conducted will be determined by the data needed for assessing the risk to human health and to evaluate the effects on the environment (Tasks 2 and 3, respectively).

Preliminary data from the sampling of the aquatic biota will be used in refining the assessment of the risk to humans. As the risk assessment model is developed, data requirements will change and the sampling program for aquatic biota will be adjusted to meet data requirements.

Subtask 2.3.2. Ingestion of Water by Man

The purpose of this subtask is to estimate the concentrations of contaminants that enter public water supplies withdrawn from the Clinch River/Watts Bar Reservoir, under normal (historic) conditions, during high-concentration events such as accidental releases, and with proposed corrective-measure/remedial-action alternatives in place.

The ingestion of drinking water withdrawn from Watts Bar Reservoir is also a potential pathway for human exposure to contaminants released from the ORR (Fig. 6.1). The contaminant concentrations that occur in drinking water are a function of the magnitude of contaminant releases from the ORR, the amount of dilution that occurs in the Clinch River, and the efficiency of the water treatment plants in removing contaminants. Two common water treatment processes can remove contaminants of interest: suspended solids removal through flocculation and/or settling can remove contaminants attached

to sediment particles, and water softening can remove dissolved cations such as cesium, strontium, inorganic mercury, and other metals.

The first step in determining the risk to human health from ingestion of water-borne contaminants is to measure or estimate the contaminant concentrations in untreated surface water at the water intake location. If risk analysis using the concentrations in untreated water indicates that the risk involved in water ingestion is insignificant, then further consideration of contaminant-removal effectiveness of water treatment will be unnecessary.

However, if significant risk is associated with drinking untreated water, then monitoring data on treated water will be examined and the effectiveness of contaminant removal by water treatment plants will be addressed by reviewing existing monitoring data on contaminant concentrations in water-plant treated drinking water, information on treatment processes used by plants withdrawing water from the Clinch River or Watts Bar Reservoir, and the contaminant removal efficiencies of the processes used. The Clinch River - Watts Bar Reservoir contaminant transport model developed in Subtask 1.7 will be used to predict contaminant concentrations in untreated surface water at water treatment plant intake locations using a variety of contaminant release - dam discharge - water-plant efficiency scenarios.

Subtask 2.3.3. Direct Exposure to Man

Floodplains, mudflats, shoreline areas exposed by reservoir drawdown, islands, and fields irrigated with Clinch River water provide opportunities for direct human contact with deposited contaminants (Fig. 6.1). These areas may contain contaminated sediment deposits, and some sites (e.g., Jones Island, located just downstream from the mouth of White Oak Creek) are known to have been the recipients of navigational-dredging spoils that may be contaminated. Deposited radioactive materials in these areas could result in a direct radiation exposure to man; both radioactive and non-radioactive materials could be inhaled or ingested from dust, water, or soil. The possibilities of direct human exposure to contaminants via work (farming, plowing, digging, walking) and recreational

activities (swimming, wading, boating, picnicking, walking, hunting, and fishing) in these areas will be evaluated to determine the extent and magnitude of the risk to human health. The possibility of ingestion of contaminated soil by small children will also be considered.

If warranted, gamma-radiation surveys will be conducted to determine the risk resulting from direct human contact with contaminants deposited in the floodplain, mudflat, and island sediments, and in sludge-disposal areas (including sludges from water treatment plants) (Fig. 6.1). The gamma-activity data will be used to focus air, soil and vegetation sampling strategies. If necessary, samples of air, soil and vegetation will then be collected and analyzed to identify contaminants of concern. Air samples will be analyzed to determine risk due to inadvertent inhalation of contaminants resuspended from the ground surface.

Potential human exposure and associated health risks via recreational activities will also be evaluated. A preliminary estimate will be made of the direct exposure of man to contaminants while in the water swimming and wading, while on the water boating and fishing, and while on the shore participating in sunning, picnicking, and walking. Contaminant concentrations in the water, sediment, and soils will be used in conjunction with preliminary exposure estimates to evaluate the potential health risks associated with these activities. Sludge disposal sites associated with water treatment plants will be a special case of the assessment of direct exposure. As data from identification, survey, and analysis of sludge disposal sites become available, risk assessment will be performed to determine potential adverse health effects to the exposed subpopulations.

The results of the preliminary screening analysis will determine whether additional exposure pathways also warrant detailed investigation. These exposure pathways include the ingestion of terrestrial food products grown from soils containing contaminated sediment or water treatment sludge and the ingestion of waterfowl and game animals. The inadvertent exposure due to soil ingestion and the possible inhalation of material resuspended to the atmosphere from the ground has been addressed in the previous sections.

Subtask 2.4. Identification of Human Subpopulations at Risk and Risk Analysis for Multiple Pathways of Exposure

This subtask will use risk analysis for multiple pathways of exposure to identify groups within the human population that may have considerably greater than average health risks due to either increased likelihood and magnitude of exposure or increased susceptibility of being affected. In addition, an analysis will be performed of the collective impact on the total population potentially utilizing water and food products derived from the Clinch-Tennessee River system. The effectiveness of water treatment facilities to remove contaminants from the Clinch and Tennessee Rivers as well as the potential for significant exposures to occur at such facilities will also be evaluated.

Certain subgroups within the human population may have considerably greater health risks from contacts with hazardous substances than other subgroups due to an increased probability of exposure, increased frequency of exposure, and/or an increased susceptibility. The subgroups at higher risk in this study will have had some exposure to the Clinch River-Watts Bar Reservoir system. Exposure can occur through the consumption of fish, the ingestion of water, the consumption of terrestrial food products, the inhalation of suspended materials, or through direct exposure to water, soils, and sediment.

Subpopulations with high fish consumption, populations receiving drinking water from the Clinch River, and populations using the recreational facilities on the Clinch River-Watts Bar Reservoir system are potentially at risk. Preschool children (ages 1-6) and children with pica (a tendency to ingest soil), for example, have a particularly greater chance of being contaminated through the ingestion of contaminated soils and sediments. Workers at water treatment facilities represent another population of potential interest.

If contaminant levels in fish tissue and preliminary risk assessment analyses indicate that a potential risk to human health exists, subpopulations at risk via fish consumption will

be identified through review of sportfishing creel census data and an evaluation of local commercial fisheries, in cooperation with the Tennessee Wildlife Resources Agency. The creel census review will help characterize the local sports fishing harvest and rate of consumption, while the commercial fishery evaluation will permit a better determination of the potential human exposure occurring through consumption of commercially available fish. This evaluation should identify the degree of contamination present in the commercial fisheries and the fate of the fish harvests so that subgroups with increased opportunities of exposure due to fish consumption can be identified.

If warranted, a survey of fish consumption habits of the identified subgroups at risk will then be conducted to evaluate the magnitude and extent of exposure represented by this exposure pathway. This information will be used to evaluate the health risks associated with fish consumption.

Enhanced risk due to consumption of contaminated water will be identified through review of water consumption habits of populations that use the Clinch River-Watts Bar Reservoir as a source of drinking water. Determination of the effectiveness of water-treatment methods to remove contaminants will be used to evaluate adverse health effects posed by consumption of contaminated water. The risk to human health involved in consuming untreated contaminated water will be estimated as an initial step.

Subpopulations at greatest risk from direct exposure due to gamma- activity and contaminant concentrations associated with floodplain, mudflat, island, shoreline, and water treatment sludge disposal will be designated. Effects of exposure to soil through dermal and internal means will be investigated.

Subpopulations exposed to contaminated surface sediments will be examined. The river and reservoir both contain sediments that are contaminated in various locations. Humans receive direct exposure to the surface of these sediments through recreational activities such as wading, swimming and skin diving. The gamma activity data and contaminant concentrations of the surface sediments will be used to estimate this risk. To determine the location, timing, and mode of exposure constituting the maximum risk

to man, various flow, contaminant release, and hydropower operation scenarios will be examined via simulation analysis (Subtask 1.7).

If the risk-assessment procedures described above indicate potentially high levels of exposure and associated risks to these subpopulations, a direct determination of the extent of human contamination will be made. Because individuals can be a member of more than one subpopulation, the individual and combined pathways that represent the maximum risk to man will be used to identify the subpopulation(s) at greatest risk.

7.3.3 TASK 3. ENVIRONMENTAL RISK ASSESSMENT

BACKGROUND AND OBJECTIVES

A diverse assemblage of fishes and other aquatic organisms reside in the Clinch River-Watts Bar Reservoir system and contribute to an active sport fishery, environmental aesthetics, and a significant regional tourism industry (see Sections 5 and 6). Sensitive components of a balanced aquatic ecosystem may be impacted by contaminants released to the Clinch River from the Oak Ridge Reservation. Environmental surveillance of the Oak Ridge environment has centered primarily on (1) physical-chemical processes related to contaminant concentrations, transport, and distributions, (2) toxicity of facility-derived effluents to bioassay organisms, and (3) contaminant levels in fish tissue relevant to ingestion of fish by man. Heretofore, little attention has been focused on the health or physiological status of the off-site aquatic biota, the potential effects of contaminant releases on ecosystem integrity, or impacts on the recreational fishery and regional tourism.

The objective of this task is to determine whether ORR-derived contaminants in the off-site aquatic environment pose a threat to aquatic populations (including water-feeding birds) or to the integrity of the Clinch River/Watts Bar Reservoir ecosystem. If so, then details of the environmental risk assessment and the associated data collection and analysis will provide specific guidance for the evaluation of potential corrective measures/remedial actions (Task 4).

This task will employ an iterative environmental risk assessment process based on evaluation procedures developed for the Environmental Protection Agency (Suter et al. 1984, Barnthouse and Suter 1986). The assessment will integrate existing information and new site characterization data on the river-reservoir system. It is intended to be responsive to public concerns and to incorporate the best available criteria and guidelines for identifying ecological effects. For problem areas, where screening-level analysis indicates potential for risk to non-human biota, this task will include evaluation of biological indicators of stress (using procedures developed for the NPDES monitoring

of East Fork Poplar Creek and White Oak Creek) and monitoring of specific aquatic or terrestrial populations determined to be at risk. Thus, the CRRFI environmental risk assessment will include both (1) risk analysis based on contaminant concentrations and regulatory criteria, and if warranted, (2) direct physiological-ecological evaluation of contaminant effects on the aquatic biota.

APPROACH

As in the Human-Health Risk Analysis (Task 2), the environmental risk analysis will include an initial screening-level risk analysis based on existing data, and a secondary screening analysis based on the results of the Phase-1 sampling and analysis. Accepted criteria (where available) will be used to group potentially hazardous materials in one of three categories: (1) imminent risk - high enough probability of risk that corrective/remedial action is warranted without further study, (2) intermediate risk - in a risk range in which there could be ecological damage and further assessment and data collection are advisable, and (3) no risk - levels so low that no damage could result (e.g., Fig. 7.8). Screening-level risk assessments will be followed by more detailed, iterative risk analyses that incorporate site-specific and/or pathway-specific data determined to be required by the preceding risk analyses (e.g., Fig. 7.9).

Steps in the iterative risk-assessment process include (1) identification of standard laboratory toxicity test data for the potentially hazardous, ORR-derived materials and local aquatic species, (2) comparison of contaminant concentration data from the Phase-1 and Phase-2 sampling and analysis efforts (Task 1) with national water-quality criteria and State of Tennessee water-quality standards, (3) application of toxicity data extrapolation methods, including error estimation, to estimate concentrations of contaminants that would affect a small proportion of species, and comparison of these estimated critical concentrations with measured concentrations, (4) measurement of key biological indicators of stress in fish populations from the zones of contaminant accumulation (identified in Task 1.2) in the river-reservoir system, (5) compilation of any effects estimated for individual organisms into an available reproductive-potential models of largemouth bass or of other game-fish species, (6) spatial and seasonal sampling and

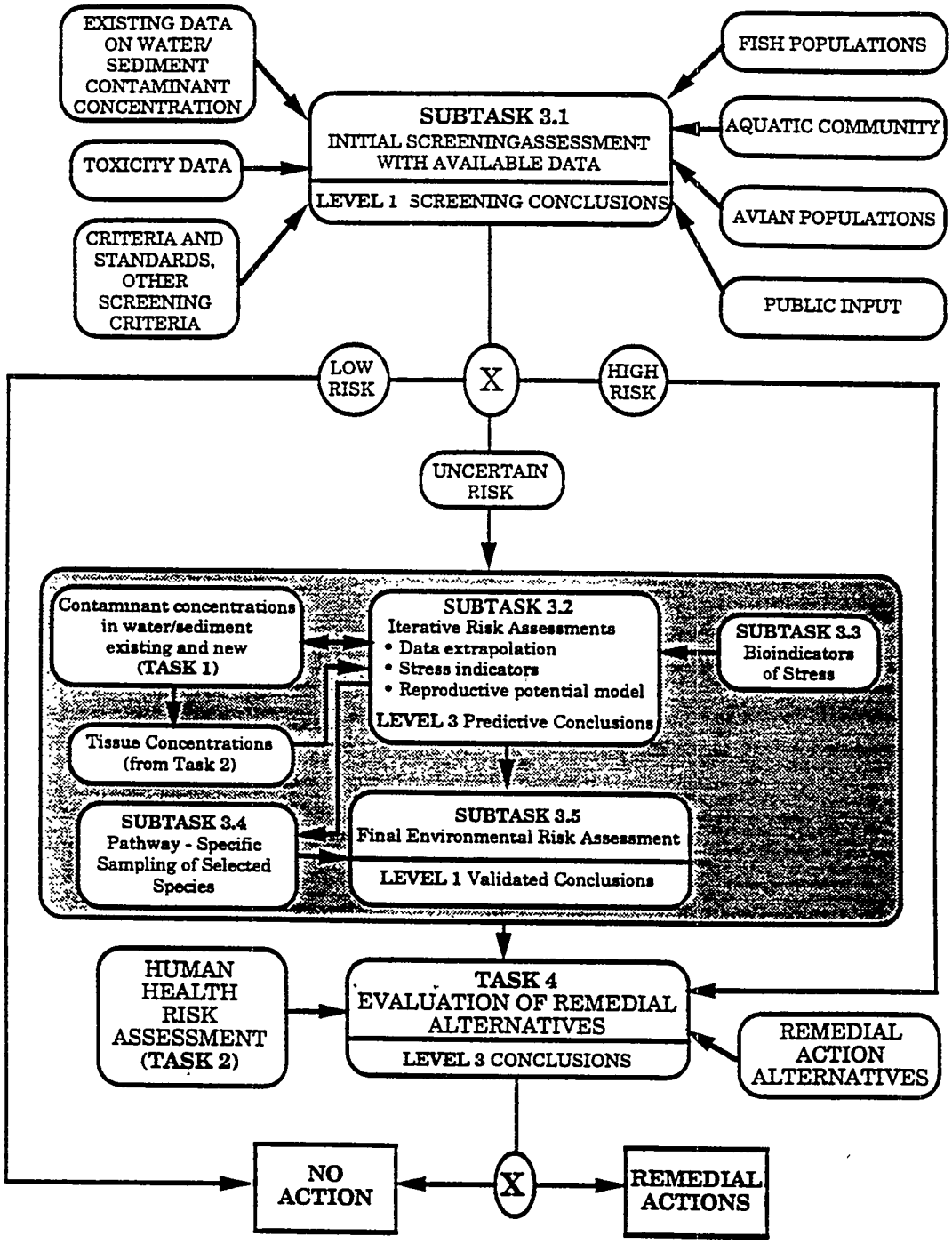

Fig. 7.9. Task 3: Environmental Risk Assessment. Interrelationship of Task 3 subtasks to each other and to Tasks 1, 2, and 4.

analysis of selected species if effects are predicted by the above analyses, and (7) further focusing of the above assessment tasks as more field information becomes available and for conditions anticipated to occur during and after the implementation of potential remedial-action alternatives identified in Task 4. The relationships among these activities and the interfaces with site characterization, human-health risk analyses, and preliminary evaluation of remedial action alternatives are illustrated in Figure 7.9 and described in the subtask descriptions below.

The information base for these analyses will consist of both existing and newly collected data. Available environmental monitoring data will be used for the initial screening-level risk analysis, and results of the Phase-1 sampling and analysis effort will be incorporated into secondary environmental risk assessment. Additional data will be gathered in the Phase-2 sampling and analysis effort to fill critical information gaps.

Because there are no criteria or standards for sediment quality (much of the ORR-derived contamination resides in sediment deposits), it will have to be assumed initially that pore-water concentrations of contaminants are the most relevant. Additional studies may be necessary to test this assumption and to evaluate the importance of contaminant remobilization (Subtask 1.6). Decision criteria for numerous toxicants are not presently available, and staff will use best professional judgement in these cases.

DESCRIPTIONS OF SUBTASKS

Subtask 3.1. Initial Screening-Level Environmental Risk Analysis

Conventionally, assessments of the environmental effects of chemicals on aquatic systems, including those assessments used in effluent permitting and waste-site evaluation, are based on standard laboratory toxicity tests. Therefore, the first tier (Level-1) of risk analysis for off-site environmental effects will be based on existing laboratory test data. Thus, the initial risk analyses will provide a basis for comparison to other sites and to current regulatory practice.

The exposure assessment portion of the risk assessment will be provided by the site characterization and contaminant transport and fate modeling activities described in Task 1. Tasks 1 and 2 will provide data on concentrations of individual contaminants in water, sediments, and selected biota, including contaminant concentrations occurring in selected on-site locations on the ORR (sources for off-site contamination). This subtask (3.1) will evaluate (1) the effects on nonhuman biota (i.e., how do organisms respond to the contaminants) and (2) the relationship of exposure and effects (i.e., how does the temporal pattern of exposure in the field relate to the onset of toxic effects).

Effects of exposure to contaminants in water will be based on four considerations: (1) ambient water quality criteria and standards for protection of aquatic life, (2) concentrations that are toxic to individuals of particular species of concern in the Clinch River and Watts Bar Reservoir, (3) concentrations that would not be toxic to most of these species, and (4) effects of toxic contaminants on populations of fish due to the combined effects on all life stages. The National Water Quality Criteria for Protection of Aquatic Life and the Tennessee Water Quality Standards will be compared to the observed and modeled concentrations of contaminants in the Clinch River-Watts Bar Reservoir system both to show how well regulatory criteria are being met and to provide a standard against which risk assessment results can be compared.

Both national and Tennessee water quality standards are intended to protect most species most of the time; however, there is a risk that environmental concentrations that fall below the criteria could affect aquatic life. In addition, it is likely that for some contaminants there will be no criteria or standards, no toxicity data for certain aquatic taxa present in the Clinch River, no chronic toxicity data for certain taxa, or toxicity data on too few taxa to determine the distribution of sensitivity across taxa. To address the problem of insufficient data, toxicity data extrapolation methods developed for the U.S. Environmental Protection Agency (Barnthouse and Suter 1986) will be applied. These methods will be used to estimate a concentration equivalent to a water quality criterion, to predict chronic toxic effects concentrations for specific important species in the Clinch River-Watts Bar Reservoir system, and to estimate the concentration that would affect a small proportion (e.g., 5%) of species. In addition, the error estimation

and propagation methods developed for these extrapolations will be used to estimate risks that effects will occur given the uncertainty concerning the actual concentration at which a particular effect will occur.

Water quality standards and criteria and the extrapolation methods discussed above all specifically address contaminant effects on individual organisms. However, human interests in aquatic biota and effects on "ecosystem integrity" concern population-level properties such as the number of organisms, the mass of organisms, or the extinction of populations, rather than effects on individuals. To address population-level concerns, the effects on individual organisms of each age class must be combined in a population model. A reproductive-potential model for largemouth bass (Micropterus salmoides, the major game-fish species in the Clinch River and Watts Bar Reservoir) is already available (Barnthouse et al. 1987) and will be used for this purpose. Laboratory toxicity data for the contaminants of concern will be translated into a complete set of toxicological parameters for the model using procedures developed for the EPA (Barnthouse and Suter 1988). Propagation of error in the extrapolation procedures and the model will provide an estimate of the probability that population performance will be reduced as much as 5%.

Sediments serve as a sink for persistent contaminants, and benthic organisms and bottom-feeding fishes are exposed to those contaminants. There are no criteria or standards for sediment quality. We will perform a screening-level risk assessment of sediment effects using existing measurements of sediment contamination (from existing data and Task 1 results) and assuming that the concentration in pore water is the relevant expression of exposure. Pore water concentrations will be estimated from sediment concentrations by assuming equilibrium partitioning. This assumption will be tested by measuring sediment and pore-water concentrations of contaminants of concern (Subtask 1.6).

These assessment procedures address risks to aquatic biota, but not to birds that feed in the aquatic environment (ducks, herons, geese, kingfishers, etc.). Historically, birds have been severely affected by aqueous pollutants. Unfortunately, they are not considered in

the setting of criteria and standards or in conventional risk assessments. In this initial assessment we will determine which contaminants occur at sufficient concentrations in water, sediments, or aquatic biota relative to their toxicity and potential to bioaccumulate. Results of this screening assessment will be used to determine which contaminants, if any, need to be analyzed for their effects on birds in addition to the analyses that will be performed for the food-chain pathway to humans (Subtask 2.2). Data recently collected on contaminant levels in waterfowl frequenting aquatic habitats on and near the ORR (Section 5.7.3) will be used for this purpose.

The staff performing this subtask will monitor the planning and results of Subtasks 3.3 and 3.4 (described below). This interaction will determine what assessment analyses should be performed in later years and will help to assure that the data collected focus on the contaminants that pose the greatest risk and are useful for assessment. In addition, we will determine whether the contaminants of concern identified in Tasks 1 and 2 on the basis of human-health risk include all of the contaminants that are of concern in regard to environmental effects.

Subtask 3.2. Iterative Pathway-Specific Assessments Based on New Data

Data collected in Tasks 1, and 2 will be used in interim assessments and in a final risk assessment of off-site effects on the aquatic biota and birds. The assessment procedures used will depend on the methods used in the other tasks and on their results.

New data on concentrations of contaminants in water and sediments will be compared to those used in the Level-1 environmental risk assessment and, if there is sufficient deviation, the assessment models will be rerun with the new concentrations. Concentrations of contaminants in fish will be compared to concentrations that have been associated with toxic effects in the laboratory or in the field.

The issue of radiation effects on aquatic populations will be addressed. Previous studies in White Oak Lake did not show such effects, even when radionuclide concentrations

were much higher than they are now (Blaylock and Trabalka 1978). Concentrations of radionuclides (Subtask 2.2) will be used to calculate estimates of doses to fish, waterfowl, and muskrats using the BIORAD program (Trubey and Kaye 1973). Concentrations and doses will be compared to those reported in the literature to cause effects in aquatic biota (IAEA 1976, Blaylock and Trabalka 1978, Woodhead 1984, and Anderson and Harrison 1986). Doses will also be correlated with the frequencies of tumors and other lesions observed in Subtasks 3.3 and 3.4. Although tumors and lesions are unlikely to be so frequent as to affect fish populations, the occurrence of such abnormalities is unaesthetic and often suggests to fishermen that human health may be endangered.

The results of biological indicator measurements (see Subtask 3.3, below) will also be integrated into the environmental risk assessment. The biological indicator methods represent a relatively new tool in ecological assessment, although similar approaches have long been employed in fishery management to assess the relative "condition" of fish populations.

Subtask 3.3. Biological Indicators of Stress

Background. Organisms inhabiting off-site areas such as Poplar Creek, White Oak Creek embayment, the Clinch River, and Watts Bar Reservoir may experience various types of detrimental biological effects due to contaminant loading from on-site point sources such as East Fork Poplar Creek (Y-12), White Oak Creek (ORNL), and Poplar Creek (ORGDP). In addition, these off-sites areas may receive contaminant inputs from non-point sources such as waste-burial ground leachates. Stress due to contaminant exposure can result in reduced growth, impaired reproductive ability, increased vulnerability to infectious diseases, and reduced capacity to tolerate additional stresses even when contaminant levels are not directly lethal (Wedemeyer et al. 1984). Effects at the physiological and organismal levels may be manifested as reduced recruitment and compensatory reserve of populations, and may ultimately result in observable changes at the community and ecosystem levels (Ryan and Harvey 1977, McFarlane and Franzin 1978).

Because risk analyses may indicate that aquatic organisms and/or populations in off-site surface waters are potentially at risk due the effects of contaminants released from the ORR, cost-effective approaches are needed to (l) determine if aquatic organisms in these off-site areas are indeed stressed, (2) predict the effects of stress before long-term or irreversible changes occur at the population, community, or ecosystem levels, and (3) evaluate the nature (type and magnitude) of stress effects in order that appropriate corrective measures can be implemented.

This assessment will use multiple indicators of stress effects on fish, because individual indicators can not be equally sensitive to the presence of a variety of contaminants (Heath 1987), and no single index can provide the predictive capability to evaluate population-, community-, or ecosystem-level changes (Cairns and van der Schalie 1980, Capuzzo 1985). The use of biological indicators is a cost-effective approach that combines the ability to maximize predictive capabilities with the ability to monitor a spectrum of sensitivities and points of ecological relevance in relation to the effects of contaminant stress on aquatic organisms.

Approach. Bioindicators were originally defined as measures of body fluids, cells, tissues, or other biotic variables that indicate the presence and magnitude of stress responses (NRC 1987). As currently viewed, the bioindicator approach is the measurement of selected components or variables of organisms, populations, or communities that respond in a variety of meaningful ways to changes in the environment. This approach includes the integration and application of these multiple-stress indices for predicting chronic changes in populations and communities before irreversible damage occurs.

A suite of selected stress responses at each of several levels of biological organization will be measured (Fig. 7.10) to (1) predict the effects of chronic stress on fish, and (2) better understand the causal relationships between stress responses and effects on populations and communities. Understanding the mechanisms and cause-effect relationships is essential for any rigorous extrapolation from effects on individual organisms to considerations of ecologically relevant impacts on populations and communities (Cairns et al. 1984, Capuzzo 1985, Baine 1985, Larsson et al. 1985, Sastry

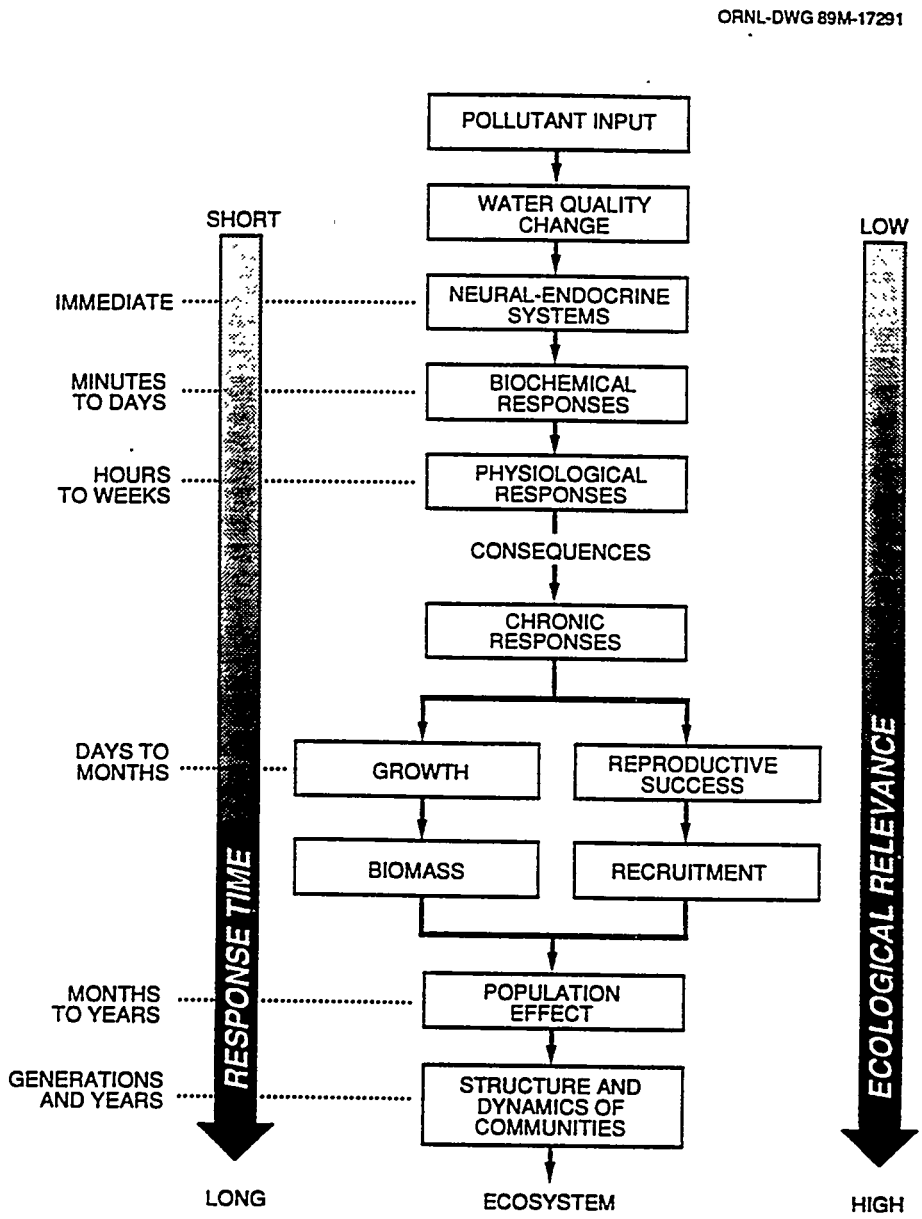

Fig. 7.10. Levels of biological responses to contaminant stress in fish. Stress responses are arranged along gradients of response time and ecological relevance. Stress responses occurring at the physiological level in individual fish may ultimately be expressed in effects at the population, community, and ecosystem levels.

and Miller 1981, Sindermann 1985). By measuring stress responses at various levels of biological organization, a spectrum of sensitivities, specificities, and points of ecological relevance can be monitored.

An understanding of the relationships between environmental stresses and organism response will allow intelligible and reliable evaluations and recommendations regarding the need for remedial actions and the nature or type of remedial actions that may be necessary. For example, by applying the bioindicator approach, effects observed at ecologically relevant response levels such as organism growth or reproductive capacity could be attributed directly to contaminant stress or to natural environmental conditions such as changes in temperature regimes or food supply of the organism. If a change is observed, e.g., in growth or condition of a sport fish such as largemouth bass, and this change is attributed to variations in natural food supply and not contaminant stress, then remedial actions in this case would not be warranted.

For the purposes of the Clinch River RFI, there are several important advantages of the biological indicator approach for assessing stress effects on aquatic organisms. These advantages are:

(1) to provide early warning signals of potentially detrimental ecological effects,
(2) to identify causal mechanisms underlying observed effects at higher levels of biological organizations such as changes in population growth, reproductive success, or age structure,
(3) to reflect the effects of various kinds of stress; thus, when a suite of bioindicators is determined, the relative contribution of different environmental stresses to the overall integrated response of fish can be evaluated, and
(4) to permit a spectrum of sensitivities, specificities, and points of ecological relevance to be evaluated simultaneously.

The biological indicator approach has been successfully applied in ongoing investigations of contaminant effects on biota in East Fork Poplar Creek and in White Oak Creek, as part of the Biological Monitoring and Abatement Program at the Y-12 Plant (Loar et al.

1988b) and at ORNL (Loar et al. 1987, Loar 1988a). In both of these projects, the first year of investigation focused on the evaluation of numerous bioindicators measured at various levels of biological organization. Based on this evaluation, the bioindicators listed in Table 7.3 proved to be the most informative and cost-effective (relative to ability to detect and predict chronic stress effects in fish) and were chosen for application in the long-term biological monitoring of the EFPC and WOC systems. Because EFPC and WOC are the primary streams that convey contaminants from the ORR to the Clinch River, the developmental work, practical experience, and data being derived from these BMAP investigations are directly relevant to and compatible with the application of the biomonitoring approach in the CRRFI to directly assess environmental risk.

Subtask Descriptions

This subtask consists of three major components (Fig. 7.11):

(1) selection of sites, species, and bioindicators to be used for population monitoring based on the results of Phase-1 sampling, analysis, and screening-level risk analysis to identify the contaminants, media, and species of concern (Subtask 3.3.1);
(2) relation of the bioindicator responses to levels of contaminants in water, sediment, and fish tissues (Subtask 3.3.2); and
(3) monitoring of the selected suite of bioindicators as a component of the Phase-2 sampling and analysis effort to obtain pathway-specific data on contaminant effects on populations of concern (Subtask 3.3.3).

Subtask 3.3.1. Selection of Sites, Species, and Bioindicators

Initial selection of sampling sites, species to be monitored, and bioindicators to be used will be contingent on the results of Phase-1 sampling and analysis efforts and the screening-level risk analyses. If potential risk to specific populations or to overall ecosystem integrity is indicated, then monitoring of biological indicators of chronic stress will be initiated in strategic sites.

Table 7.3. Selected biological indicators used to investigate the effects of chronic stress on fish populations in the East Fork Poplar Creek and White Oak Creek Biological Monitoring and Abatement Programs.

Indicators of Nutrition or Indirect Effects via the Food Chain	Indicators of Water Quality-Direct Effects of Contaminants	Indicators Which Integrate Direct and Indirect Effects
• Serum Triglycerides	• Liver Enzymes	• Growth
• Total Lipids	• Serum Sodium	• RNA/DNA Ratio
• Total Body Triglycerides	• Serum Protein	• Total Lipids
• Liver-Somatic Index (If Liver Enzymes Low)	• Phospholipid Ratios	• Condition Factor
	• Liver-Somatic Index (If Liver Enzymes High)	• Liver Somatic Index
		• Visceral-Somatic Index

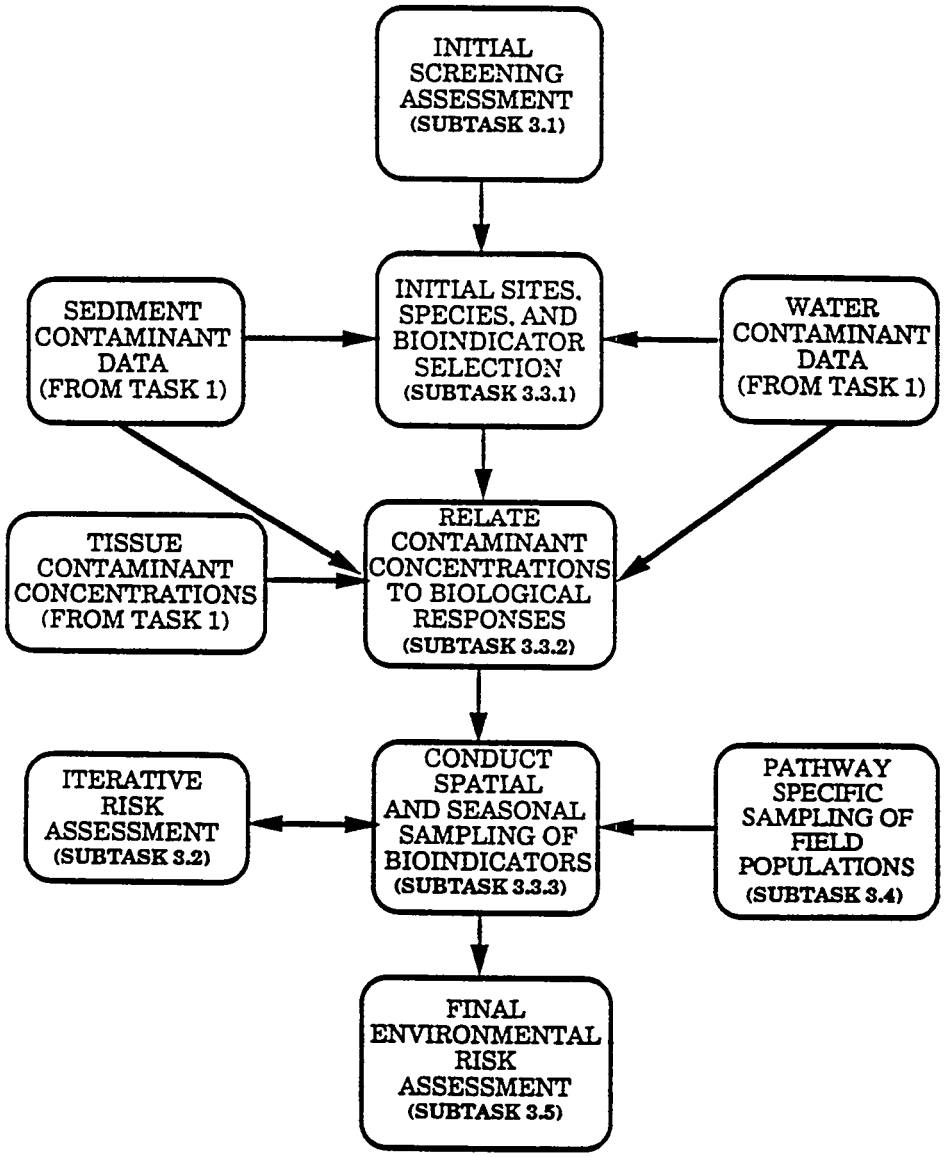

Fig. 7.11. Components of Subtask 3.3, Biological Indicators of Stress, and the interrelationships between Subtask 3.3 and other CRRFI tasks.

Initial sampling sites for biomonitoring activities will include the WOC embayment, Poplar Creek and the Poplar Creek embayment, Watts Bar Reservoir at Kingston, a down-lake location in Watts Bar Reservoir, Melton Hill Reservoir, and Norris Reservoir (as an uncontaminated reference site). These sampling locations correspond to those chosen for the Phase-1 sampling and analysis effort to bracket the anticipated range of different levels of contamination and contaminant exposure of biota in off-site surface waters (see CRRFI Sampling and Analysis Plan, Section 9).

Fish species to be selected for an initial evaluation of biological indicators of chronic stress (listed in Table 7.4) will be representative of various trophic levels and relative importance to both the river-reservoir food web, commercial fishery, and recreational sport fishery. A selected suite of biological indicators (e.g., see Table 7.3) will be measured as part of the focused, Phase-2 sampling and analysis efforts. The methods and approaches for determining and evaluating the important bioindicators to be used in the monitoring studies will be based on the same selection procedures as used for the EFPC and WOC studies (Loar et al. 1987, Loar et al. 1988a,b), respectively.

Subtask 3.3.2. Relationship of Contaminant Concentrations to Biological Responses

Levels of contaminants of concern (such as PCBs, mercury, and ^{137}Cs) in the tissues of fish collected in Phase-2 sampling and analysis efforts in specific problem areas will be related to biological indicators such as body-lipid levels, detoxification-enzyme induction levels, and indicators of histological and reproductive disturbance. Both the type and magnitude of the bioindicator responses and the concentration of contaminants in tissues will be related to and correlated with levels of contaminants in the water and sediment. These correlations will be performed for all species sampled at each sampling site to determine both the sites to be monitored and the species to be used as indicators of risk to the environment. Also, these correlations and relationships between contaminant levels in the tissues, water, and sediment, and the types and magnitude of the bioindicator responses will provide specific criteria for identifying contaminant-related stresses to aquatic biota and relating those directly to environmental risk analysis procedures.

Table 7.4. Fish species likely to selected for an initial evaluation of biological indicators of chronic stress in off-site surface waters.

Name	Trophic Level	Prey	Importance
Largemouth Bass	Top Predator	Limnetic and Benthic Prey	Game fish
Striped Bass	Top Predator	Limnetic (shad)	Game fish
Channel Catfish	Top Predator	Limnetic and Benthic Prey	Game/food fish
Bluegill Sunfish	Intermediate-level Predator	Zooplankton, Benthos	Game fish
Smallmouth buffalo, Carp	Benthic omnivore-detritivore	Detritus, Benthic prey	Rough/Commercial fish
Threadfin, Gizzard Shad	Primary consumer-detritivore	Zooplankton, Benthic detritus	Primary forage fish

Subtask 3.3.3. Spatial and Seasonal Sampling of Bioindicators in Selected Species

This task will be conducted only if the screening-level risk analyses and the preliminary bioindicator evaluations indicate a need for additional site-specific and/or pathway-specific data for environmental risk assessment. The specific bioindicators or biological responses measured in this task will depend on (1) the results of the initial screening-level risk analyses (Subtasks 3.1 and 3.2), and (2) the screening and selection of bioindicators in Subtask 3.3.1. The selected biological indicators will be determined for those species of concern identified in Subtask 3.3.1. If determined to be necessary, sampling will be conducted on a spatial and seasonal basis in conjunction with that required for Subtask 3.4.

Information from the bioindicator sampling program will be used to (1) determine if aquatic organisms in the off-site areas are stressed by contaminants released from the Oak Ridge facilities, (2) predict the effects of stress before long-term or irreversible changes occur, and (3) evaluate the nature (type and magnitude) of stress effects in order that appropriate remedial actions can be implemented. Results from the spatial and seasonal monitoring will also be utilized in Subtask 3.2 as principal data inputs to the iterative risk assessment models for estimating the risk of contaminant stress to the environment (see Fig. 7.10).

Subtask 3.4. Pathway-Specific Sampling of Selected Species

The initial screening-level risk analyses will identify the important contaminants and the sensitive aquatic species or ecosystem processes (Subtask 3.1); the critical problem areas in the Clinch River-Watts Bar Reservoir system for organism exposure will be indicated preliminarily by the ^{137}Cs scoping study (Subtask 1.2) and by contaminant transport simulations (Subtask 1.7), and more specifically as a result of the Phase-1 sampling and analysis effort; and bioindicator monitoring of field populations (Subtask 3.3) will indicate where and to what degree biological effects occur. However, more extensive field collections of the sensitive populations, their physiological condition, and corresponding water and sediment quality may be required to corroborate the initial risk

analyses with field data and to contribute in an iterative way to the final environmental risk assessment (Subtask 3.5, Fig. 7.10).

