ER005622

[redacted]

ENVIRONMENTAL RESTORATION
DIVISION DMC

Y/SUB/91-YP507C/1 Part 2

Y-12

OAK RIDGE
Y-12
PLANT

MARTIN MARIETTA

GROUNDWATER QUALITY ASSESSMENT
FOR THE BEAR CREEK
HYDROGEOLOGIC REGIME
AT THE Y-12 PLANT:

Data Interpretations and
Proposed Program Modifications

June 1991

CLEARED FOR

PUBLIC RELEASE

DM for DPO

Prepared by
HSW ENVIRONMENTAL CONSULTANTS, INC.
Under Purchase Order 77Y-YP507C
for
Environmental Management Department
Health, Safety, Environment, and
Accountability Division

ON DIVISION
T CENTER
56

ChemRisk Document No. 1099

1099

ETTA ENERGY SYSTEMS, INC.
ED STATES
OF ENERGY

RECORD COPY

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Y/SUB/91-YP507C/1/Part 2

GROUNDWATER QUALITY ASSESSMENT FOR THE BEAR CREEK HYDROGEOLOGIC REGIME AT THE Y-12 PLANT, 1990

Data Interpretations and Proposed Modifications

Prepared by

HSW Environmental Consultants, Inc.
under Purchase Order 12Y-00206C

June 1991

for

Environmental Management Department
Health, Safety, Environmental,
and Accountability Division

Oak Ridge Y-12 Plant
Oak Ridge, Tennessee 37831
managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the U.S. DEPARTMENT OF ENERGY
Under Contract No. DE-AC05-84OR21400

TABLE OF CONTENTS

Section		Page
1.0	INTRODUCTION	1-1
2.0	BACKGROUND INFORMATION	2-1
3.0	HYDROLOGIC FRAMEWORK	3-1
3.1	GROUNDWATER SYSTEM	3-1
3.2	SURFACE-WATER SYSTEM	3-9
4.0	GROUNDWATER QUALITY ASSESSMENT	4-1
4.1	INTERPRETIVE ASSUMPTIONS	4-1
4.1.1	Nitrate	4-1
4.1.2	Metals	4-1
4.1.3	Volatile Organic Compounds	4-10
4.1.4	Radiochemical Parameters	4-12
4.2	BACKGROUND CONDITIONS	4-13
4.2.1	Inorganic Geochemistry	4-13
4.2.2	Background-Water Quality	4-20
4.3	GROUNDWATER QUALITY	4-29
4.3.1	Nitrate	4-29
4.3.2	Metals	4-32
4.3.2.1	Primary Drinking-Water Metals	4-33
4.3.2.2	Other Trace Metals	4-41
4.3.3	Volatile Organic Compounds	4-42
4.3.3.1	S-3 Site	4-43
4.3.3.2	Spoil Area I	4-45
4.3.3.3	Rust Spoil Area	4-45
4.3.3.4	Oil Landfarm Waste-Management Area	4-46
4.3.3.5	Bear Creek Burial Grounds Waste-Management Area	4-47
4.3.4	Radionuclides	4-51
4.3.4.1	Alpha Radioactivity	4-51
4.3.4.2	Beta and Photon Radioactivity	4-55
4.3.4.3	Dose Equivalent Calculations	4-57
4.4	EXIT-PATHWAY MONITORING	4-59
4.4.1	Groundwater	4-59
4.4.2	Surface Water	4-61
5.0	SUMMARY	5-1
6.0	RECOMMENDATIONS	6-1
7.0	REFERENCES	7-1

TABLE OF CONTENTS - (Cont'd)