A few key populations or ecosystem functions will be selected for detailed monitoring in the river-reservoir system, if required. Emphasis will be placed on those attributes identified in the initial risk assessment as being the most likely to be both observable and of environmental importance (including values for human uses, such as fisheries yield). Iterations between risk analyses and the field sampling and analysis of biological indicators and sensitive populations will provide substantive input to the final environmental risk analysis. The specific work plan for this subtask will be determined based on the data requirements indicated by the initial environmental risk analyses (Subtasks 3.1 and 3.2), Phase-1 sampling results (Subtask 1.3), and the initial results of the biological indicators analyses (Subtask 3.3).

Subtask 3.5. Final Environmental Risk Assessment

The final Level-2 task will be to prepare a final environmental risk assessment for the No-Action Alternative, based on all available data and the iterative risk analyses. This assessment will provide the environmental risk input to the Level-3 analysis in Task 4, the preliminary evaluation of potential corrective-measures/remedial-action alternatives.

7.3.4 TASK 4. IDENTIFICATION AND PRELIMINARY EVALUATION OF POTENTIAL CORRECTIVE-MEASURES/REMEDIAL-ACTION ALTERNATIVES

BACKGROUND AND OBJECTIVES

A detailed evaluation of corrective-measures/remedial-action (CM/RA) alternatives properly falls within the scope of the RCRA Corrective Measures Study and the CERCLA Feasibility Study. However, identification of potentially appropriate CM/RAs early in the remedial investigation process is essential to (1) ensure that data collected during the course of the RFI/RI are relevant and applicable for the CM/RA selection process, and (2) permit an intelligent selection of an interim CM/RA if such is found to be necessary for protection of human health and/or the environment. Additionally, because certain CM/RA would potentially result in significant environmental impacts, it is essential to ensure that the data are collected suitably for a NEPA assessment (Levine et al. 1989).

Considerable information on contaminant distributions in the Clinch River-Watts Bar Reservoir system already exists (see Section 5 of this document), and additional data will be obtained as part of the site characterization activities (Task 1). Tasks 2 and 3 will provide estimates of the risks to human health and to the environment associated with off-site contamination derived from past and present contaminant releases from the ORR to the Clinch River. Additional focused sampling and analysis efforts and risk analyses will specifically identify the risks associated with specific locations and contaminants within the system. Thus, by means of Tasks 1, 2, and 3, the CRRFI will be focused progressively on specific problem areas in which significant risk to human health or welfare or to the environment may exist.

The specific objectives of this task are to (1) preliminarily identify potential off-site problem areas that may conceivably require corrective/remedial action, (2) preliminarily identify potentially appropriate corrective/remedial actions applicable to specific off-site problem areas or area groupings, (3) apply site-characterization data, results of risk

analyses, and understanding of the nature and extent of off-site contamination gained during the CRRFI to assess, on an iterative basis, the human-health and ecological consequences of potential CM/RA alternatives (including the No-Action Alternative), and (4) advance a set of recommendations for use in CM/RA selection and implementation.

APPROACH

As previously described, the Clinch River RFI will be a phased investigation. Depending on the results of progressive phases of the investigation (e.g., availability of existing data, risk analyses, acquisition of necessary additional data, etc.), the No-Action Alternative will either be evaluated or additional information will be required for its evaluation. Given sufficient information to evaluate the No-Action Alternative, there are three possible findings:

(1) Imminent risk to human-health or to the environment - immediate interim corrective/remedial action is required.
(2) Insignificant potential risk to human health or to the environment - no corrective/remedial action is necessary or advisable.
(3) Sufficient risk to human health or to the environment exists to warrant evaluation of corrective/remedial actions - additional analysis is required to further evaluate the specific problem area(s) for the purpose of identifying the most appropriate (i.e., the most effective, technologically feasible, environmentally acceptable, and cost-efficient) CM/RA alternative.

The decision-making process summarized above and depicted diagrammatically in Fig. 7.1 will be employed for acquiring the information necessary for (1) determining the human-health and environmental risks associated with off-site contamination, and (2) identifying and preliminarily evaluating potential CM/RA alternatives.

Remediation of existing contamination problems, if necessary, is the objective of the RFI process. Data collected during the CRRFI will be used for site characterization, human-

health and environmental risk assessment, and identification of potential CM/RA alternatives. To ensure that the combination of existing data and new data to be collected will be adequate for these purposes, the potential pathways leading to human health and environmental risks, potential off-site problem areas that could require remediation, and categories of potential remediation alternatives must be identified early in the remedial-investigation process.

DESCRIPTION OF SUBTASKS

Subtask 4.1. Preliminary Identification of Potential Problem Areas

As site-characterization data and results of risk analyses become available, information gathered in the previous tasks will be compiled on an iterative basis in Subtask 4.1 to identify (1) specific sites in the Clinch River-Watts Bar Reservoir system that represent potential problem (high or uncertain risk) areas, and (2) groupings of specific sites with similar problems that can be treated as common problem areas with their own candidate CM/RA alternatives.

Sites that have been identified as potentially causing unacceptable health and environmental risks will be evaluated. Sites will then be grouped into problem areas potentially requiring remediation. This approach will limit the scope of the RFI investigation to areas where contamination problems actually occur, and will help identify candidate CM/RAs that may be appropriate to remediate any significant problems. For example, sites may have different candidate CM/RAs depending on the types of contaminants posing risks, the exposure pathways, the species affected, the contaminated materials, and the site characteristics. Sites that are proximal and have similar conditions may be treated as a single problem area with a common set of CM/RAs.

Potential off-site problem areas that need further evaluation have been preliminarily identified (Table 7.5).

Table 7.5. Preliminary identification of potential off-site problem areas associated with the Clinch River-Watts Bar Reservoir system that may require remediation.

- Mouths and/or lower reaches of White Oak Creek and Poplar Creek.
- Sediment deposition and contaminant accumulation zones in the river, reservoirs, or off-channel embayments.
- Dredge-spoil disposal sites; e.g., Jones Island.
- Sediment and soil in floodplain, mudflats, shoreline areas.
- Public water supplies, water treatment facilities, water-treatment sludge disposal sites.
- Contamination of the biota.
- Impairment of other uses of water resources; e.g., recreation, navigation, commercial fishing, gravel dredging, irrigation.

Subtask 4.2. Preliminary Identification of Potential Corrective Measures/Remedial-Action Alternatives

Several general categories of potential CM/RAs will be considered for all of the identified problem areas (e.g., Table 7.6). A specific remedial action for a particular problem area could include combinations of activities in these remediation categories. A variety of potential remedial actions will be considered due to the number of media, contaminants, and locations involved. All remedial actions that provide at least a minimum level of risk reduction will be considered.

Potential CM/RAs to be assessed will include both on-site and off-site remedial actions, and variety of emergency-response strategies and scenarios. Both on-site and off-site CM/RAs must be considered because a selected CM/RA can impact all downgradient areas. Emergency response strategies and scenarios are important because not all CM/RAs involve removing or treating the contaminants. Contaminants that remain are subject to freaks of nature, unauthorized access by humans, and unintended exposure to the environment.

The search for CM/RAs for specific problem areas will be refined and focused as data become available and as quantitative assessments are performed. Candidate CM/RAs that are clearly inappropriate will be eliminated from further consideration.

Subtask 4.3. Preliminary Evaluation of Potential Corrective Measures / Remedial-Action Alternatives

The primary benefits associated with a CM/RA are the reductions in risk to human health, welfare, and the environment. The benefits of each candidate CM/RA for a problem area will be estimated relative to other potential CM/RAs for that area. Specifically, in the Clinch River RFI, increased risks to human health or to the environment during the implementation of the CM/RA must be carefully considered.

Table 7.6. Categories of potential corrective measures/remedial actions.

1) No Action - data show that no significant potential risk to human health or to the environment exists.

2) Restricted Access, Restricted Use - no trespassing in contaminated terrestrial areas; no swimming and no fishing, etc. in contaminated aquatic environments; recommend no dredging permits issued in "hot spots".

3) In-place Isolation or Stabilization of Contaminated Media - in situ fixation of contaminated sediment, sediment covers, treatment.

4) Bulk Removal and Storage of Contaminated Media - bulk removal of contaminated soil and/or sediment, etc.; must consider human health and environmental consequences of disposal (e.g., dredging of contaminated sediments and land disposal, stripping of contaminated soil from terrestrial areas).

5) Treatment of Contaminated Media

6) Control of Sources, Discharges - on-site remedial actions will address these controls.

The factors to be included in the preliminary assessment of potential CM/RAs include (1) the effectiveness of the risk reduction to health and the environment associated with the CM/RA, (2) new risks to health or environment that will be posed during implementation of the CM/RA, (3) the public acceptance of the recommended CM/RA, (4) the feasibility and reliability of the remediation, (5) compliance with all ARARs.

For the factors which do not already have quantitative measurements, a ranking system will be employed to estimate the relative benefits of the CM/RA alternatives associated with a problem area. Each of these factors will be assigned weights to indicate their relative importance in the decision-making process.

The contaminant transport and fate simulation model, contaminant remobilization models, and the risk assessment models developed in Tasks 1, 2, and 3 will be used to help evaluate ecological and human health risks. Risks will be evaluated for (1) existing conditions, (2) for CM/RAs alternatives during their implementation stage, and (3) for CM/RAs once they are completed. These risks will be used to rank the relative benefits of each of the alternatives.

Rankings for acceptance of the CM/RAs and the feasibility/reliability of the remediation will be assigned using expert judgments. The feasibility criteria include the availability of technology and the possibility of implementation in the desired location and that RCRA-approved facilities exist that can receive generated (removed) wastes. A committee of technical experts will be used to evaluate the subjectivity of the ranking process. Technical judgments that a CM/RA is not feasible or is totally unreliable will cause it to be eliminated from further consideration.

8. PROJECT ORGANIZATION AND MANAGEMENT PLAN

8.1 PROJECT ORGANIZATION AND RESPONSIBILITIES

The DOE and Martin-Marietta management structure for the Environmental Restoration Program at Oak Ridge, and the position of the Clinch River RFI Project in that organizational structure is shown diagrammatically in Fig. 8.1.

The CRRFI staff organization is summarized in Fig. 8.2. The CRRFI staff, personnel, and summaries of their credentials and specific areas of expertise are listed in Appendix A. Functional responsibilities for project activities are listed below:

8.1.1 Project Manager

The Project Manager is the principal project contact between the CRRFI Project Staff, the MMES Environmental Restoration Program, and DOE. He has primary responsibility for technical, financial, and scheduling matters. Specific duties of the CRRFI Project Manager are:

- Ensure excellence in meeting the goals and objectives of the CRRFI in a timely and cost-effective manner.
- Provide project planning, coordination, and supervision;
- Assign duties to the project staff and orient the staff to the needs and requirements of the project.
- Allocate resources to facilitate achievement of project objectives and requirements.
- Provide budget and schedule control.
- Evaluate project staff training and performance.
- Coordinate preparation of the RI General Document and Work Plan.
- Obtain DOE approval for proposed variances to any of the support plans, if required.
- Obtain Quality Assurance Specialist (QAS) approval for proposed QA variances to the support plans, if required.

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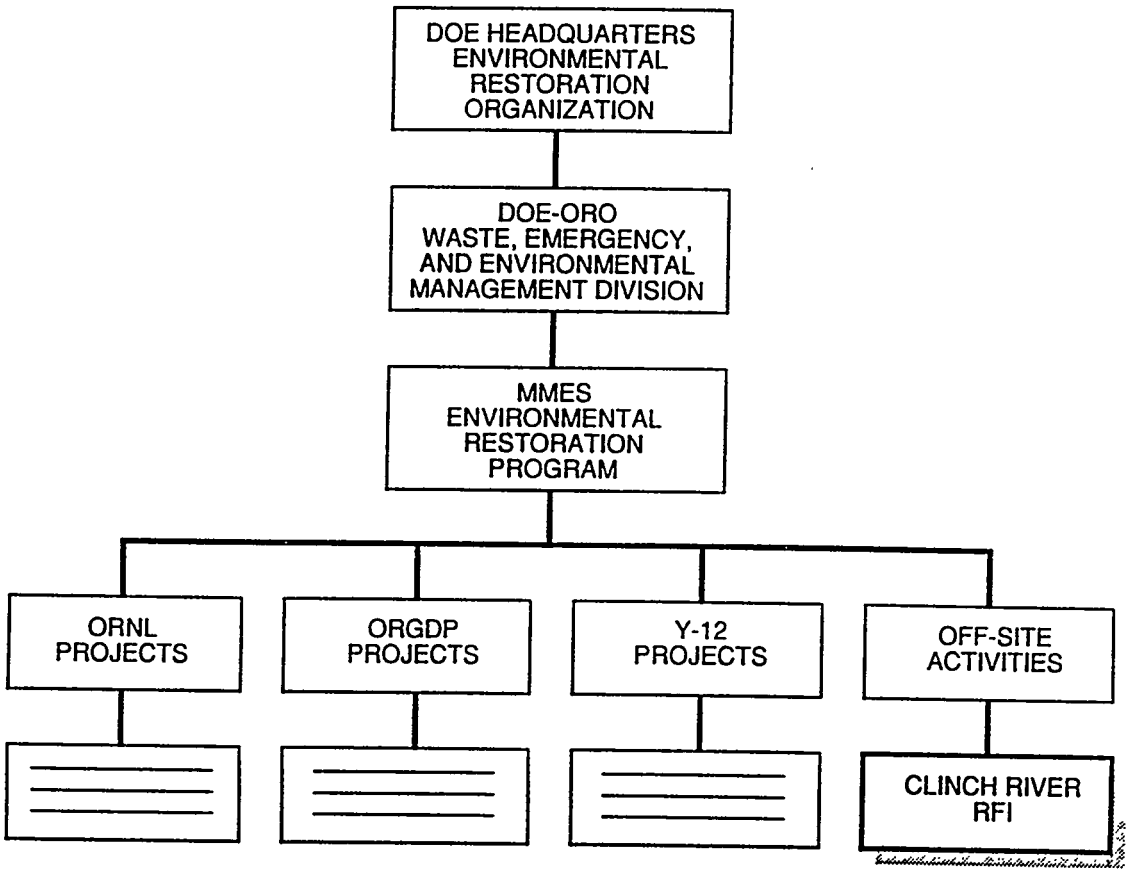

Fig. 8.1. The position of the Clinch River RFI Project within the organizational framework of the Environmental Restoration Programs of the U.S. DOE and Martin-Marietta Energy Systems, Inc.

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Clinch River RFI (CRRFI) Project Organization

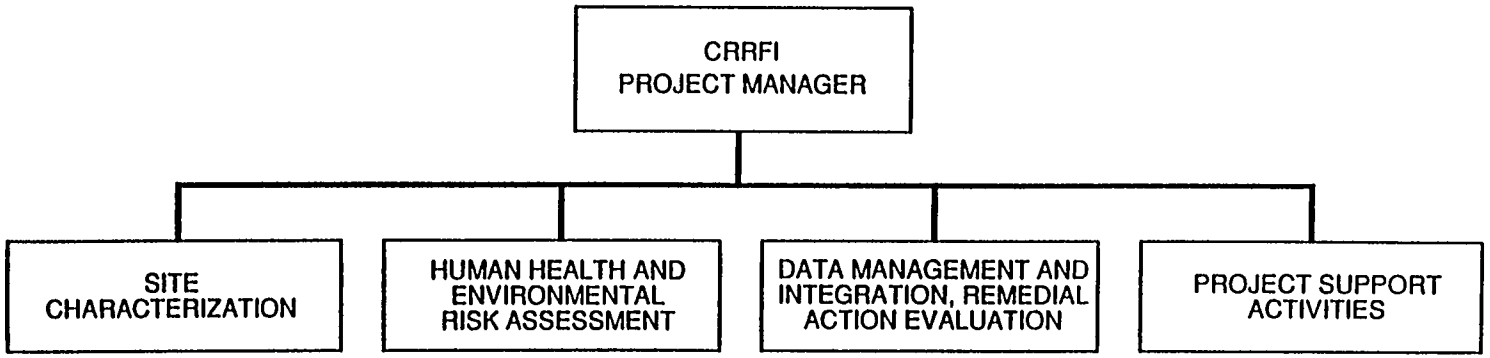

Fig. 8.2. The organizational and management structure of the Clinch River RFI Project.

- Approve Corrective Actions, Nonconformance Reports, Quality investigations and Quality Event Reports.
- Review subcontract work and approve subcontract invoices.
- Establish and maintain project files, and submit materials to the Records Control Database (RCDB).
- Identify all record items and forward them to the RCDB.
- Ensure that field records and raw data submitted by CRRFI investigators are safeguarded in secure project files and approved for inclusion in the Numeric Data Base (NBD) and the RCDB.
- Review the RCDB for completeness.
- Approve access to data and information in the NDB and RCDB.
- Ensure that project reports and submissions are reviewed for technical accuracy and completeness.
- Ensure that project milestones and deliverables are achieved and submitted according to the project schedule.

8.1.2 Task Leaders

Task leaders are responsible for integrating available information and collected data to meet the objectives and requirements of their specific tasks. Responsibilities of the task leaders include the following:

- Assist the Project Manager in achieving the goals and objectives of the CRRFI project.
- Assist in project management and provide the Project Manager with project progress reports.
- Provide input and review for the CRRFI Plan.
- Supervise and review subcontractor activities as appropriate.
- Maintain records in accordance with the Data Management Plan.
- Final validation of field and analytical laboratory data, review of data for completeness, documentation, procedures, and consistency with known physical-chemical principles.

- Resolve any technical questions concerning the data.
- Implement appropriate staff training and ensure that all project staff comply with project QA/QC, health and safety, waste management, and data management requirements,

Specific responsibilities for individual task leaders are listed below.

Site Characterization Task Leader

The Site Characterization Task Leader is responsibility for defining the nature, distribution, and downstream extent of off-site contamination, and for providing these data in support of the human-health and environmental risk analyses.

Risk Assessment Task Leader

The Risk Assessment Task Leader has responsibility for quantifying any risks to human health and the environment resulting from off-site contamination, and for employing risk analysis to help focus data collection efforts.

Data Management, Integration, and CM/RA Evaluation Task Leader

The Data Management, Integration, and CM/RA Evaluation Task Leader has responsibility for management of project data, transport and fate modeling, and identification and preliminary evaluation of potential CM/RA alternatives. Duties specific to the Data Management, Integration, and CM/RA Evaluation Task Leader are:

- Prepare and implement the Data Management and QA/QC plans.
- Monitor chain-of-custody forms, Corrective Actions, Nonconformance Reports and variances.
- Ensure proper management of all records, data, and documents generated during the project.

- Ensure that submitted data are encoded and entered correctly into the NBD and RCDB.
- Assist with the manipulation, analysis, assessment, display, and output of verified data.

8.1.3 Field Sampling and Analysis Coordinator

The Field Sampling Coordinator is responsible for all field sampling and analysis activities. Designated responsibilities include:

- Organize and coordinate all field sampling and analysis activities through field sampling team leaders so that all required data are available within an acceptable time frame.
- Ensure that all sampling and analytical activities and data collection meet the objectives of the CRRFI phased approach with regard to data requirements for site characterization, risk assessment, and identification and preliminary evaluation of CM/RA alternatives.

8.1.4 Sampling Team Leaders

Sampling Team Leaders are responsible for the management and coordination of specific field sampling teams. General responsibilities of the Sampling Team Leaders are:

- Coordinate and supervise field sampling activities.
- Provide input and review for the CRRFI Plan.
- Coordinate activities with project management.
- Provide orientation, hazard information, and training to technical staff, based on the requirements of the support plans.
- Ensure that field-related activities are performed correctly and documented as required by the support plans.
- Review daily entries in the field logbooks, and maintain field records management system in accordance with the Data Management Plan.

- Perform initial validation of all field and analytical data, prior to data transfer.
- Transfer custody of original field notes to the Project Manager.
- Transfer custody of original field data to the Analytical Services Coordinator (ASC).
- Initiate procedural variances and maintain a log on particular variances, as necessary.
- Ensure sample custody until transferred to the ASC.
- Ensure that chain-of-custody and request-for-services forms are properly completed and cross referenced prior to transfer of sample custody.
- Receive custody of sample results from laboratory supervisors.
- Submit laboratory results to ORGDP Data Entry and oversee manual entry of data by Data Entry staff.
- Transfer results from ORGDP Data Entry to respective task leaders.
- Field implementation of the H&S Plan, including communication of requirements to all personnel, field supervision, and ensuring that site personnel adhere to the site safety requirements.
- Inform the Project H&S Coordinator of any changes in sampling plans so that they may be appropriately addressed.
- Ensure that Corrective Actions and Nonconformance Reports are initiated, if necessary.

Specific responsibilities for individual sampling team leaders are given below:

Biota Field Team Leader

The Biota Field Team Leader is responsible for collection of biological samples. He is responsible for preparation and review of proposed variances to the supporting documents.

Sediment and Surface Water Quality Team Leader

The Sediment and Surface Water Quality Field Team Leader is responsible for collection of sediment and surface-water samples. He is also responsible for the quality

and technical adequacy of work accomplished in the Sediment Processing Laboratory and the Surface Water Processing Laboratory.

8.1.5 Sample Custodians

The sample custodians will maintain custody of samples. Sample custodians will be required to follow the chain-of-custody procedures given in the CRRFI Plan. General responsibilities include:

- Maintain integrity of samples during collection, transport, processing or storage.
- Initial tagging, identification custodizing of field samples.
- Ensure proper completion and cross referencing of chain-of-custody and request-for-services forms.

Staff from both the sampling teams and laboratories may assume the role of sample custodian during sample collection, processing, analysis and storage.

8.1.6 Technical Staff

The technical staff are responsible for conducting field and laboratory activities to achieve the objectives of the CRRFI. Technical staff responsibilities include:

- Collect field samples and perform field and laboratory analyses according to prescribed standard operating procedures at the sampling team leader's direction.
- Prepare samples for analysis.
- Prepare request for analytical services and chain-of-custody forms.
- Maintain proper sample documentation and sample chain-of-custody.
- Safeguard record materials including, but not limited to, field notebooks, raw data sheets, and chain-of-custody forms.
- Maintain complete, factual, detailed, and objective program notes.
- Retain records of all analyses and procedures, used for the CRRFI.
- Ensure that proper waste management procedures are followed.

- Ensure that the requirements of the S&A, QA/QC, Data Management and H&S plans are satisfied.

Technical staff will consist of individuals who have the appropriate training and who are qualified to conduct the activities specified in the CRRFI Plan (See Appendix A).

8.1.7 Analytical Services Coordinator

The CRRFI Analytical Services Coordinator (ASC) is responsible for all aspects of custody and transfer of samples and results between the sampling teams and analytical laboratories. He is the main contact for the laboratories concerning chain-of-custody and requests-for-services. ASC duties involve:

- Review of the General RFI, QA/QC and Data Management plans.
- Contribution to and review of the S&A Plan.
- Preparation and review of the H&S Plan.
- Establish and maintain a chain-of-custody and request-for-services forms control system. Numbered forms will be used to cross-reference custody and request-for-services and for sample tracking.
- Receive chain-of-custody samples from the field crews and transfer to analytical laboratories.
- Ensure that chain-of-custody and request for services forms are properly completed and cross referenced prior to transfer of sample custody.
- Ensure that corrective actions and nonconformance reports are initiated, if necessary.
- Review the variances to any of the support plans, if required.
- Oversee manual entry of field data by ORGDP Data Entry Staff.
- Oversee final disposal of samples.

8.1.8 Analytical Laboratory Supervisors

The analytical laboratory supervisors are responsible for supervision of laboratory personnel and maintaining the integrity of samples analyzed and data generated for the CRRFI. Lab supervisor responsibilities are:

- Provide orientation, hazard information and necessary training to technical staff, based on the requirements of the S&A, QA/QC, Data Management and H&S Plans.
- Ensure laboratory implementation of the H&S Plan.
- Inform the Project H&S Coordinator of any changes in procedures so that they may be appropriately addressed.
- Maintain and execute internal laboratory QA/QC procedures, providing these procedures to CRRFI project management and regulators as requested.
- Perform routine QA checks of sample handling procedures, methods of analysis, QA data, and sample analysis results before releasing data reports and the results of QA checks to team leaders.
- Maintain copies of data until results are verified.
- Transfer custody of data reports to team leaders.
- Report any laboratory deficiencies and subsequent corrective actions to CRRFI management.

8.1.9 Quality Assurance Specialist

The Quality Assurance Specialist (QAS) is the official contact for quality assurance matters relevant to the CRRFI project. He is independent of the CRRFI staff. The duties of the QAS are:

- Actively identify and respond to QA/QC needs, resolve problems, and answer requests for guidance or assistance in complying with the QA/QC Plan.
- Review, evaluate, and approve quality-related aspects of and variances to the support documents where technically competent.

- Ensure that quality aspects of training, field sampling and chain-of-custody activities meet CRRFI plan requirements.
- Schedule and perform internal audits and surveillances to ensure compliance with requirements and procedures specified by the support plans.
- Prepare and approve Quality Investigation and Quality Event Reports.
- Approve corrective actions and NCR, and ensure that Corrective Actions are taken for any nonconformance, as required for all aspects of the CRRFI.
- Prepare and submit Project QA/QC reports summarizing audit and surveillance activities to CRRFI project management.

8.1.10 QA/QC Coordinator

The CRRFI QA/QC coordinator is the intermediary between the CRRFI sampling team personnel and the QAS. Responsibilities of the QA/QC Coordinator are:

- Review QA/QC, H&S and S&A Plans and chain-of-custody procedures.
- Instruct CRRFI personnel on the chain-of-custody and sample labeling procedures, as necessary.
- Verify that methods specified are appropriate for obtaining data of known quality and integrity.
- Conduct field and laboratory evaluations of sampling methods and analytical procedures to ensure that procedures adhere to chain-of-custody requirements.
- Review field QC sample results to ensure that field measurement and sampling protocols have been followed.
- Report the results of these reviews to the QAS for forwarding to the Project Manager.
- Ensure that all Corrective Actions, Nonconformance Reports and variance activities are initiated, if necessary.

8.1.11 Health and Safety Coordinator

The Health and Safety Coordinator is responsible for ensuring that site personnel adhere to the site health and safety requirements. Duties of the Health and Safety Coordinator are:

- Review S&A and QA/QC Plans.
- Develop, coordinate, and implement the H&S Plan.
- Revise the H&S plan as warranted by changed site conditions.
- Approve all variances to support documents or the CRRFI Work Plan which are relevant to H&S, as required.
- Ensure that all CRRFI personnel adhere to H&S requirements.

Agency liaison on matters relating to health and safety is handled by the Project Manager with the assistance of Health and Safety Coordinator. During field work, the Sampling Team Leaders will normally assume the responsibilities of the Health and Safety Coordinator.

8.1.12 Subcontractor Activities

The selection of qualified subcontractors will be in accordance with the ORNL Procurement and Quality Assurance Procedures. Subcontractors, such as analytical services, surveyors, and environmental monitoring specialists, must meet predetermined qualifications developed by the Project Manager, as defined in the procurement bid packages. Each subcontractor bid submittal is reviewed by technical, purchasing, and quality assurance personnel to ensure that the bidders are qualified and can satisfy bid requirements. Subcontractors involved in environmental measurements will be monitored by the Sampling Team Leaders to ensure compliance with the CRRFI Plan.

8.1.13 Qualifications and Training of Personnel

All ORNL and subcontractor personnel working on the CRRFI will be properly trained and qualified individuals. To ensure this, prior to commencement of work, all sampling team personnel will be given instructions specific to the remedial investigation, covering the following areas:

- Organization and lines of communication and authority
- Description of the Oak Ridge Reservation and the Clinch River-Watts Bar Reservoir system
- Overview of the S&A, QA/QC, H&S, and Data Management Plans
- Documentation requirements
- Personal protection procedures
- Waste management procedures
- Decontamination procedures
- Emergency procedures

Training of field personnel will be provided by a sampling team leader. All training will be documented and certified.

8.1.14 Waste Management

All waste generated as a result of CRRFI activities will be segregated as to type and disposed of following laboratory procedures in accordance with RCRA requirements and the ORNL Environmental Protection Manual (ORNL Environmental and Occupational Safety Division, 1988). Conventional waste shall be sent to the sanitary waste landfill. Glass items will be cleaned and placed in special containers for disposal. Procedures for the disposal of radioactive and mixed (radioactive plus other hazardous waste) are provided in the ORNL Environmental Protection Manual.

8.2 PROJECT SCHEDULE

Given the phased nature of the Clinch River RFI and the unknown nature and extent of the off-site contamination, it is difficult to provide a firm schedule for all but the initial phases of the CRRFI.

Phase-1 and Phase-2 sampling and analysis efforts, site characterization, human-health and environmental risk assessments, and preliminary evaluation of remedial actions will likely require a 5- to 6-year effort. Funding for the Clinch River RFI must be obtained annually from the U.S. Department of Energy; budget reductions would have the effect of extending the project. At this early stage, costs are not budgeted specifically for corrective measures/remedial actions which may or may not be necessary. Additional costs for implementing CM/RAs will be budgeted specifically as needs for remediation, if any, are identified.

Major project milestones, as listed on the USDOE Activity Data Sheets (ADSs 413-G1 and 413-C1), are shown below:

MILESTONES

DATE	
10/31/89	Submit draft Clinch River RFI Workplan and Documents to DOE
03/31/90	Submit Clinch River RFI Workplan and Documents to EPA
03/31/91	Complete Phase-1 Sampling and Analyses
06/30/91	Complete Phase-1 Human-Health & Environmental Risk Assessment
09/30/91	Submit Phase-1 Site Characterization Summary
03/31/92	Initiate Phase-2 Sampling and Analysis
03/31/93	Submit Preliminary Phase-2 Site Characterization Summary

Interim CM/RAs will be initiated at any time in the course of the project that sampling, analysis, and risk assessment activities indicate a significant potential risk to the environment or to public health and welfare.

An overall project schedule, organized by major project phases, is provided in Fig. 8.3. This schedule is designed in accordance with the specific requirements of the Oak Ridge Federal Facilities Agreement being negotiated between the USDOE, the USEPA Region IV, and the TDHE. To expedite the progress of the Clinch River RFI, the Phase-1 sampling and analysis effort, Phase-1 human-health and environmental risk assessment activities, and some preliminary site characterization activities are being conducted in FY 90.

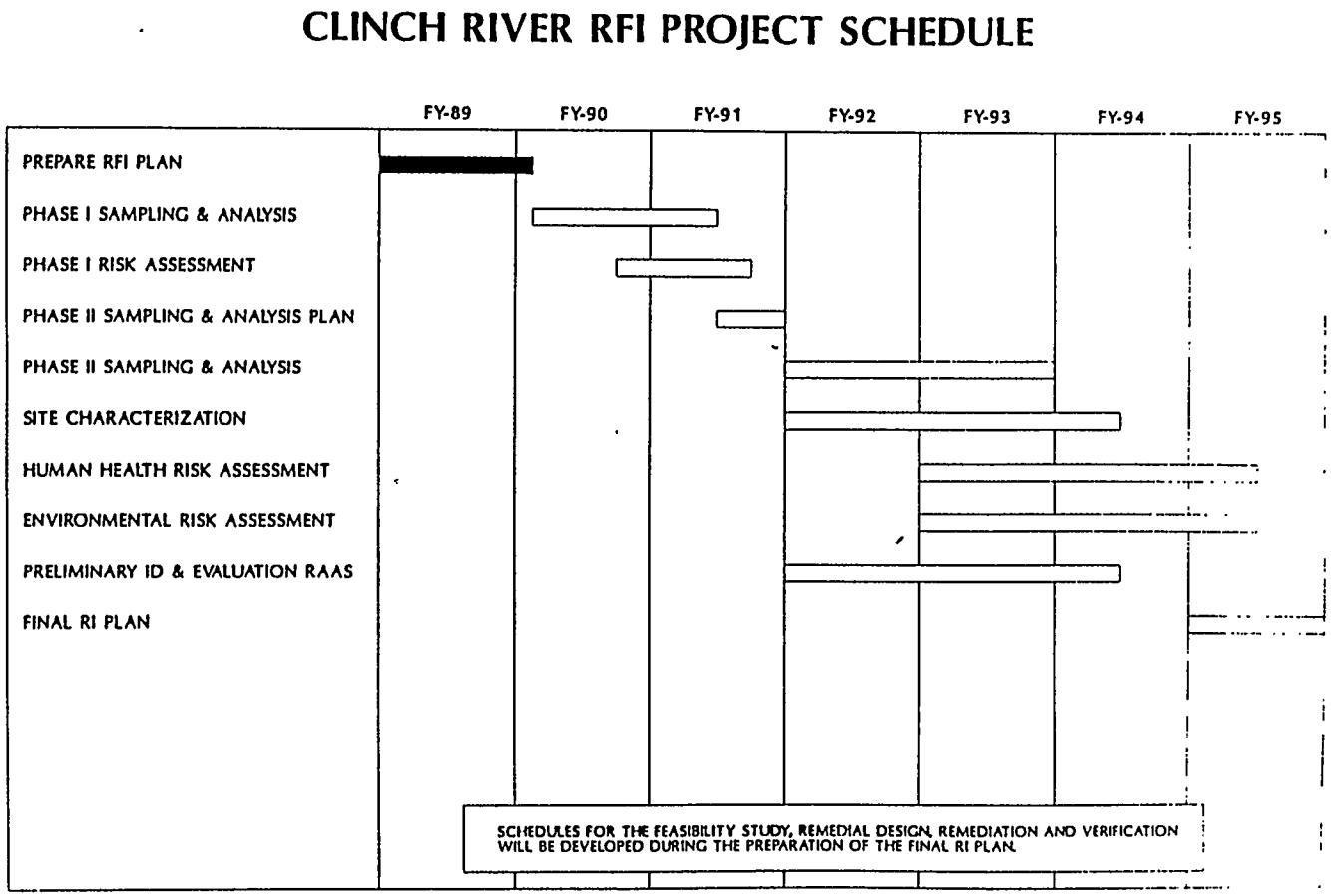

Fig. 8.3. Clinch River RFI project schedule showing primary project phases and deliverables.

9. FIELD SAMPLING AND ANALYSIS PLAN

9.1 INTRODUCTION

The Field Sampling and Analysis (S&A) Plan supports the Department of Energy's (DOE) Clinch River RCRA Facility Investigation (CRRFI) of surface water environments beyond the boundary of the DOE Oak Ridge Reservation. These locations consist of surface water, drainage ways, and portions of the Clinch and Tennessee rivers that may have become contaminated as a result of past operations and waste management practices on the Oak Ridge Reservation (ORR). Existing data and an initial survey of Watts Bar Reservoir indicate that contaminants released from the ORR have accumulated in the sediments downstream (see Section 5). The emphasis of the Field Sampling and Analysis Plan on Melton Hill Reservoir, the Clinch River downstream of the Oak Ridge facilities, and Watts Bar Reservoir.

The organizational structure of the field sampling and analysis activity is shown in Fig. 9.1.

9.2. PURPOSE

The purpose of the field sampling and sample analysis program is collection and analyses of biotic and abiotic environmental samples to support the three primary objective of the CRRFI:

(1) defining the nature and extent of off-site contamination,
(2) quantifying any risk to human health and the environment resulting from existing off-site contamination, and
(3) evaluating potential corrective/remedial actions.

A phased approach will be taken in the field sampling program. All phases of sampling will provide data that are required (1) to characterize contamination of off-site areas and (2) to complete a human health and environmental risk assessment for off-site

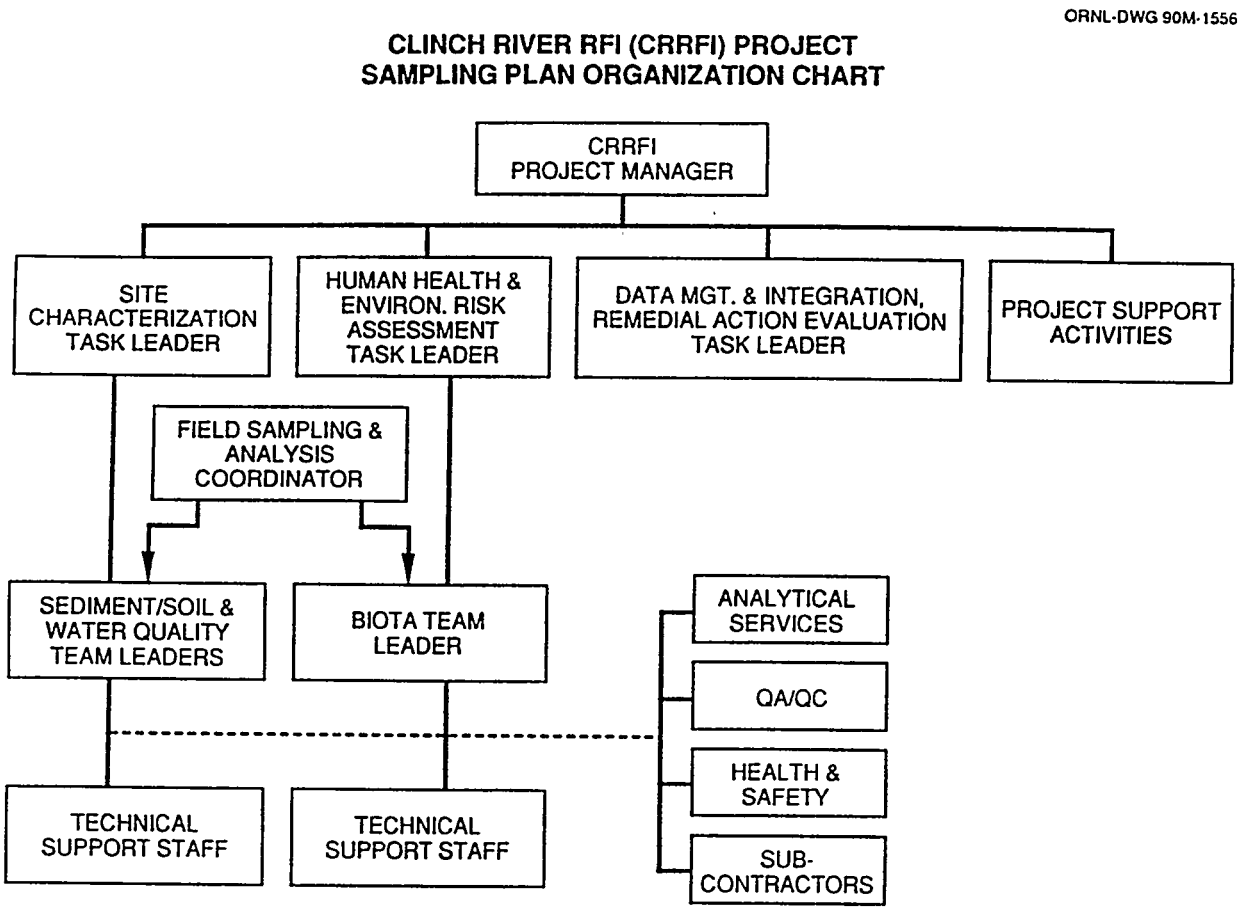

Fig. 9.1. Organizational structure of the Clinch River RFI field sampling and analysis activities.

contamination. Although the initial samples will be for preliminary risk assessments, the data will also be utilized for defining the nature and extent of off-site contamination and for evaluating potential corrective/remedial actions. The processes of data collection, risk assessment, and corrective/remedial action evaluation are iterative; each is dependent upon and influential of the others.

The phased approach for field sampling and analysis relies heavily on results of the human health and environmental risk assessments (Tasks 2 and 3, Section 7.3) and is based on providing the data necessary for evaluating CM/RA alternatives (Task 4). Because of the iterative approach, only the first phase of field sampling can be described in detail. However, sampling plans for the succeeding phases will be developed in detail and included as addenda to the sampling plan as the site characterization, risk analysis, and CM/RA identification and evaluation proceed. Sections of the Sampling and Analysis Plan such as chain-of-custody, quality assurance/quality control, safety, etc. are generic to the sampling plan and will be applicable to all phases as the plan develops.

9.3. BACKGROUND

9.3.1 Radioactive Pollutants

Since the 1940s, radioactive materials have been central to the operation of DOE's Oak Ridge facilities. Over the years, monitoring at these facilities has emphasized radioactive releases; and, only within the past decade has monitoring of other pollutants received serious attention (Rogers et al. 1988a). The exception to this procedure was mercury released from the Y-12 Plant, see Section 9.3.2 below. Historical releases of radionuclides from the Oak Ridge Facilities have been documented (DOE 1988) and were reviewed in Section 4 of this document.

The amount of radioactive material and other types of waste generated at each of the three DOE facilities at Oak Ridge depends on the operations performed at the facility (see Section 4). Currently, the most significant radionuclides released from ORNL into off-site surface waters are ^{90}Sr, ^{3}H, and ^{137}Cs, which leak from waste disposal areas. An estimated 70 to 80% of the material released over the White Oak Dam leaches from the

waste disposal areas, 10% comes from operating facilities, and 10% consists of runoff from contaminated surfaces and soil (DOE 1988).

Liquid releases from Y-12 have generally been uranium particles from metal machining and chemical processing operations. Historically, wastewater discharges from the Y-12 plant have been the most significant source of ^{238}U in Poplar Creek embayment and in Watts Bar Reservoir (Ashwood et al. 1986). In addition to uranium, some thorium in process solutions from research programs has been discharged into East Fork Poplar Creek (EFPC). From 1951 until 1984, liquid releases were discharged into Bear Creek from the S-3 ponds along with runoff from the Bear Creek Burial Grounds. Both Bear Creek and EFPC come under separate RFIs; however, their effluents contribute to the contamination of Poplar Creek which is included in the CRRFI.