Figures		Page
1-1	Regional Location of the Y-12 Plant	1-2
2-1	Hydrogeologic Regimes at the Y-12 Plant	2-2
2-2	Bear Creek Valley Waste Disposal Sites	2-4
3-1	Stratigraphic Column of Bedrock Units at the Y-12 Plant	3-2
3-2	Bedrock Geology in the Bear Creek Hydrogeologic Regime	3-3
3-3	Regional Geologic Cross-Section at the Y-12 Plant	3-4
3-4	Conceptual Groundwater Flow Patterns at the Y-12 Plant	3-7
3-5	Water-Table Surface in the Bear Creek Hydrogeologic Regime, April 16-19, 1990	3-8
3-6	Bear Creek and its Tributaries in Bear Creek Valley	3-10
4-1	Well Network Used in the 1990 Assessment Program	4-4
4-2	Groundwater Geochemistry in the Unconsolidated Zone	4-15
4-3	Groundwater Geochemistry at Shallow Depths in the Conasauga Group Limestones	4-16
4-4	Groundwater Geochemistry at Intermediate Depths in the Conasauga Group Limestones	4-17
4-5	Groundwater Geochemistry at Shallow Depths in the Conasauga Group Shales	4-18
4-6	Groundwater Geochemistry at Intermediate Depths in the Conasauga Group Shales	4-19
4-7	Wells Used to Determine Background Geochemistry of Groundwater	4-23
4-8	Geochemistry of Groundwater in Bear Creek Valley	4-26
4-9	Occurrence of Maximum Trace Metal Concentrations in 1990 Exceeding Maximum Contaminant Levels	4-37
4-10	Relationship between TSS and Chromium Concentrations in wells GW-63 and GW-621	4-39

TABLE OF CONTENTS - (Cont'd)

Figures		Page
4-11	Relationship between TSS and Lead Concentrations in wells GW-58 and GW-226	4-40
4-12	Exit-Pathway Monitoring Locations, 1990	4-60
6-1	Monitor-Well Network Proposed for Assessment Monitoring in 1991	6-2
6-2	Exit-Pathway Monitoring Locations Proposed for Assessment Monitoring in 1991	6-7

Tables		Page
2-1	Regulatory Classification of Waste Sites Located in the Bear Creek Hydrogeologic Regime	2-3
4-1	Groundwater Quality Assessment Parameters, 1990	4-2
4-2	Screened and Open Interval Depths, and Aquifer Zones Monitored by the 1990 Assessment Wells	4-5
4-3	Background Monitor Wells in Bear Creek Valley, 1990	4-21
4-4	Background Groundwater Quality in the Bear Creek Valley, 1990	4-24
4-5	Background Surface-Water Quality in the Bear Creek Hydrogeologic Regime, 1990	4-27
4-6	Trace Metal Concentrations Considered Anomalous	4-34
4-7	Trace Metal Concentrations Which Exceeded Maximum Contaminant Levels	4-35
4-8	Nitrate, Annual Mean Gross Alpha Activity, and Gross Beta Activity Exceeding MCLs, 1990	4-52
4-9	Dose Equivalent Calculations, 1988-1990	4-58
4-10	Surface-Water Quality in Bear Creek Downstream of the S-3 Site, 1990	4-62
6-1	Sampling Sequence and Analytical Parameters Proposed for the 1991 Assessment Program	6-4

TABLE OF CONTENTS - (Cont'd)

Plates

Plate 1 Occurrence of Nitrate in Groundwater in the Bear Creek Hydrogeologic Regime

Plate 2 Occurrence of Dissolved VOCs in Groundwater in the Bear Creek Hydrogeologic Regime

Plate 3 Distribution and Summed Average Concentration of VOCs in Groundwater in the Bear Creek Hydrogeologic Regime

Plate 4 Mean Gross Alpha Activity in Groundwater in the Bear Creek Hydrogeologic Regime

Plate 5 Mean Gross Beta Activity and Photon Radioactivity in Groundwater in the Bear Creek Hydrogeologic Regime