From the 1940s until 1964, uranium was enriched to high concentrations of ^{235}U for weapons production at the Oak Ridge Gaseous Diffusion Plant (ORGDP). After 1964, only low-concentration enrichment was performed for use in commercial power generating facilities. From 1950 to 1968, ORGDP also operated as a feed plant where uranium from spent fuel was fluorinated to uranium hexafluoride (UF_6). The latter process was the primary source of ^{99}Tc, ^{237}Np, and ^{239}Pu released in liquid effluents entering Poplar Creek. Surface waters from the sanitary wastewater treatment plant (PCK 2.9) and the K-1007B holding pond outfall (PCK 2.2) contained elevated levels of ^{99}Tc and ^{238}U (<224 and 0.25 Ci respectively, activity per unit time or volume not available; Rogers et al. 1988b). Elevated concentrations of uranium (maximum >8 pCi/L) were found in surface waters at PCK 0.5, during 1986 and 1987 (Oakes et al. 1987, Rogers et al. 1988b). Since 1985, the uranium enrichment operations at ORGDP have been discontinued.

9.3.2 Nonradioactive Pollutants

A production-scale process for the separation of isotopes of lithium operated from 1955 to 1963. Many millions of kilograms of mercury were used in the project, and relatively large quantities of mercury, which were measured and reported quarterly, were lost to

EFPC. Estimates of the amount of mercury released into EFPC range from 1.0 to 2.1 x 10^5 kg (Wilcox 1983).

Elevated concentrations of mercury and PCBs have been measured both in fish and benthic invertebrates collected near the mouth of East Fork Poplar Creek (PCK 8.5; Loar et al. 1981). Further downstream, sediments sampled from a pipe outfall downstream of the K27 facility (PCK 2.4) contained elevated levels of chromium (610 ug/g), zinc (590 ug/g) and PCBs (5 ug/g; Ashwood et al. 1986). At PCK 0.5, mercury concentrations in white bass, largemouth bass and Lepomis exceeded 0.1 μg/g of tissue (Loar et al. 1981), while PCB concentrations in white bass, channel catfish and longnose gar exceed 2 μg/g of tissue (Loar et al. 1981). Other nonradioactive pollutants that have been released into aquatic systems from the Oak Ridge facilities are identified in Loar et al. (1987), Loar (1988), Hoffman et al. (1984), TVA (1985a), Travis et al. (1986), Turner et al. (1988), Smith et al. (1988), and Rogers et al. (1988a) and are summarized in Sections 4 and 5 of this document.

9.4 SCOPE

9.4.1 Contaminants of Concern

The Environmental Protection Agency has established an extensive list of priority pollutants. However, not all of these pollutants are expected to be present in the sampling area. It is therefore reasonable to reduce the list of potential pollutants and concentrate on those contaminants of concern, but still have confidence that no pollutant of concern is overlooked.

The contaminants of concern for the Clinch River RFI field sampling and analysis plan (see Section 5, Table 5.12) were identified by using existing data (Sections 4 and 5; Rogers et al. 1988 a,b; Oakes et al. 1982; Loar et al. 1987; Loar 1988; DOE 1988; Turner et al. 1988; TVA 1985a) to perform screening-level human-health and environmental risk analyses. The intent of these analyses was to identify those contaminants whose concentration in fish, water, or sediment warrant further study. In

addition, results from previous screening analyses (Hoffman et al. 1984, Travis et al. 1986, Loar et al. 1987, Loar 1988) and historical release data for radionuclides (DOE 1985, 1988) and monitoring data (Oakes et al. 1982; TVA 1985a; Rogers et al. 1988b) were considered in establishing the list of contaminants.

Historical release data are of concern because previous releases of particle-associated pollutants which accumulate in sediment, can have much higher concentrations at greater sediment depth than would be predicted from current surface sediment monitoring data. A good example is provided by the ^{137}Cs survey of Watts Bar Reservoir which shows higher concentrations of ^{137}Cs and mercury at greater sediment depths than at the surface in Watts Bar Reservoir (see Section 5). These higher sediment concentrations can be related to mercury and ^{137}Cs releases in the 1950s from Oak Ridge facilities. From the standpoint of a screening analysis, a scenario can be developed in which higher concentrations in sediment become more available for human exposure, either directly or through the food chain, through remobilization or physical disturbances such as dredging operations (see Section 6, Fig. 6.1).

The methods used in the initial preliminary screening analysis employed conservative estimates of contaminant concentrations in biota and the consumption of organisms by humans. The calculated daily ingestion of each contaminant was compared with estimated allowable daily intakes, and if the ratio was ≥ 1, the contaminant was classified as a pollutant of concern. The screening factor for a given contaminant (X) is a unitless number used for conservatively estimating the concentration of contaminant X in aquatic organisms resulting from a concentration of X in water or sediment. A screening factor of 10^{-5} for carcinogenic chemical contaminants and 10^{-5} (1 mrem) for radionuclides (Hoffman et al. 1984, Travis et al. 1986) was used in the initial preliminary screening of off-site contaminants.

Using a screening factor of 10^{-5} (1 mrem) and data from the latest annual surveillance report (Rogers et al. 1988b), ^{3}H, ^{137}Cs, and ^{90}Sr were identified as radionuclides of concern from ORNL. External exposure to contaminated floodplain soils or sediments may be an important pathway for off-site exposure to gamma-emitting radionuclides

(Table 6.1). According to Rogers et al. (1988a) a hypothetical maximally exposed individual could receive a dose of 5.6 mrem from an experimental ^{137}Cs field located adjacent to the Clinch River near CRM 20.5. Another scenario, in which a homesite is located on sediments dredged from Watts Bar Reservoir, involves ^{239}Pu as the radionuclide of concern for the inhalation pathway (Section 6). Because of the long radioactive half lives and the uncertainty associated with releases of transuranic radionuclides from the Oak Ridge Facilities (DOE 1985,1988), ^{241}Am, ^{244}Cm, and uranium isotopes are included in the list of radionuclides of concern. These radionuclides are included for off-site characterization purposes rather than for human-health or environmental risks. Technetium-99 is also included in the list because of the historical releases (DOE 1988) and the uncertainties associated with current releases from ORGDP (Rogers et al. 1988b). All the radionuclides of concern that will be analyzed in the initial phase of sampling are given in Table 5.12.

The list of metals of concern (Table 5.12) includes those identified by Hoffman et al. (1984) that were measured in Clinch River and Poplar Creek sediments by TVA (1985b,c). The list also includes metals that were measured in fish tissue by TVA (1985b), those identified as being of concern by Travis et al. (1986), and those known to be released to the aquatic environment from the Oak Ridge facilities (Rogers et al. 1988b).

The only organics above detection levels in fish (TVA 1985e) and exceeding the screening levels (Travis et al. 1986) were PCBs and Aldrin. It has been documented that the Oak Ridge facilities are a source of some of the PCB contamination in the Clinch River, but certainly not the only source (Loar 1988). The Tennessee Valley Authority (TVA 1985b) reported total concentrations of PCBs in fish in Melton Hill Reservoir, White Oak Creek Embayment, Poplar Creek, and East Fork Poplar Creek that exceeded the FDA's action level (2 ug/g). Fish with PCB concentrations $\geq$1 ug/g were also found at Clinch River mile 2, 6, and 11 and in the Tennessee and Emory Rivers. Elevated levels of PCBs were reported in bluegill from White Oak Creek above White Oak Dam (Loar 1988). The PCB mixture found in these fish closely resembled commercial mixtures, Arochlor 1254 and 1260 (referred to as PCB-1254 and PCB-1260),

which is the same mixture reported by TVA (1985e). Chlordane has also recently been detected in fish from White Oak Creek and the Clinch River (Loar et al. in preparation). The environmental samples (fish, water, and sediments) collected in the initial phase of the sampling plan will be analyzed for pesticides and PCBs.

Anthracene, phenanthrene, fluoranthene, and pyrene, all indicators of PAH pollution, were present at concentrations above detection limits in sediments in off-site locations (TVA 1985b,c). These were identified by Hoffman et al. (1984) as being contaminants of concern. These organic compounds, which are from coal or petroleum products, are common in effluents from many industrial facilities. They are released from the Oak Ridge facilities as well as from other facilities located on the Clinch River, such as TVA coal-fired generating plants. The additional organic compounds (Table 5.12) included in the analysis of semivolatile organics or pesticides, are compounds that were detected in Clinch River fish (TVA 1985e) at concentrations slightly above detections levels but not exceeding the screening factor (Travis et al. 1986).

Volatile organic compounds will not be analyzed in environmental samples collected in the initial phase of the sampling program. Volatile organics are not particle associated and do not accumulate in sediments. Although volatile organics have been identified in the Bear Creek disposal areas, they have not been detected in the main-stream waters of Bear Creek (Turner et al. 1988). Volatile organics released from the Oak Ridge facilities into surface waters should not be transported great distances from their source, because they are rapidly lost from the water column. Ground water inputs of volatile organics from disposal areas to surface waters should also be rapidly lost from the surface waters.

9.4.2 Environmental Samples

Environmental and human-health risk will be determined from a combination of existing contaminant data and data collected to supplement or confirm the existing data. The field sampling program is similarly designed to collect data needed to supplement or confirm existing data. Both existing and supplementary data will be used to define the

nature and extent of off-site contamination, quantify the human-health and environmental risks, and identify and evaluate potential corrective/remedial actions.

The screening-level (Phase-1) sampling and analysis effort will provide the data necessary to identify specifically (1) the potential contaminants of concern, and (2) the need for additional sampling data. The Phase-2 sampling and analysis program will then focus on determining the distribution, bioavailability, transport and exposure pathways, environmental effects, and human-health and environmental risks associated with those contaminants of concern. Depending on the results of the iterative risk assessments, the scope of the field sampling program the scope of the field sampling program could ultimately include the collection and analysis of surface water, sediment, near-shore and floodplain soils, aquatic flora and fauna, near-shore vegetation, floodplain vegetation, animals, and products (milk, beef, etc) from animals feeding on aquatic or floodplain vegetation. Sampling and analysis plans for sediment, water, and biota are described in Sections 9.5, 9.6, and 9.7, below.

9.4.3 Field Sampling Locations

Surface-water environments to be considered in the Clinch River RFI have been segmented into study reaches and reference reaches (Fig. 9.2, Table 9.1). The review of existing data (Subtask 1.1) was combined with the results from the off-site sediment scoping effort, which used the distribution of ^{137}Cs in sediment to identify contaminant accumulation patterns in the sediments of the Clinch River and Watts Bar Reservoir (Subtask 1.2, also see Section 5), to establish the sampling sites for the initial phase of the field sampling program.

Based on the known release points of effluents from DOE's Oak Ridge Reservation into the aquatic environment and on the results of the ^{137}Cs scoping survey of the Watts Bar Reservoir sediments, the sampling sites shown in Fig. 9.3 and Fig. 9.4 were selected. Included is a reference site on Norris Reservoir (CRM 89.5, reach 10) and sites on Upper Melton Hill Reservoir (CRM 43, reach 12) and lower Ft. Loudon Reservoir (TRM 602.5, reach 16). The purpose of the latter two sites is to establish whether

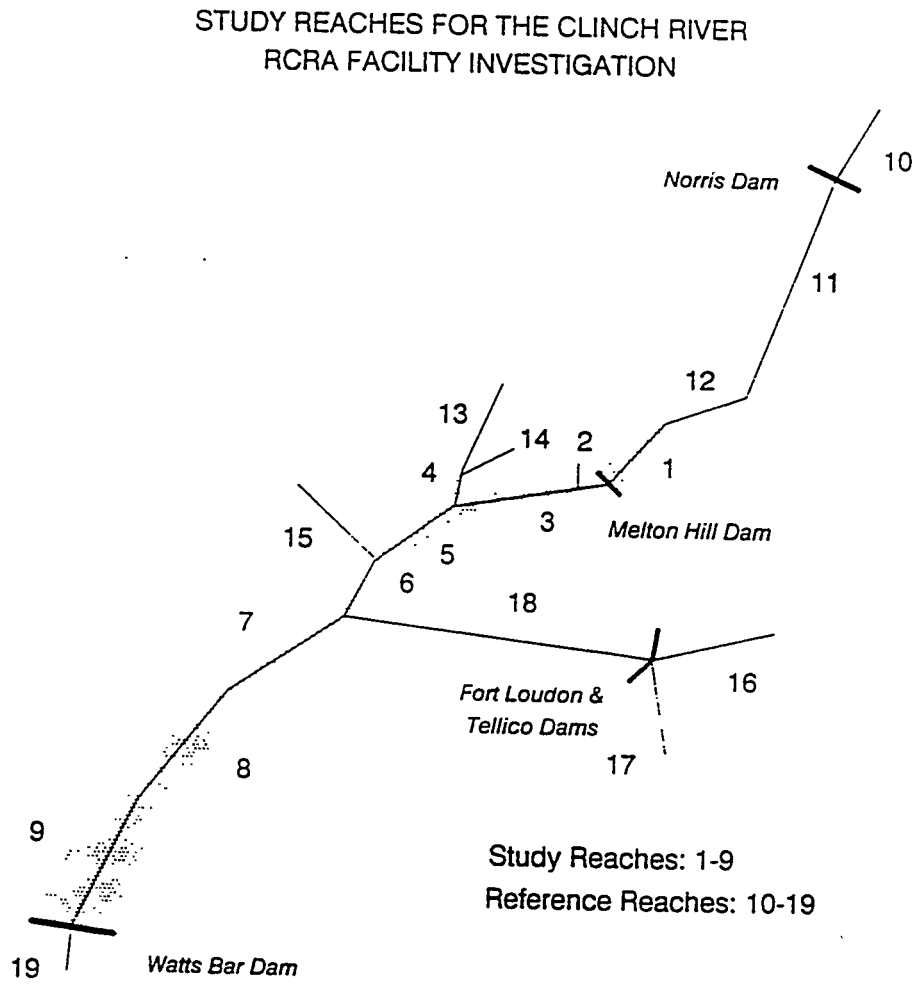

Fig. 9.2. Clinch River RFI study reaches. Reaches located downstream from the ORR are shown as stippled areas.

Table 9.1. Clinch River RFI Reaches

	River	Reach	Upstream river mile	Downstream river mile	EPA river reaches
		Study Reaches			
1	Clinch	CARL to M. Hill Dam	42.0	23.4	06010207-007
2	White Oak Creek	Embayment	(WO dam)	0.0	N/A
3	Clinch	MH Dam to Poplar Crk	23.4	12.0	06010207-005,003
4	Poplar Creek	E. Fork to mouth	5.5	0.0	06010207-020
5	Clinch	Poplar Crk to Emory	12.0	4.5	06010207-001
6	Clinch	Emory R. to mouth	4.5	0.0	06010201-002
7	Tennessee	Clinch to Thief Neck	568.0	555.4	05010201-001
8	Tennessee	Thief Neck to RM 543	555.4	542.7	06010201-001
9	Tennessee	RM 543 to Watts Bar	542.7	529.9	06010201-001
		Reference Reaches			
10	Clinch	Norris Reservoir			06010205-001
11	Clinch	Norris to Bull Run		48.0	06010207-013,015,019
12	Clinch	Bull Run to CARL	48.0	42.0	06010207-007
13	Poplar Creek	above East Fork		5.5	06010207-022
14	E Fk Poplar Creek	East Fork		0.0	06010207-021
15	Emory	Emory Embayment	14.0	0.0	06010208-001
16	Tennessee	Fort Loudon Res.		602.3	06010201-059,060,062
17	Little Tennessee	Tellico Reservoir		0.0	06010204-001
18	Tennessee	Ft. Loudon to Clinch	602.3	568.0	06010201-019,010 012,014,016,017,018
19	Tennessee	below Watts Bar Dam	529.9		06020001-046

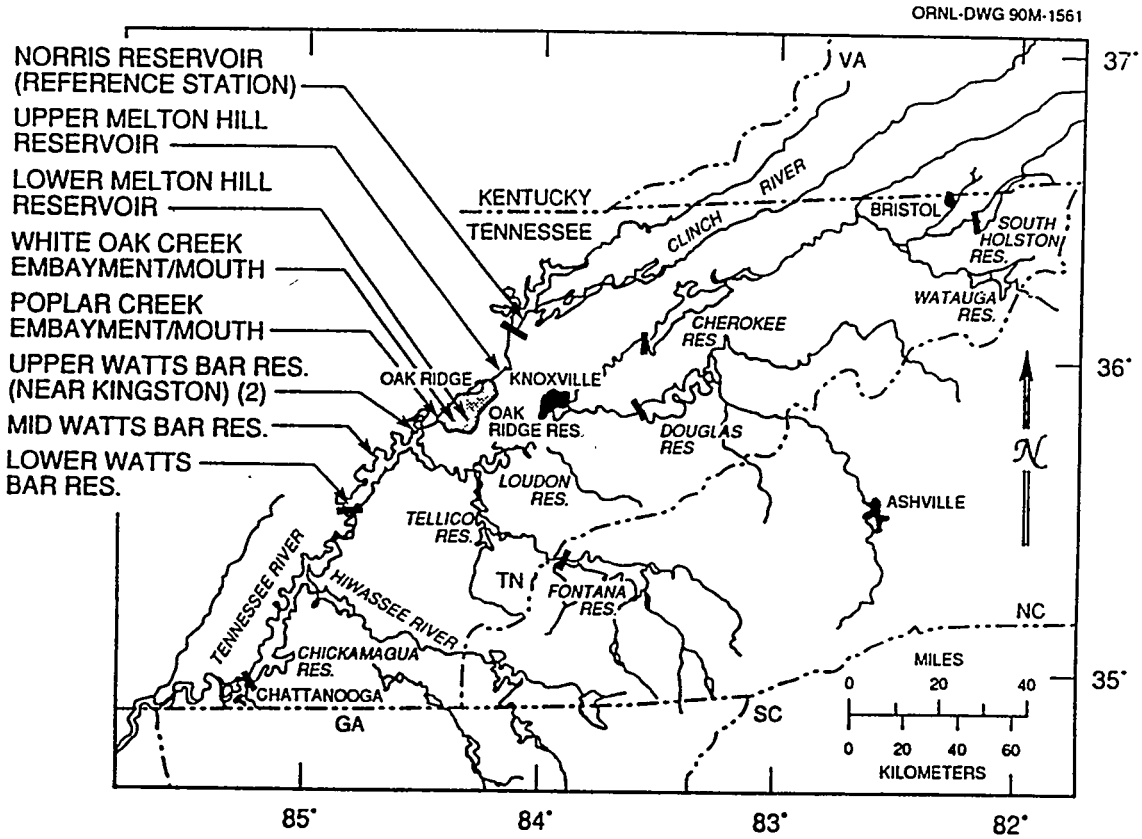

Fig. 9.3. Clinch River RFI sites selected for screening-level sampling and analysis

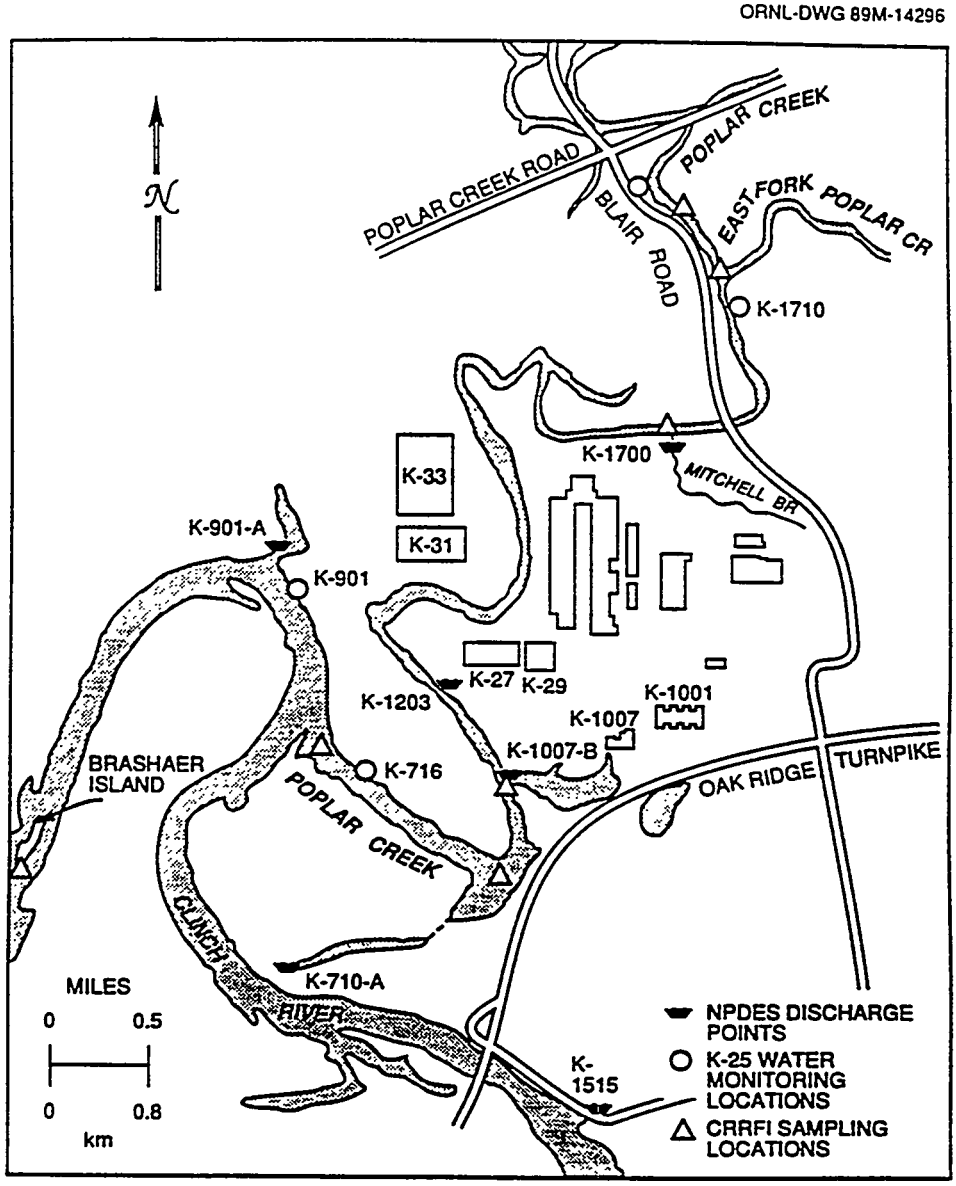

Fig. 9.4. Clinch River RFI sites selected for screening-level sampling and analyses in the Poplar Creek.

there are upstream releases of contaminants into the Clinch and Tennessee River systems. Samples from the White Oak Creek and Poplar Creek embayments will potentially have the highest levels of off-site contamination. The remaining sites and the justification for their selection are listed below.

Lower Melton Hill Reservoir (CRM 24.0, reach 1). Effluents originating from the Y-12 fly ash pond located on Fannys Nob flow through Roger's Quarry into Melton Hill Reservoir via McCoy Branch.

White Oak Creek Embayment/Mouth (CRM 20.9, reach 2). White Oak Dam located at WOCM 0.8 is the final release point for liquid effluents from the ORNL facilities and waste burial grounds. White Oak Lake has served as a final settling basin for radioactive effluents and other contaminants since 1943. Public access to White Oak Creek is at the mouth of the creek or CRM 20.9.

Jones Island (CRM 20.6, reach 3). Jones Island is located about 0.2 miles downstream from the mouth of White Oak Creek. During 1961-63, as a result of dredging operations related to the construction of Melton Hill Dam, contaminated spoils were deposited on the upstream end of Jones Island.

Poplar Creek. Liquid effluents from both Y-12 and ORGDP operations enter Poplar Creek and then flow into the Clinch River at CRM 12 (CRK 18.5). The five sampling sites in Poplar Creek are all in Reach 4. They include:

(i) West Fork Poplar Creek mile 6 (PCK 9.6), up the west fork of Poplar Creek, approximately 0.5 miles past its confluence with the East Fork of Poplar Creek. This will serve as a reference for contaminants from coal mining operations.

(ii) Poplar Creek confluence with East Fork Poplar Creek (EFK 0.0, PCK 8.9). This site receives effluent from the Y-12 plant (at the East Fork headwaters) and the Oak Ridge Wastewater Treatment Facility. East Fork Poplar Creek appears to be a source of metal, radionuclide and organic contamination.

(iii) Poplar Creek Mile 4.6 at the Mitchell Branch outfall (PCK 7.4, K-1700 stream, NPDES discharge 001). This receives effluent from several diverse sources. Among all ORGDP NPDES regulated discharges, this point has the greatest potential for radionuclide emissions due to facilities operating nearby (Rogers et al. 1988a).

(iv) Poplar Creek mile 1.4 (PCK 2.2, K-1007B holding pond outfall, NPDES discharge 006). This area is downstream from, and may serve to integrate contamination from: 1) ORGDP sanitary treatment facility (K-1203, NPDES discharge 005), has the second greatest potential for radionuclide emissions within ORGDP (Rogers et al. 1988a); 2) K27 facility, outfalls contained elevated levels of metals and organics (Ashwood et al. 1986); and 3) K1007B holding pond, contains elevated concentrations of metals, organics and ^{238}U activity (Ashwood et al. 1986).

An additional location, Poplar Creek mile 0.25 (PCK 0.5, near water monitoring location K-716) may be added if fish or sediment collection results indicate that it is necessary. This area receives contaminants from the above sources, and may receive runoff from the uranium-contaminated scrap metal stored adjacent to the K-710A powerhouse area. Elevated levels of uranium were observed in surface waters at K-716 during 1986 and 1987 (Oakes et al. 1987, Rogers et al. 1988b).

Clinch River downstream from Poplar Creek (CRM 9.5, Reach 5), in the Brashear's island tail waters. This site is the first site downstream from Poplar Creek effluent.

Upper Watts Bar Reservoir (Kingston) (TRM 567.5, reach 7), Mid Watts Bar Reservoir (TRM 546.0, reach 8), Lower Watts Bar Reservoir (TRM 534.0, reach 9). These sites were identified in the preliminary survey of ^{137}Cs in sediments of Watts Bar Reservoir as locations where particle-associated contaminants have accumulated.

Photographs will be taken of the sampling sites in each of the previously described sampling areas to document the location with regards to prominent environmental features. A copy of the photographs will be included in the field logbooks. The specific

locations at which biota, water, and sediment are collected will be identified using TVA navigation charts, with reference to corresponding shore markers and/or channel buoys. In addition, prominent shore features (such as TVA power lines, bridges, barge moorings, etc.) will be described at each sampling location. The site descriptions will be recorded in the field logbook at the time of each sample collection.

9.4.4 Sampling Frequency

The screening-level (Phase-1) sampling program will include only one series of field samples. The first series of samples is being collected in Fall 1989 through Spring 1990 at selected sites (Fig. 9.2 and 9.3). The number of samples and descriptions of the methods for collecting the samples (sediment, water, and biota) are detailed in Sections 9.5, 9.6, and 9.7, below.

In additional phases of the field sampling, the frequency and extent of sample collections will depend upon the results of the human health and environmental risk analyses, the nature and extent of off-site contamination as revealed by the results of the screening-level sampling and analysis effort, and the identification evaluation of potential CM/RA alternatives.

9.4.5 Focused Sampling and Analysis

Preliminary screening-level risk assessments were performed using data collected during previous studies of the Clinch River system. Screening-level sampling and analyses will provide additional data for more specifically estimating human health and environmental risks. These screening-level risk assessments identify contaminants of concern that will be targeted for more detailed investigation. The contaminants may accumulate variously in sediments, water, or biota. Each of these media requires a specialized sampling design.

Sediments

The processes that determine the concentrations of contaminants in the sediments are characterized by time scales greater than the residence time of water in the system. Therefore, in all phases of the CRRFI, sampling of contaminants of concern in sediments will be designed to quantify accurately and precisely the spatial variability in chemical concentration. A stratified random design can be used to ensure sufficient areal extent of sampling and to provide data for legitimate statistical analyses. Spatial statistics (e.g., kriging, co-spectral analysis, etc.) will be used to estimate the variance of chemical concentrations throughout the sediments based on current data in order to refine the risk estimates and guide additional sampling. Sediment sampling designs will also be evaluated using a model of sediment dynamics constructed for the Watts Bar impoundment.

Water

The dissolved concentration of contaminants of concern will be influenced by the water-residence time, hydrodynamics, and operating schedules of the Clinch River and Tennessee River impoundments. The sampling design will emphasize temporal variability in relation to the physical mixing characteristics of the system and loading events. The mixing of the system will be determined from existing data, additional monitoring, and by using simulation models of the system. Iterations between collection and analysis can be used to modify the sampling design to realize acceptable precision.

Biota

Accumulation of contaminants by the biota will be influenced by the spatial distribution of target organisms (e.g., fish, invertebrates, plankton) in the system and their temporal patterns of growth and reproduction. Existing information concerning these patterns, plus basic ecological understanding of the biota, will be used to design effective sampling plans for all phases of the project. Life history data and knowledge of patterns of movement will be used to design sampling plans for fishes in the Clinch River and its

impoundments during the initial phase of the project. If food-web interactions appear important for accumulation of specific contaminants by fish (e.g., PCBs), the sampling plan can be expanded to include benthic invertebrates, plankton, and other prey. Sampling plans will similarly reflect a quantitative understanding of the temporal production dynamics and spatial distribution of these organisms. Existing data, subsequent measurements, and simulation models will be used in an iterative fashion to assist in the design of biological sampling during all phases of the project.

9.5 SEDIMENT SAMPLING PLAN

9.5.1 Introduction

The objective of the sediment sampling and analysis program is to determine contaminant levels in off-site sediments. These results will provide input data needed both for the health and environment risk assessment and to characterize the nature and extent of environmental contamination. The ultimate focus of all field data collection is an assessment of corrective/remedial action alternatives.

Most contaminants of concern are chemically and biologically reactive and rapidly become associated with particles in freshwater systems. Uptake or sorption onto particles is the primary mechanism for removing chemically reactive contaminants from the water phase, with sedimentation the principal mechanism for accumulation in off-site areas over long time periods. Collection will be phased so that initial results can be used to determine task priorities, refine plans, and better focus subsequent sampling efforts. This phased approach will allow for more efficient characterization of off-site areas and, therefore, reductions in time and costs.

Zones of quiescent water, such as those encountered in embayments and reservoirs, promote particle settling and subsequent accumulation. Sediments in these areas must be considered in terms of both potential traps of and sources for contaminants (Section 9.4.1). Sediment sampling in off-site areas will be critical for (1) detecting the presence of contaminants, (2) screening contaminants on the basis of environmental and

health risks, (3) characterizing both the extent and history of contamination, and (4) assessing CM/RA alternatives.

Sampling locations in the Clinch and Tennessee River systems will be identified using TVA navigation charts with corresponding shore markers and/or channel buoys. In addition, a description of prominent shore features at each sampling location (such as TVA power lines, bridges, barge moorings, etc.) will be recorded in a logbook. Sediment sample collection will be closely coordinated with the collection of water and biota samples. One set of samples will be collected from each site for the initial, screening-level sampling. The sediment samples will be analyzed for the primary contaminants of concern (Table 5.12) and the results will be used for preliminary risk assessment analyses.

9.5.2 Sediment Collection

Standard procedures will be followed for collection of samples (Kimbrough et al. 1988). The types of analyses to be performed on sediment core samples collected at each site are summarized in Table 9.2. In contrast to biotic sampling, field measurements will be made to quantify general water quality parameters: water temperature, pH, dissolved oxygen, conductivity, oxidation-reduction potential, and water flow rate. Surface sediment grab samples will be collected for gamma-ray spectrometry (Kimbrough et al. 1988). A free-fall gravity corer (Wildco KB) will be used to obtain sediment profiles from deep water sites (depth greater than 5 m). Gravity cores will be collected using liners (120 cm long, 4.7 cm diameter) constructed of either cellulose acetate butyrate (CAB) resin, polyvinyl chloride (PVC), or stainless steel, depending on the analytical requirements of the samples to be collected (Fig. 9.5, Table 9.2). A vibracore device, will be used to collect core samples from shallow water (depth less than 5 m) sites (Lanesky et al. 1979, Kimbrough et al. 1988). Vibracores will be collected using core pipes (approx. 7 m length, 7 cm internal diameter) constructed of either PVC plastic (nonpigmented, schedule 40) or stainless steel, depending on the analytical requirements of the samples to be collected (Fig. 9.6, Table 9.2). Sampling location, container identification number, sediment depth increment, intended analysis, and any other

Table 9.2. Summary of the types of analyses and procedures to be performed on the sediment core samples collected at each site.[a]

Analysis	Analytical Procedures Reference[c]	Core Tube Material
Gamma-EmittingR Radionuclides	Appendix A-2	PVC or CAB
Alpha- or Beta-Emitting Radionuclides	ORAU-ACD procedures	PVC or CAB
XRF/XRD	UT procedures	PVC or CAB
Total Carbon	ORNL-ESD prodcedures	PVC or CAB
Mercury	ORGDP-ACD procedures	PVC or CAB
Other Metals	ORGDP-ACD procedures	PVC or CAB
PCBs and Other Organics	ORGDP-ACD procedures	Stainless steel
Archived		PVC or CAB and Stainless steel

[a]Subject to final review.
[b]Each core will be divided into depth-incremented sections, the number of which will depend on the length of the sediment core. Assuming an average core length of 80 cm, the average number of depth increment samples will be 23 (see sediment sectioning in Section 8.2).
[c]Specific references in Table 8.2.
[d]PVC - polyvinyl chloride; CAB - cellulose acetyl butyrate

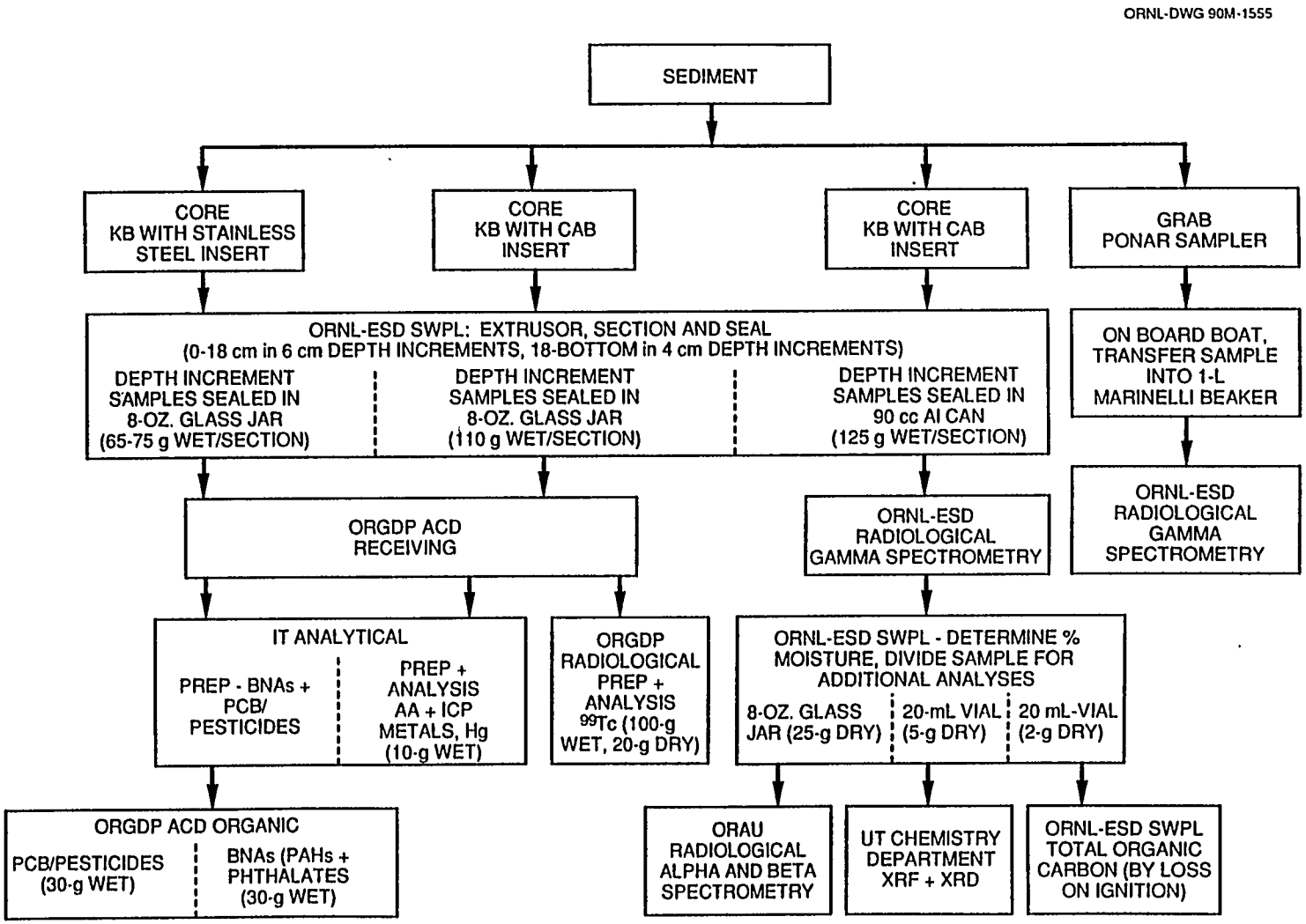

Fig. 9.5. Sample apportionment and analysis scheme for sediment samples collected with a gravity corer.

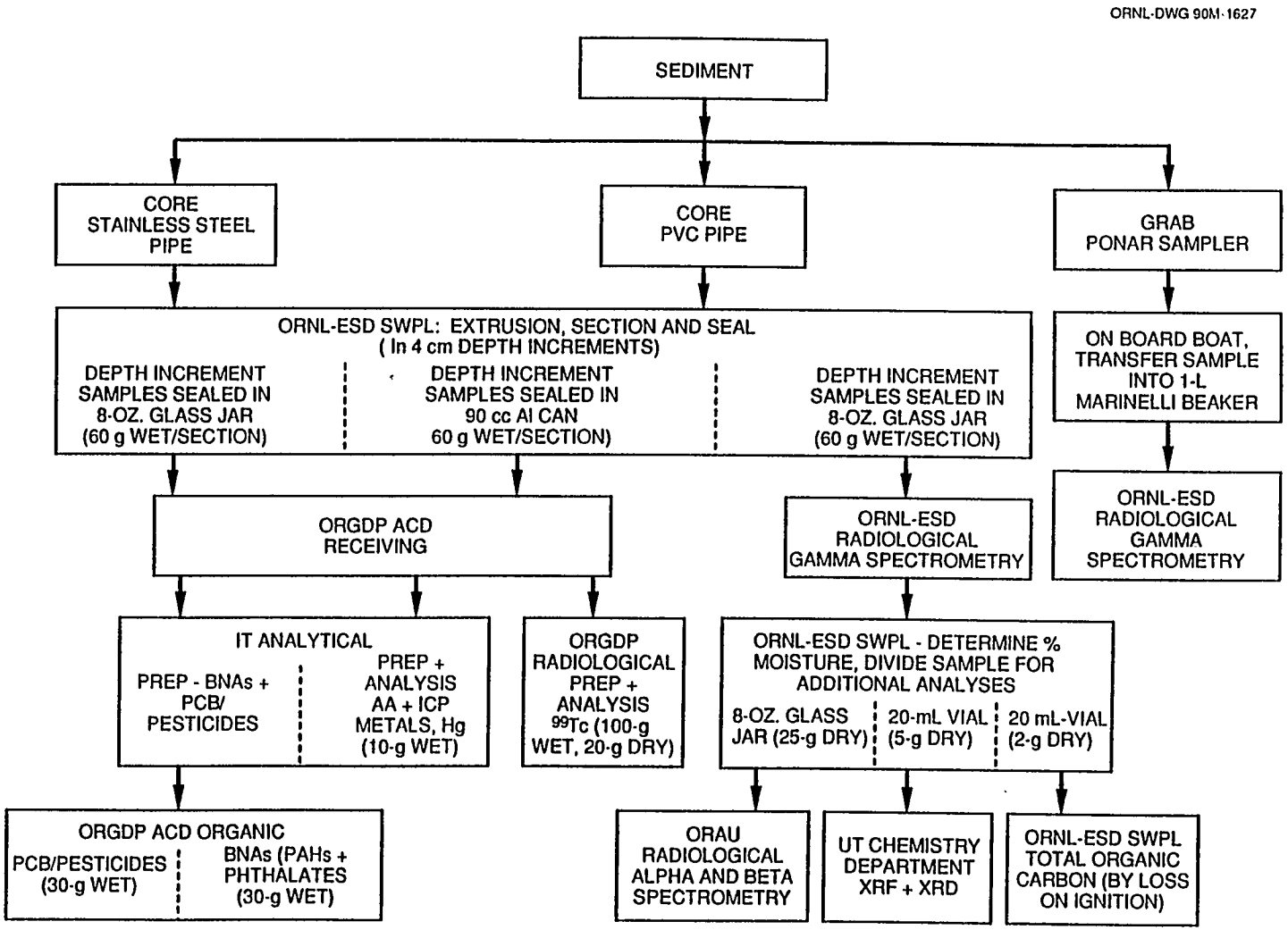

Fig. 9.6. Sample apportionment and analysis scheme for sediment samples collected with a vibracorer.

identifying information will be recorded on the field chain-of-custody forms (Appendix B), the field notebook, and the container itself (Appendix B) as appropriate (Appendix B). Field notes will be entered into the logbook regarding sample identification, the sediment texture, color, amount of detritus, changes in composition, total length of core obtained, and any other notable properties.