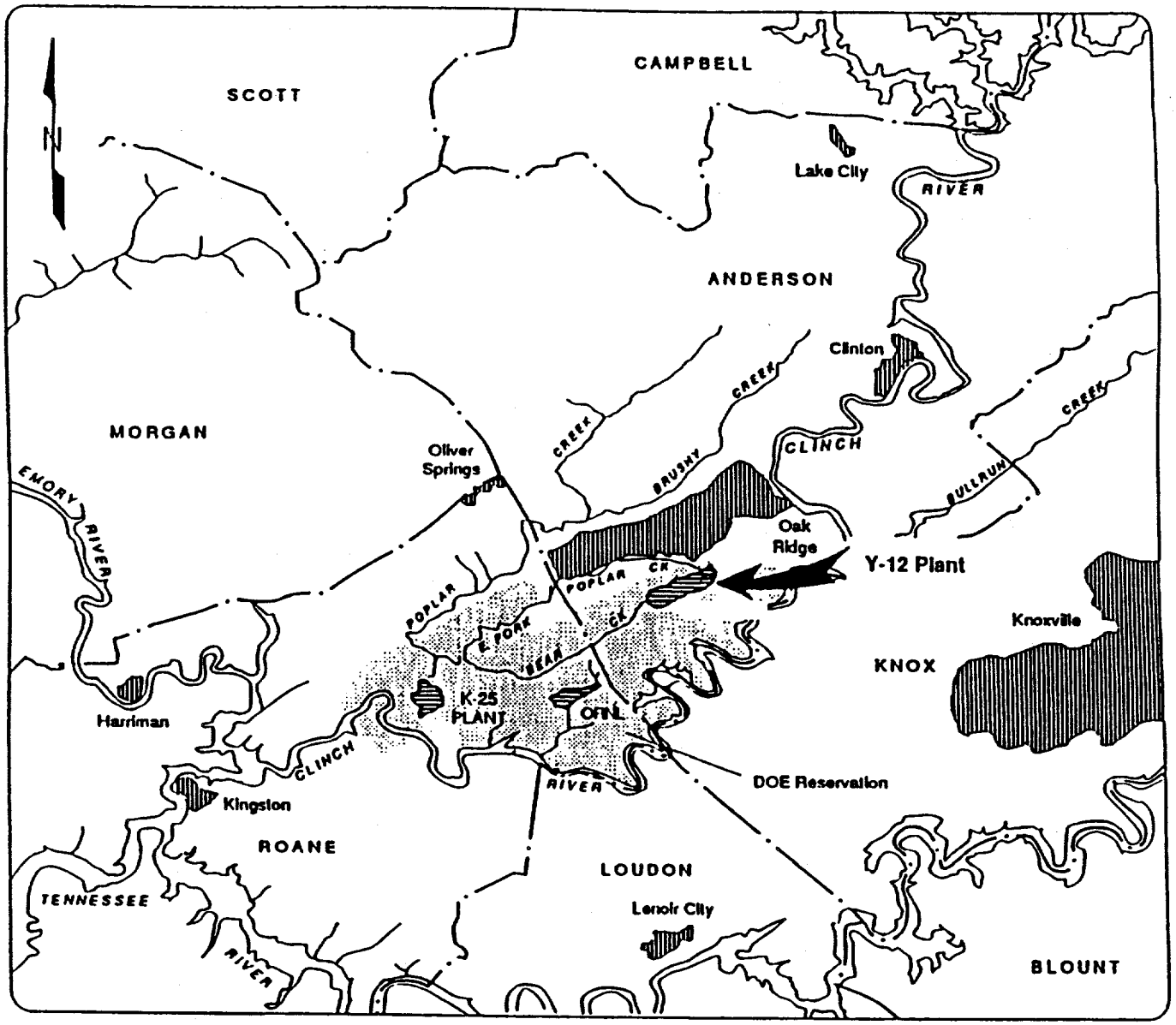
ACRONYMS

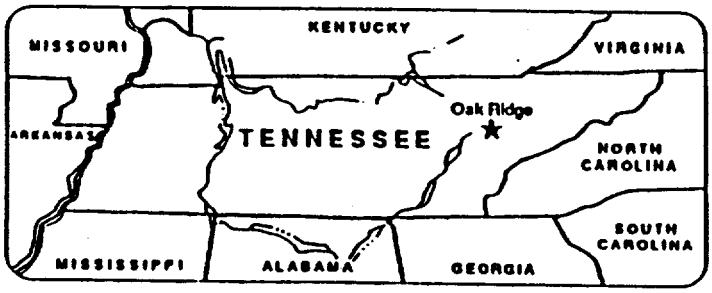
AAS	Atomic Absorption Spectroscopy
ANAP	Abandoned Nitric Acid Pipeline
BCHR	Bear Creek Hydrogeologic Regime
BCK	Bear Creek Kilometer
BCV	Bear Creek Valley
BQR	Blank Qualification Results
DNAPL	Dense Non-Aqueous Phase Liquid
DOE	Department of Energy
EPA	U.S. Environmental Protection Agency
GWQAR	Groundwater Quality Assessment Report
HSW	HSW Environmental Consultants, Inc.
ICP	Inductively-Coupled Plasma Spectroscopy
K-25	K-25 Site; Formerly the Oak Ridge Gaseous Diffusion Plant
MCL	Maximum Contaminant Level
NEPA	National Environmental Policy Act
PCPA	Post-Closure Permit Application
RCRA	Resource Conservation and Recovery Act
SWDU	Solid Waste Disposal Unit
SWMU	Solid Waste-Management Unit
TDC	Tennessee Department of Conservation
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UEFPC	Upper East Fork Poplar Creek
UEFPCHR	Upper East Fork Poplar Creek Hydrogeologic Regime
VOC	Volatile Organic Compound
WMA	Waste-Management Area