After collection, the cores will be returned to the laboratory for extrusion, sectioning and sealing following standard procedures (Kimbrough et al. 1988). Gravity cores will be sectioned by 6-cm depth increments from the surface to 8 cm deep, and by 4-cm intervals from 18 cm to the bottom. Duplicate samples from each core will be collected by homogenizing two contiguous 4-cm depth increment sections and splitting the homogenate into equal portions. Duplicate samples will be collected at the same depth for all cores collected from a given location. These sections are hermetically sealed in either aluminum cans or in precleaned (IChem, 300 series), 250-mL clear glass jars with teflon-lined lids, depending upon analytical requirements (Fig 9.5, Fig. 9.6, and Table 9.3). Sampling date, location and time, sample identification number, sediment depth increment, intended analysis and any other identifying information will be recorded on the laboratory chain-of-custody forms (Appendix B), request-for-services forms (Appendix B) and the container itself as appropriate. Cores designated as reference material will be completely homogenized by placing the entire core in a glass mixing bowl and stirring with a teflon spoon. Appropriate-sized aliquots will be placed in glass jars and frozen until submitted for analysis. Laboratory notes will be entered into the logbook regarding sample identification, the texture and consistency of individual sediment sections, color, amount of detritus, changes in composition, total length of core obtained, and any other notable properties.

Samples will be in the possession of the sample custodian (Section 6.4) immediately after collection. They will remain in custody, following established sample custody (Section 9.8) and QA/QC procedures (Section 10). The sample custodian will be responsible for all sediment samples from the time of collection to the time of transfer to either the ASC or ESD laboratory supervisor.

Table 9.3. Summary of methods selected for preparation and analysis of sediment samples for metals and organics[a].

Parameter	Analysis Method[b]	Method Detection Limit (MDL)[c]	Approximate Detection Limit (ADL) (μg/L)[d]	Comments[e]
Antimony	204.2 CLP-M	60	3	ADL For GFAA
Arsenic	200.7 CLP-M	10	53	ADL For ICP
	206.2 CLP-M		1	ADL For Gas Hydride
Lead	200.7 CLP-M	5	42	ADL For ICP
	239.2 CLP-M		1	ADL For GFAA
Selenium	200.7 CLP-M	5	75	ADL For ICP
	270.2 CLP-M		2	ADL For GFAA
Silver	272.2 CLP-M	10	0.2	ADL For GFAA
Thallium	279.2 CLP-M	10	1	ADL For GFAA
Mercury	245.5 CLP-M	0.2	0.2[f]	ADL For Cold Vapor AA
Beryllium	200.7 CLP-M	5	0.3	ADL For ICP
Cadmium	200.7 CLP-M	5	4	ADL For ICP
Chromium	200.7 CLP-M	10	7	ADL For ICP
Copper	200.7 CLP-M	25	6	ADL For ICP
Nickel	200.7 CLP-M	40	15	ADL For ICP
Zinc	200.7 CLP-M	20	2	ADL For ICP
Bis-(2-Ethyl-Hexyl)-Phthalate	Semivolitales	330		GC/MS
Di-N-Butyl-Phthalate	Semivolitales	330		GC/MS
Anthracene	Semivolitales	330		GC/MS
Fluoranthene	Semivolitales	330		GC/MS
Phenanthrene	Semivolitales	330		GC/MS
Pyrene	Semivolitales	330		GC/MS
Aldrin	Pesticides/PCBs	8		GC
Chlordane	Pesticides/PCBs	0.014		GC
4,4-DDD	Pesticides/PCBs	16		GC
4,4-DDE	Pesticides/PBCs	16		GC
PCBs	Pesticides/PCBs	16		GC, CRQL for PCB-1242

[a]Subject to final review.
[b]Preparation method specified by EPA Contract Laboratory Program Statement of Work (CLP SOW) methods (EPA 1987, 1988).
[c]For inorganic analyses: Contract Required Detection Limits (CRDLs) in μg/L are instrument detection limits obtained in pure water that must be met using procedures specified by the CLP SOW (EPA 1987). For organic analyses, Contract Required Quantitation Limits (CRQLs) in μg/Kg are based upon wet weight; the quantation limits calculated by the laboratory (based upon dry weight as required by contract) will be higher. Specific limits are highly matrix dependent.
[d]Approximate Detection Limits (ADL) from CLP SOW methods (EPA 1987). Not available for organic analyses.
[e]GFAA: Graphite Furnace AA; ICP: inductively-coupled plasma spectrometry; GC: gas chromatography; GC/MS: gas chromatography/mass spectrometry; CLP-M: Contract Laboratory Program modified
[f]Approximate detection limit for method 245.5 CLP-m in μg/g.

9.5.3 Analyses

Sediment grab samples, sealed in Marinelli beakers, and sediment-core interval samples, sealed in aluminum cans, will be analyzed for gamma-emitting radionuclides by gamma-ray spectrometry (Fig. 9.5 and Fig. 9.6, Kimbrough et al. 1988). Sample custody will be transferred to the Analytical Services Coordinator (ASC) for delivery to the ORNL-ESD Radiological Laboratory for analyses. After initial gamma-ray spectrometry, sample custody will be returned to the processing laboratory, the samples will be weighed and the wet weight recorded. Each depth-increment sample will be oven dried (60°C for 16 hours) and reweighed for percent moisture determinations. Dried samples will be homogenized and split for alpha-beta, XRF/XRD and total organic carbon determinations (Fig. 9.5 and Fig. 9.6, Table 9.2). Sample custody will be transferred to the ASC for delivery to the appropriate analytical laboratories.

Custody of depth-increment samples for inorganic analyses will be transferred to the ASC. Core samples will be submitted within 24 hours of collection and sectioning to ORGDP-ACD sample receiving (Fig. 9.5 and Fig. 9.6, Table 9.2, Table 9.3). QA samples for inorganic analyses will be submitted with the following minimum frequency: 1) Duplicate, once per core, 2) reference material, twice per core, and 3) NSF standard reference material, once per sampling week. A portion of each sample will be archived by the receiving laboratory for later reference.

Custody of depth-increment samples for organic analyses (listed in Table 5.12) will be transferred to the ASC. Core samples will be submitted within 24 hours of collection and sectioning to ORGDP-ACD sample receiving (Fig. 9.5 and Fig. 9.6, Table 9.2, Table 9.3). QA samples for organic analyses will be submitted with the following minimum frequency: 1) duplicate, once per core, 2) reference material, twice per core, 3) matrix spike (reference material), once per core, 4) matrix spike duplicate, twice per core. A portion of each sample will be archived by the receiving laboratory for later reference.

Processing, validation and reporting of data obtained from field observations and laboratory analyses will strictly adhere to procedures given in the Data Management Plan (Section 11.4). Data printout records will be filed and stored for future reference. All data resulting from laboratory analyses will be handled according to procedures in Section 9.8, and in the Data Management Plan (Section 11). Results of analyses will be presented in a table format with the sample identification and value for each parameter at each sampling location. Statistical evaluations of the data will use SAS procedures (SAS 1985). Data files will be transferred to Data Management staff for inclusion in the numeric data base (Section 11.4). Radionuclide concentrations and sediment characteristics will be mapped using a Geographic Information System with ARC/INFO software. This mapping procedure will allow the accurate representation of contaminant inventories in specific areas.

9.6 WATER SAMPLING PLAN

9.6.1 Introduction

Specific objectives for the surface water sampling program are 1) to identify contaminant transport pathways, 2) to determine the degree of current contamination, 3) to provide data for environmental and human-health risk analyses, and 4) to identify and evaluate potential CM/RAs. These objectives will be addressed on a limited basis in the initial phase of the sampling plan and, as needed, will be assessed to a greater extent in later phases as suggested by initial results. Measurement of surface water characteristics provides critical data regarding the short time-scale distribution of contaminants, as well as information on potential biotic and sediment accumulation of contaminants downstream from the Oak Ridge Reservation. Contaminant transport patterns depend on seasonal factors affecting water quality, biota, particulate matter dynamics, and shifts in near-term deposition zones.

Field measurements will be made to quantify general water quality parameters: water temperature, pH, dissolved oxygen, conductivity, oxidation-reduction potential, water flow rate, turbidity, and Secchi transparency (Table 9.4). One set of samples will be collected

Table 9.4. Summary of surface water characteristics to be measured at each site, and procedures for analyses of field parameters[a].

Parameter[b]	Level[c]	Analytical Procedure
Temperature	II	ESP 307-1, ESP 307-8 (Kimbrough et al., 1988); Hydrolab Corp. 1984.
pH	II	ESP 307-A2, ESP 307-8; Hydrolab Corp. 1984.
Dissolved oxygen	II	ESP 307-3, ESP 307-8; Hydrolab Corp. 1984.
Conductivity	II	ESP 307-4, ESP 307-8; Hydrolab Corp. 1984.
Oxidation-Reduction Potential	I	ESP 307-5; ESP 307-8; Hydrolab Corp. 1984.
Water flow rate	II	ESP 307-8; Marsh McBirney Corp. 1981.
Field Turbidity	I	ESP 307-8; Monteboro Whitney Corp. 1980
Secchi transparency	I	ESP 307-8

[a]Subject to final review.
[b]For field analyses, all data are collected in situ for real-time site characterization. Number of measurements will depend upon local environmental conditions.
[c]Analysis level from Kimbrough et al., (1988) ESP-700 Section IV.

for the initial sampling and analysis effort to specifically identify potential contaminants of concern. If potential risk to the environment and/or man is indicated, then additional sampling will be conducted to address those concerns and to characterize the extent of the contamination. The phased approach described earlier will determine future sampling sites, frequency, and water quality measurements to be made.

Sampling locations will be identified using TVA navigation charts with corresponding shore markers and/or channel buoys. Prominent shore features (such as TVA power lines, bridges, and barge moorings) will be described for each location. Specific sampling locations are described in Section 9.4.3.

9.6.2 Water Collection and Field Measurements

Water samples for laboratory analyses will be collected from a boat, following the standard procedures set forth in ESP 301-4 (Kimbrough et al. 1988). Collection of water samples will occur on different days than collection of sediment samples to eliminate the potential for degradation of water quality from disturbed sediments. Representative sampling depths will be determined by location, water flow rates, relative turbidity layers, and water column stratification, properties determined for each site by coincident field measurements (Table 9.4). A thermally stratified water column is one in which there is a 1°C degree or greater decline in temperature for every 1-m change in depth. The metalimnion refers to the depth range in which there is a maximal rate of decrease in temperature with change in depth. For water columns with uniform properties, samples will be taken 1.0 meter below the surface. During thermal stratification (as identified by vertical water temperature profiles), composite samples will be obtained from at least three portions of the water column: 1) at mid-depth within the surface mixed layer as indicated by dissolved oxygen and temperature profiles; 2) at mid-depth in the metalimnion; and 3) 0.5 m above the bottom or at the dissolved-oxygen minimum. The number of samples taken will range from 1 to 3 for each of the fifteen sites.

Depth-specific water samples will be collected using Kemmerer or Van Dorn style samplers (Kimbrough et al. 1988). Stainless-steel sample bottles with silicone end seals will be used to collect samples for organic analyses, while PVC samplers (Plumb 1981) with silicone end seals will be used for metals, radionuclides, and other analyses. Sample containers will be collapsible polyethylene cubitainers (20-L or 4-L), 2.3-L amber glass bottles, or 0.25-L high-density polyethylene bottles, as required for analysis (Fig. 9.7, Table 9.5). Composite water samples will be split as required to fill containers for specific laboratory analyses. A duplicate set of organic and inorganic samples will be collected for each batch of samples submitted (1 batch per sampling week). A trip blank (defined in Section 10.7.1 of the QA/QC Plan) will also be collected for each batch submitted. A rinse blank (also defined in Section 10.7.1) will be collected between multiple sample locations on a given day. Sampling location, identification tag number, collection depth, intended analyses and other pertinent information will be recorded on the sample tag, water data collection form (Appendix B) chain-of-custody forms (Appendix B), and in the field notebook. Sample tags and forms will be initialed by the sample collector and samples will be placed in secured ice chests (4°C).

Chain-of-custody will be initiated at the time of sample collection, and samples will be in the possession of the sample custodian. They will remain in custody following established QA/QC procedures (see Section 9.8, below). The sample custodian will be responsible for all water samples, from collection until custody is transferred either to the ASC or the ESD laboratory supervisor. All sampling bottles and sample containers will be precleaned to meet EPA specifications or the particular parameters being measured (ESP-900, Kimbrough et al. 1988; EPA 1986; sample containers pre-cleaned by I-CHEM Research Corp., New Castle, DE).

All data collected for this project will be subject to quality assurance, quality control, and chain-of-custody procedures as described in Section 9.8 and in the QA/QC Plan (Section 10). Data will be recorded in black indelible ink and corrections will be made by drawing a single line through incorrect entries. Corrections will be initialed and dated by the individual making the changes.

Table 9.5. Summary of surface water analysis for the contaminants of concern.[a] Analysis level from ESP-700 Section (Kimbrough et al., 1988).

Parameter	Analytical level	Container[b] and processing specifics	Analytical Procedure
$^{3}H + ^{90}Sr$	IV	4L Cubitainer, chill return to lab and acidify (HNO_3) pH < 2	Method 906.0, EPA-600/4-80-032 1980.
Gamma radionuclides		21 L Cubitainer, chill to be used for:	
Particle-Associated	IV	filter all of Gamma, collect, air dry filters	
Dissolved	IV	filtrate from Gamma, evaporate to 90 mL	
Inorganics		4 L Cubitainer, chill, to be used for:	
Total metals	IV	1 L PPE bottle, HNO_3 pH < 2, chill	CLP SOW (EPA 1987)
Dissolved metals	IV	Filter into 1 L PPE bottle, HNO_3 pH < 2, chill	CLP SOP (EPA 1987)
Major Ions	III	Filter into 1 L PPE bottle, chill	Ion Chromatography
Organics (as listed in Table 4.1)	IV	2.3 L Amber glass bottle, teflon lined, chill	CLP SOW (EPA 1988)
Particles		4 L cubitainer, chill, to be used for:	
Chlorophyll-a	III	Filter, 0.5 L duplicate per sample, freeze.	Fluorometric determination (Ford 1990)
Total suspended particles	III	Filter, 1 L duplicate per sample, oven dry (100 °C)	Gravimetric determination (Ford 1990)
Alkalinity	III	0.25 L Polycarbonate bottle, no aeration, chill, 100 mL duplicate used for titration. Sample used for:	Titration (Ford 1990)
Turbidity	III	5 mL aliquot from Alkalinity sample	Direct measurement.

[a]Subject to final review.
[b]All containers precleaned to EPA specifications. Cubitainers are manufactured from polycarbonate materials.
[c]Presume no residual chlorine present.

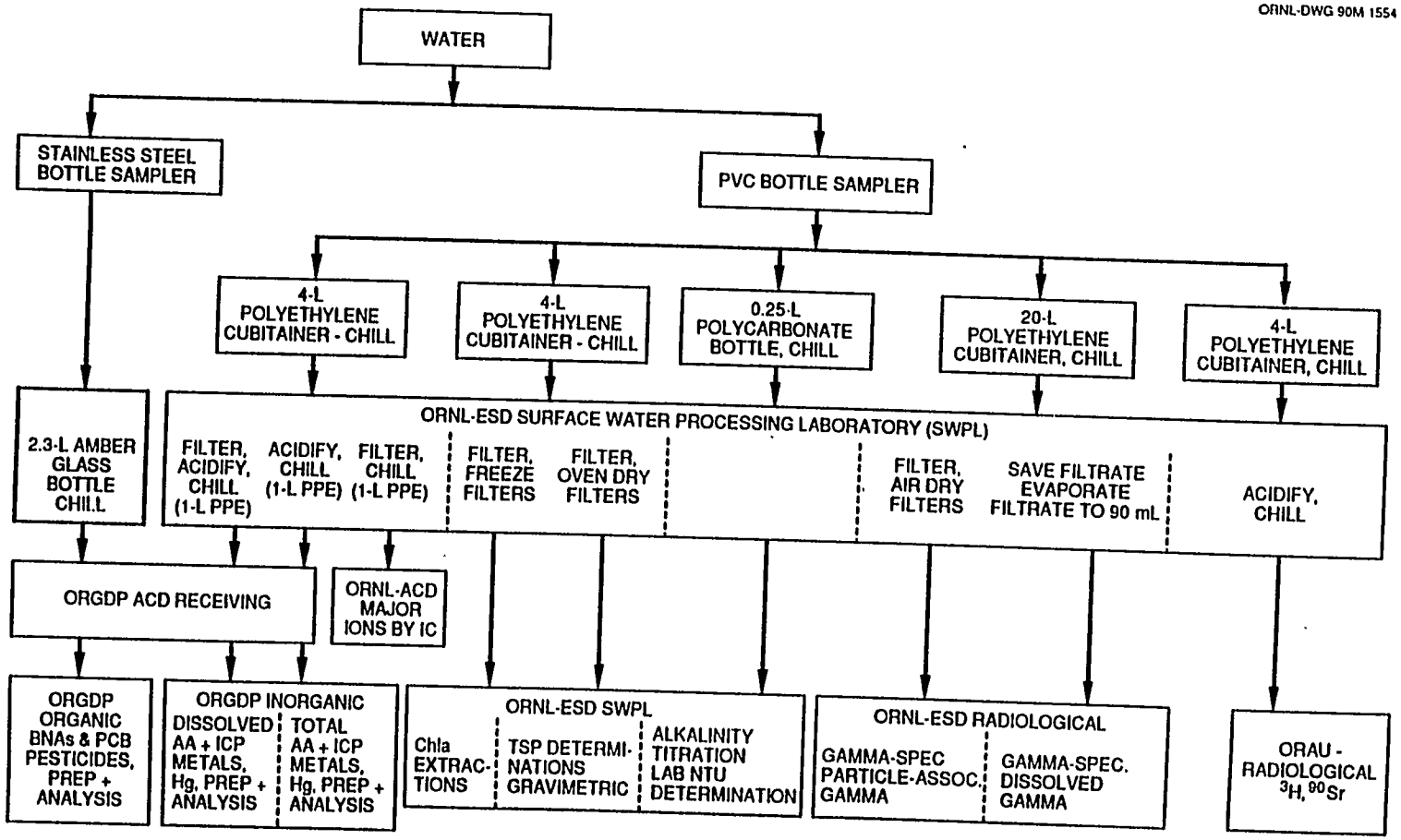

Fig. 9.7. Sample apportionment and analysis scheme for surface water samples.

9.6.3 Analyses

Water samples for analysis of gamma-emitting radionuclides will be filtered. Both filters (particulate) and filtrate (dissolved) portions of samples will be analyzed for gamma spectrometry (Table 9.5). Laboratory chain-of-custody forms and request for services forms (Appendix B) will be completed. Sample custody will be transferred to the Analytical Services Coordinator (ASC) for delivery to the ORNL-ESD Radiological Laboratory for analyses.

Samples for inorganic analyses will be split into three aliquots (see Table 9.6): 1) dissolved trace metals will be filtered, acidified, and chilled; 2) total trace metals will be acidified and chilled; and 3) major ions will be filtered and chilled. Laboratory chain-of-custody forms and laboratory request for services forms (Appendix B) will be completed. Custody of inorganic samples will be transferred to the ASC. Samples will be submitted within 24 hours of collection to ORGDP-ACD sample receiving. QA samples for inorganic analyses will consist of field duplicates, trip blanks and rinsate blanks to be submitted as described in Section 10.

Laboratory chain-of-custody forms and request for services forms (Appendix B) for organic analyses will be completed. Custody of organic samples will be transferred to the ASC. Chilled samples will be submitted within 24 hours of collection ORGDP-ACD sample receiving (Table 9.6). Quality assurance samples for organic analyses will consist of field duplicates, trip blanks and rinsate blanks to be submitted as described in Section 10.

Procedures to be performed in the ORNL-ESD Surface Water Processing Laboratory include filtration, titration, and turbidity measurements (Table 9.5). Particulate matter samples will be filtered for determination of chlorophyll-a and total suspended particles. Samples will be titrated for hardness and alkalinity determinations. Sample pH and turbidity will also be checked. The routine use of replicate filtration and analyses will be used to provide an estimate of precision. Processing, validation and reporting of data

Table 9.6. Summary of methods selected for preparation and analysis of water samples for metals and organics[a].

Parameter	Analysis Method[b]	Method Detection Limit (MDL) μg/L)[c]	Approximate Detection Limit (ADL) (μg/L)[d]	Comments[e]
Antimony	200.7 CLP-M	60	32	ADL For ICP
	204.2 CLP-M		3	ADL For GFAA
Arsenic	200.7 CLP-M	10	53	ADL For ICP
	206.2 CLP-M		1	ADL For Gas Hydride
Lead	200.7 CLP-M	5	42	ADL For ICP
	239.2 CLP-M		1	ADL For GFAA
Selenium	200.7 CLP-M	5	75	ADL For ICP
	270.2 CLP-M		2	ADL For GFAA
Silver	272.2 CLP-M	10	0.2	ADL For GFAA
Thallium	279.2 CLP-M	10	1	ADL For GFAA
Mercury	[f]	0.2	0.2	ADL For Cold Vapor AA
Beryllium	200.7 CLP-M	5	0.3	ADL For ICP
Cadmium	200.7 CLP-M	5	4	ADL For ICP
Chromium	200.7 CLP-M	10	7	ADL For ICP
Copper	200.7 CLP-M	25	6	ADL For ICP
Nickel	200.7 CLP-M	40	15	ADL For ICP
Zinc	200.7 CLP-M	20	2	ADL For ICP
Bis-(2-Ethyl-Hexyl)-Phthalate	Semivolitales	10		GC/MS
Di-N-Butyl-Phthalate	Semivolitales	10		GC/MS
Anthracene	Semivolitales	10		GC/MS
Fluoranthene	Semivolitales	10		GC/MS
Phenanthrene	Semivolitales	10		GC/MS
Pyrene	Semivolitales	10		GC/MS
Aldrin	Pesticides/PCBs	0.05		GC
Chlordane	Pesticides/PCBs	0.014		GC
4,4-DDD	Pesticides/PCBs	16		GC
4,4-DDE	Pesticides/PBCs	16		GC
PCBs	Pesticides/PCBs	80		GC, CRQL for PCB-1242

[a]Subject to final review.
[b]Preparation method specified by EPA Contract Laboratory Program Statement of Work (CLP SOW) methods (EPA 1987, 1988).
[c]For inorganic analyses, Contract Required Detection Limits (CRDLs) are specified in the CLP SOP for Inorganic analyses (EPA 1987). For organic analyses, Contract Required Quantitation Limits (CRQLs) are specified in the CLP SOW for Organic analyses (EPA 1988). Specific limits are highly matrix dependent.
[d]Approximate Detection Limits (ADL) from CLP SOW methods (EPA 1987). Not available for organic analyses.
[e]GFAA: Graphite Furnace AA; ICP: inductively-coupled plasma spectrometry; GC: gas chromatography; GC/MS: gas chromatography/mass spectrometry; CLP-M: Contract Laboratory Program modified
[f]Mercury analysis in water will use either the maunal (245.1 CLP-M) or automated (245.2 CLP-M) procedure.

obtained from field observations and laboratory analyses will strictly adhere to standard procedures (Section 11).

Upon completion of the specified analyses, the original chain-of-custody forms, any residual sample material, and sample custody will be transferred to the Analytical Services Coordinator who will return the forms and samples to the Sampling Team Leader. The final deposition of the samples will be recorded in the appropriate logbook. All data resulting from field and laboratory analyses will be handled according to procedures in the Data Management Plan (Section 11). Results of the analyses will be provided in a tabular format with the sample identification and value for each parameter at each sampling location. Statistical evaluations of the data will use SAS procedures (SAS 1985).

9.7 BIOTA SAMPLING PLAN

9.7.1 Introduction

The objective of this sampling program is to measure the concentration of contaminants in key aquatic organisms, especially fish.

9.7.2 Biota Collection

The two primary pathways for human exposure to contaminants are direct exposure from water and sediment, and indirect exposure via the food chain. Because fish are at the apex of aquatic food chains, they are integrators and accumulators of many environmental contaminants. Fish, other aquatic organisms (e.g., zooplankton, clams, turtles), and fish predators (e.g., herons, mergansers, ospreys, and man) may be deleteriously affected by water-borne contaminants. Fish species may provide a direct link in the transfer of contaminants from the aquatic environment to man. Contaminant impact on the food chain pathway will initially be assessed by sampling fish species representative of three trophic feeding levels. Other food-chain components (aquatic

and terrestrial) may be sampled as dictated by the results of the screening-level sampling and analysis effort.

Fish species representative of three trophic levels will be sampled: 1) an omnivorous bottom feeder, the channel catfish (Ictalurus punctatus); 2) an omnivorous midwater fish, the bluegill sunfish (Lepomis macrochirus); and 3) a top piscivore, the largemouth bass (Micropterus salmoides). Channel catfish are good indicators of PCBs in the environment because of their relatively high body lipid levels. Bluegill sunfish tend to remain within a well-defined and restricted range (Gerking 1959; Gatz 1989). They are the primary prey of many higher predators in the Clinch and Tennessee River systems, and are also a popular pan fish. The largemouth bass is a preferred species for sport fisherman.

These three fish species are usually readily available in adequate numbers and are preferred sport fish, making them important potential pathways for human exposure. Also, because much is known about the ecology and physiology of these three species, this information should be an aid in assessing contaminant-related effects on the environment. Results from the screening-level sampling and analysis effort will indicate if 1) other aquatic and terrestrial biota should be sampled in future studies and, 2) complementary bioindicator studies should be initiated to assess the effects of contaminant stress on key biological and ecological processes in the Clinch and Tennessee River systems.

9.7.3 Sampling of Biota

Specific sampling locations in the Tennessee and Clinch River systems will be identified using TVA navigation charts with corresponding shore markers and/or channel buoys. In addition, prominent shore features (such as TVA power lines, bridges, barge moorings, etc) will be described at each location. Specific sampling locations are described in Section 9.4.3. Collection of fish will be coordinated with the collection of water and sediment samples. For screening-level sampling, one set of samples will be collected from each site. The sampled fish will be analyzed for the primary contaminants of

concern (Table 5.12). The results will be used to conduct a preliminary human and environmental risk assessment. If potential risk to the environment and/or man is indicated from the preliminary sampling analysis, then additional sampling will be conducted.

Standard sampling procedures will follow those of Kimbrough et al. (1988). Fish samples will be taken by boat electrofishing (single boom, 500 watt, high cycle generator), gill netting (experimental monofilament), or angling (trot lines) using standard DOE field sampling protocols (Appendix E, USDOE 1987). Eight individuals of each of the three species (channel catfish, bluegill sunfish, largemouth bass) will be taken at each site (Table 9.7). Geographic markers will be noted in a field logbook to insure that the area sampled corresponds with the location of sediment and water samples. If possible, the fish retained for analysis will be restricted to fish of sizes likely to be taken by sport fishermen.

Fish collected at each site will be immediately fitted with a unique four-digit tag wired through the lower jaw. Catfish collected from gill nets will be placed on ice in a labeled and secured ice chest. Live fish (largemouth bass and bluegill) will be placed in labeled and secured 20 gallon plastic containers. Sampling location, tag number, fish species, intended analysis and any other pertinent information will be recorded in the field notebook, the data collection form (Appendix B), and on the chain-of-custody forms (Appendix B) as appropriate. The sample custodian will be responsible for all fish samples from the time of collection to the time of transfer to either the Analytical Services Coordinator (ASC), or the ESD laboratory supervisor. Established procedures for sample chain-of-custody and field logbooks (Section 9.8), and QA/QC (Section 10) will be followed.

After collection, sampled fish will be returned to the laboratory. Each fish will be weighed, the total length recorded, liver enzyme and blood samples obtained, and filets with the skin removed will be taken from both sides of the fish. A 1-2 g sample will be excised from the anterior dorsal portion of the axial muscle and used for mercury determination. The remainder of this filet will be retained and analyzed for metals and

Table 9.7. Summary of the number of fish samples to be collected at each site and procedures followed for analysis of priority pollutants.[a]

Parameter	Fish Species	No. of Samples	Analytical Procedures Reference
Mercury	Largemouth Bass	[c]	ORNL
	Bluegill	8	ORNL ACD Procedures #10915 & 1214922
Other Metals[c]	Largemouth Bass	[c]	EPA (1980a)
	Bluegill	8	
Radionuclides[d]	Bluegill	8	EPA (1979)
	Catfish	8	
PCBs and Other Organics[c]	Catfish	8	PPB 12/83 in EPA (1984)
	Largemouth bass	[c,e]	
Archived	Largemouth Bass	[c]	
	Bluegill	8	
	Catfish	8	

[a]Subject to final review.
[b]Samples will be wrapped in aluminum foil and stored in secure freezer until processed.
[c]No. of samples dependent on availability at each site.
[d]Refer to Table 4.1 for the other metals, radionuclides, and other organics to be analyzed.
[e]PBCs only for largemouth bass.

radionuclides. Four to five grams of the other filet will be used for organic analyses (including PCBs) and the remainder archived (Fig. 9.8). Samples for analyses to be performed in different analytical laboratories will have separate chain-of-custody and request-for-services forms. Samples for radionuclide analyses will be freeze-dried, wrapped in aluminum foil, and stored at room temperature in a secure location until analysis. Samples for metals and organic analysis will be divided, wrapped in heavy-duty aluminum foil, labeled, and stored at -20 degrees C in a locked, restricted access freezer. Cross-contamination between samples will be avoided by cleaning all equipment (knives, etc.) thoroughly between the processing of each fish (ESP-900, Kimbrough et al. 1988).

9.7.4 Fish Tissue

Gamma-emitting radionuclides will be analyzed by ESD personnel (Appendix A.2). Specific preparation and analytical methodologies to be used for PCBs, organics, total mercury and total metals are given in Table 9.8. The QA/QC for the analysis of biological monitoring samples is handled by the internal laboratory QA program as described in Section 7.2 of Rogers et al. (1988). Approximately one duplicate, one blank, and one spiked blank per 16 fish will be prepared for the organic (including PCBs) and heavy metal analysis. In addition split lab samples for organics may be prepared for analysis by TVA, EPA, and TWRA.

Handling and formatting of data will be according to procedures outlined in Section 9.8 and the CRRFI Data Management Plan (Section 11). Results of the analyses will be presented in table format with the number of samples and mean and range of each contaminant of concern given for each species at each sampling station. Statistical evaluations of the data will use SAS (SAS 1985) procedures for analysis of variance, Tukey's or Dunnett's test, linear regression analysis, and t-test for comparisons of paired observations.

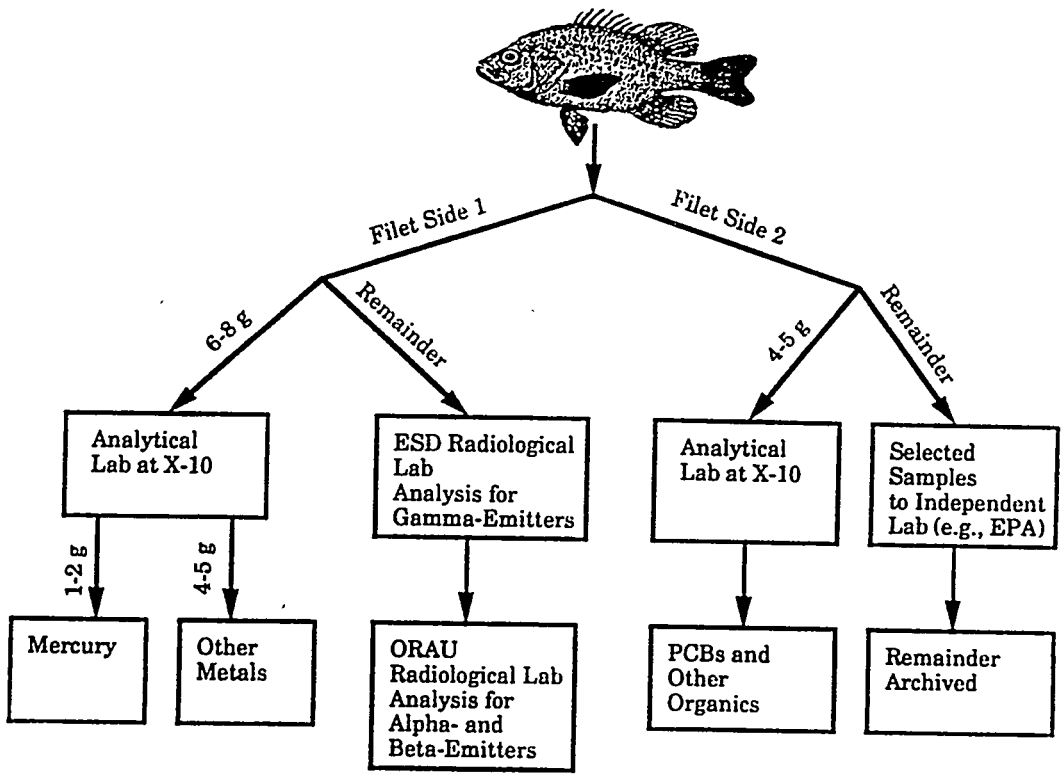

Fig. 9.8. Sample apportionment and analysis scheme for fish tissue.

Table 9.8. Summary of proposed standard preparation and analysis methods for metal and organic parameters in fish tissue[a].

Parameter	Preparation Method[b]	Analysis Method[c]	Method Detection Limit (MDL) (ug/L)[d]	Comments[e]
Antimony	3050	6010	3	ICP
Arsenic	3050	206.2	1	GFAA
Lead	3050	6010	100	ICP
Selenium	3050	6010	2	ICP
Silver	3050	6010	7	ICP
Thallium	3050	279.2	1	GFAA
Mercury	3050	245.5	0.2	Cold Vapor AA
Beryllium	3050	210.2	0.2	GFAA
Cadmium	3050	6010	4	ICP
Chromium	3050	6010	7	ICP
Copper	3050	6010	6	ICP
Nickel	3050	6010	15	ICP
Zinc	3050	6010	2	ICP
Bis-(2-ethyl-Hexyl)-phthalate	g	8270	2	GC/MS
Di-N-Butyl-Phthalate	g	8270	0.36	GC/MS
Anthracene	g	8270	0.66	GC/MS, PAH
Fluoranthene	g	8270	0.21	GC/MS, PAH
Phenanthrene	g	8270	0.64	GC/MS, PAH
Pyrene	g	8270	0.27	GC/MS, PAH
Aldrin	g	8080	0.004	GC, Pesticide
Chlordane	g	8080	0.014	GC, Pesticide
4,4-DDD	g	8080	0.011	GC, Pesticide
4,4-DDE	g	8080	0.004	GC, Pesticide
PCBs	g,h	8080	0.065	GC, MDL for PCB-1242

[a]Subject to final review.
[b]Reference from SW-846 (EPA 1986).
[c]Reference from SW-846 (EPA 1986). Method is compatible with either preparation method or MDL.
[d]These detection limits are in terms of ug of PARAMETER per liter of prepared sample. They depend upon the actual preparation and analysis methods chosen.
[e]FLAA: FLame Atomic Absorption; GFAA: Graphite Furnace AA; ICP: inductively-coupled plasma spectrometry; GC: gas chromatography; GC/MS: gas chromatography/mass spectrometry; PAH: polycyclic aromatic hydrocarbons; MDL: method detection limit.
[f]Preparation method specified in the Analysis Method referenced.
[g]Tissue preparation will be by Soxhlet extractions. Cleanup method (SW-846, 3600 Series methods) may be added.
[h]PCBs will be analyzed following protocols established in Loar (1988).

9.8. SAMPLE TRACKING AND RECORDS MANAGEMENT

This section describes the records management procedures for field sampling. The objectives of the Records Management program are to provide organization, protection, retrievability and accountability of the data and documents generated by field sampling activities as specified by the Data Management Plan (Section 11). These procedures will also ensure that quality assurance objectives are met, as specified by the QA/QC Plan (Section 10).

9.8.1 LOGBOOKS

Bound, registered logbooks with numbered pages will be used to record all information concerning the collection, handling, and current location of samples (Fig. 9.9). Data will be recorded directly in an official logbook or on a data form. Charts and other printed material of suitable size will be glued or otherwise securely fastened in the logbook. Pages that are too large to go in the logbook will be kept in a designated place which will be referenced in the logbook. All logbook entries will be made in indelible ink with a single line drawn through errors. Changes will be initialed and dated by the individual making the correction (Kimbrough et al. 1988). Either the Team Leader or a responsible designee will be the custodian of the logbook. Each page will be signed by the recorder upon completion of that page of entries.

9.8.2 Sample Custody and Request for Services

Sample custody will be documented from the time the sample is collected in the field until final disposal. The documentation will trace sample possession through all transfers of custody, (Section 10). A sample is considered to be under a person's custody if any of the following conditions are met:

(1) The sample is in the person's physical possession;
(2) The sample is in line of sight of the person after he/she has taken possession;
(3) The sample is secured by that person so any tampering can be detected; or

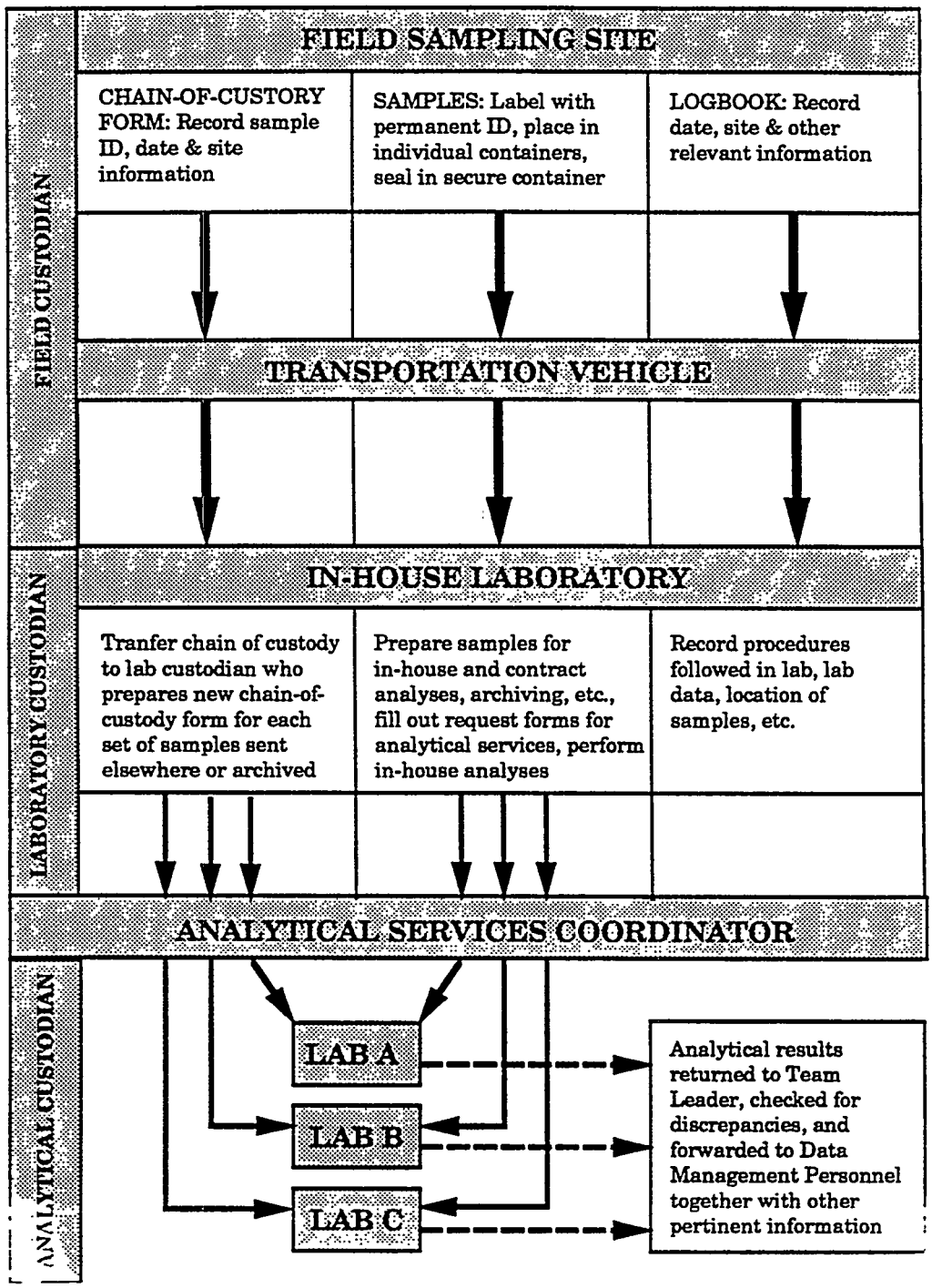

Fig. 9.9. Procedures for handling field samples and the required documentation.

(4) A sample is secured by the person in possession in an area which only authorized personnel can enter.

All sample custody procedures will be in accordance with ESP-500 (Rev. 0), "Manual Chain of Custody Procedures" (Kimbrough et al. 1988).

The Analytical Services Coordinator (ASC) will establish and maintain a chain-of-custody and request for analytical services forms control system. Examples of chain-of-custody and request-for-services forms are shown in Appendix A.1. A chain-of-custody form will accompany all samples as they are transferred from one custodian to another and will be signed and dated by the person who relinquishes custody as well as the person who accepts custody (Fig. 9.9). If samples are subdivided or separated into groups for transfer to a different custodian, a separate chain-of-custody form will be prepared for each group.

When samples are sent to another laboratory for analysis, a request-for-services form, as well as a chain-of-custody form, will accompany the samples. These forms will be filled out by the sample custodian and transferred to the Analytical Services Coordinator along with the samples. The Analytical Services Coordinator will then deliver the samples to the appropriate analytical laboratory and transfer custody to the person in charge. Upon final disposal of the samples, the completed original chain-of-custody form will be returned to the CRRFI Project Manager and then submitted to the Records Control Data Base (Section 11).

9.8.3 Data Management

Data that are generated in-house will be given to the Sampling Team Leader for verification. Data will then go to Data Management. A hard copy of the data provided by analytical laboratories will be sent to the respective Task Leaders, Sampling Team Leaders, and Data Management. The Task and Sampling Team Leaders will verify that the requested services have been performed, and that there are no discrepancies in the data. If discrepancies exist, the ASC will be notified to coordinate resolution of the

problem. Once the data have been entered into the appropriate data base, a copy of the output will be returned to the Task and Sampling Team Leaders for their records.

Data management will utilize the numeric data base (NDB) for management and storage of field, analytical and simulation model data (Voorhees et al. 1988, 1989). The CRRFI Record Control Data Base (RCDB) will be used for management of record material. The RCDB serves as a computerized index for retrieval of information generated by the CRRFI project from serially numbered archived files. All records (NDB and RCDB) will be permanently maintained.

10. QUALITY ASSURANCE/QUALITY CONTROL PLAN

10.1 INTRODUCTION AND PROJECT DESCRIPTION

This Quality Assurance/Quality Control (QA/QC) Plan supports the Clinch River RFI. The QA/QC plan defines procedures that will be followed in the collection and analysis of data used in the CRRFI program. These procedures are intended to ensure that results achieve the QA/QC goals established for the CRRFI. They are also intended to minimize field measurement errors, analytical errors, and errors occurring in data transfer and management.

The mechanisms employed to ensure quality are:

- Prevention of defects in quality through planning and design, documented instructions and procedures, and careful selection of personnel
- Assessment through regular audits and surveillances to supplement continual informal review
- Permanent correction of conditions adverse to quality.

This plan describes the quality assurance program and the quality control procedures to be implemented by the CRRFI.

Data produced by the CRRFI program will be used to meet the RFI objectives given above. The methods used to meet these objectives are described in the Clinch River RFI Plan (Sections 1 through 9).

This QA/QC plan is designed to comply with both the U.S. Environmental Protection Agency (EPA) QAMS-005/80 and the ANSI/ASME NQA-1 guidelines. EPA QAMS-005/80 (EPA 1980a) contains EPA's guidance for project QA/QC plans. ANSI/ASME NQA-1 (ANSI/ASME 1986) has been adopted by Oak Ridge National Laboratory (ORNL) as the main QA/QC standard. This project falls under both RCRA and CERCLA regulation. Therefore this project QA plan is subject to OSWER directive

9502.00-6C (EPA 1987c), OSWER directive 9355.0-76 (EPA 1987a) and OSWER directive 9355.3-01 (EPA 1988). This plan is structured around the QAMS-005/80 guidelines (EPA 1980), but Table 10.1 cross-references the NQA-1 requirements with the contents of this plan. This project has a category I QA rating (Roberson and Logsdon, 1989) due to the QA programs imposed by regulatory agencies. The NQA-1 Modular Profile (Table 10.1) shows the relationship between the elements of this plan, those of the ORNL Quality Assurance Program and the procedures of the ESD Quality Assurance Program (Roberson and Logsdon, 1989).

10.1.1 Project Schedule

Project activities and schedules for field sampling are shown in Fig. 8.3 of the CRRFI Project Plan.

All organizations performing tasks for the CRRFI must have a QA plan that meets project requirements. If there is no approved QA plan for the task, then the organization will be required to develop an acceptable plan. It may be necessary to add project specific attachments such as organization charts, functional responsibility matrixes, and surveillance plans to otherwise adequate plans. CRRFI tasks, responsible organizations, and QA plans are listed in Table 10.2.

10.1.2 Quality Assurance Awareness and Training

All CRRFI personnel will be evaluated in their roles to assure the quality of the remedial investigation. QA awareness will addressed by information sessions and distribution of the project QA plan. The QA Coordinator will be responsible for conducting the sessions and distributing the plans. This plan has been developed to include interpretations and descriptions of how OR facility policies are to be incorporated into the CRRFI QA plan, as well as how this plan addresses the needs and problems of the CRRFI. All CRRFI personnel will attend briefing sessions or otherwise obtain information describing this project's QA plan. Receipt of information shall be documented by attendance and document sign-out sheets.

Table 10.1. Modular Profile and cross-reference of EPA QAMS-005/80 and NQA-1 elements[a].

EPA QAMS-005/80 ELEMENT[b]	NQA-1 ELEMENT[c]	ORNL QA PROCEDURES	ORNL-ESD PROCEDURES[d]
1. Title Page	6. Document Control	QA-L-6-100	QA-ES-6-100 QA-ES-6-101
2. Table of Contents	6. Document Control	QA-L-6-100	QA-ES-6-100 QA-ES-6-101
3. Project Description	2. QA Program	QA-L-2-100 QA-L-2-101 QA-L-2-103 QA-L-2-104 QA-L-2-105 QA-L-2-106	QA-ES-2-100 QA-ES-2-101 QA-ES-2-102 QA-ES-2-103
	6. Document Control	QA-L-6-100	QA-ES-6-100
4. Organizational Responsibility	1. Organization	QA-L-1-100	QA-ES-1-100
5. QA Objectives for Measurement of data	3. Design Control	QA-L-3-100 QA-L-3-101 QA-L-3-102	QA-ES-3-100
6. Sampling Procedures	3. Design Control	QA-L-3-100 QA-L-3-101 QA-L-3-102	QA-ES-3-100
	6. Document Control	QA-L-6-100	QA-ES-6-100
7. Sample Custody	13. Handling Storage & Shipping	QA-L-13-100	QA-ES-13-100
	6. Document Control	QA-L-6-100	QA-ES-6-100
8. Calibration Procedures and Frequency	8. Identification and Control of Items	QA-L-8-100	QA-ES-8-100
	12. Control of Measuring & Test Equipment	QA-L-12-100	QA-ES-12-100
9. Analytical Procedures	9. Control of Processes	QA-L-9-100	QA-ES-9-100
10. Data Reduction Validation and Reporting	3. Design Control	QA-L-3-100 QA-L-3-101 QA-L-3-102	QA-ES-3-100

Table 10.1. (continued)

EPA QAMS-005/80 ELEMENT[b]	NQA-1 ELEMENT[c]	ORNL QA PROCEDURES	ORNL-ESD PROCEDURES[d]
11. Internal QC Checks and Frequenc	3. Design Control	QA-L-3-100 QA-L-3-101 QA-L-3-102	QA-ES-3-100
12. Performance Audit and Frequency	18. Audits & Surveillances	QA-L-18-100 QA-L-18-101 QA-L-18-102	QA-ES-17-100
13. Preventive Maintenance Procedures	12. Control of Measuring & Test Equipment	QA-L-12-100	QA-ES-12-100
14. Statistical Assessment of Data Quality	3. Design Control	QA-L-3-100 QA-L-3-101 QA-L-3-102	QA-ES-3-100
15. Nonconformances & Corrective Action Procedures	18. Audits & Surveillances	QA-L-18-100 QA-L-18-101 QA-L-18-102	QA-ES-17-100 QA-ES-17-101 QA-ES-17-102
	15. Control of Nonconforming Items	QA-L-15-100	QA-ES-15-100
16. QA Reports to Management	2. QA Program		
	16. Corrective Action	QA-L-16-100	QA-ES-15-100
17. Other QA/QC Measures to Meet NQA-1 Guidelines	4. Procurement Document Control	QA-L-4-100 QA-L-4-101	QA-ES-4-100
	5. Instructions Procedures & Drawings	QA-L-5-100	QA-ES-5-100
	7. Control of Purchased Items and Services	QA-L-7-100 QA-L-7-101 QA-L-7-102	QA-ES-7-100
	10. Inspection	QA-L-10-100	QA-ES-10-100
	11. Test control	QA-L-11-100	QA-ES-11-100
	14. Inspection Test & Operating Status	QA-L-14-100 QA-L-14-101	QA-ES-14-100
	19. Software	QA-L-19-100	QA-ES-18-100

[a]Subject to final Approval.
[b]EPA 1980a, number correspond to sections of this plan.
[c]ANSI/ASME 1986.
[d]Reference Roberson and Logdson, 1989.

Table 10.2. CRRFI Project quality assurance plan matrix.

Project Description: Clinch River RFI (CRRFI)

Task/Activity	Responsible Organization(s)	QA Plan Title/QAP No.
RFI of contaminants released from DOE Oak Ridge Reservation	CRRFI Project Manager (this plan)	CRRFI QA/QC Plan
Analytical laboratory support for CRRFI	ORGDP-ACD	TP 2300, R-10 (ORGDP-ACD 1988d)
Radiological laboratory support for CRRFI	ORAU Laboratory	QA Manual for ORAU Radiological Site Assessment Program (Weaver 1988)

10.2 QUALITY ASSURANCE OBJECTIVES FOR MEASUREMENT OF DATA

The purpose of this section is to implement applicable regulatory requirements and to provide internal control and review so that the data are scientifically sound and legally defensible.

QA objectives for data are:

- Scientific data generated will withstand scientific scrutiny.
- Data will be gathered using appropriate procedures for field sampling, chain-of-custody, laboratory analyses, and data reporting.
- Data will be of known precision and accuracy.

The QA requirements for the CRRFI are defined above. The procedures to be used for assessing the quality of field and analytical laboratory data are described in Section 11 (CRRFI Data Management Plan). Analytical laboratories selected for this project must meet criteria for laboratory certification and adherence to regulator QA requirements.

10.2.1 Level of Analysis

The specific QA objectives for all data are to obtain reproducible, precise and accurate measurements consistent with the intended use of the data and the limitations of the sampling and analytical procedures used. This is accomplished through the assignment of measurement tasks to the appropriate analytical level (I - V) as defined in Data Quality Objectives for Remedial Response Activities (EPA 1987a). Table 10.3 gives the analytical level to which CRRFI measurement tasks have been assigned.

10.2.2 Data Quality Parameters

Typical quantitation limits applicable to this project are presented in either the Test Methods for Evaluating Solid Waste (SW-846, EPA 1986d), or the EPA Contract

Table 10.3. QA/QC levels to which CRRFI measurement tasks have been assigned[a].

Parameter[b]	Analytical Level[c]	Media
^{3}H	III	water
^{137}Cs	IV	sediment, water
^{90}Sr	IV	sediment
^{99}Tc, $^{239,240}Pu$, ^{241}Am, ^{244}Cm, and ^{238}U	IV	biota, sediment, water
Total metals	IV	biota, sediment, water
Dissolved metals	IV	water
Organics (as listed in Table 4.1, CRRFI 1989b)	IV	biota, sediment, water
Alkalinity and hardness	IV	water
Temperature	II	water
pH	II	water
Dissolved oxygen	II	water
Conductivity	II	water
Oxidation-reduction potential	I	water
Water flow rate	II	water
Secchi transparency	I	water
Chlorophyll-a	III	water
Total suspended particles	III	water
Turbidity	III	water

(a) Subject to final review.

(b) For field analyses, all data are collected in situ for real-time site characterization. Number of measurements will depend upon local environmental conditions.

(c) Analysis level from MMES (1988a) ESP-700 Section IV.

Laboratory Program statements of work (EPA 1986b, 1987c) as applicable, as are sample precision, accuracy, and completeness objectives. The quality assurance objectives for quality control data are designed (1) to screen out data of unacceptable precision or accuracy and (2) to provide data that will meet the data quality goals for this project.

This project will follow the definitions for precision, accuracy, completeness, comparability and sensitivity given in the Handbook for Analytical Quality Control in Water and Wastewater Laboratories (EPA 1979a).

10.2.2.1 Field Activities

Precision between monitoring instruments is determined by comparison of readings during calibration to a standard. Precision in sampling is measured through the use of field duplicates.

Accuracy is addressed by the use of standard criteria for container and equipment cleaning, sample collection, personnel training and performance criteria, uniform sample handling techniques, and blanks to detect contamination.

Representativeness of samples collected is controlled through adherence to detailed descriptions of sampling procedures as contained in the CRRFI Field Sampling and Analysis Plan (Section 9).

The QA completeness objective for this project is to obtain valid and analytical results for at least 95% of the samples collected during the project. This means that completeness of sample collection (number planned versus number collected for which valid data can be obtained) must be essentially 100% to allow for some laboratory wastage. Accountability of samples collected, from field to final disposal, must be 100% complete.

Objectives for comparability between samples are meet by the following: 1) narrowly defined sampling methodologies; 2) site surveillance, use of standard sampling devices

and monitoring devices; 3) training of personnel; 4) documentation of sampling point; 5) stringent control limits for the daily QC checks; and 6) reporting results in appropriate, comparable units.

Procedures to attain sensitivity objectives include 1) uniform training and certification for staff, 2) standard provisions for inspection, maintenance, and repair, 3) provision of standard operating procedures (SOPs), to technical staff, 4) reference of SOPs in the S&A Plan, 5) and field inspections by the QA/QC Coordinator to determine compliance with the items specified in the support plans. Procedures regarding measurement and test equipment calibration will be developed and will include appropriate calibration information for each piece of equipment.

Staff responsible for particular instruments must maintain a log of calibration procedures and results, to remain with the instrument, as a means of establishing a record of calibration. The Sampling Team Leaders will inspect such logs, which will become part of the project records. Each operator must be trained in the proper use of the instrument, be familiar with the instrument's use, and be able to properly interpret data from the instrument.

10.2.2.2 Laboratory Activities

The QA objectives for precision and accuracy in the laboratory are defined by control limits established by the EPA Contract Laboratory Program (CLP; EPA 1986b, 1987c). The laboratory will be required to submit the results of all control sample analyses to the CRRFI ASC to ensure conformance with established control limits and other QA requirements.

The QA completeness objective for this project is to obtain valid analytical results for at least 95% of the samples collected. Laboratory completeness will be determined by the extent to which data are substantiated by hard-copy documentation, which includes chain-of-custody request for services and instrument calibration forms. Comparability

and sensitivity criteria are established by either CLP (EPA 1986b, 1987c) or SOPs for particular analytical laboratories.

Field procedures for the collection of samples are discussed in the S&A Plan (Section 9). The equipment and the techniques that will be employed to obtain representative samples will be in accordance with approved Environmental Surveillance Procedures (ESP-300 series, Kimbrough et al. 1988).

10.2.3 Prevention of Cross Contamination

Sampling equipment will be decontaminated before use and between each sample per ESP-900 (Kimbrough et al. 1988). Each decontamination activity will be recorded in the field logbook.

10.2.4 Sample Identification

The identification of samples will be established and maintained as specified by the chain-of-custody procedures described in Section 10.3 and specifically as described in the S&A Plan (Section 9).

10.2.5 Sample Turnaround Time

Sample analyses will be scheduled according to site investigation needs and consistent with the sample holding times. The S&A Plan is organized to provide a turnaround time that will meet the project schedule and objectives. These requirements shall be included in any contractual agreement between the CRRFI Project and contract laboratories, when possible.

10.2.6 Field Documentation

An integral part of the QA/QC Plan for the field activities will be to maintain accurate and complete field records, including logbooks and appropriate field data forms. Field

log books shall be of hardcover construction with stitched binds and water resistant pages. Information identified in these records will be obtained from the site exploration and sampling activities and will be reviewed by the Sampling Team Leader. All information pertinent to field activities will be recorded. Entries in the logbooks or on the data forms will be made in water-resistant ink and will include as a minimum:

- The names and affiliations of field personnel
- A general description of the day's field activities
- Documentation of weather conditions during the previous 48 hours, as well as current conditions
- Field equipment and instrument number
- Field equipment calibration data
- Field readings from personnel safety instruments.
- Field data measurements such as temperature, secchi depth and turbidity will be recorded on data forms.

Appropriate field-generated data forms will be prepared based on the requirements in the CRRFI Plan. Data to be recorded will include such information as the monitored location (e.g., depth, sampling station, reservoir elevation, and field coordinates) and applicable sample analyses to be conducted.

10.2.7 Shipping and Handling

Handling, shipping and storage of samples and data resulting from field activities will adhere to custody (Section 10.3) and safety procedures (Section 12), and will ensure that sample integrity for analytical purposes is maintained. Specific shipping and handling procedures for each sample medium are given in Sections 9-7–9.9 of the S&A Plan.

10.2.8 Variance System

Procedures that properly anticipate all conditions encountered during a field sampling program cannot be prepared. Variances from approved operating procedures in the

CRRFI Plan, S&A Plan, the QA/QC Plan, or the Health and Safety Plan will be documented in a deviation request form (Exhibit 10.1).

The Sampling Team Leaders will initiate and chronologically maintain a variance log. A variance requires the approval of the CRRFI Project Manager and the QA Specialist (QAS) before work proceeds. As appropriate, regulatory agencies will be notified of any variances that significantly affect project scope or objectives. Any variances from the Health and Safety Plan must be approved by the Health and Safety Coordinator. Approval by the CRRFI Project Manager and QAS can be initiated on a verbal basis via the telephone or radio with follow-up sign-off. In no case will non-CRRFI project personnel initiate a variance. Copies of the deviation request forms will be maintained by sampling teams until the field work is complete and will then be forwarded to the CRRFI Project Manager and sent to the CRRFI RCDB.

10.2.9 Field Data Management

Field records will be recorded in permanent ink, legible, and sufficiently complete to permit reconstruction of data-gathering activities by a qualified individual (other than the originator) when data are reduced. Field notebook entries should be factual, detailed, and objective. The field records will be the basis for later written reports and all entries must be free of terminology which might prove inappropriate. The method of data reduction will be identified and recorded. Field-generated data sheets will be collected and reviewed daily for accuracy and completeness by the Sampling Team Leaders before being transferred to the Analytical Services Coordinator (ASC). Manual entry of field data by ORGDP data entry will be coordinated by the ASC. Data entry will enter field data into specified computer systems to facilitate retrieval by CRRFI personnel. Quality will be checked by double entry and verification of entered data. The CRRFI Project Manager will forward field notebooks to the RCDB at the conclusion of field activities.

MARTIN MARIETTA ENERGY SYSTEMS, INC.

DEVIATION REQUEST

DEVIATION NO.

DIVISION

TYPE: ☐ MATERIAL ☐ PART ☐ SYSTEM ☐ ASSEMBLY ☐ OTHER

PROJECT TITLE | PROGRAM

ITEM NAME | SPECIFICATION

DRAWING NO | SHOP ORDER | WORK/PURCHASE ORDER

DESCRIPTION OF DEVIATION

COST IMPACT

NAME | TITLE | DATE

JUSTIFICATION AND LIMITATIONS

☐ QAA/P REVISION REQUIRED

☐ CHECK IF DRAWING OR DOCUMENT IS TO BE REVISED ☐ DESIGN REQUEST INITIATED

NAME | TITLE | DATE

APPROVED BY:				
	TASK LEADER	DATE	OTHER	DATE
	LEAD DESIGNER	DATE	OTHER	DATE
	ITEM USER	DATE	QAC	DATE

UCN-5488A
(23 5-86)

Exhibit. 10.1. Deviation Request form.

10.2.10 Decontamination of Equipment and Supplies

The guidelines for decontamination of sample containers and sampling devices given in ESP-900 (Kimbrough et al. 1988) will be followed. Specific decontamination procedures are addressed in Section 12.9 of the Health and Safety Plan.

10.3 SAMPLE CUSTODY PROCEDURES

Chain-of-custody procedures require documented sample possession from the time of collection to disposal, in accordance with MMES procedure ESP-500 (Kimbrough et al. 1989). Additional details of document control are included in the CRRFI Data Management Plan (Section 11). A sample is considered in custody if:

- It is in the sampler's or the transferee's actual possession.
- It is in the sampler's or the transferee's view, after being in his/her physical possession.
- It was in the sampler's or the transferee's physical possession and then he/she secured it to prevent tampering.
- It is placed in a designated secure area.

Sample custody will be initiated at the time of sample collection. Field samples will be identified by sample tags or other appropriate labels with the following information: unique sample identification code, date and time of sampling, sampling location or station, preservation, analysis, and any additional comments that are applicable. Descriptions of sampling activities and sample identification data will also be recorded in a field notebook. Field chain-of-custody forms containing the same information will be completed for each set of samples. A line item on the sample chain-of-custody form will be completed for each sample and the sampling technician will confirm by signature the completeness of the information on the form. Each individual who assumes responsibility for the samples will sign the chain-of-custody form.

Sample custody will be maintained by CRRFI staff until custody is transferred to the ASC. The ASC delivers samples and transfers custody to particular analytical laboratories where their intra-laboratory chain-of-custody procedures will be in effect. Upon completion of analyses, sample custody will be returned to CRRFI staff. Remaining sample may be archived as directed by the ASC or disposed as prescribed in ESP-1000 (Kimbrough et al. 1989) and the Environmental Sciences Division Waste Disposal Procedure for Radioactive and Nonradioactive Waste Materials Disposal (ESD 1986). The chain-of-custody form terminates upon final disposal of the sample. A notation on the form will indicate that the completed form is to be forwarded to the Analytical Service Coordinator. The CRRFI Project Manager will be responsible for assuring that the original chain-of-custody form is submitted to the RCDB.

10.3.1 Field Custody Procedures

Field custody procedural activities include the following steps:

- Before sampling begins, the CRRFI QA/QC Coordinator will instruct sampling personnel on the chain-of-custody and sample labeling procedures, as necessary.
- A chain-of-custody record will be initiated in the field for each sample and correspond to the sample identification label.
- Each time sample custody is transferred, the person relinquishing the sample and the new custodian will sign the record, note the date, and indicate the reason for transfer of custody.
- The analyses to be performed for each sample will be recorded on a request for analysis form.
- Confirmation by the Sampling Team Leader that proper custody procedures and report forms were used during the field work and that results were documented in the field logbook.
- Samples transferred to analytical laboratories are recorded in the field log book by the ASC at the end of the collection period.

10.3.2 Sample Labeling

Sample labels or tags will contain sufficient information to identify the sample in the absence of other documentation. Labels will include as a minimum:

- Project name
- Unique sample number
- Sample location
- Sampling date and time
- Signature of individual collecting the sample
- Preservation method employed.
- Comments regarding sample characteristics

The label or tag will be directly affixed to the sample container and will be completed using indelible ink.

10.3.3 Laboratory Receipt and Handling of Samples

Upon receipt at the laboratory, each sample identification is compared to the information contained on the included chain-of-custody documents. If discrepancies exist, appropriate notes (signed and dated) will be made on the chain-of-custody document, and the ASC and the contract laboratory programs manager will be notified.

After receipt and initial inspection of samples and accompanying forms, the following items are checked and recorded:

- The seals and tapes on the cooler are unbroken and uncut.
- The sample containers in the cooler are intact.
- The identification on the sample bottles corresponds to the entire description on accompanying forms.
- The number of sample containers received is equal to the number of samples listed on the chain-of-custody forms.

In the event that samples arrive damaged or custody seals have been broken, a Nonconformance Report (Section 10.11) will be initiated. The Project Manager and ASC will be advised, and the ASC will make a decision as to the fate of the nonconforming sample. The CRRFI Project Manager and CRRFI Quality Assurance Specialist will sign the Nonconformance Report, noting the reason for sample disposition, and initiate corrective actions if necessary.

Once samples are in the possession of the laboratory, their internal chain-of-custody and sample handling procedures will be in effect (Table 10.4). If samples are to be shipped from one laboratory to another, proper chain-of-custody and packaging procedures will be maintained. Pre-analysis sample storage procedures used are described in the Contract Laboratory Program (CLP) Statement Of Work (EPA 1987c). Anticipation of re-analysis requires proper environmental control of samples following analysis. Samples requiring refrigeration will remain refrigerated for three months unless prior arrangements have been made by the CRRFI Project Manager. Unused sample portions will be archived. If re-analysis is not anticipated, environmental conditions are not observed, and the samples are stored at room temperature. Sample residues will be disposed of by contractor laboratories in accordance with ESP-1000 (Kimbrough et al. 1988), ESD Waste Disposal Procedure, Radioactive and Non-radioactive Waste Materials Disposal (ESD 1986), or other EPA approved procedures.

10.4 CALIBRATION PROCEDURES AND FREQUENCY

10.4.1 Instrument Calibration Procedures and Frequency

A list of all measuring and test equipment to be used, along with a schedule for calibration, will be prepared prior to initiating field work. In general, field calibration methods will be those recommended by the manufacturer. Instrument log books will be established.

Table 10.4. Analytical Laboratory QA/QC Summary.

Laboratory	QA/QC Coordinator	Laboratory Certifications	Performance Evaluation Programs	Calibration of Laboratory Equipment	Intra-Laboratory Chain-of-custody	Data Validation
ORAU Radiological	C. F. Weaver	TBP	TBP	Weaver 1988 Section 6	Weaver 1988 Section 8	Weaver 1988 Section 10
ORGDP-ACD	M. S. Dill	State of TN U. S. EPA	TP 2300, R-10 (ORGDP 1988c)	TP 2308, R-3 (ORGDP 1988c)	TP 2053, R-2 (ORGDP 1988b) TP 2055, R-1 (ORGDP 1988a)	TP 2309, R-3 (ORGDP 1987)
ORNL-ACD	P. L. Howell	U. S. EPA	SW-846, CLP SOW (EPA 1986, 1988a, 1988b)	SW-846, CLP SOW (EPA 1986, 1988a, 1988b)	SW-846, CLP SOW (EPA 1986, 1988a, 1988b)	SW-846, CLP SOW (EPA 1986, 1988a, 1988b)
ORNL-ESD	L. E. Roberson	---	---	---	---	---
Radiological	I. L. Larsen	U. S. EPA	Participate in EPA PEP	Appendix this document	Section 10 this document	Section 11 this document

Laboratory equipment will be calibrated in accordance with the Contract Laboratory Program (CLP; EPA 1986b, 1987c), the ORGDP-ACD TP 2308, R3 (ORGDP-ACD 1988c, 1988d), the ORAU QA Manual (Weaver 1988), or other contractor laboratory QA manual when CLP protocol is not established. Calibration frequency will be based on the analytical methods employed, type of equipment, inherent stability, manufacturer's recommendations, values given in national standards, intended use, and experience.

Calibrated equipment will be uniquely identified by using either the manufacturer's serial number or other means. All equipment shall be categorized as one of the of the following:

- Category A: Casual devices and systems (rulers, tape measures, graduated cylinders, pipettes, etc.) that are not to be calibrated in service (i.e., not calibrated other than by the manufacturer).
- Category B: Routine devices and systems (balances, spectrophotometers, etc.) that are to be included in a calibration recall program on a regular cycle.
- Category C: Experimental devices and systems (fluorometers, pH meters, turbidimeters, etc.) that are to be calibrated by, or at the direction of, the user as deemed necessary.

The appropriate category decal with the identification number and the due date of the next calibration will be attached to the equipment. If this identification is not possible, records traceable to the equipment will be readily available for reference.

10.4.2 Calibration Failures

Scheduled periodic calibration of equipment will not relieve field or laboratory personnel of the responsibility of employing properly functioning equipment. If an individual suspects an equipment malfunction, they should remove the device from service, tag it so it is not inadvertently used, and notify project management. If equipment is found to be out of calibration, the sampling team leader or laboratory supervisor shall evaluate and document (in the instrument log book) the validity of previous inspection or test results

and the acceptability of similar equipment previously inspected or tested. The responsible supervisor shall ensure that devices which are out of calibration are (1) tagged or segregated from other equipment and (2) disposed of or not used until they are recalibrated. Any equipment which is consistently found to be out of calibration shall be repaired or replaced. Any such action should be recorded in the instrument logbook.

All standards used for equipment calibration will be traceable to the EPA, National Bureau of Standards, or a commercially available certified standard. The source of the standard used must be documented in a calibration logbook.

10.4.3 Calibration Records

Calibration data shall be recorded in the instrument log book. Records will be prepared and maintained for each piece of calibrated equipment to indicate that established calibration procedures have been followed. The sampling team leader or laboratory supervisor will ensure that records of calibration data are kept current. Records for field equipment used will be maintained by the sampling team leader and kept in the project files.

10.5 ANALYTICAL PROCEDURES

A detailed Field Sampling and Sample Analysis Plan (Section 9) for the CRRFI has been prepared to document the analytical procedures to be used in sample analysis.

10.5.1 Field Analyses

All field measurements will be recorded in the field notebooks or on specially designed data forms. All data will be directly entered in the field, signed, and dated. If entry changes are made, one line will be drawn through the error and the change and explanation will be signed and dated in the notebook or on the data form. Changes made to original notes should not obliterate the original information. All field data

records will be organized into standard format when possible. Team leaders are responsible for review of daily entries in the field log books.

10.5.2 Laboratory Analyses

CRRFI samples will be analyzed for potential contaminants of concern using established procedures (EPA 1979b; 1980b,c; 1983; 1984; 1986b,d; 1987c; Kimbrough et al. 1988, ESP, Appendices A.2, A.4).

10.5.3 Analytical Laboratories

The Oak Ridge National Laboratory's Analytical Chemistry Division (ORNL-ACD) will provide analyses of all tissue samples for organic and metal parameters. The ORNL-ACD laboratory currently maintains appropriate State of Tennessee certification and participates in the EPA CLP program.

The K-25-ACD laboratory will analyze all water and sediment samples for organic and metal parameters. The ORGDP-ACD laboratory currently maintains appropriate State of Tennessee certification, participates in the EPA CLP program, and is approved by the Department of the Navy. Its QA program is described in a series of Technical Procedures beginning with an overview in TP-2300, R-10 (ORGDP-ACD 1988d).

The Oak Ridge Associated University (ORAU) Radiological Laboratory will provide radiochemical analytical services for the alpha-beta radionuclide analysis of all samples. The laboratory maintains the necessary State of Tennessee and EPA certifications. QA activities are identified in Weaver (1988) and standard laboratory procedures are described in Weaver et al. (1988).

The Oak Ridge National Laboratory (ORNL-ESD) will be responsible for analysis of gamma emitting radionuclides (gamma spectroscopy) of biota, sediment, and water. Radionuclide analyses will be performed using standard procedures. The ORNL-ESD

surface water processing laboratory will perform water processing, and water quality analyses using standard procedures.

Each contractor laboratory which analyzes samples will provide quantification limits for each constituent analyzed. The method detection limit (MDL) is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the value is above zero. The MDL actually achieved in a given analysis will vary depending on instrument sensitivity and interferences. The objectives for precision and accuracy for each chemical are based mainly on the capabilities of the approved EPA analytical method with respect to laboratory quality control.

In addition to evaluating each set of data for accuracy and precision, an assessment will also be made of the completeness of the data. This assessment will involve computing the fraction of the reported values that remain valid after the sampling procedures have been reviewed and the results have been assessed for precision and accuracy.

For those analyses conducted using the EPA CLP protocol, current acceptance criteria established by the EPA will be used.

10.6 DATA SUMMARIZATION, VALIDATION, AND REPORTING

Data validation is a systematic process for reviewing a body of data against a set of criteria (Section 10.10) to provide assurance that the data are adequate for their intended use. Data validation consists of data editing, screening, checking, auditing, verification, certification and review (EPA 1980).

All data for this project will be evaluated by QA/QC methods and internal peer review. Data reduction, verification, and reporting will be in accordance with the ongoing ORNL Remedial Action Program Data Base Management activities (Voorhees et al., 1988). Data will be entered into common, standardized formats. In addition to following field sampling documentation and QA/QC procedures, data are verified using a variety of computerized checks for reasonableness. These procedures will ensure that data are

entered, encoded, and manipulated in a consistent way and available to CRRFI investigators in a useable format.

10.6.1 Field Data Reduction and Evaluation

Data collected during field activities will be evaluated by checking the procedures used and comparing the data to previous measurements. The QA/QC Coordinator and sampling team leaders will be responsible for checking field quality control sample results to ensure that field measurement and sampling protocols have been observed. These reviews will check:

- Date and time sampled
- Preservation
- Standard operating procedures
- Calibration method and frequency
- Chain-of-custody documentation

Reviewers are responsible for ensuring that data reduction calculations are documented and checked by qualified personnel.

Written reports including reduced and summarized data will include the raw data in appendices. Specific calculations used for data reduction will also be included.

10.6.2 Analytical Laboratory Data Reduction and Evaluation

Analytical data generated during the CRRFI will be evaluated for completeness. This will include, but is not limited to, review of completed custody logs, photocopied pages of laboratory notebooks and data forms completed by the technical staff, including sample weights, dilutions, concentrations, data reduction, instrument logs, and all raw data. Reviewers of materials will include the CRRFI QA/QC Coordinator and the assigned contract laboratory Program Manager, however, the CRRFI Task Leader has primary responsibility for review. In the data review process, the data are compared to

information such as the sample history, sample preparation, and quality control sample data to evaluate the validity of the results. Data validation includes:

- Dated and signed entries by technical staff and supervisors on the worksheets and logbooks used for samples,
- The use of sample tracking and numbering systems to track the progress of samples through the laboratory, and
- The use of quality control criteria to reject or accept specific data (Section 14).

ORNL-ACD validation procedures are described in ORNL-ACD documents. ORGDP-ACD specific validation procedures are described in TP 2309, R-3 (ORGDP-ACD 1987). ORAU Radiological Laboratory validation procedures are outlined in Weaver (1988).

10.6.3 Data Reporting of Analytical Results

The format and content of data reports will adhere to project needs. These include contract requirements of DOE and regulatory agency reporting formats. The laboratory supervisors are responsible for the preparation of each technical report including the process of data validation. The QA/QC plan does not specify a report format; however, the following items are applicable to data presentation:

- Final data presentation shall be checked in accordance with data validation requirements (Section 10.10) and approved by the appropriate sampling team leader or laboratory manager.
- Data shall be presented in a tabular format whenever possible.
- Each page of data will be identified with the project number, project name, and date of issue.

Data presentation in the report will include:

- Sample identification number used by the laboratory and/or the sample identification provided to the laboratory, if different than that used in the laboratory,

- Chemical parameters analyzed, reported values, data qualifiers and units of measurement,
- Quantification limit of the analytical procedure,
- Results of quality control sample analysis,
- Achieved accuracy, precision, and completeness of data,
- References to specific data if required to explain reported values, and
- Analytical methods used.

These methods will be specifically referenced on all laboratory reports. Any method modification will be included in the comments or case narrative. Data for field quality control samples will be reported in the same format as actual samples. A modified CLP data package consisting of QA/QC summary data sheets will be provided for all internal ESD laboratory quality control analyses for contaminants of concern. Laboratory data shall be stored so that complete CLP data packages can be subsequently assembled for review if requested by regulatory agencies.

10.7 INTERNAL QUALITY CONTROL CHECKS AND FREQUENCY

The basic elements of quality control are listed below, proceeding from general to specific; each element depends on the ones preceding it (adapted from Taylor 1987):

- Technical competence of staff
- Appropriate equipment and instruments
- Good sampling practices
- Good measurement practices
- Project procedures
- Field implementing procedures
- Inspection
- Documentation
- Training

The staff must have the necessary competence (defined as education, skill, technical judgement, experience, and professional attitude) to reduce variability in executing procedures, taking measurements, and obtaining data in the field.
The QC procedures presented in this section are designed to:

- Achieve the QA objectives for precision, accuracy, completeness, representativeness, comparability, and sensitivity.
- Document data quality and provide accountability information about data received from each laboratory.
- Provide criteria to ensure that analytical results are statistically valid.
- Provide sufficient documentation of analytical procedures to establish that the resulting parameter estimates are defensible and the comparability of estimates from each laboratory is quantifiable.

Internal QC procedures involve review of the documentation of maintenance and operational procedures and inspection of the instruments and equipment by personnel other than instrument users. Inspection entails the spot inspections conducted by the QA Specialist in combination with the continuous process of inspection conducted by the sampling team leaders and laboratory supervisors as part of normal procedures.

Achieving the highest level of documentation quality is imperative to QC. Bound notebooks with numbered pages will be used to record all events and activities. Data forms will be used to record selected field and laboratory measurements (Appendix A-1). All notebooks and data forms will be subject to custody requirements including limited distribution, secure storage, and long-term retention (30 years after completion of sample collection and analysis.

10.7.1 Field Quality Control Procedures

Field quality control sampling will be established to check sampling. All quality control samples will be shipped according to the chain-of-custody procedures specified in Section 9.5. Field quality control samples will include blanks and replicates as follows:

Trip Blank. A trip blank, consisting of a sealed container of organic-free water will travel from the field to the laboratory with the samples to be analyzed for the contaminant of concern. The trip blank identifies contamination that may have been contributed to the field samples during the transport (receives same treatment as sample containers). Trip blanks will be collected no less than once per week during field sampling.

Field Rinsate. A field rinsate consisting of final rinse water from the decontamination of field sampling equipment. Analysis of the field rinsate determines if the decontamination procedure is adequate to avoid carryover of contamination from one sampling location to another. One field rinsate will be collected during between each site sampled on days when multiple sites are to be sampled.

Laboratory Rinsate. A lab rinsate consisting of final rinse water from the decontamination of field sampling equipment. Analysis of the lab rinsate determines if decontamination procedures are adequate. Lab rinsates will be collected prior to each day of field activities.

Field Blank. One field blank consisting of rinse water used for final issue during decontamination will be collected from the source of final rinse water (distilled/deionized water).

Field Duplicate. Field duplicates, which consists of a duplicate sample from one sampling location, indicate whether the field sampling technique is reproducible. Duplicate samples will be obtained for all sample matrices.

Field quality control samples will have discrete sample numbers and be submitted as "blind" to the laboratories. The quantities and collection procedures for each field quality control sample type are specified in Sections 7, 8 and 9 of the S&A Plan (Section 9). Results of these samples will be included in the analytical data report. Results for quality control samples will not be used to adjust the results obtained for original samples. If contaminants are found in the blanks, attempts will be made to

identify the source of contamination, and corrective action will be initiated in accordance with Section 10.13.

10.7.2 Laboratory Quality Control Procedures

A number of laboratory QC samples will be used to check sample preparation and analysis and to monitor laboratory performance. The control samples listed below are defined in general terms. Analysis-specific control samples may be required as indicated by EPA CLP procedures. QC samples will consist of blanks, duplicates and spikes. Laboratory standards will also function as QC components. Quality assurance procedures for laboratory processing include laboratory duplicates of all field samples to determine the precision of laboratory results. Laboratory Quality Control samples will include the following:

Method Blank. A method blank is a blank sample made up of a pure, non-contaminated substance of the matrix of interest (usually distilled/deionized water or silica sand) that is subjected to all of the sample preparation (e.g., digestion, distillation, extraction) and analytical methodology applied to the samples. The purpose of the method blank is to check for contamination from within the laboratory that might be introduced during sample analysis.

Calibration/Continuing Calibration Blank. A calibration blank is the substance that is used to zero the instrument. The calibration blank is comprised of the solvent used for the preparation of the calibration standards and samples. The calibration blank accounts for any interferences from the solvent matrix.

Sample Container Cleaning Blanks. If sample containers are cleaned in the laboratory, "sample container cleaning blanks" are taken for each batch of containers that goes through the cleaning process. If contamination is detected, the containers associated with the contaminated blank will be re-cleaned and another blank taken and analyzed.

Laboratory Duplicates. Laboratory duplicates are prepared by the laboratory analyst for each sample and are obtained by homogenizing a sample as thoroughly as possible and taking two separate aliquots of that sample for analysis. The duplicate sample, however, should never be a method blank, trip blank, or a field blank. The purpose of laboratory duplicates is to check the precision of the analyst, the sample preparation methodology, and the analytical methodology.

Matrix Spikes. A matrix spike is a sample to which a known concentration of the compounds of interest has been added. The matrix spike is subjected to the same sample preparation and analytical methodology applied to the samples. The sample to be spiked is selected prior to sample submittal by the ASC; however, the spiked sample cannot be a method blank, trip blank, or field blank. The purpose of the matrix spike is to check for interferences or false readings caused by the sample matrix. The sample matrix effect is measured by calculating the percent recovery (%R, Section 14) of the compounds added to the sample.

Blank Spike/Laboratory Control Sample (LCS). The blank spike, or LCS, is a blank sample (usually distilled/deionized water or silica sand) to which a known concentration of the compounds of interest has been added. The blank spike is subjected to the same sample preparation and analytical methodology applied to the samples. The purpose of the blank spike is to check the accuracy of the analyst, the sample preparation methodology, and the analytical methodology. The level of accuracy is measured by calculating the %R.

The Laboratory QA/QC Coordinator is responsible for preparing quality control standards and for sending quality control samples into the laboratory for analysis. Statistical analyses will then be performed utilizing the results of quality control sample analyses. Each laboratory will apply precision and accuracy criteria to each parameter that is analyzed. When analysis of a sample set is completed, the quality control data are reviewed and evaluated through the use of control charts to validate the data set. The ORGDP-ACD Laboratory QA Procedures (TP 2309; ORGDP 1987) describes the

methodology used for the statistical evaluation of quality control data. Laboratory QC standards will include the following:

Calibration Standards. Calibration standards are standards comprised of the compounds of interest at known concentrations. Calibration standards are prepared from EPA reference material or commercially available, certified reference materials traceable to the National Bureau of Standards (NBS). Calibration standards are prepared using the same solvent used for sample preparation at the same concentration. Calibration standards for each analyte are prepared for at least three concentration levels throughout the calibration range required for the analysis. Calibration standards are not subjected to all of the preparation (e.g., extraction, distillation, digestion) that is applied to the sample. Calibration standards are used to initially calibrate the instrument by providing reference points throughout the calibration range and to establish linearity throughout the calibration range and working range of the instrument. The instrument is then checked continually throughout the analysis with the calibration standards to check for any instrument drift that may have occurred.