1.0 INTRODUCTION

This report is a detailed assessment of groundwater quality at several hazardous waste-management facilities associated with the Department of Energy (DOE) Y-12 Plant in Oak Ridge, Tennessee (Figure 1-1). The sites are located in an area defined as the Bear Creek Hydrogeologic Regime (BCHR), which is one of three hydrogeologic regimes that have been defined at the Y-12 Plant in an effort to unify and coordinate site-specific monitoring activities for planning and reporting purposes. This assessment is based on site-specific groundwater quality data obtained during the 1990 calendar year. The data are presented in Part I of the 1990 Groundwater Quality Assessment Report (GWQAR) for BCHR, which was prepared for the Y-12 Plant Groundwater Protection Program by HSW Environmental Consultants, Inc. (HSW), and submitted by Martin Marietta Energy Systems, Inc. to the Tennessee Department of Conservation (TDC) prior to March 1, 1991.

Section 2.0 contains background information regarding the monitored sites located in the BCHR and a discussion of the 1990 assessment program objectives. An overview intended to provide the reader with a basic understanding of the complex hydrogeologic system in the BCHR is provided in Section 3.0. A discussion of the interpretive assumptions used in evaluating the 1990 assessment data, a review of groundwater geochemistry and background water quality, detailed descriptions of groundwater contaminant plumes, and a discussion regarding the quality of groundwater and surface water exiting the BCHR are presented in Section 4.0. Findings of the 1990 assessment program are summarized in Section 5.0. Modifications to the assessment monitoring program proposed for implementation in 1991 are presented in Section 6.0, and a list of references (Section 7.0) concludes the report.