Performance Evaluation (PE) Samples. Performance evaluation samples consist of known concentrations of the analyses submitted to the laboratory being audited. These samples are obtained through various EPA sponsored programs and private vendors to provide an objective evaluation of laboratory performance and comparison with other participating laboratories.

Control charts are statistical representations of the laboratory's performance and are used to monitor laboratory performance and to establish control limits or the acceptance criteria for all compounds of interest. For each analyte, a separate control chart is required for each type of control sample that measures precision or accuracy (blank spike, matrix spike, and duplicate) and for each matrix type and concentration level (high, medium, and low). A minimum of ten measurements of precision and accuracy are required before control limits can be established. Control limits of three standard deviations shall be utilized for all samples.

Once established, control limits are updated as additional precision and accuracy data become available to the Lab Quality Control Coordinator. Any control sample data point that falls beyond the control limits or any data trend (indicated by seven or more consecutive points on either side of the mean), will require an investigation and corrective action. For all identified contaminants of concern (e.g., Table 5.12), control limits and corrective actions will be in accordance with EPA protocol. Additional statistics for organics work will be done in accordance with SW-846 (EPA 1986d) or the CLP SOW (EPA 1986b) as applicable.

10.8 PERFORMANCE AND SYSTEMS AUDITS AND FREQUENCY

Audits are performed to review and evaluate the adequacy of field and laboratory performance, and to ascertain whether the QA/QC Plan is being completely and uniformly implemented. The following requirements are adapted from basic requirement 18, "Audits," of ANSI/ASME NQA-1 (ANSI/ASME 1986) and ESP.18.1 (Martin Marietta Energy Systems Quality Procedures Manual). Planned and scheduled audits shall be performed to verify compliance with all aspects of the QA program and to determine the program's effectiveness. These audits shall be conducted in accordance with written procedures and checklists and shall be performed by personnel who do not have direct responsibility for performing the activities being audited. Audit results shall be documented and reported to and reviewed by responsible management. Follow-up action shall be taken by the responsible line organization when necessary, and the corrective actions will be monitored by the ORNL Manager of Quality Audits.

The objectives of performance and systems audits are to 1) ensure that the quality assurance program developed for this project is being implemented according to the specified requirements, 2) assess the effectiveness of the quality assurance program, 3) identify nonconformances, and 4) verify that identified deficiencies are corrected. Upon discovery of any significant deviation from the quality assurance program, the Project Manager shall be informed of the nature, extent, and corrective action taken to remedy the deviation (Section 10.13).

An individual audit plan will be developed to provide a basis for each audit. This plan will identify the audit scope, the activities to be audited, the audit personnel, any applicable documents, and the schedule. Records of audits will be maintained in the project files. Audit files will include, as a minimum, the Surveillance Report (Exhibit 10.2), the reply to audit, and any supporting documents. It is the responsibility of the CRRFI Project Manager to conform to the ORNL QA audit procedures, particularly as to timely replies to audit reports and implementation of such corrective action as indicated.

10.8.1 Frequency of Audits

The ESD QA Specialist is responsible for internal audits and will perform them according to a schedule which coincides with appropriate activities on the project schedule and sampling plans. Such scheduled audits may be supplemented by additional audits for one or more of the following reasons:

- When significant changes are made in the QA/QC Plan
- When it is necessary to verify that corrective action has been taken on a nonconformance reported in a previous audit
- When requested by the Project Manager.

In addition to these internal audits, surveillance of selected activities may be performed on a periodic basis, as outlined in Table 10.5.

10.8.2 Performance Audits

A performance audit can be defined as a review of the existing project and quality control data to determine the accuracy of a total measurement system(s) or a component part of the system. The analysis of laboratory performance evaluation samples and the participation in scheduled inter-laboratory studies may be included as part of the performance audit. Laboratory audits are further described in QA/QC procedures for particular analytical laboratories (ORNL-ACD; ORGDP-ACD 1987; ORAU-ACD).

SURVEILLANCE REPORT

ORGANIZATION: _____ *REPORT NO.:* _____

PROJECT/ACTIVITY: _____ *SURVEILLANCE DATES(S):* _____

REQUIREMENTS DOCUMENT(S): _____

_____

_____

REQUIREMENTS/ACTIVITIES TO BE VERIFIED	SAT	UNSAT	OBSERVATIONS

CHECKLIST APPROVED: _____ _____
QA Specialist Date

SURVEILLANCE COMPLETED BY: _____ _____
Surveillant Date

FAILURE REPORT REQUIRED? (Y/N) _____ *TYPE: NCR* ____, *QIR*____, *UOR*____

APPLICABLE REPORT NUMBER(S): _____

ADDITIONAL SURVEILLANCE REQUIRED? (Y/N) ____ *FREQUENCY OR DATE:* _____

APPROVAL:

_____ _____ _____ _____
Project Manager Date QA Specialist Date

Exhibit. 10.2. Surveillance Report form.

Table 10.5. Surveillance activities.

Activity	Frequency
Spot-checking technical notebooks	weekly
Tracking water samples through sampling, analysis and report phases	quarterly
Participating in laboratory meetings and discussions	monthly
Verifying statistical computations on final reports	monthly

A performance audit will also be made of the laboratory activities during the first sampling phase. The QA Specialist or his designee will check on the logging of the samples, proper chain-of-custody and related documentation. Any irregularities in quality assurance procedures which are not immediately corrected will be brought to the attention of the CRRFI Project Manager.

10.8.3 Systems Audits

A systems audit consists of an evaluation to determine if the components of a measurement system were properly selected and are being used correctly. A system audit includes a careful evaluation of field and laboratory quality control procedures. Systems audits are conducted as deemed necessary by the QA Specialist, or on an annual basis. The system audit is reported in formal audit reports distributed by the Laboratory Manager.

10.8.4 Field Surveillance

An individual surveillance plan will be developed to provide a basis for each field surveillance. This plan will identify the scope, activities, and personnel to be involved, any applicable documents, and the schedule for each field surveillance. Checklists will be prepared by the auditors and used to conduct all surveillances. They will be developed to accomplish the review of necessary items and to document the results of the surveillance.

Field surveillance may involve an on-site visit by the auditor. Items to be examined may include, but are not limited to, the availability and implementation of approved work procedures; calibration and operation of equipment; packaging, storage, and shipping of samples obtained; documentation procedures and instructions; and nonconformance documentation.

The records of field operations will be reviewed to verify that field-related activities were performed in accordance with standard procedures. Items reviewed may include, but are

not limited to, the calibration records of field equipment, daily field activity logbooks, chain-of-custody records, and data resulting from field operations.

During a surveillance and upon its completion, the auditors will discuss the observations or deviations with the individuals surveyed and discuss and agree on corrective actions to be initiated. A surveillance report will be completed for each surveillance activity (Exhibit 10.2).

Minor administrative findings that can be resolved to the satisfaction of the auditors during a surveillance are not required to be cited as items requiring corrective action. Findings that are not resolved during the course of the surveillance and findings affecting the overall quality of the project will be noted on the checklists and included in the surveillance report. In addition to these internal audits, surveillance of selected activities may be performed on a periodic basis, as outlined in Table 10.5.

10.9 PREVENTIVE MAINTENANCE PROCEDURES

Periodic preventive maintenance is required for all measuring and test equipment. Instrument manuals will be kept on file for reference purposes if equipment needs repair. Maintenance frequency will be based upon manufacturer's recommendations, intended use and experience. The troubleshooting section of factory manuals may be used to assist personnel in performing maintenance tasks. Routine maintenance will be performed on instruments to reduce the incidence of extensive repairs immediately prior to sampling and analysis.

10.9.1 Field Instruments

The frequency of preventive maintenance for field equipment is usually indicated in each operating instruction manual. Maintenance will be documented and maintained in permanent records by the individual responsible for each instrument. Critical spare parts will be identified and stocked to minimize equipment downtime and lost field sampling effort.

10.9.2 Laboratory Instruments

Laboratory equipment requiring routine maintenance have a control system indicating the date of required maintenance, person maintaining the equipment, and the next maintenance date. Information pertaining to life histories of equipment maintenance will be kept in individual logs for each instrument. Preventative maintenance for ESD laboratory equipment will follow the procedures established in QA-ES-12-100 (Roberson and Logsdon 1989).

10.10 STATISTICAL ASSESSMENT OF DATA QUALITY

A statistical evaluation of laboratory analytical results will be performed that will apply precision and accuracy criteria for each parameter that is analyzed. When the analysis of a sample set is completed, the quality control data generated will be reviewed and evaluated to validate the data set. All quality control data will be reported to the CRRFI Project Manager along with the sample analysis results. The quality control data will be reviewed for precision and accuracy.

The evaluation criteria of the quality control sample data for the target compound list (TCL) have been established for the EPA Contract Laboratory Program (CLP) (EPA 1986b, 1987c). The control limits for other compounds are derived from laboratory control charts. These criteria provide a means of categorizing a data set as being quantitative, semiquantitative, or qualitative. Where applicable, contract laboratories will use data qualifiers to clearly identify results as qualitative and semiquantitative. Otherwise, reported data are to be considered quantitative. These results provide information on the relative quality of sampling and analytical procedures. Deviations suggested by these assessments (in combination with other quality parameters) will be utilized in nonconformance and corrective action procedures (Section 10.13).

10.10.1 Precision

Precision will be assessed by conducting separate analyses of the duplicate samples. The level of precision is determined by calculating the relative percent difference (RPD) between the two measurements, where

$$RPD = \frac{(D_1 - D_2) \times 100}{(D_1 + D_2) / 2}$$

where: D_1 = Value of first measurement
D_2 = Value of second measurement.

10.10.2 Accuracy

Accuracy will be assessed by splitting a sample into two portions, spiking (i.e., adding known quantity of the constituents of interest to one of the portions), and then analyzing both portions for these parameters. The difference in the concentration levels of the constituents of interest should be equal to the quantity of the spike added to one of the two portions. The percent recovery is calculated as follows:

$$\%R = \frac{O_i - O_s}{T_i} \times 100$$

where: O_i = Observed spiked sample concentration,
O_s = Observed sample concentration,
and
T_i = True or actual concentration of the spike.

One hundred percent recovery is equivalent to 100 % accuracy. Values less that 100 % may indicate a sample matrix effect and a false reading. A periodic program of sample spiking is required, eg., 1 matrix spike and 1 matrix spike duplicate per 20 samples.

Blank spikes or laboratory control samples check the accuracy of the analyst, the sample preparation, and the analytical methodology free of sample matrix effects. Blank

samples are spiked with known concentrations of the compounds of interest then prepared and analyzed as samples. The level of accuracy is measured by calculating the %R as follows:

$$\%R = (O/T) \times 100$$

where: %R = percent Recovery,
O = Observed or measured concentration,
and
T = True or known concentration.

The coefficient of variation (C_v) of the percent recovery values is calculated as follows:

$$C_v = (SD/APR) \times 100$$

where: SD = Standard Deviation of the percent recoveries for the various spiked constituents,
and
APR = Average or mean Percent Recovery.

10.10.3 Determinations of Significance

Statistical tests for determination of significance are to be added.

10.11 DEVIATIONS FROM ESTABLISHED PROCEDURES

This section identifies methods and policies for the documentation, evaluation, corrective action and verification activities necessary when a deviation from established procedure occurs. Requirements for the documentation and implementation of corrective actions are also included.

Any unplanned deviation or nonconformance, will be evaluated with respect to their possible impact on reportable data. All unplanned deviations from standard operating procedures, equipment calibrations or any aspect of the QA plan will be evaluated and documented. Significant deviations identified using the statistical assessment of quality

data will also be utilized in Nonconformance and Corrective Action Procedures (Section 10.13).

Planned deviations or variance from Standard Operating Procedures (SOPs) may be necessary given that procedures properly addressing the entire range of conditions encountered during a field sampling program cannot be prepared. Requirements for issuance and implementation of variance from SOPs are included.

10.11.1 Responsibilities of Project Participants

CRRFI personnel will ensure the prompt identification, control, and disposition of nonconforming items. Each laboratory participant is responsible for submitting records of all potential nonconformance events to the appropriate Sampling Team Leader and/or the Project QA/QC Coordinator within a reasonable period of time following the initial identification and documentation of the potential nonconformance. The potential nonconformance will then be evaluated by Team Leaders, QA Specialist, Project Manager, and others as is deemed relevant. This evaluation will determine if 1) the event has adversely affected results of particular analyses, and 2) the event justifies the issuance of a Quality Event Report (QER), a Nonconformance Report (NCR), or a Quality Investigation Report (QIR).

10.11.2 Nonconformances and Corrective Action Procedures

Nonconforming equipment, items, activities, conditions, and unusual incidents that could affect compliance with project requirements will be identified, controlled, and reported in a timely manner. A nonconformance is defined as a malfunction, failure, deficiency, or deviation which renders the quality of an item unacceptable or indeterminate. The originator of a NCR will describe the finding on the form provided for this purpose (Exhibit 10.3, ESI.15.1, MMES QPM) and notify the CRRFI project management, QA Specialist and QA/QC Coordinator. Each nonconformance will be reviewed and a disposition given for the item, activity, or condition. Evaluations also will determine if the event justifies the issuance of a QER (Exhibit 10.4; ORNL QA Procedure

NONCONFORMANCE REPORT (NCR)

MARTIN MARIETTA

Sheet ____ of ____

This form should be completed when one or more distinct, describable and measurable properties or characteristics of an item (hardware or software) do not conform to documented technical requirements

1. NONCONFORMANCE REPORT NO. NCR-

2. OCCURRENCE DATE	3. ORIGINATOR	4. PLANT/ORGANIZATION	5. DIVISION	6. ADDRESS	7. PHONE NUMBER

8. PURCHASE ORDER/WORK ORDER OR CONTRACT/STORES NO.	9. ITEM NO.	10. REC. REPORT NO.	11. DWG/SPEC/DOC. NO.	12. REV. NO.	13. QTY REC'D. OR PRODUCED	14. QTY. NONCONFORM.

15. DESCRIPTION

15A SPECIFIED REQUIREMENT(S)	15B NONCONFORMANCE(S)

16A. NONCONFORMANCE DISPOSITION	16B. REMEDIAL ACTION(S) AND JUSTIFICATION
☐ ACCEPT; USE-AS-IS ☐ REWORK (TO SPEC.) ☐ REPAIR (TO USABLE COND.) ☐ RETURN TO VENDOR/SHOP ☐ REJECT/SCRAP	

17. DISPOSITION APPROVALS

17A. ENGINEER/REQUISITIONER	DATE	17B. CUSTOMER/USER	DATE	17C. QA SPECIALIST	17D. DATE

18. CORRECTIVE ACTION(S) TO PREVENT RECURRENCE

18A ACTION	18B TECHNICAL OR SYSTEM	18C RESPONSIBILITY	18D. SCHEDULED COMPLETION DATE

19. CORRECTIVE ACTION APPROVALS

19A. ENGINEER/REQUISITIONER	DATE	19B. RESPONSIBLE MGR. OR BUYER	DATE	19C. QA SPECIALIST	19D. DATE

20. COST/SCHEDULE DELAY SUMMARY

COST ITEM	TOTAL
• COST OF REPAIR/REWORK - the cost of correcting failed and defective items to make them fit for intended use.	
COST OF REPLACEMENT - the cost of procuring and installing a fit substitute for failed and defective items.	
• COST OF DELAY - the cost occurring as a result of delays caused by the nonconformance.	
• COST OF REDESIGN - the cost of revising, deviating, eliminating or approving the design of items due to nonconformance.	
• COST OF CONSEQUENTIAL DAMAGE - the cost of actual, nominal, tangible, or intangible damage directly related to nonconformance.	
20A. TOTAL COST IMPACT	

WAS SCHEDULE IMPACTED? ☐ YES ☐ NO 20B. SCHEDULE DELAY (DAYS) ____

ENERGY SYSTEMS QUALITY INFORMATION SYSTEM ATTRIBUTES

21. REF. QER NO. (IF APPLICABLE): ____ 22. OTHER APPLICABLE QIRS, UORS, OR NCRS: ____

23. ☐ HARDWARE ☐ SOFTWARE | 24. ITEM | 25. DEFECT

26. QUALITY INDICATOR CATEGORY | 27. PROJECT NO. (IF APPLICABLE)

28. ☐ VENDOR SUPPLIED ☐ IN-HOUSE FABRICATED/DEVELOPED/CONSTRUCTED ☐ AE/SUBCONTRACTOR SUPPLIED/CONSTRUCTED | 29. NAME OF VENDOR, SHOP/ORGANIZATION, CONTRACTOR/AE, ETC.

30. KEYWORD | 31. PRIMARY PROBLEM CAUSE CATEGORY: | 32. PROBLEM DISCIPLINE CATEGORY:

Exhibit. 10.3. Nonconformance Report (NCR) form.

MARTIN MARIETTA

QUALITY EVENT REPORT (QER)

THIS FORM MAY BE COMPLETED BY ANY EMPLOYEE WHO WISHES TO DOCUMENT CONCERNS/FAILURES WE CAN POSSIBLY LEARN FROM RELATIVE TO AN ITEM (HARDWARE OR SOFTWARE), FACILITY SYSTEM (MANAGEMENT OR HARDWARE) OR FUNCTION (SERVICE) THAT HAVE NOT PREVIOUSLY BEEN DOCUMENTED OR ARE NOT CURRENTLY BEING ADDRESSED TO HIS/HER KNOWLEDGE.

1. TODAY'S DATE: _____ SHIFT: _____ TIME: _____

DATE OF EVENT (If applicable) _____

2. LOCATION: _____

3. BRIEFLY DESCRIBE WHAT HAPPENED OR WHAT YOUR CONCERN INVOLVES

4. WHAT IMMEDIATE ACTION WAS TAKEN (If related to an occurrence)

5. WAS WORK DELAYED? IF SO, ESTIMATE THE TOTAL TIME.
   ___ YES
   ___ NO _____ HOURS _____ DAYS _____ WEEKS

6. ARE YOU AWARE OF ANY SIMILAR OCCURRENCES OR RELATED AREAS OF CONCERN? IF SO, PLEASE EXPLAIN.

7. DO YOU HAVE A RECOMMENDED RESOLUTION TO THIS OCCURRENCE OR CONCERN?

8. WAS THE PROBLEM OR CONCERN CORRECTED OR RESOLVED? ___ YES ___ NO

9. WHO WOULD HAVE MORE DETAILS?

10. INITIATOR SIGNATURE (OPTIONAL):

11. WOULD YOU LIKE FEEDBACK ON THE RESOLUTION OF THIS EVENT OR CONCERN? ___ YES ___ NO FORWARD TO DIVISION QA SPECIALIST (PRE-ADDRESSED)

TO BE COMPLETED BY DIVISION QA SPECIALIST QER NO QER- _____

QER TITLE _____

QIR, UOR, or NCR TO BE INITIATED? ___ YES ___ NO QIR/UOR/NCR NO _____ DATE _____

ITEM: _____ DEFECT: _____ KEYWORD _____

RESOLUTION OF EVENT OR CONCERN:

SIGNATURE: _____

NOTE HIGHLIGHTED AREAS INDICATE ESQIS DATA BASE ENTRIES

UCN-16033 (1235 3-87)

Exhibit. 10.4. Quality Event Report (QER) form.

QA-L-16-103), a QIR (Exhibit 10.5; ORNL QA Procedure QA-L-16-102), or a Corrective Action Report and Status (CARS, Exhibit 10.6). The appropriate report will document the event, the findings of the evaluation, and the required corrective actions. The disposition of a nonconformance will be documented and approved by the CRRFI Project Manager. The QA Specialist will concur with the disposition of the nonconformance.

The QA/QC Coordinator for a particular laboratory (ORNL-ACD, ORGDP-ACD, ORAU-ACD, or ORNL-ESD) is responsible for the assessment of laboratory quality control sample information. If data fall outside accepted limits, established laboratory procedures for identifying the problem and taking appropriate corrective actions will be employed (ORGDP-ACD TP 2300, R-10 1988d; Weaver 1988; Ford in prep.). Completion of corrective action should be evidenced by deviations returning to prescribed acceptable limits.

The modification, repair, rework, or replacement of nonconforming equipment, items, or activities will require the reverification of acceptability. In certain instances, as determined by project management (including the Project Manager, Laboratory Program Manager, or QA Specialist) these activities may require that corrective action be completed and verified before site work continues.

If, in the opinion of project management and QA Specialist, the nonconformance does not significantly affect the technical quality or use of the work, the work may continue pending resolution of the nonconformance. The basis for such a decision will be documented on the Nonconformance Report and submitted to the QA Specialist for review and approval. The documentation will include the statement that the decision was made before continuing with the work. The records of nonconformance and their dispositions will be maintained by the CRRFI Project Manager and forwarded to the RCDB.

SHEET 1 OF 2

MARTIN MARIETTA

QUALITY INVESTIGATION REPORT (QIR)

QIR NO

REPORT DATE
Initial ☐
Final ☐

PLANT OR ORG _____ DIVISION _____ QUALITY INDICATOR CATEGORY _____ ORIGINATOR _____

1. TITLE _____ KEYWORD _____ DATE OF PROBLEM _____

2. DESCRIPTION OF PROBLEM AND SIMILAR OCCURRENCES (Refer to Quality Event Report and TPS Step I) | ITEM | DEFECT

REF. QER NO _____ ☐ VENDOR SUPPLIED ☐ IN HOUSE FAB DEV COSST ☐ AL SUBCONTRACTOR SUPPLIED COSST | NAME OF VENDOR SHOP ORG CONTRACTOR AL etc

2A. DESCRIBE THIS PROBLEM

2B. DESCRIBE ANY SIMILAR PROBLEMS

OTHER APPLICABLE QIR's, UOR's, or NCR's

3. IMMEDIATE ACTION TAKEN (Refer to Quality Event Report)

4. INVESTIGATION TEAM | Chairperson | QA Representative

5. TECHNICAL INVESTIGATION AND EVALUATION (Developed from a summary of all TPS information) PROBLEM DISCIPLINE CATEGORY ☐

5A. CAUSE OF PROBLEM - STATE THE MOST PROBABLE TECHNICAL CAUSE (Refer to TPS Step VIIA)

5B. VERIFICATION OF CAUSE - ARE FURTHER ACTIONS REQUIRED TO VERIFY THAT THE CHOICE OF CAUSE IS CORRECT?

☐ YES ☐ NO IF YES, DESCRIBE ACTION REQUIRED:

IF NO, STATE THE REASONS WHY:

NOTE HIGHLIGHTED AREAS INDICATE QIS DATA BASE ENTRIES

ICN-10994 (1235 3-87)

Exhibit. 10.5. Quality Investigation Report (QIR) form.

CORRECTIVE ACTION REPORT AND STATUS

CORRECTIVE ACTION SOURCE: Initiation Date: _____

AUDIT# _____ UOR# _____

NCR# _____ QIR# _____

FINDING AND/OR RECOMMENDATION:

CORRECTIVE ACTION:

RESPONSIBLE PERSON: _____

SCHED. COMPLETION DATE: _____ *REVISED COMPLETION DATE:* _____

Commit to Corrective Action: _____ _____
Division/Program Manager/Director Date

Accept and Understand Task: _____ _____
Responsible Person Date

Reviewed for Adequacy: _____ _____
Division/Program QAS ESQIS Entry Date

STATUS:

CORRECTIVE ACTION COMPLETION:

_____ _____
Responsible Person Date Completed

QAS: _____

Date Verified Completion and Effectiveness: _____

Date Entered in ESQIS: _____

Exhibit. 10.6. Correction Action Report and Status (CARS) form.

10.11.3 Variance Procedures

Variances from approved operating procedures in any of the plans associated with this project will be documented on a deviation request form. Sampling Team Leaders will initiate and chronologically maintain deviation request forms. If, in the opinion of project management and QA Specialist, the variance does not affect safety or quality of work, the work may continue pending resolution of the nonconformance. The basis for such a decision will be documented on the deviation request form. Variances affecting project scope, costs, or schedule must be approved by CRRFI Project Manager. As appropriate, regulatory agencies will be notified of any variances that significantly affect project scope or objectives. Any variances from the Health and Safety Plan must be approved and acknowledged by the Health and Safety Coordinator. Variance approval by the Project Manager can be initiated on a verbal basis via the telephone or radio with follow-up written acknowledgement.

10.12 QUALITY ASSURANCE REPORTS TO MANAGEMENT

The active participation of management in the CRRFI Project is fundamental to the success of this QA/QC Plan. Management will be aware of project activities and will participate in development, review, and operation of the project. Management will be informed of quality assurance status and activities through the receipt, review, and/or approval of:

- Regular ESD Quality status reports
- Laboratory and project-specific QA/QC plans and procedures
- Post audit reports and audit closures
- Surveillance reports
- Corrective-action overdue notices
- Nonconformance reports.

Copies of these reports will be distributed to appropriate MMES and Oak Ridge Operations management, and regulatory agencies. In addition, periodic assessment of

QA/QC activities and data precision, accuracy, representativeness, completeness and comparability will be conducted and reported by the analytical laboratories.

Project management will inform the QA Specialist, as appropriate, of the QA status of the project, especially any significant quality accomplishments. CRRFI personnel are required to inform the Project Manager or project support staff of all nonconformances or quality failures (Section 15). The Project Manager will document and immediately report any nonconformance or quality failure to the QA Specialist. It is the responsibility of the ESD QA Specialist to report all quality associated activities to the ORNL Quality Assurance Manager.

10.13 OTHER QA/QC MEASURES TO MEET NQA-1 STANDARDS

The ANSI/ASME NQA-1 standards, that are implemented for ORNL projects, contain criteria that are not included in the EPA QAMS-005/80 requirements for QA/QC plans. Only NQA-1 criterion 14 "Inspection, Test and Operating Status" is specifically excluded from this plan. NQA-1 criteria overlapping with the EPA QAM-005/80 criteria, or explicit in other relevant documents include "Procurement Document Control" (Criterion 4), "Instructions, Procedures, and Drawings" (Criterion 5), "Development and Control of Procedures" (Criterion 5), "Purchased Items and Services Control" (Criterion 7), "Inspection" (Criterion 10), and "Test Control" (Criterion 11). These NQA-1 elements are invoked for this QA/QC plan by the following rationale.

10.13.1 Procurement Document Control (NQA-1 Criterion 4)

This criterion is to ensure that purchasing documents such as bid specifications are properly prepared. Purchasing for the CRRFI project will be through normal ORNL procedures, which implement NQA-1 procurement document control requirements (ORNL 1988).

10.13.2 Instructions, Procedures, and Drawings (NQA-1 Criterion 5)

This criterion is to ensure that activities effecting quality be conducted in accordance with documented instructions and procedures. This criterion is met for the CRRFI Project through preparation and implementation of the CRRFI general document and work plan (Section 1-7), project organization and management plan (Section 8), field sampling and analysis plan (Section 9), QA/QC plan (Section 10), data management plan (Section 11), and health and safety plan (Section 12). This criterion is also implemented for ORNL activities through the ORNL Quality Assurance Manual (ORNL 1988).

10.13.3 Document Control (NQA-1 Criterion 5)

This criterion for Development and Control of Procedures (QA-ES-5-101, Roberson and Logsdon 1989) is also met through the preparation and implementation of these CRRFI plans. Quality Assurance for each of these documents is provided for by in the Data Management Plan list of items of record to be included in the RCDB (Table 11.1, Section 11). Laboratory operations manuals are available for the analytical laboratories involved in CRRFI work. This criterion is also implemented for ORNL activities through the ORNL Quality Assurance Manual (ORNL 1988).

10.13.4 Purchased Items and Services Control (NQA-1 Criterion 7)

This criterion is to ensure that quality is maintained in purchasing items or services. Purchasing for the CRRFI project will be through normal ORNL procedures. These procedures implement NQA-1 procurement control requirements, as described in the ORNL Quality Assurance Manual (ORNL 1988).

10.13.5 Inspection (NQA-1 Criterion 10)

This criterion is to ensure that inspections sufficient to verify conformance with specified requirements are planned and executed. This QA/QC Plan specifically addresses procedures including instrument calibration (Section 10.4), review and validation of data

(Section 10.6), and audits (Section 10.7). This criterion is also met for the CRRFI project by the QA/QC requirements in the Sampling and Analysis, and Data Management plans. This criterion is also implemented for ORNL activities through the ORNL Quality Assurance Manual (ORNL 1988).

10.13.6 Test Control (NQA-1 Criterion 11)

This criterion is to ensure that tests sufficient to verify conformance with specified requirements are planned and executed. This criterion is met for the CRRFI project by the QA/QC requirements in the Sampling and Analysis, and Data Management Plans. Sections 10.4 and 10.6 of this plan ensure that procedures such as instrument calibration and review and validation of data conform to specific requirements. This criterion is also implemented for ORNL activities through the ORNL Quality Assurance Manual (ORNL 1988).

10.13.7 Inspection, Test, and Operating Status (NQA-1 Criterion 14)

This criterion is to ensure that 1) established procedures requiring inspections and tests are performed, 2) items which have not passed the necessary inspections or tests are not installed, used, or operated. This criterion is met for the CRRFI project by the QA/QC requirements in the Sampling and Analysis and QA/QC plans for procedures such as instrument calibration (including Section 8 of the plan). This criterion is also implemented for ORNL activities through the ORNL Quality Assurance Manual (ORNL 1988).

10.13.8 Nonconforming Items Control (NQA-1 Criterion 15)

This criterion is to ensure that nonconforming items are controlled to prevent inadvertent installation or use. This criterion is met for the CRRFI project by the QA/QC requirements in the Sampling and Analysis and QA/QC plans for procedures such as instrument calibration (Section 10.4) and nonconformances and corrective action procedures (Section 10.13). In addition, ORNL procedures for control of

nonconforming items are specified in the ORNL Quality Assurance Manual (ORNL 1988).

10.13.9 Quality Assurance Records (NQA-1 Criterion 17)

This criterion is to ensure that documentary evidence of quality is specified, prepared, and maintained; and that QA records are protected against damage, deterioration, or loss. This criterion is implemented by the ORNL Quality Assurance Manual and by the CRRFI project QA/QC and Data Management plans. The Data Management Plan includes specific procedures for retention of QA/QC records in the project RCDB. Quality control of all records, their retention period, and other pertinent information is included in Table 10.1. Quality assurance reports are implemented by Section 10.8.

11. DATA MANAGEMENT PLAN

11.1 INTRODUCTION

The CRRFI will generate data from many sources, including field measurements, laboratory analyses of environmental samples, and output from simulation models. Important records regarding the collection, analysis, and disposition of the samples and data will also be generated. The handling of these data and records along with documents related to project organization, health and safety, employee training, and quality assurance/quality control (QA/QC), among others, are described in Section 11, the Data Management Plan.

11.2 OBJECTIVES

The objectives of Data Management Plan are to provide organization, protection, retrievability, and accountability of the data and documents generated during the CRRFI. All documents required to provide a complete and accurate history of data collection and analyses will be included in the records management system (EPA 1988). The procedures in this plan are necessary to ensure that such data and records are documented to the extent necessary to support any future legal or administrative actions. The data management procedures will assure that data are made available for uses such as statistical analysis and modeling without the introduction of additional uncertainty from data entry and management activities.

This Plan identifies the documents, records, and data to be retained and describes the management structure and organization necessary to assure their integrity and retrievability.

There are three general types of information and documents that will constitute the necessary CRRFI record:

1. Records - any documentation (printed material) that must be maintained permanently unless directed otherwise by project management; see Tables 11.1 and 11.2.
2. Nonrecord Material - documentary materials that have little or no value from an overall operational standpoint and are used for short-term reference purposes.
3. Data - primarily numerical results obtained from environmental monitoring and sampling activities; see Table 11.2.

Items of record are listed in Table 11.2. Record materials will be maintained in the Records Control Data Base (RCDB, Section 11.4). Controlled documents are considered to be record material and have controlled distribution. Controlled documents are maintained in the RCDB (Section 4.2) and subject to document control procedures outlined in Section 11.5. Numeric data are maintained in the Numeric Data Base (NDB; Section 11.3.1). The Records Control Data Base will support the provision of all project documents required for the Administrative Record (see Section 11.6).

11.3 DATA MANAGEMENT

Data management for this project will utilize the CRRFI Numeric Data Base (NDB) for management and storage of field, analytical, and simulation model data as described in Voorhees et al. (1988, 1989). Numeric data are manipulated primarily with SAS software and stored as SAS data sets on the ORNL mainframe computers. SAS and various other compatible products (e.g., Lotus 1-2-3 and dBASE III Plus) are utilized with individual personal computers. The CRRFI RCDB will be used for management of record material. The RCDB serves as a computerized index for retrieval of information generated by the program (e.g., correspondence, project plans, field notebooks, chain-of-custody records, hard-copy data reports, etc.) from serially numbered archived files. All records will be permanently retained. Data management activities will support the preparation of all documents required for the Administrative Record (Section 11.6).

Table 11.1. Records to be included in the Record Control Data Base (RCDB) and the originating office.[a] Items of record (duplicate or original) are to be transmitted to the CRRFI Project Manager for inclusion in the RCDB.

Record Origination	Items of Record	Comment
ORNL Medical	Employee physician statements	Duplicates transmitted at the Project Manager's request through S&H Coordinator
ORNL Industrial Safety	Inspections Reports	Duplicates transmitted Safety Reports at the Project manager's request through S&H S&H Coordinator
ORNL Technical Resources and Training	Training/qualification records OSHA training RCRA training Employee training Category III training	Duplicates transmitted at the Project manager's request through S&HC Coordinator
ORNL Industrial Hygiene Division	Personnel monitoring Equipment monitoring Logbooks Routine surveillance reports Respirator fit testing and training	Duplicates transmitted at the Project manager's request through S&H Coordinator
ORNL Radiation Protection Department (Health Physics)	Personnel monitoring Equipment monitoring Decontamination records Unusual occurrence reports Routine Surveillance reports Logbooks	Duplicates transmitted through S&H Coordinator, at Project Manager's request
Environmental Monitoring and Compliance Division (EMC)	ALARA memoranda Engineering permits Environmental documents (ADM, EAM)	Duplicates transmitted at Project Manager's request through the S&H Coordinator
Quality Assurance	Audits Readiness review Surveillance reports	Originals transmitted to and maintained by the Project Manager

Table 11.1. (continued)

Record Origination	Items of Record	Comment
Contract Analytical Laboratories	Chain-of-custody procedures Analytical procedures QA/QC data	Duplicates transmitted by Laboratory Manager, originals are kept by the laboratory
CRRFI Project Manager		Plans to be prepared, reviewed and submitted in technical manual format
CRRFI Task Leaders	Field and Laboratory notebooks Personnel training Reports Analysis procedures	Duplicates kept by Task Leaders, originals are transmitted
CRRFI Sampling Team Leaders	Sampling procedures Personnel training Field and Laboratory notebooks	Duplicates kept by Team Leader, originals are transmitted to RCDB
Analytical Services Coordinator	Chain-of-custody forms	Duplicates kept by ASC, originals are transmitted to RCDB
Field and laboratory technical support staff	Field and laboratory notebooks	Duplicates are kept by staff, originals are transmitted to RCDB

[a]Subject to final approval.

Table 11.2. Items of record to be included in the RCDB[a]. All records shall be maintained for the lifetime of the project plus 30 years.

Project Title: CLINCH RIVER RCRA FACILITY INVESTIGATION

Name of Record	Master File Point[b]	Duplicate File Point[c]
Employee physician Statements	Medical	RCDB
Inspections & Reports	Industrial Safety	RCDB
Training Qualifications and Records	Technical Resources and Training	RCDB
Monitoring records	Health Physics	RCDB
Environmental documents	EMC Division	RCDB
Audits, Surveillance Reports	Project Manager (RCDB)	Quality Assurance Specialist
Laboratory Chain-of-Custody procedures, Analytical procedures, and QA/QC data	Analytical Laboratories	RCDB
Field/Lab notebooks, Personnel training, Reports, and Analysis procedures	RCDB	Task Leaders
Sampling procedures, Personnel training, and Field/Lab notebooks	RCDB	Team Leaders
Chain-of-custody forms	RCDB	Analytical Services Coordinator
Field/Lab notebooks	RCDB	Technical Support Staff

[a]Subject to final approval.
[b]Master File Point: Location of master records. See Table 11.1 for details. EMC: Environmental Monitoring and Compliance; RCDB: Records Control Data Base.
[c]Duplicate File Point: Location of duplicate records. See Table 11.1 for details.

Table 11.3. Data to be included in the Numeric Data Base (NDB) and the originating office.[a] All data are to be transmitted to the CRRFI Project Manager for inclusion in the NDB.

Record Origination	Category of Data Record	Comment
Biota Sampling Team	Organism vital statistics ESD laboratory data	Recorded in field notebooks, duplicates transferred to Program Manager
Sediment Sampling Team	Sediment characteristics Water quality data Water flow rate data Sediment core length ESD laboratory data	Recorded in field notebooks, data forms duplicates to Program Manager
Surface Water Sampling Team	Water quality data Field turbidity data Water flow rate data ESD laboratory data	Recorded on standard field data sheets, duplicates to Program Manager
Data Management, Integration, and Remedial Action Evaluation Task	Contaminant fate and transport model data	Retention of model input, output, and calibration data
K-25 Analytical Chemistry Division	Metal contaminant data (sediment, water) Organic contaminant data (sediment, water)	Transfer to NDB originals to Program Manager
ORAU Analytical Chemistry	Alpha-Beta spectroscopy data (sediment, fish)	computer transfer to NDB originals to Program Manager
ORNL Analytical Chemistry Division	Metal contaminant data (fish) Organic contaminant data (fish)	computer transfer to NDB originals to Program Manager
ORNL ESD Radiological Laboratory	Gamma spectroscopy data (sediment, water, fish)	originals to Manager

[a]Subject to final approval.

11.3.1 Numeric Data Base

The principal steps for processing data to be included in the NDB are identified in Fig. 11.1. These procedures will be followed for entry and verification of all numeric data generated during the CRRFI. Data are stored on a mass storage device on the ORNL IBM-3033 system and backed up weekly on magnetic tape by computer operations staff. Access to the files is controlled under the ACF2 security system installed on the ORNL computer system. Changes to the data sets can be made only with approval of the CRRFI Data Base Manager. Data management activities, reference to programs used to manipulate the data, and documentation to the data base are recorded in technical notebooks (QA-ES-6-100, Roberson and Logdson, 1989). Changes to the data base, initiated by the analytical laboratory, will be provided in writing. Correction to the database initiated by the CRRFI staff will be submitted in writing to the appropriate analytical laboratory. They shall be responsible for subsequent verification, correction, and reissuance of the data in question. All requests for direct "read only" access to CRRFI data or hard-copy and graphical output will require the approval of the CRRFI Project Manager.

The following sections discuss the various types of numeric data which may be generated during the CRRFI and their processing from entry through verification.

11.3.2 Field Data Measurements and Observations

Field notes are the primary record that will provide sufficient data and observations that enable reconstruction of events that occurred. Field notebook entries should be factual, detailed, and objective.

All field measurements, such as pH, temperature, conductivity, water flow, sediment characteristics, instrument calibration data, etc., will be recorded in the field notebooks or on specially designed data forms. All data will be directly entered in the field, signed, and dated. Changes made to original notes should not obliterate the original

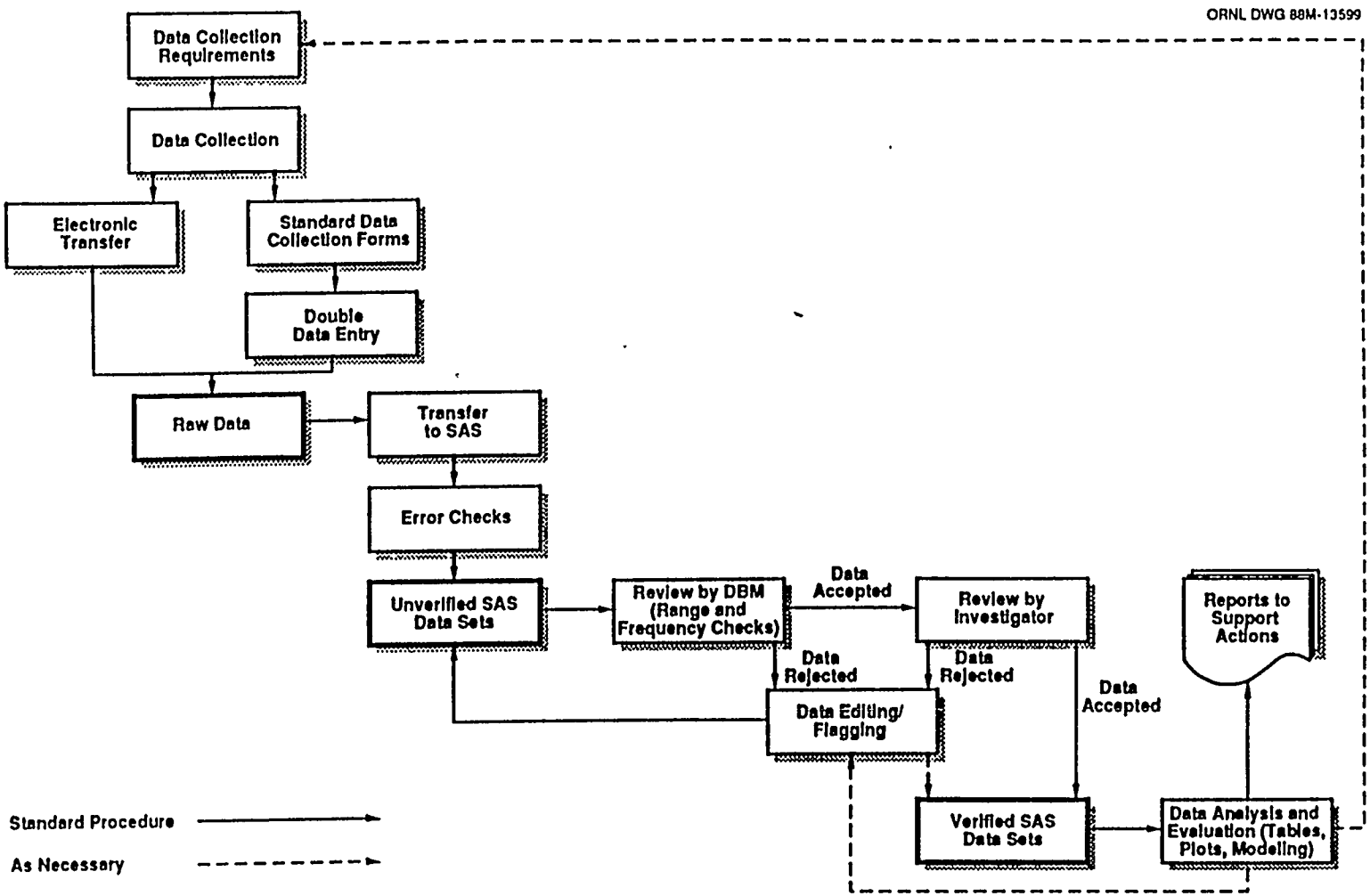

Fig. 11.1. Generalized flow diagram for processing data.

information. All field data records will be organized into standard format when possible. Team leaders are responsible for review of daily entries in the field logbooks.

It is the responsibility of the individual investigators and the CRRFI Project Manager to safeguard these records. Manual double entry of field data by ORGDP Data Entry Staff will be coordinated by the Analytical Services Coordinator. The CRRFI Project Manager will forward field notebooks to the RCDB at the conclusion of field activities.

11.3.3 Analytical Laboratory Data

Two contract analytical laboratories, Oak Ridge Gaseous Diffusion Plant-Analytical Chemistry Department and ORNL-Analytical Chemistry Division, use the AnaLIS computerized laboratory management system to track samples and report analytical results. Data management staff have access to completed and approved data files in AnaLIS and will electronically copy results to ORNL computers. Transfers will be accomplished with software which incorporates accepted error checking protocols. Data will be included in the NDB only after the hard copy of such data has been submitted by the CRRFI Project Manager to RCDB.

The Radiological Laboratory of the Oak Ridge Associated Universities (ORAU) will provide their data as verified annotated ASCII files which data management staff can directly input to SAS. Data will be included in the NDB only after the hard copy has been submitted by the CRRFI Project Manager to RCDB.

Results of water quality analyses performed at the Environmental Sciences Division Aquatic Ecology and Radiological Laboratories will be recorded directly on data sheets, reviewed by the analysts, signed, and copies sent to ORGDP Data Entry where data will be double entered and verified to assure accurate entry.

11.3.4 Simulation and Risk Assessment Models and Data

Documentation of contaminant fate and transport models will be retained. Documentation includes descriptions of the model equations, assumptions, solution methods, and initial and boundary conditions used. The input data, output, and program files for calibration and for analyses used as bases for important programmatic decisions will be available to outside reviewers. All data input, output, program files, and equations, factors, and assumptions employed in the screening-level risk analyses and in subsequent risk analyses conducted for the CRRFI Project will also be retained and available to outside reviewers.

11.3.5 Validation of Existing Data

Data from numerous sources, which were collected for various programs and under varying degrees of QA, will be included in contaminant fate and transport models, risk assessment analyses, and potentially the NDB. Validation of these data is the responsibility of the principal investigator. Investigators must evaluate the historical data with respect to their needs and determine whether it is appropriate to use.

11.3.6 CRRFI Data

Data reduction, verification, and reporting will be in accordance with the ongoing ORNL Remedial Action Program Data Base Management activities (Voorhees et al. 1989) QA/QC procedures, data are verified using a variety of computerized checks for reasonableness.

Field data will be reviewed by the appropriate CRRFI Task Leader who will be responsible for resolving any questions regarding the data.

Laboratory data will be checked for both internal consistency and transmittal errors by the laboratory supervisor. Errors will be corrected and documented. The analytical data

reports will be reviewed using QA/QC procedures outlined in the of CRRFI QA/QC Plan (Section 10).

11.4 RECORDS CONTROL DATA BASE (RCDB)

All information that is required to provide a complete and accurate history of the project organization, sample collection, and analysis activities are designated as "record documents". The RCDB and associated hard copy repository provides for organization, protection, retrievability, and accountability of such information. The structure, format, and content of the RCDB are described in Appendix C. All requests for access to CRRFI information from RCDB will require the approval of the CRRFI Project Manager and the CRRFI Data Base Manager.

Protocols for communication of necessary documents and data between the RCDB and the Administrative Record will be implemented as part of the CRRFI Data Base Management activities.

11.4.1 Records Control Process

Records to be controlled as well as responsible organizations and personnel are shown in Table 11.1. Those responsible for the preparation, review, and approval of records will transmit the original to the CRRFI Project Manager and maintain an indexed, retrievable duplicate file. Major changes to documents must be reviewed and approved by the same organizations that performed the original review and approval. The CRRFI Project Manager has the responsibility to identify all record items and will forward appropriate information to the RCDB. Each submittal will be attached to a submittal cover sheet (Exhibit 11.1).

11.4.2 Document Index and Archive

The RCDB serves as a computerized index for retrieval of record documents generated by the program. All documents submitted will be indexed and permanently retained

COVER SHEET FOR CLINCH RIVER CRRFI SUBMITTALS TO RECORDS CONTROL

NAME _____ DATE SUBMITTED _____

PHONE _____ BUILDING _____ ROOM _____ MAIL STOP _____

TITLE/SUBJECT OF ITEM: (if not obvious, please describe briefly)

_____

_____

_____

DATE WHEN DATA/INFORMATION WAS COLLECTED:

_____

DATE WHEN ITEM/RECORD ATTACHED WAS PREPARED:

_____

SITE NAME: (Include site name or number, if known or a general description of the area addressed by the item attached.)

_____

_____

_____

IF YOU WANTED TO RETRIEVE THIS ITEM FROM THE DATA BASE OR IF IT IS A PART OF A PARTICULAR PORTION OF YOUR COLLECTION, LIST SOME TERMS OR DESCRIPTIVE PHRASES THAT WOULD IDENTIFY IT FOR QUICK RETRIEVAL.

_____

_____

_____

Approved for Submittal to RCDB

_____

Clinch River RFI Project Manager

Exhibit 11.1. Cover sheet for submittals to the Records Control Data Base.

unless directed otherwise by the CRRFI Project Manager. Backup files of the document index will be created at the end of each day during which new records were created or existing records edited. A copy of the entire data base will be transferred on a monthly basis and stored in another location to minimize the loss of the data base in the event of catastrophe.

11.5 DOCUMENT CONTROL

A procedure developed for the ORNL-RAP which defines the management system to control the issuance and distribution of documents, has been adapted for use with CRRFI documents (See Appendix C). The Project Manager is responsible for ensuring that the document has been fully reviewed, assigned a correct document number, and if appropriate, had document approval forms filed before being sent to RCDB. This procedure ensures that once a reproducible copy of the document has been sent to RCDB, the document will be reproduced in sufficient quantity, distributed with return receipts for numbered copies, updated when necessary with instructions and return receipts, and returned to the RCDB when no longer needed. Controlled documents are generally those associated with QA/QC of projects, safety of workers, and construction or engineering plans.

11.6 ADMINISTRATIVE RECORD

The DOE will maintain and preserve the complete Administrative Record, including supporting documents, for a minimum of ten years following the termination and satisfaction of the project. The DOE shall notify the EPA and the TDHE at least ninety days before the destruction of any such records or documents. The DOE will upon request by the EPA or the TDHE make such documents (or copies) available.

Copies of the current index to the Administrative Record shall be available at a location in the City of Oak Ridge that provides convenient access to the public. The index and selected documents shall be available to the public during normal working hours at the DOE Operations Office, currently located in Oak Ridge.

12. GENERAL HEALTH & SAFETY PLAN

12.1. INTRODUCTION

This CRRFI Health and Safety (H&S) Plan presents the concepts and methodologies to be used during the Clinch River Project to protect the health and safety of sampling team personnel.

12.1.1 Policy

The procedures that must be followed while performing site investigations for the CRRFI are prescribed by this H&S Plan. Personnel working on the CRRFI project shall be informed of existing and potential hazards associated with the tasks to be performed through presampling briefings. Information decimated and personnel in attendance shall be received in the field log book. This knowledge will allow effective application of required safety precautions. Specific health and safety information (personnel protective equipment, water safety, organizational structure, etc.) is given in the following sections.

This H&S Plan complies with all applicable Occupational Safety and Health Administration (OSHA) regulations including 29 CFR 1910.120. The provisions of this plan are mandatory for all personnel and subcontractors assigned to the project, as well as, all authorized visitors. As appropriate, written addenda to the plan will be provided by the Project Health and Safety Coordinator. No changes to the plan will be implemented without prior approval of the H&S Coordinator.

12.1.2 Adherence to Quality Assurance/Quality Control Plan

The philosophy, activities, and procedures which implement requirements of the CRRFI H&S Plan comply with and complement the requirements of the CRRFI Quality Assurance/Quality Control (QA/QC) Plan (Section 10).

12.1.3 Off-Site Health and Safety Information and Procedures

The principal hazards expected during these activities are related to physical and aquatic activities, and heat and cold stress.

Site-specific health and safety information and procedures shall be developed and made available to all site employees. Hazards for each task or phase where activities are conducted in areas that are excluded for purposes of radiation or chemical exposure or as designated by the health and safety coordinator shall be addressed. This information shall include the following:

- Names of key health and safety personnel
- Health and safety risks or hazard analysis for each site task and operation described in the General H&S Plan Overview (Section 12.1.8) and the Site Characterization and Evaluation (Section 12.2), and Safe Sampling Practices (Section 12.3)
- Medical surveillance requirements (if requirements other than those stated in Section 12.5 are necessary)
- Personnel protection requirements (Section 12.6)

The H&S Coordinator shall make audits and inspections of sampling sites to determine the effectiveness of the site health and safety plan. Deficiencies shall be noted in the site log. Any deficiencies noted shall be corrected immediately and the corrective action taken noted.

12.1.4 Off-Site Health and Safety Practices

The collection of samples from off-site environments poses a minimal risk of exposure levels requiring personal monitoring or personal protection equipment. However, to ensure the safety and well-being of all project personnel, the following steps will be taken routinely:

1. The H&S Coordinator will review each task before it begins. The coordinator will determine which, if any, requirements shall be required; changes to the health and safety plan must be documented.
2. Sections of the H&S Plan that relate to physical hazards must be satisfied.
3. All personnel must wear a thermoluminescent dosimeter badge (TLD) issued by ORNL.

12.1.5 Laboratory Health and Safety Practices

Laboratory analysis of samples returned from the off-site environment may involve hazards unrelated to the constituents of a particular sample. It must be documented that all contract program laboratories will be in compliance with relevant DOE, OSHA, and ORNL health and safety requirements. Laboratory specific H&S requirements will be addressed by the Standard Operating Procedures (SOPs) for each laboratory.

12.1.6 Information Programs

Employees will be informed regularly (Section 12.1.5, 12.2, and 12.4.4) of site-specific health and safety hazards and the requirements of 29 CFR 1910.120, Hazardous Waste Operations and Emergency Response.

12.1.7 Regulatory Requirements

The environmental, safety and health protection requirements applicable to the CRRFI are set forth in Department of Energy (DOE) orders, Martin Marietta Energy Systems (MMES) and ORNL procedures, and applicable federal, state and local regulations and standards. However, it is not anticipated that personnel involved in site characterization activities outside of the ORR will encounter contaminants at concentrations which represent health hazards. Certain DOE orders are applicable to site characterization. As most recently revised, these may include, but are not limited to relevant DOE orders, OSHA regulations, and ORNL manuals.

Concurrently, DOE and its contractors have adopted Permissible Exposure Limit (PEL) guidelines for chemical substances and physical agents, as listed in 29 CFR 1910. Where 29 CFR 1910 is silent for relevant chemical substances or physical agents, the values listed in the following order will be used in the order given:

- American Conference of Governmental Industrial Hygienists Threshold Limit Values (TLV).
- National Institute of Occupational Safety and Health Recommended Exposure Limits (REL).

Where more than one standard exists, the more conservative value will be applied.

The packaging and shipment of samples to and from laboratory facilities shall be performed in accordance with federal Department of Transportation (DOT) regulations set forth in Title 49 CFR and with Tennessee DOT regulations. Other codes applicable to safe operations include National Fire Protection Association (NFPA) codes and federal and local fire codes.

12.1.8 H&S Plan Overview

The health and safety sections of the CRRFI Plan, specifically those concerned with organization and responsibility of personnel, and training, are designed to ensure that the safety and health of personnel is not endangered by negligence or inadequate training. Specifically the H&S Plan addresses the following:

- Personnel: Discussion of the requirements and responsibilities for personnel involved in this program.
- Training: Discussion of the implementation of the employee informational program, training and certification program, medical surveillance programs, personnel protection, water safety, decontamination and emergency procedures.

All personnel involved in operations who handle, sample, dispose of, or otherwise have a potential for exposure to site-specific contaminated materials are subject to this H&S Plan. Maintaining a safe and healthful work environment is the responsibility of supervisors and each team member. Through the training program (Section 12.4), all team members shall be informed of potential hazards, proper use of protective equipment, applicable procedural requirements, and their responsibilities for maintaining safe working environments. Personnel are required to adhere to all safety requirements. All subcontractors will be trained as necessary according to the specifications set forth in Section 6.

General responsibilities for CRRFI staff:

- Safeguard record materials including, but not limited to, field notebooks, raw data sheets, and chain-of-custody forms.
- Maintain complete, factual, detailed, and objective program notes.
- Retain records of all analyses and procedures, used for the CRRFI.
- Ensure that proper waste management procedures are followed.
- Ensure that the requirements of the S&A, QA/QC, Data Management, and H&S Plans are satisfied.

All CRRFI contractors and subcontractors performing each sampling task at each sampling site shall be informed of the potential hazards associated with these procedures. All plans relevant to the health and safety of any sampling personnel as outlined in this document shall be made available to the contractor and the subcontractor.

12.2 SITE CHARACTERIZATION AND EVALUATION

Each sampling site shall be evaluated to identify specific site hazards and to determine the appropriate health and safety procedures needed to protect employees from the identified hazards.

12.2.1 Site Evaluations

Data from preliminary site evaluations will be used to aid in the selection of appropriate personnel protection methods prior to the initial sampling phase. Methods will be selected according to ORNL-ESD Industrial Safety Program (McConathy 1990). After the initial phase of sampling and after each subsequent phase as data become available, more detailed evaluations of each site shall be performed to aid in the selection of appropriate protective equipment and controls. All potentially hazardous conditions shall be identified during the site evaluations.

12.2.2 General Site Information

The following health and safety information shall be included in the site-specific characterization and evaluations:

- Location of the site
- Description of sampling task(s)
- Site hydrology or topography (as relevant)
- Site accessibility
- Potential pathways for hazardous substance dispersal and exposure.

Hazardous substances and health hazards involved or expected and their chemical and physical properties shall be included in the form of Material Safety Data Sheets (MSDS). It should be noted that MSDS information relates to pure forms of a chemical. Wastes are often admixtures of greater hazard than encountered from component contaminants.

12.2.3 Health and Safety Site Characterization

The review of existing data (Subtask 1.1) was combined with the results from the off-site scoping effort, which used the distribution of ^{137}Cs in sediment to identify contaminant accumulation patterns (Subtask 1.2) in the sediments of the Clinch River and Watts Bar

Reservoir, to establish the sampling sites for the initial phase of the field sampling program. Based on these results and the known release points of effluents from ORR, ten to fifteen sites have been selected for screening-level sampling and analysis (S&A Plan, Section 9.4.3, Figs. 9.3 and 9.4). Access to all sites is by river, after boat launching from a TVA public launch ramp. The off-site area has also been segmented into study reaches (Fig. 9.2, Table 9.1). Environmental samples from the White Oak Creek embayment and the Poplar Creek sites potentially have the highest levels of off-site contamination as a result of releases from the Oak Ridge Operations. Included in these sampling sites are a reference site on Norris Reservoir (CRM 89.5, reach 10) and Upper Melton Hill Reservoir (CRM 43, reach 12). The purpose of the latter site is to establish whether there are upstream releases of contaminants into the Clinch River system.

The principal physical hazards associated with the Clinch River (CRM 4 to CRM 22), White Oak Creek Embayment (CRM 20.9) and Poplar Creek Embayment (CRM 12) sites involve sudden increases in water velocity and depth caused by hydroelectric power generation from the TVA Melton Hill Dam (CRM 22.9). Other sites are predominately lake-like.

12.3 SAFE SAMPLING PRACTICES

The procedures for obtaining sediment and water samples for this project are found in the Sampling and Analysis Plan (Section 9).

12.3.1 General Site Health and Safety Requirements

The following health and safety requirements will be implemented at each sampling site:

- At least one copy of this plan shall be available at the sampling site.
- Flotation devices, such as life vests, shall be worn by all personnel, both team members and visitors, under the conditions specified in the Water Safety Section (Section 12.8) and in the Boat Safety Procedures (Section 12.3.4).

- Legible and understandable precautionary labels shall be affixed prominently to containers of contaminated scrap, waste, debris, and clothing. Labels shall include date, location, and suspected or known contaminant material.
- Removal of contaminated soil from protective clothing or equipment by blowing, shaking, or any other means that disperses contaminants into the environment is prohibited.
- Samples shall be stored in tightly closed containers in well ventilated areas, as specified by the S&A and QA/QC Plans.
- Containers shall be moved only with the proper equipment and shall be secured to prevent dropping or loss of control during transport.
- Emergency equipment shall be readily accessible.
- DOT transportation requirements will be met.

12.3.1.1 Personnel Safety

When sampling from a boat (in the Clinch or Tennessee rivers or their tributaries), sampling teams shall consist of at least two persons. Crew members must observe each other for signs of temperature or other stresses, as discussed in the Medical Surveillance Section (Section 12.5, 12.6). Also, employees shall inform each other of nonvisual effects of stress.

12.3.1.2 Other Regulations

All personnel and visitors shall abide by the following at all sampling sites:

- No food or beverages shall be present or consumed while collecting samples.
- No tobacco products shall be present or used, and no cosmetics shall be applied at the sampling site.
- The use of alcohol or drugs is prohibited.
- Workers using prescription medication shall disclose this fact to the CRRFI Project Manager, the Sampling Team Leader, and (if needed) to the Occupational Physician so that potential complications can be avoided.

- Visitor inspection of the sampling sites will be left to the discretion of the Sampling Team Leader.

12.3.2 Field Communications

Field communication procedures are outlined in the Emergency Procedures Section (Section 12.10), in the ESD Radio Use Procedures (ESD 1988b) and in the Guidelines for Field Work and Safety.

12.3.3 Hazard Communication

Once hazards associated with either particular sampling sites or with sampling in general have been identified, the risks of these hazards shall be communicated to the site personnel. The methodologies of hazard communication are outlined in Section 12.4. MSDS shall be made available to all employees.

12.3.4 Boat Safety

Sampling personnel should inform ESD personnel of the nature of their sampling trip, their destination and their estimated time of return. They also should carry and monitor a laboratory radio for field communications. Gear should always be loaded into the boats prior to launch, as the water and shoreline surrounding most launch ramps is uneven and steep. General hazards to be avoided when sampling water, biota or sediment from boats include the following:

- Make as few movements as possible.
- Personnel should always keep the center of their mass low to help avoid loss of balance.
- Personnel should be aware of the speed at which river conditions will change, especially when sampling downstream from any dam.
- Personnel should also be alert to rapidly changing weather conditions, especially if inclement weather has been predicted. Personnel should be prepared to immediately seek shelter on shore if lightening threatens.

- Boat decks should be maintained as free from obstructions as possible.

Additional water safety requirements are given in Section 12.8.

12.3.5 Water Sample Collection

Operation of sampling devices (Kemmerer or Van Dorn style bottles, Section 9.8) may present hazards to extremities. This is primarily due to the rapid, forceful spring action required to close these devices. Prior to collecting a sample, the following precautions should be taken:

- The line for lowering and retrieving the device should be free from tangles.
- Sampling devices should be opened (set) immediately before being lowered into the water.
- Sampling personnel should have good footing and should be able to steady themselves if the boat should shift suddenly.
- For particular samplers:
  - Van Dorn style bottles should be held by the side handle, away from the body before being lowered into the water.
  - Kemmerer bottles should be held by the top metal sleeve.

The sampling device will be lowered by hand to the prescribed depth. As the sampling device is retrieved, the personnel responsible should ascertain whether the device failed to close at depth. If so, the device should be triggered while below the water surface, retrieved, drained and reset. A "set" sampler should not be brought on board.

Precautions should be taken while filling sample containers and moving them to storage locations. Both sample devices and containers have considerably more mass when filled with sample, and in the case of sample containers, no handle is present to facilitate carrying the container.

12.3.6 Electroshocker Operation

Any general cautions listed above will apply to the collection of fish by electroshocking. Sampling team personnel should wear appropriate insulating clothing (gloves and boots) to prevent inadvertent shock. Hearing protection should be worn. Another hazard is derived from the exhaust noise and fumes produced by small gasoline engines. If fume concentrations reach irritation levels, sampling should be discontinued until sensitive organs have recovered and fumes have dispersed. The cautions concerning center of balance and maintaining an uncluttered work space are critically important to safe sampling with electroshockers.

12.3.7 Sediment Sample Collection

Sediment samples will be collected using ponar grab, vibracorer, or gravity corer. Each of these devices has sharp edges, is heavy, and is not easily manipulated. It is crucial to keep boat decks free from mud and other obstructions. Leather gloves, safety goggles and reinforced toe boots are required in order to operate this equipment. Whenever devices are being lowered or raised using steel cable, that cable should be handled using leather gloves to protect hands from cuts. Proper rest breaks, and sharing of tasks among personnel should alleviate exhaustion.

The ponar grab sampler should only be transported with the device locked open. When preparing to collect sediment, the locking pin should be removed with the jaws of the sampler supported by a photo tray. Whenever the locking pin is removed and the jaws are open, personnel should hold the trigger bar in place and pick up the sampler under the cross arms. If the open sampler is picked up immediately under the cable connection, it may be triggered, causing injury. Closed samplers should be picked up immediately under the cable connection, as specified above.

The vibracorer presents additional hazards, involving exhaust noise and fumes from the engine and vibrating machinery. Hearing protection shall be worn while the vibracore is in operation. If fume concentrations reach irritation levels, the engine should be turned

off and sampling discontinued until sensitive organs have recovered and fumes have dispersed. Special care must be taken to avoid damage to appendages caused by the vibrating head attached to the sample pipe.

12.4 EMPLOYEE TRAINING AND CERTIFICATION PROCEDURES

12.4.1 Duration

All personnel involved in the Clinch River RFI Project are subject to training in accordance with 29 CFR Part 1910.120. All personnel will have previous experience in field sampling, and will receive a minimum of 3 days of actual field experience under the direct supervision of the appropriate Sampling Team Leader. Personnel engaged in sampling site management and supervision shall receive a minimum of 8 hours of additional training. All employees having the required previous experience, 3 days of field experience and acknowledging their understanding and intent to comply with procedures outlined in these plans will be certified as sampling personnel. It is necessary for each person involved in the CRRFI sampling receive annual refresher training on the items outlined in this section.

12.4.2 Sample Site Personnel Course Content Outline

Following is a general list of topics to be covered in the training course:

- General sampling operation safety.
- Physical hazards (noise, heat stress).
- Names of personnel responsible for site safety and health.
- The specific nature of the sampling operation relevant to contaminant exposure levels.
- Purpose, proper selection, fitting, use and limitations of personal protective equipment and clothing applicable to field sampling.
- Medical surveillance requirements
- Personnel Right-to-Know (Hazard Communication, 29 CFR 1910.1200).

- Information concerning adverse health effects associated with exposure to contaminants.
- Routes of exposure to contaminants.
- Engineering controls and safe sampling practices.
- Components of the sample collection program.
- Boat safety procedures
- Radio use procedures
- Decontamination practices for personnel and equipment.
- Emergency response plan.
- Waste disposal procedures.

Certification procedures for both sediment and water sample collection are found in the Sampling and Analysis Plan (Sections 9.5 and 9.6). Training for operation of electroshockers is conducted by the Biota Sampling Team Leader or a qualified designee. Additionally, certification in American Red Cross lifesaving and first aid procedures, specifically procedures such as CPR, are advisable for sampling team personnel.

12.4.3 Radiation Protection

All personnel involved with this project will participate in a training course (e.g., ORNL SARA/OSHA Training for Hazardous Waste Site Activities) to review the health physics (personnel radiation protection) precautions, to be used to reduce exposures to as-low-as-reasonably-achievable (ALARA). This training will be based on job requirements and training shall be documented. This course will comply with the requirements of ORNL HP Procedure 1.2.

12.4.4 Pre-Sampling Briefings

The following training sessions and informational materials will be provided on site:

- A safety meeting will be conducted at the beginning of each sampling run or whenever new personnel are to be employed at particular sampling sites. The health and safety considerations for the day's activities will be discussed, and the necessary protective equipment outlined. All information discussed shall be recorded in log books.
- Material Safety Data Sheets - Completed MSDS for the toxic materials identified as being present at hazardous concentrations at the site shall be available.
- Site Safety Plan - All persons entering the site shall be informed of the contents of the site safety and health plan.

12.5 MEDICAL SURVEILLANCE

12.5.1 Physical Examination

As required by OSHA regulation 29 CFR 1910.120, all personnel on site will have successfully completed a preplacement or periodic/update physical examination. This examination has been designed to comply with 29 CFR 1910.120 requirements for hazardous waste site operations. Less thorough examinations may be required for sampling team personnel.

All subcontractor personnel who have potential for exposure to hazardous materials must have successfully completed an examination similar to the preplacement physical. The cost for medical surveillance will be paid by the subcontractor. All physicals will be approved by a physician who is board certified in Occupational Medicine.

12.5.2 Medical Records

Medical and personnel exposure monitoring records will be maintained in accordance with the requirements of 29 CFR 1910.20 and shall be kept for 30 years after employee termination. Employee confidentiality shall be maintained.

12.5.3 Injury and Illness Treatment

A physician familiar with occupational medicine will be identified before job start-up. This physician will be familiar with the effects of the chemicals on site and will be used as a consultant in the event of a job-related illness. If an injury or illness is the result of a chemical exposure, a supervisor shall promptly initiate the steps necessary to identify the chemical(s). Chemical identification shall be accomplished through use of monitoring equipment (photoionization detectors in conjunction with detector tubes and/or conventional industrial hygiene monitoring) and any prior sampling results that are available. Such information shall be made available to the treating physician and the Health and Safety Coordinator.

An injury or illness requires the completion of a "Supervisor's Incident Report" (Exhibit 12.1). An injury/illness not limited to a first-aid response requires that the Sampling Team Leader immediately notify the Health and Safety Coordinator. This notification allows the coordination of internal resources to assist the treating physician in rendering appropriate care.

Any employee or subcontractor who is suspected of having an overexposure to the chemicals on site will be given another complete physical examination. Any employee or contractor who develops a lost-time illness or sustains a lost-time injury will be reexamined. The physician will certify in writing that the employee is fit to return to work by completing the "Request for Pre-placement/Health Evaluation/Medical Restriction" form (Exhibit 12.2). If necessary, activity restrictions will be specified on the Exhibit 12.2 form.

12.6 PERSONNEL PROTECTION

Protective equipment to be employed at all sites includes U. S. Coast Guard (USCG) approved Personal Flotation Devices (PFDs, worn as specified in Section 12.8) and clothing appropriate to season. Protective equipment to guard against contamination of personnel will be specified by an industrial hygienist or health physicist. Personal

SUPERVISOR'S INCIDENT REPORT

INJURED EMPLOYEE | EMPLOYEE NO. | AGE | SEX ☐ MALE ☐ FEMALE

JOB TITLE | DIVISION | DEPARTMENT

TYPE OF INJURY | PART OF BODY AFFECTED

PROPERTY AFFECTED

DESCRIPTION	ESTIMATED LOSS	ESTIMATED COST OF REPAIR

EMPLOYEES INVOLVED

NAME	EMPLOYEE NO.

DATE OF INCIDENT | TIME OF INCIDENT ☐ AM ☐ PM | LOCATION OF INCIDENT | CAUSE CLASS

REPORTED TO (Name) | DEPARTMENT | DATE | TIME ☐ AM ☐ PM

DESCRIPTION OF INCIDENT

CAUSE OF INCIDENT

RESPONSIBILITY

ACTION TAKEN TO PREVENT A SIMILAR INCIDENT

ADDITIONAL ACTION THAT SHOULD BE TAKEN

CORRECTIVE ACTIONS AND CAUSE OF THE INCIDENT HAVE BEEN REVIEWED WITH THE EMPLOYEE(S) CONCERNED ☐ YES ☐ NO

SUPERVISORS SIGNATURE | DEPARTMENT | DATE

DIVISION SUPERINTENDENT OR REPRESENTATIVES SIGNATURE | DATE

JCN-103
1235 4-82)

DISTRIBUTION: (1) Safety (2) Division

Exhibit 12.1. Supervisor's Incident Report.

MARTIN MARIETTA ENERGY SYSTEMS, INC.

☐ ORGDP ☐ ORNL ☐ Y-12 ☐ PGDP ☐ PORTS

REQUEST FOR PRE-PLACEMENT/HEALTH EVALUATION/MEDICAL RESTRICTIO

☐ New Applicant ☐ Former Employee ☐ Transfer ☐ Return From Disability/Leave ☐ Health/Restriction Evaluation

NAME | RESIGNATION/LEAVE DATE

BADGE NUMBER | DATE OF BIRTH | JOB TITLE (Please Attach JOB Restriction/Requirements)

SEND REPORT TO (Supervisor/Employment)

TITLE | DEPARTMENT | ADDRESS

TELEPHONE | CITY | STATE

NOTIFIED | DATE-TIME

MEDICAL RECOMMENDATIONS

☐ Fit For Employment Without Restrictions

☐ Fit For Employment With The Following Restrictions
(See Reason Below, Be Specific, Duration of Time, Circumstances, Etc

☐ Desk work only
☐ Sedentary: seated most of the time, minimal physical exertion
☐ Light Work: sit or move about, some walking, stair climbing, bending, stooping or squatting. Lifts or handles up to 25 lbs.
☐ Moderate Work: Lift up to 50 lbs., capable of all other work.
☐ No Lifting over _____ pounds
☐ No excessive walking or standing
☐ No repeated squatting or bending
☐ No work requiring good hearing
☐ No work in area with excessive noise(85dB+)

☐ No work requiring good visual acuity
☐ No work requiring true color vision
☐ Limited respirator use
☐ No respirator use
☐ No working alone
☐ No motor vehicle operation
☐ No rotating shifts
☐ No work at elevation
☐ No rung ladder climbing
☐ No work around dangerous machinery
☐ No exposure to weather extremes

☐ Minimum repetitive motion of _____
☐ Re-evaluate prior to Re-assignment
☐ Other _____

Reason:

☐ Recommend Employment Be Deferred (See reason below, e.g., acute infection, awaiting medical information; specific diagnoses will NOT be stated.)

Reason: _____

☐ Not Fit for Employment (Specify extent and permanence of health problem.)

Reason: _____

☐ Re-Evaluation May Be Scheduled In (Days, weeks, months, years, specify) _____

Review Dates:

HANDICAP CLASSIFICATION

Is this applicant handicapped? ☐ YES ☐ NO

Date | Signed | M.D./P.A./R.N.

UCN-16305
(6 7-87)

DISTRIBUTION:
WHITE - Employment
GREEN - Health Services
YELLOW - Employee
BLUE - Supervisor Copy
PINK - Division

Exhibit 12.2. Request for Pre-placement/Health Evaluation/Medical Restriction Form.

protective equipment may be limited to use of gloves and splash gear when obtaining samples from specific sites (Section 12.6.3). First aid kits shall be available at all times when sampling.

Field sampling clothing should not interfere with operation of instruments, recording of data and collection of samples while protecting against thermal extremes. When environmental conditions persist that prevent these requirements from being met practically, then sampling should be postponed until more favorable conditions prevail. Adequate cold weather clothing (as listed in Section 12.6.2) shall be made available to all sampling team personnel.

12.6.1 Heat Stress

The following measures can be used to monitor and control heat stress:

- Adequate water to replace lost body fluids must be provided.
- All breaks are to be taken in a shaded rest area, or in a moving boat.
- Employees shall always decontaminate their hands and face before rest periods.
- Employees shall remove impermeable protective garments during rest periods.
- All employees shall be informed of the importance of adequate rest, acclimatization, and proper diet in the prevention of heat stress.

12.6.2 Cold Stress

Aquatic sampling may expose sampling personnel to cold stress during extremely cold weather. Cold stress may also strike inadequately clothed personnel during summer rain storms. One or more of the following measures should be used to help control cold stress:

- Thermal clothing needs to be capable of retaining warmth when wet. Articles manufactured from wool, silk, neoprene or thinsulate are preferred to articles made of cotton or nylon.

- Areas of the body with high surface-area-to-volume-ratios, such as limbs, feet, hands, the head and ears are most susceptible to cold stress. Thermal socks, gloves and hats may be necessary.
- Dress in layers: Jackets, shirts and sweaters should be layered over long thermal underwear.
- Personnel should avoid getting wet during any season. Adequate rain gear should be available, and it should be maintained in good condition, or replaced periodically.
- If personnel should find themselves in the water, techniques such as keeping head out of the water and the inverted jelly fish float should be used to reduce heat loss.
- Adequate extra clothing should be carried in the boat in a secure, dry location.
- Warm drinks (other than caffeinated coffee), and warm break areas are essential.
- Emergency equipment should include thermal blankets.
- All employees shall be informed of the importance of adequate rest, acclimatization, and proper diet in the prevention of cold stress.

Cold stress should always be considered a most serious threat to health and safety when conducting aquatic sampling. Conditions in which cold stress may be encountered include:

- Ambient temperatures at or below freezing may cause unprotected skin to be frostbitten over time. Extreme cold for a short time may cause sever injury to the surface of the body or result in profound generalized cooling.
- A second factor influencing the development of a cold injury is wind chill. Wind chill effects may be eliminated by covering exposed skin and seeking a wind block on board.
- Wet conditions add substantially to the possibilities for cold stress.

12.6.3 Protective Equipment for Specific Sites

The sampling task may expose sampling team personnel to potentially hazardous concentrations of contaminants in Poplar Creek or in White Oak Creek Embayment.

Existing data indicate that sampling of other sites does not constitute a contamination hazard.

Potential contaminant hazards of sampling PCE results from direct contact with sediment. Protective clothing to be worn by personnel involved in sediment collection and processing shall include anti-contamination gloves, splash gear, and boots. Personnel responsible for recording data and chain-of-custody procedures not in direct contact with the sediments shall not be required to wear protective clothing.

Contaminant hazards to sampling personnel in WOCE result from direct contact with sediment contaminated by hazardous concentrations of industrial wastes and radioactive materials. Principal hazards originate from gamma emitters. Protective clothing to be worn by personnel involved in sediment collection and processing shall include contamination zone coveralls, anti-contamination gloves and boots, and disposable rain paints. Additional protection in the field will be provided by the use of pocket dosimeters. Personnel responsible for recording data and chain-of-custody procedures outside of the contamination zone shall not be required to wear protective clothing. A beta-gamma scan shall be performed in the field on collected coves. If environmental conditions permit, sediment cores should be processed in the field. Scans of potentially contaminated sampling devices and clothing shall be completed by HP personnel before returning to ESD laboratories. If radioactivity exposure levels greater than 10 millirem per hour are detected, further sampling should be postponed and all personnel moved a safe distance from the contaminated area. The procedures outlined in the Decontamination section (Section 12.9) shall be followed before sampling is allowed to resume.

12.6.4 Protective Equipment for Specific Tasks

Specific protective equipment requirements are summarized by task. Protective equipment will be provided and must be inspected during use to ensure suitability. The team leader or the user is responsible for equipment inspection.

BOAT ELECTROSHOCKING: Personnel operating electroshockers and those netting fish are required to wear the following protective equipment:

- Insulating gloves.
- Insulating boots.
- Personal flotation devices.
- Safety glasses.
- Hearing protection

SEDIMENT CORING: Personnel collecting sediment samples, by ponar grab sample, gravity core, or vibracore device are required to wear the following protective clothing:

- Protective gloves.
- Boots.
- Safety glasses.
- Hearing protection (only for using vibracorer).

12.7 AIRBORNE CONTAMINANTS

Airborne concentrations of chemical and radiological contaminants should not be routes of exposure significant enough to justify air monitoring. No site monitoring for airborne contaminants is planned in conjunction with the CRRFI. Certain tasks involving the use of internal combustion engines in sampling (specifically, electroshocking and sediment coring) shall be conducted in a manner to minimize exhaust fumes and noise pollution. Adequate ventilation shall be provided, and engine operation times shall be limited to achieve minimal exhaust and noise pollution.

12.8 WATER SAFETY

Primary attention shall be given to USCG and ESD boating safety procedures. These regulations include the following requirements:

- At least one USCG approved fire extinguishers shall be carried on each boat.
- Decks and other working surfaces shall be maintained in a safe condition.

- One USCG approved 30 inch life-ring with not less than 90 feet of line attached shall be on each boat.
- One portable ladder which will reach from the top of the gunwale to the surface of the water shall be on each boat.
- No smoking, matches or open flames of any sort will be permitted in the boats.
- Daily inspection of all safety equipment and systems shall be documented by team leaders.

Additional requirements and training procedures are found in Section 12.3.4, and in the ESD Boating Safety Procedures. An annual training course in water safety and safe boating practices will be required for all ORNL-ESD and subcontractor personnel involved in field sampling on the CRRFI Project.

12.9 DECONTAMINATION

12.9.1 Regulated Areas

12.9.1.1 Delineated Zones

Each laboratory working area that is restricted for purposes of minimizing the spread of contamination shall be divided into three zones, as follows:

- Contaminated Zone: This zone includes the actual areas of contamination. This zone has the highest exposure potential and/or presents a high probability of skin contact with contaminants.
- Contamination Reduction Zone: This zone includes the areas immediately surrounding the Contamination Zone. This zone does not have a high probability of skin contact with cutaneous or percutaneous effecting chemicals.
- Clean Zone: This zone covers all areas outside of the contamination reduction zone. Adverse exposure to contaminants is unlikely.

The H&S Coordinator and Sampling Team Leader shall establish these zones based on the amount and nature of contamination present and the specific sampling activities. The criteria to establish a delineated zone for purposes of radiation protection is outlined in the ORNL HP procedure 2.7. In general, a contamination zone shall be established when the limits given in Table 12.1 are exceeded.

12.9.1.2 Access

Access to contaminated working areas (contaminated and contamination reduction zones) shall be regulated and limited to authorized persons. Entrance and exit from a contamination zone will be made through a specified point, equivalent to a step off pad, as described in ORNL Procedure 2.7. If the areas is restricted in order to control radioactive contamination a portable instrument shall be used to frisk one's clothing, hands and feet before exiting. The HP department will select the appropriate instrument based on the type of radiation, detecting limits and radiation background. A monitoring procedure will be established in accordance with ORNL HP procedure 3.5.

12.9.1.3 Posting

Warning signs shall be affixed in readily visible locations in or near contaminated work areas. The information contained thereon shall be arranged as in Fig 12.1. Provisions to post areas for purposes of radiation protection are specified in ORNL HP procedure 2.3. Where radiation contamination is of concern, the standard radiation symbol shall be displayed with the appropriate colors, magenta on a yellow background.

12.9.2 Employee Decontamination

Decontamination is accomplished through a step-by-step procedure whereby the protective clothing and equipment is either washed or disposed of. The H&S Coordinator or his designee is responsible for the establishment of the contamination reduction zone. Monitoring during sampling activities may indicate the need for additional stations under certain conditions. It is also possible that extraneous stations

Table 12.1. Exposure limits for the establishment of contamination zones[a].

Type of radiation	Fixed Contamination ($dpm/100cm^2$)	Removable Contamination ($dpm/100cm^2$)
Alpha	300	30
Beta-gamma	0.24 mr/hr	1000

[a]Subject to final review.

CAUTION

CONTAMINATED AREA

AUTHORIZED PERSONNEL ONLY

Fig. 12.1. Example of warning signs to be affixed in readily visible locations in or near contaminated work areas.

may be combined. Allowances must be made for the type of protective equipment being worn; for example, nondisposable, steel-toed outer boots need not be removed if properly decontaminated.

Procedures to remove protective clothing and minimize the spread of radioactive material are established in ORNL HP procedure 2.10 and 2.11. Specific procedures will be developed by the Health and Safety coordinator and the ORNL Health Physics department and posted near the step off area.

12.9.3 Equipment Decontamination

12.9.3.1 Personnel Protective Equipment

In a designated area within the contamination reduction zone, the following procedures shall be followed:

- All reusable protective equipment shall be decontaminated.
- Protective clothing removed from contamination reduction zone for cleaning or laundering shall be bagged and appropriately labeled.
- All disposable protective clothing shall be bagged and labeled. These bags shall be treated as hazardous waste (chemical and/or radioactive).

12.9.3.2 Equipment Decontamination

Before returning to the laboratory, potentially contaminated equipment will be decontaminated or containerized. Verification that equipment has been adequately decontaminated is the responsibility of the Sampling Team Leader. Decontamination equipment shall include: plastic garbage barrels, liners for garbage barrels, alconox detergent concentrate, long handle soft bristle brushes, large sponges, small stools or step ladders, plastic bags, liquid detergent, and paper towels.

12.9.4 Decontamination Zone General Rules

The following rules shall apply to all decontamination zone activities:

- An area in the decontamination zone shall be designated as the break areas. Employees shall wash their faces and hands before eating or drinking. No eating, drinking, or smoking shall take place in the contaminated zone.
- Eyewash facilities and shower capabilities shall be provided at the laboratory work site.
- All entry to and exit from the decontamination zone shall be strictly controlled.
- The H&S Coordinator shall monitor the effectiveness of the decontamination procedures and shall take appropriate steps to correct any deficiencies or modify the plan if needed.

12.10 EMERGENCY PROCEDURES

These supplementary emergency response procedures have been developed to cover extraordinary conditions that might possibly occur at the site. All emergencies and injuries, other than minor events, will be reported to the Health and Safety Coordinator.

12.10.1 General

All incidents will be dealt with in a manner to minimize adverse health risks to site workers and spread of contamination. In the event an incident occurs, the following procedure will be followed:

- First aid or other appropriate initial action will be administered by properly trained personnel who are closest to the incidents. This assistance will be conducted in a manner to ensure that those rendering assistance are not placed in a situation of unacceptable risk.

- All incidents will be reported to the Sampling Team Leader. The Sampling Team Leader will decide if off-site assistance and medical treatment are required and will arrange for assistance.

- All sampling team personnel are responsible for conducting themselves in a manner to avoid spreading the danger to themselves and surrounding workers.

The following emergency equipment will be available at the site:

- First-aid kit
- Fire extinguisher and blanket
- Appropriate decontamination equipment and material

The Sampling Team Leader will document all H&S risk incidents.

12.10.2 Responses to Specific Situations

Emergency procedures for specific situations are given in the following subsections.

12.10.2.1 Personal Injury

If a sampling team member is physically injured, Red Cross first-aid procedures will be followed. Depending on the severity of the injury, emergency medical response may be sought. Seriously injured personnel shall not be removed from the scene unless imminent hazards exist. Professional medical help should be present before moving victims to prevent additional injury. If the injuries are minor, additional first aid will be conducted at a safe distance from the work site.

If the injury to the worker is chemical in nature (e.g., overexposure), the following first-aid procedures are to be instituted:

- Eye Exposure - If contaminated soils or liquids get into the eyes, wash eyes for at least 15 minutes. Obtain medical attention immediately. Safety glasses will be worn when performing specified tasks.

- Skin Exposure - If contaminated solids or liquids get on the skin, promptly wash the contaminated skin using soap or mild detergent and water for at least 15 minutes. Obtain medical attention immediately when exposed to concentrated solids or liquids.

Other potential hazards to personnel include those from animals (snake bite, insect sting, or puncture wounds from fish), poisonous plants and slip/trip/fall hazards. Additionally, there is always the potential for drowning accidents. In the event an injury results from these hazards, Red Cross first aid procedures will be followed by certified personnel. If necessary, emergency medical response will be sought.

12.10.2.2 Fires

As a fire prevention measure, no smoking, matches or open lights will be permitted in any boat. Dry chemical fire extinguishers, rated for class A, B, and C fires, will be provided. If a localized fire breaks out, dry chemical fire extinguishers will be used to bring the fire under control. If necessary and feasible, a fire blanket, soil, or other inert materials will be placed on the burning area to extinguish the flames and to minimize the potential for spreading. If appropriate, the fire department will be contacted for assistance. All fires and use of fire extinguishers will be reported to the Health & Safety Coordinator.

If an uncontrolled fire develops releasing potentially toxic gases, all persons in the immediate vicinity will be evacuated. Contact with the fire department will be made immediately to notify them of the materials involved.

12.10.2.3 Spills

In the event of a spill in a boat, the area will be isolated from traffic by the sampling team leader. Spilled solids will be removed and loaded into appropriate containers for subsequent placement or taken to the original destination. Liquid spills will be contained with absorbent material and then the absorbent will be loaded into appropriate containers for disposal.

12.10.3 Notification

Maps showing routes to the hospital, clinic, fire department, and police will be located in the boats along with the emergency phone numbers and radio instructions (ESD 1988b). Emergency telephone numbers are found in Table 12.2.

The Sampling Team Leader will be responsible for contacting these organizations if necessary. If the fire department or paramedic emergency services are required, the will provide transportation to the hospital. For less serious circumstances, the Sampling Team Leader or designated representative will provide transportation to the hospital or on-site medical facilities. Communications will be established prior to conduct of off-site sampling runs. The nearest phone to each sampling site will be identified. Each sampling team shall be equipped with an ORNL laboratory band radio.

12.10.4 Documentation

In the event of an emergency, or a H&S risk incident, the sampling team leader will produce a report describing the following:

- The incident (including date and time) that necessitated the notification and the basis for that decision.
- Date, time, and names of all person/agencies notified and their responses.
- Resolution of the incident (including duration) and the method/corrective action involved.

Table 12.2. Emergency telephone and ORNL radio call numbers.[a]

Responder	Radio call	Number Telephone
ORNL Shift Superintendent	KIN-294	4-6606
Fire Department		911
Paramedic/Rescue		911
Emergency Hospital		911
National Response Center (for toxic chemicals and oil spills, USCG and EPA will be notified)		(800) 424-8802
CHEMTREC (For information and assistance in the event of a chemical release)		(800) 424-9300

[a]Subject to final review.

This report will be submitted to the H&S Coordinator within 5 working days of the resolution of the event.

12.11 SANITATION

An adequate supply of potable water will be transported to the sampling site each day. Portable containers used to dispense drinking water will be capable of being tightly closed and will be equipped with a tap. Water will not be dipped from the container. Containers used to distribute drinking water will be clearly marked and not used for any other purpose. When single service cups (to be used but once) are supplied, both a sanitary container for the unused cups and a receptacle for disposing of the used cups will be provided. Containers of nonpotable water (such as DI water used for rinsing sampling devices) will be identified to clearly indicate that the water is not to be used for drinking or washing.

The location of the nearest available toilet facilities will be determined in advance. Sampling team personnel should make optimal use of laboratory toilet facilities. Rest stops will be made during long sampling runs. Toilet facilities will not be located at sampling sites.

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APPENDIX A

CRRFI STAFF: PERSONNEL AND CREDENTIALS

S. MARSHALL ADAMS

Ph.D., Marine Science, 1974, University of North Carolina

PROJECT POSITION: Biota Sampling Team Leader, Risk Assessment Staff; ORNL-ESD

AREAS OF EXPERTISE: Bioindicators of chronic contaminant stress in aquatic systems, reservoir and marine ecology, food chain relationships and energy flow in aquatic systems.

STEVEN M. BARTELL

Ph.D., Oceanography and Limnology, 1978, University of Wisconsin-Madison

PROJECT POSITION: Data Management Task Leader; ORNL-ESD

AREAS OF EXPERTISE: Systems ecology, ecological modeling, risk analysis.

B. A. BERVEN

Ph.D., Radiology and Radiation Biology, 1979, Colorado State University

PROJECT POSITION: Site Characterization Staff; ORNL-HASRD

AREAS OF EXPERTISE: Radiological risk assessments, radiation measurement instrumentation and dosimetry.

B. GORDON BLAYLOCK

Ph.D., Zoology, 1963, University of Tennessee

PROJECT POSITION: Risk Assessment Task Leader, Sampling and Analysis Coordinator; ORNL-ESD

AREAS OF EXPERTISE: Radiation effects and toxicity of environmental pollutants, trace elements and radionuclide cycling in aquatic systems, environmental assessment.

ROBERT B. COOK

Ph.D, Geochemistry, 1981, Columbia University

PROJECT POSITION: Site Characterization Task Co-Leader; ORNL-ESD

AREAS OF EXPERTISE: Aqueous geochemistry, chemical limnology, biogeochemistry, mechanisms controlling pH in aquatic ecosystems.

W. DENNIS CRUMBY

M.S., Fisheries, 1987, Tennessee Technological University

PROJECT POSITION: Risk Assessment Staff; ASG

AREAS OF EXPERTISE: Age and growth of centrarchid fishes, fisheries management.

K. F. ECKERMAN

Ph.D., Environmental Health Engineering, 1972, Northwestern University

PROJECT POSITION: Risk Assessment Staff; ORNL-HASRD

AREAS OF EXPERTISE: Radiological assessment.

E. L. ETNIER
M.A., Zoology, 1965, University of Tennessee
PROJECT POSITION: Risk Assessment Staff; ORNL-HASRD
AREAS OF EXPERTISE: CERCLA sites, ARARs determination.

CLELL J. FORD
M.S., Ecology, 1988, University of Tennessee
PROJECT POSITION: Water and Sediment Sampling Team Leader, Analytical Services Coordinator, Site Characterization Staff; ASI
AREAS OF EXPERTISE: Contaminant transport and fate in river- reservoir ecosystems, watershed-river-reservoir interaction, production and fate of organic matter.

MARILYN L. FRANK
M.S., Radiation Biology, 1970, University of Tennessee
PROJECT POSITION: Risk Assessment Staff; ORNL-ESD
AREAS OF EXPERTISE: Radiation effects on aquatic organisms, radionuclide cycling in aquatic environments.

MARILYN L. GENTRY
B. S., Education, 1973, Mississippi State University
PROJECT POSITION: Data Management Staff; SAIC
AREAS OF EXPERTISE: Data Management

JACQUELINE M. GREBMEIER
Ph.D., Biological Oceanography, 1987, University of Alaska, Fairbanks
PROJECT POSITION: Site Characterization Staff; University of Tennessee
AREAS OF EXPERTISE: Sediment biogeochemistry, benthic carbon cycling, radiochemistry, benthic faunal population studies.

F. OWEN HOFFMAN
Ph.D., Ecology, 1981, University of Tennessee
PROJECT POSITION: Risk Assessment Staff; ORNL-ESD
AREAS OF EXPERTISE: Validation of environmental assessment models, food chain bioaccumulation of toxic substances, development and application of methods for environmental risk analysis.

LESLIE A. HOOK
Ph.D., Zoology, 1988, Southern Illinois University
PROJECT POSITION: Data Management Staff; SAIC
AREAS OF EXPERTISE: Research data management, assessment of contaminant effects on aquatic ecosystems.

BRUCE L. KIMMEL

Ph.D., Ecology, 1977, University of California, Davis

PROJECT POSITION: Project Manager; ORNL-ESD

AREAS OF EXPERTISE: Organic matter production and processing in streams, lakes, reservoirs, and river-reservoir systems; nutrient cycling; phytoplankton productivity and ecophysiology; pelagic-benthic coupling; terrestrial-aquatic linkages; ecosystem resilience; biogeochemical processes; contaminant transport and fate.

INGVAR LAUREN LARSEN

M.S., Oceanography, 1971, Oregon State University

PROJECT POSITION: Site Characterization Staff; ORNL-ESD

AREAS OF EXPERTISE: Radioecology of marine and aquatic environments, gamma-ray spectrometry, trace metals analysis, activation analysis, atomic absorption spectrophotometry, geochemistry, Cerenkov radiation counting, quality assurance/quality control.

P. Y. LU

Ph.D., Environmental Toxicology, 1974, University of Illinois

PROJECT POSITION: Risk Assessment Staff; ORNL-HASRD

AREAS OF EXPERTISE: Environmental toxicology of toxic/hazardous substances.

RON K. McCONATHY

M.S., Forestry, 1976, University of Tennessee

PROJECT POSITION: Health & Safety Coordinator; ORNL-ESD

AREAS OF EXPERTISE: Safety, quality assurance, waste management, training, radiation safety, forest ecology, forest physiology.

SCOTT L. NIEMELA

M.S., Biology, 1989, Tennessee Technological University

PROJECT POSITION: Site Characterization, Risk Assessment Staff; ASG

AREAS OF EXPERTISE: Fisheries management techniques, habitat analyses of stream fishes.

CURTIS R. OLSEN

Ph.D., Geochemistry, 1979, Columbia University

PROJECT POSITION: Site Characterization Task Co-Leader; ORNL-ESD

AREAS OF EXPERTISE: Fate of particles, radionuclides, and pollutants in aquatic systems; oceanography; sediment geochemistry; sedimentology.

LARRY E. ROBERSON
M.S., Zoology, 1973, University of Tennessee
PROJECT POSITION: Project QA Specialist; ORNL-QA Division
AREAS OF EXPERTISE: Certified quality assurance lead auditor.

KENNETH A. ROSE
Ph.D., Fisheries, 1985, University of Washington
PROJECT POSITION: Data Management Staff; ORNL-ESD
AREAS OF EXPERTISE: Simulation modeling and techniques; population, community, and ecosystem dynamics; ecotoxicology; toxicant fate and effects; aquatic systems, uncertainty analysis, trend detection.

R. H. ROSS
M.S., Biology, 1974, East Tennessee State University
PROJECT POSITION: Risk Assessment Staff; ORNL-HASRD
AREAS OF EXPERTISE: Ecological and human health risk assessments.

GLENN W. SUTER II
Ph.D., Ecology, 1976, University of California, Davis
PROJECT POSITION: Risk Assessment Staff; ORNL-ESD
AREAS OF EXPERTISE: Ecological toxicology, environmental risk assessment, soil ecology.

S. S. TALMAGE
Ph.D., Environmental Toxicology, 1989, University of Tennessee
PROJECT POSITION: Risk Assessment Staff; ORNL-HASRD
AREAS OF EXPERTISE: Environmental and human health risk assessment at CERCLA sites.

C. C. TRAVIS
Ph.D., Mathematics, 1971, University of California at Davis
PROJECT POSITION: Risk Assessment Staff; ORNL-HASRD
AREAS OF EXPERTISE: Human health risk assessment.

KAREN L. VON DAMM
Ph.D., Oceanography, 1983, Massachusetts Institute of Technology-Woods Hole Oceanographic Institution
PROJECT POSITION: Site Characterization Staff; ORNL-ESD
AREAS OF EXPERTISE: Geochemistry, oceanography, sea-floor hydrothermal systems, groundwater chemistry, mineral solubilities, water-rock interaction.

LARRY D. VOORHEES

Ph.D., Zoology, 1976, North Dakota State University

PROJECT POSITION: Director, Data Information Management System, Data Management Staff; ORNL-ESD

AREAS OF EXPERTISE: Computerized data acquisition, manipulation, analysis, and presentation; population and community ecology; wildlife management; environmental impact assessment.

R. K. WHITE

Ph.D., English, 1985, University of Tennessee

PROJECT POSITION: Risk Assessment Staff; ORNL-HASRD

AREAS OF EXPERTISE: Hazardous waste risk assessment and management, document preparation.

APPENDIX B

DATA MANAGEMENT FORMS

CLINCH RIVER RFI FIELD CHAIN-OF-CUSTODY FORM FOR SEDIMENT SAMPLES

Site:	Field Custodian Signature: _____	C-of-C Form No.:
	Sampling Team Signatures:	Page 1 of ____
Date:		Return to: C. J. Ford P.O. Box 2008, MS-6351 Oak Ridge, TN 37831-6351
Time __:__ (military) hh mm		

Sample Identification	Core Liner /Container Type	FIELD (INITIALS) Custody Seals	Collection Form Attach	Requested Analysis	Transfer Custody to: C-of-C Form No.	LABORATORY (INITIALS) Section	Custody Storage	Samples to Analysis

1) Sample custody transfer Date: __ __ __ (dd mmm yy) Time __:__ (hh mm)	2) Sample custody transfer Date: __ __ __ (dd mmm yy) Time __:__ (hh mm)
Relinquished by: _____ of _____ (org.)	Relinquished _____ of _____ (org.)
Received by: _____ of _____ (org.)	Received by: _____ of _____ (org.)

V.1.1 1/18/90

Exhibit B.1 Clinch River RFI Field Chain-of-custody form for sediment samples.

CLINCH RIVER RFI FIELD CHAIN-OF-CUSTODY FORM FOR SEDIMENT SAMPLES (Continuation Sheet)

Site:	Field Custodian Signature: _____	C-of-C Form No.:
	Continuation Sheet: See Page 1 of this C-of-C Form No. for sampling team signatures. [redacted]	Page ____ of ____
Date:		Return to: C. J. Ford P.O. Box 2008, MS-6351 Oak Ridge, TN 37831-6351
Time __:__ (military) hh mm		

Sample Identification	Core Liner /Container Type	FIELD (INITIALS) Custody Seals	Collection Form Attach	Requested Analysis	Transfer Custody to: C-of-C Form No.	LABORATORY (INITIALS) Section	Custody Storage	Samples to Analysis

V.1.1 1/18/90

Exhibit B.2 Clinch River RFI Field Chain-of-custody form for sediment samples (continuation page).

SEDIMENT DATA COLLECTION FORM

(AFFIX TO OUTSIDE OF SEDIMENT CORE LINER)

DATE:__ ___ __ SITE:_____ TIME: __:__
dd mmm yy hh mm

SAMPLE IDENTIFICATION CODES: _____

_____

ANALYSES:_____

_____

SAMPLING TEAM MEMBERS:_____

_____

FIELD CUSTODIAN:_____/SIGNATURE:_____

CORE TUBE LINER IDENTIFICATION:

Exhibit B.3 Sediment data collection form.

CLINCH RIVER RFI LAB CHAIN-OF-CUSTODY FORM FOR SEDIMENT SAMPLES

Site:	Lab Custodian Signature: _____	C-of-C Form No.:
	Processing Team Signatures:	Page 1 of ____
Date:		Return to: C. J. Ford P.O. Box 2008, MS-6351 Oak Ridge, TN 37831-6351
Time __:__ (military) hh mm		

Sample Identification	Depth Increment of section	Container Type	Requested Analysis	Sample transferred from: C-of-C Form No.	Preservative Action (Initial when preserved)

1) Custody transfer: Date: __ __ __ (dd mmm yy) Time __:__ (hh mm) Relinquished by: _____ of _____ (org.) Received by: _____ of _____ (org.)	2) Custody transfer: Date: __ __ __ (dd mmm yy) Time __:__ (hh mm) Relinquished by: _____ of _____ (org.) Received by: _____ of _____ (org.)
3) Custody transfer: Date: __ __ __ (dd mmm yy) Time __:__ (hh mm) Relinquished by: _____ of _____ (org.) Received by: _____ of _____ (org.)	4) Custody transfer: Date: __ __ __ (dd mmm yy) Time __:__ (hh mm) Relinquished by: _____ of _____ (org.) Received by: _____ of _____ (org.)

V.1.1 1/18/90

Exhibit B.4 Clinch River RFI Lab Chain-of-custody form for sediment samples.

CLINCH RIVER RFI LAB CHAIN-OF-CUSTODY FORM FOR SEDIMENT SAMPLES (continuation sheet)

Site:	Lab Custodian Signature: _____	C-of-C Form No.:
Date:	Continuation Sheet: See Page 1 of this C-of-C Form No. for processing team signatures. [redacted]	Page ____ of ____
Time __:__ (military) hh mm		Return to: C. J. Ford, P.O. Box 2008, MS-6351, Oak Ridge, TN 37831-6351

Sample Identification	Depth Increment of section	Container Type	Requested Analysis	Sample transferred from: C-of-C Form No.	Preservative Action (Initial when preserved)

V.1.1 1/18/90

Exhibit B.5 Clinch River RFI Lab Chain-of-custody form for sediment samples (continuation page).

REQUEST FOR ORNL ANALYTICAL SERVICES

SEE REVERSE SIDE FOR INSTRUCTIONS

ACD REQUEST NO.

PAGE ___ OF ___

*[4] CHAIN OF CUSTODY YES [ ]

[5] SAMPLE MATRIX

[6] DEADLINE (MM/DD/YY)

[7] PROJECT NO

[8] SERIES

[9] CUSTOMER NAME

BUILDING · MAIL STOP

[10] CHARGE NO.

[12] CUST. DEPT. NO.

[13] SAMPLED FROM

[16] FREQUENCY

[19] MATERIAL DESCRIPTION

COMMENTS:

NOTE: Customers should pick up samples within 10 days of reporting results. Additional charges may result if ACD is required to dispose of samples

Compliance Sample? RCRA [ ] NPDES [ ] OTHER [ ]

If *Other*, please specify in comments

ACD NUMBER	[11] CUSTOMER SAMPLE ID (15)	[17] SAMPLE DATE MM/DD/YY	TIME	[23] ANALYSIS (30)	METHOD ID (14)	DETECTION LIMITS

* [AnaLIS Field No] Field Name (No Char)

To arrange E-trans of data send E-mail to STC : NTJ or TEASLEYNAJR on OA VAX

RECEIVED BY:

SUBMITTED BY./PHONE

UCN-16522

Exhibit B.6 Request for ORNL analytical services form.

WATER DATA COLLECTION FORM (AFFIX TO OUTSIDE OF COOLER)

SITE: _____ DATE: __ ___ __ (dd mmm yy) TIME: __:__ (hh mm)

SAMPLE IDENTIFICATION CODES: _____

_____

ANALYSES: _____

_____

SAMPLING TEAM MEMBERS: _____

_____

FIELD CUSTODIAN: _____ /SIGNATURE: _____

COOLER #: COOLER TEMP (deg C)
THERMOMETER #:
(RESET AFTER EACH READING)

TIME	MAX	MIN

Exhibit B.7 Water data collection form.

CLINCH RIVER RFI FIELD CHAIN-OF-CUSTODY FORM FOR SURFACE WATER SAMPLES

Site:	Field Custodian: _____	C-of-C Form No.:
	Sampling Team Signatures:	Page 1 of ____
Date:		Return to: C. J. Ford P.O. Box 2008, M.S. 6351 Oak Ridge, TN 37831-6351
Time __:__ (military) hh mm		

Sample Identification	Collection Bottle Type	Container Type	Preservative Action (init compl.)	Requested Analyses	LABORATORY (INITIALS) Sample transferred to: (Samp ID # & init.) 1	2	3	C-of-C Form No.	Sample to Analysis

1) Sample custody transfer DATE: __ __ __ (dd mmm yy) TIME __:__ (hh mm)	2) Sample custody transfer DATE: __ __ __ (dd mmm yy) TIME __:__ (hh mm)
Relinquished by:	Relinquished by:
Received by: _____ of _____(org.)	Received by: _____ of _____(org.)

V.3.2 1/18/..

Exhibit B.8 Clinch River RFI Field Chain-of-custody form for water samples.

CLINCH RIVER RFI FIELD CHAIN-OF-CUSTODY FORM FOR SURFACE WATER SAMPLES

Site:	Field Custodian:_____	C-of-C Form No.:
	SEE PAGE 1 SAME C-OF-C FORM FOR Sampling Team Signatures:	Page 1 of ____
Date:	[redacted]	Return to: C. J. Ford P.O. Box 2008, M.S. 6351 Oak Ridge, TN 37831-6351
Time __:__ (military) hh mm		

Sample Identification	Collection Bottle Type	Container Type	Preservative Action (init compl.)	Requested Analyses	LABORATORY (INITIALS) Sample transferred to: (Samp ID # & init.) 1	2	3	C-of-C Form No.	Sample to Analysis

V.3.2 1/18/

Exhibit B.9 Clinch River RFI Field Chain-of-custody form for water samples (continuation page).

CLINCH RIVER RFI LAB CHAIN-OF-CUSTODY FORM FOR SURFACE WATER SAMPLES

Site: Date: Time __:__ (military) hh mm	Custodian: _____ Processing Team Signatures:	C-of-C Form No.: Page 1 of ____ Return to: C. J. Ford P.O. Box 2008, M.S. 6351 Oak Ridge, TN 37831-6351

Sample Identification	Container Type	Preservative Action (init compl.)	Requested Analyses	Sample transferred from: C-of-C Form No.	Sample to Analysis

1) Sample custody transfer DATE: __ __ __ (dd mmm yy) TIME __:__ (hh mm) Relinquished by: _____ of _____(org.) Received by: _____ of _____(org.)	2) Sample custody transfer DATE: __ __ __ (dd mmm yy) TIME __:__ (hh mm) Relinquished by: _____ of _____(org.) Received by: _____ of _____(org.)
3) Sample custody transfer DATE: __ __ __ (dd mmm yy) TIME __:__ (hh mm) Relinquished by: _____ of _____(org.) Received by: _____ of _____(org.)	4) Sample custody transfer DATE: __ __ __ (dd mmm yy) TIME __:__ (hh mm) Relinquished by: _____ of _____(org.) Received by: _____ of _____(org.)

V.1.2 1/19/90

Exhibit B.10 Clinch River RFI Lab Chain-of-custody form for water samples.

CLINCH RIVER RFI LAB CHAIN-OF-CUSTODY FORM FOR SURFACE WATER SAMPLES (continuation sheet)

Site:	Custodian: _____	C-of-C Form No.:
	Continuation Sheet: See Page 1 of this C-of-C Form No. for processing team signatures. [redacted]	Page ____ of ____
Date:		Return to: C. J. Ford P.O. Box 2008, M.S. 6351 Oak Ridge, TN 37831-6351
Time __:__ (military) hh mm		

Sample Identification	Container Type	Preservative Action (init compl.)	Requested Analyses	Sample transferred from: C-of-C Form No.	Sample to Analysis

V.1.2 1/19/90

Exhibit B.11 Clinch River RFI Lab Chain-of-custody form for water samples (continuation page).

DATA COLLECTION FORM

SITE _____

TIME _____

DATE _____

TAG NUMBERS _____

_____

SPECIES _____ No _____

_____ _____

_____ _____

_____ _____

COLLECTORS _____

_____

FIELD CUSTODIAN _____

Exhibit B.12 Data collection form.

BIOACCUMULATION STUDIES - CHAIN OF CUSTODY FORM

COLLECTION DATA:

Site _____

Date _____

Time _____

Collectors _____

TRANSFER, Collector to Custodian

Relinquished by _____ Date/Time _____

Received by _____ Date/Time _____

Program _____

Form No. _____

Page _____ of _____

SAMPLE DATA:

Fish Tag No.	Species	Sample ID No.	Analyses					Archive		Comments
			Hg	PCB	Other					

TRANSFER, _____ samples from Custodian to _____
(Analysis) (laboratory)

Relinquished by _____ Date/Time _____

Received by _____ ACD Req. No. _____

TRANSFER, _____ samples from Custodian to _____
(analysis) (laboratory)

Relinquished by _____ Date/Time _____

Received by _____ ACD Req. No. _____

TRANSFER, _____ samples from Custodian to _____
(Analysis) (laboratory)

Relinquished by _____ Date/Time _____

Received by _____ ACD Req. No. _____

TRANSFER, _____ samples from Custodian to _____
(analysis) (laboratory)

Relinquished by _____ Date/Time _____

Received by _____ ACD Req. No. _____

Exhibit B.13 Bioaccumulation studies - chain of custody form.

APPENDIX C

CRRFI DOCUMENT CONTROL

CRRFI DOCUMENT CONTROL

A PROCEDURE DEVELOPED FOR THE ORNL REMEDIAL ACTION PROGRAM'S CLINCH RIVER RCRA FACILITY INVESTIGATION (CRRFI) PROJECT

1. PURPOSE

The purpose of this procedure is to describe the management system that has been developed for the issuance and distribution of controlled documents and any updates to these documents that have been prepared for, or by, the Clinch River RCRA Facility Investigation
(CRRFI) Project.

2. DEFINITIONS

1. Controlled Document - any document that has been designated by the CRRFI Project Manager to be issued, distributed and updated according to the document control activities described in this procedure. For the CRRFI project, the control activities are limited to the issuance and distribution of controlled documents and to any updates to these documents. This procedure does not address any control activities that may be involved in the preparation, i.e. editing, proofreading, and review of the document. This procedure affects only the activities that take place after a camera-ready copy of the document is available from the CRRFI Project Management.

2. Controlled Document Logbook - a logbook which contains: (1) a list of all controlled documents issued and (2) a log of all recipients of each controlled document. The document control manager will maintain the controlled document logbook until directed by the CRRFI project manager to transfer it to another program staff member.

3. Document Control - an activity which involves the issuance and distribution of controlled documents and any updates to the documents that have been prepared for, or by, the CRRFI project. This activity also provides a mechanism to account for all copies prepared (both assigned and unassigned extra copies retained) of all controlled documents.

4. Document Control Archive - a hardcopy resource collection which is maintained by the CRRFI Document Control Center. The archive contains the controlled document logbook, all verification receipt transmittal forms, and all unissued copies of controlled documents.

5. Document Control Center - a group supported by the Clinch River RCRA Facility Investigation (CRRFI) Project to develop and maintain a management system for the issuance and distribution of all CRRFI controlled documents as specified by CRRFI project management.

6. Document Control Manager - the individual assigned by the CRRFI project manager to implement and supervise the document control activity. The current Document Control Manager is Park T. Owen, Health and Safety Research Division, Building 2001, MS-6050 (6- 0568).

7. CRRFI Data Base Manager - the person responsible for the management of all textual and numeric data resources developed for the CRRFI Project. The Data and Information System (DIMS) is the organization that develops and manages these resources. The current DIMS Manager is Larry D. Voorhees, Building 1505, MS-6036 (4-7309).

8. Record Document - any document for which long-term storage or permanent retention is required.

9. CRRFI Project Manager - the current CRRFI Project Manager is Bruce L. Kimmel, Building 1504, MS-6351 (4-7833).

10. Verification Receipt Transmittal - a form attached to each controlled document which must be signed and dated by the recipient to verify that the attached document has been received and is currently being retained. The form is to be returned to the CRRFI Document Control Manager.

3. SCOPE

This procedure applies to the issuance and distribution of all controlled documents and all subsequent updates to these documents. The CRRFI documents to be controlled by this procedure will be designated by the CRRFI Project Manager. A copy of the list of the documents to be controlled will be contained in the controlled document logbook.

4. IMPLEMENTATION ACTIVITIES

The following activities will be performed by the Document Control Center to implement this procedure:

1. Obtain from the CRRFI Project Manager a master copy (reproducible) of each document to be issued as a controlled document.

2. Ensure that the document has been: (1) approved for publication by the CRRFI project manager, and if appropriate (2) assigned a report number by ORNL Laboratory Records (if appropriate),

3. Prepare an ORNL Document Approval form for each publication and obtain all needed approvals before the release of the document,

4. Produce a sufficient number of copies to satisfy current distribution and a minimum of five extra documents to satisfy emergency distribution needs. The distribution list for each controlled document is established by the CRRFI Project Manager. DOE-ORO has requested the CRRFI Project Manager to ensure that one controlled copy and eleven uncontrolled copies of each controlled document be issued to the

DOE-ORO Project Manager for the ORNL CRRFI Project. The current DOE Project Manager is Clayton Gist, Federal Office Building, MS-8621 (6-6821).

Recipients of uncontrolled copies are to be designated on the distribution list with an asterisk (*). Revisions to all controlled documents will be sent to all recipients of controlled and uncontrolled copies. It is the responsibility of the recipient of a uncontrolled copy to update the document and to ensure that anyone receiving a copy is made aware of the current status of the document(s). Neither the Document Control Manager, nor the CRRFI Project Manager, can: (1) assure that these copies are being properly maintained and updated, or (2) accept any responsibility or accountability for the status of these documents.

5. Attach a document control classification label to the front cover of each controlled document assigned. The label will contain the following:

> This is a controlled copy. You are responsible for the maintenance of this copy. When no longer needed, return to Document Control.
>
> Park T. Owen (6-0568)
> CRRFI Document Control
> Building 2001, MS-6050

6. Attach a document assignment label, which lists the assignee, copy number, document number (if appropriate), and the document title, to the inside of the front cover of each copy of the controlled document assigned. A sample label follows:

> Assignee: B.L. Kimmel
> Copy Number: 16
> ORNL/RAP/Sub-87/99053/9&V1/R1
> Closure Plan for SWSA 6 - Vol. 1: Closure Plan

7. Enter into the controlled document logbook for each controlled copy and uncontrolled copy assigned and distributed the following information:

    1. Assignee (name, division, building number, mail stop, telephone number),

    2. Document copy number,

    3. Date the copy was distributed,

    4. Date the verification receipt transmittal was received, and

    5. Date the copy was returned, if the document has been sent back to the Document Control Center. The lists for each document will be contained in a separate section of the controlled document logbook. In each section of the logbook, the list of controlled copies will be followed by the list of uncontrolled copies.

8. Attach a document control classification label to the front cover of each uncontrolled document assigned. The label will contain the following statement:

    This is an uncontrolled copy. Revisions will be sent to original addressee only. For further information contact Document Control.

    Park T. Owen (6-0568)
    CRRFI Document Control
    Building 2001, MS-6050

9. Issue uncontrolled copies to U.S. Department of Energy staff and others as directed by the CRRFI Project Manager.

10. Attach a cover letter and a blue verification receipt transmittal form (see Attachment B) to each copy of a controlled document distributed.

11. Maintain the verification receipt transmittal forms received for each controlled document in a three-ring binder, which will reside in the Document Control Archive. The forms for each document will be kept together arranged in numerical order by copy number. The documents will be arranged in binders in numerical order according to the document or report number.

12. Attach to each update of a controlled document an instruction sheet to describe which sections are being removed, replaced, or added. A sample instruction sheet is provided as Attachment C.

13. Send a copy of each section of a controlled document that is added or removed to the manager of the CRRFI Records Control Database. This will ensure that a complete record of all versions of each controlled document is archived.

5. CONTROLLED DOCUMENT LOGBOOK

The Document Control Manager will maintain the controlled document logbook. The manager will ensure that an accurate, permanent record exists and is retained for all copies produced and issued of all controlled documents prepared for the CRRFI Project. Each page of the logbook will identify the document that was issued (document title, report number, and the date issued). The information to be listed for each copy assigned is given in item number seven in Section 4.0.

At the end of each section in the logbook, a separate list of uncontrolled copies distributed for each controlled document will be included. A copy of the form to be used in the controlled document logbook is enclosed as Attachment D.

6. CONTROLLED DOCUMENT ARCHIVE

A dedicated space will be designated for the CRRFI Document Control Archive in Building 2001, Room B-108 under the control of the CRRFI Document Control Manager.

The archive will contain: the controlled document logbook, all verification receipt transmittal forms received, and all unassigned copies of all controlled documents.

Access to the archive will only be given to staff designated by the CRRFI Project Manager.

7. RECORDS RETENTION

All records related to the document control function, which include: (1) the controlled document logbook, (2) the verification receipt transmittal forms, and (3) other record material will be permanently retained by the Document Control Center. Five years after termination of the project, two unassigned copies of each controlled document will be assigned to the Document Control Archive. These copies along with the rest of the contents of the archive will be retained indefinitely. The remainder of the unassigned copies will be destroyed by the present custodian of the archive.

8. RESPONSIBILITIES

The CRRFI Project Manager is responsible for ensuring overall compliance to this procedure for the issuance and distribution of, as well as updates made for, all controlled documents prepared for the CRRFI project. Specific responsibilities include:

1. Identify which documents are to be issued as controlled documents,

2. Prepare a standard distribution list and a supplemental list, if needed, for each document to be issued,

3. Approve all additions to the distribution list,

4. Review the distribution list on a periodical basis to ensure that the list is kept current,

5. Provide a priority list for the issuance of controlled documents if a backlog exists.

The Document Control Center Manager is responsible for ensuring performance of specific implementation activities identified in Section 4.0 of this procedure and for the overall management of the preparation, issuance, and distribution of all CRRFI controlled documents.

9. RELATED INFORMATION RESOURCES

The ORNL/RAP Bibliographic Database and Archive (P. T. Owen, ORNL Health and Safety Research Division, personal communication, 1989) were developed in FY 1987 to include all formal publications, i.e. reports, journal articles, conference papers, theses, etc. that relate to the ORNL Remedial Action Program. A single copy of each controlled document will be assigned to the manager of the RAP Bibliographic Database.

In FY 1988, the ORNL/RAP Records Control Database and Archive activities (P. T. Owen, ORNL Health and Safety Division, personal communication, 1989) were initiated to develop an online database and hardcopy archive of all record documents received by, or prepared by or for the ORNL Remedial Action Program. A computerized record consisting of: bibliographic citation, brief abstract or comment, and appropriate indexing information is prepared for each record document added to the database.

10. INFORMATION RESOURCE MANAGEMENT

All information management activities performed for CRRFI which include: (1) CRRFI Document Control Center, (2) CRRFI Records Control Database and Archive, and (3) CRRFI Bibliographic Database and Archive are performed under the auspices of the CRRFI Data and Information System (DIMS). The current DIMS Manager is Larry D. Voorhees, ORNL, Building 1505, MS-6036 (4-7309).

DISTRIBUTION

1. S. M. Adams, 1505, MS6036
2. L. W. Barnthouse, 1505, MS6036
3. S. M. Bartell, 1505, MS6036
4. L. D. Bates, K1210, MS7256
5. B. G. Blaylock, 1505, MS6036
6. K. L. Brady, 9116, MS8098
7. G. E. Butterworth, 1037, MS7357
8. T. R. Butz, 9116, MS8098
9. J. S. Colley, K1210, MS7256
10. K. W. Cook, 3001, MS6029
11. R. B. Cook, 1505, MS6036
12. C. C. Coutant, 4500N, MS6251
13. E. L. Etneir, 2001, MS6050
14. C. J. Ford, 1504, MS6351
15. M. L. Frank, 1505, MS6036
16. C. E. Frye, K1210, MS7256
17. C. W. Gehrs, 1505, MS6036
18. M. Gentry, 1505, MS6038
19. J. Grebmeier, 1505, MS6038
20. C. S. Haase, 1503, MS6352
21. J. L. Haymore, K1020, MS7206
22. S. G. Hildebrand, 1505, MS6036
23. F. O. Hoffman, 1505, MS6036
24. L. A. Hook, 1505, MS6038
25. D. D. Huff, 1505, MS6036
26. S. V. Kaye, 4500S, MS6124
27. C. Kimbrough, 9115, MS8219

28-47. B. L. Kimmel, 1504, MS6351

48. I. L. Larsen, 1505, MS6036
49. J. M. Loar, 1505, MS6036
50. L. W. Long, 1001, MS7155
51. P.-Y. Lu, 2001, MS6050
52. A. P. Malinauskas, 4500S, MS6135
53. L. W. McMahon, 9704-1, MS8060
54. L. E. McNeese, 3047, MS6023
55. M. E. Mitchell, 1001, MS7155
56. C. E. Nix, 4500S, MS6102
57. C. R. Olsen, 1505, MS6036
58. P. T. Owen, 2001, MS6050
59. T. P. Perry, 1001, MS7155
60. S. F. Railsback, 1505, MS6036
61. D. E. Reichle, 4500N, MS6253
62. P. S. Rohwer, 4500S, MS6102
63. T. H. Row, 4500N, MS6198
64. M. J. Sale, 1505, MS6036
65. C. L. Stair, K1001, MS7155
66. J. E. Stone, 9704-1, MS8060
67. S. H. Stow, 1505, MS6038
68. G. W. Suter, 1505, MS6038
69. D. W. Swindle, K1210, MS7256
70. C. C. Travis, 4500S, MS6109
71. R. R. Turner, 1505, MS6036
72. R. I. Van Hook, 1505, MS6037
73. W. Van Winkle, 1505, MS6038
74. K. Von Damm, 1505, MS6036
75. L. D. Voorhees, 1505, MS6036
76. S. H. Welch, 9115, MS8219
77. R. K. White, 7509, MS6383
78. L. F. Willis, 9704-2, MS8104
79. Central Research Library
80. Enrichment Technology Library

81-100. ER Document Management Center

101-103. ESD Library

104-105. Laboratory Records Department

106. Laboratory Records, RC
107. ORNL Patent Section
108. PGDP Library
109. X-10 Library (Portsmouth)
110. Y-12 Technical Library

EXTERNAL DISTRIBUTION

111. R. R. Colwell, Director, Maryland Biotechnology Institute, Microbiology Building, University of Maryland, College Park, MD 20742
112. W. E. Cooper, Department of Zoology, College of Natural Sciences, Michigan State University, East Lansing, MI 48824
113. C. Gist, Oak Ridge Operations, U.S. Department of Energy, Oak Ridge, TN 37830
114. S. Glover, Oak Ridge Operations, U.S. Department of Energy, Oak Ridge, TN 37830
115. G. M. Hornberger, Professor, Department of Environmental Sciences, University of Virginia, Charlottesville, VA 22903
116. T. Joseph, Oak Ridge Operations, U.S. Department of Energy, Oak Ridge, TN 37830

117. G. E. Likens, Director, The New York Botanical Garden, Institute of Ecosystem Studies, The Mary Flagler Cary Arboretum, Box AB, Millbrook, NY 12545

118-137. R. Sleeman, Research and Waste Management Division, ER-12, Oak Ridge Operations, U.S. Department of Energy, Oak Ridge, TN 37830

138. Office of Assistant Manager for Energy Research and Development, Oak Ridge Operations, P.O. Box 2001, U.S. Department of Energy, Oak Ridge, TN 37831-8600