MODIFIED FROM: G&M 1990b

FIGURE 1-1
REGIONAL LOCATION
OF THE Y-12 PLANT

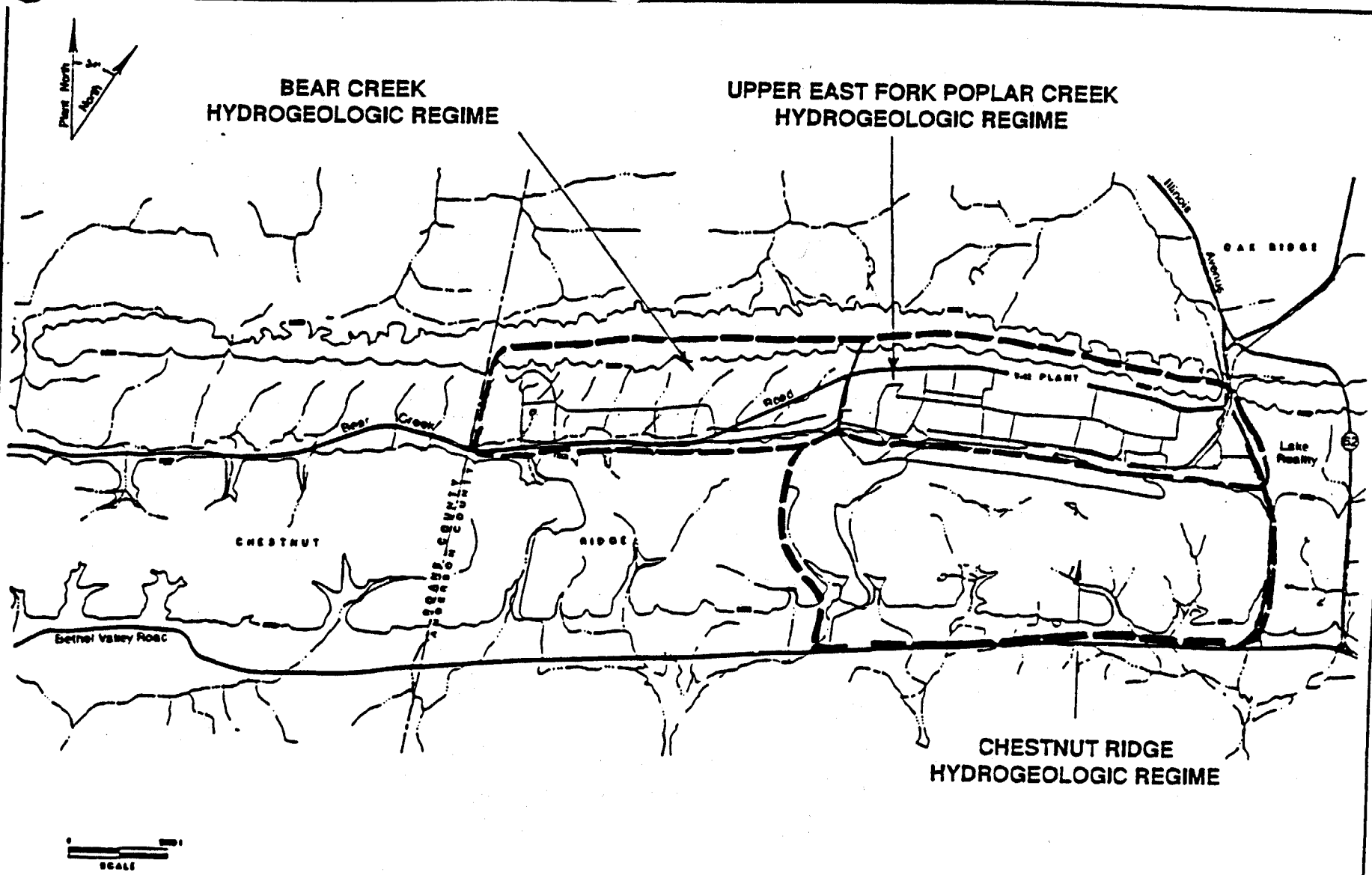
2.0 BACKGROUND INFORMATION

The Y-12 Plant is located in Bear Creek Valley (BCV) which is flanked on the north by Pine Ridge and on the south by Chestnut Ridge. For the purpose of groundwater quality assessment, BCV has been divided into the BCHR and the Upper East Fork Poplar Creek Hydrogeologic Regime (UEFPCHR) (Figure 2-1). A topographic and hydrologic divide located near the west end of the Y-12 Plant separates the two hydrogeologic regimes.

There are three basic types of regulated units located within the BCHR: (1) Resource Conservation and Recovery Act (RCRA) interim status land based treatment and disposal units, (2) individual RCRA interim status units with waste-management areas (WMAs) that include other RCRA regulated Solid Waste-Management Units (SWMUs), and (3) individual SWMUs which are not located within the WMA of any treatment or disposal unit. A listing of all sites included in the BCHR is provided on Table 2-1 and the locations of these sites are shown on Figure 2-2. Site descriptions and waste-disposal histories are provided in Section 2.1 of Part I of the 1990 GWQAR (HSW Environmental Consultants, Inc. 1991).

Several SWMUs and underground storage tanks (USTs) located near the west end of the Y-12 Plant were included in the waste-management area (WMA) defined for the S-3 Site. During recent discussions regarding the RCRA post-closure permit application (PCPA) for the S-3 Site, the WMA was redefined to exclude these SWMUs (D.J. Bostock, Martin Marietta Energy Systems, Inc., letter to T. Tiesler, Tennessee Department of Conservation, May 8, 1991). However, reference to the S-3 WMA has been retained to maintain continuity with the Part I of the 1990 GWQAR, which was submitted to the TDC prior to the change in the S-3 WMA.

Several modifications to the assessment program in the BCHR were recommended in Part II of the 1989 GWQAR for implementation in 1990. The assessment-well network was modified to include new wells and omit "internal plume" wells for which up to 4 years of quarterly data are available. A standardized suite of analytical parameters was proposed and a standardized monitor-well sampling sequence was recommended to avoid future instances of cross-



MODIFIED FROM: G&M 1990b

FIGURE 2-1

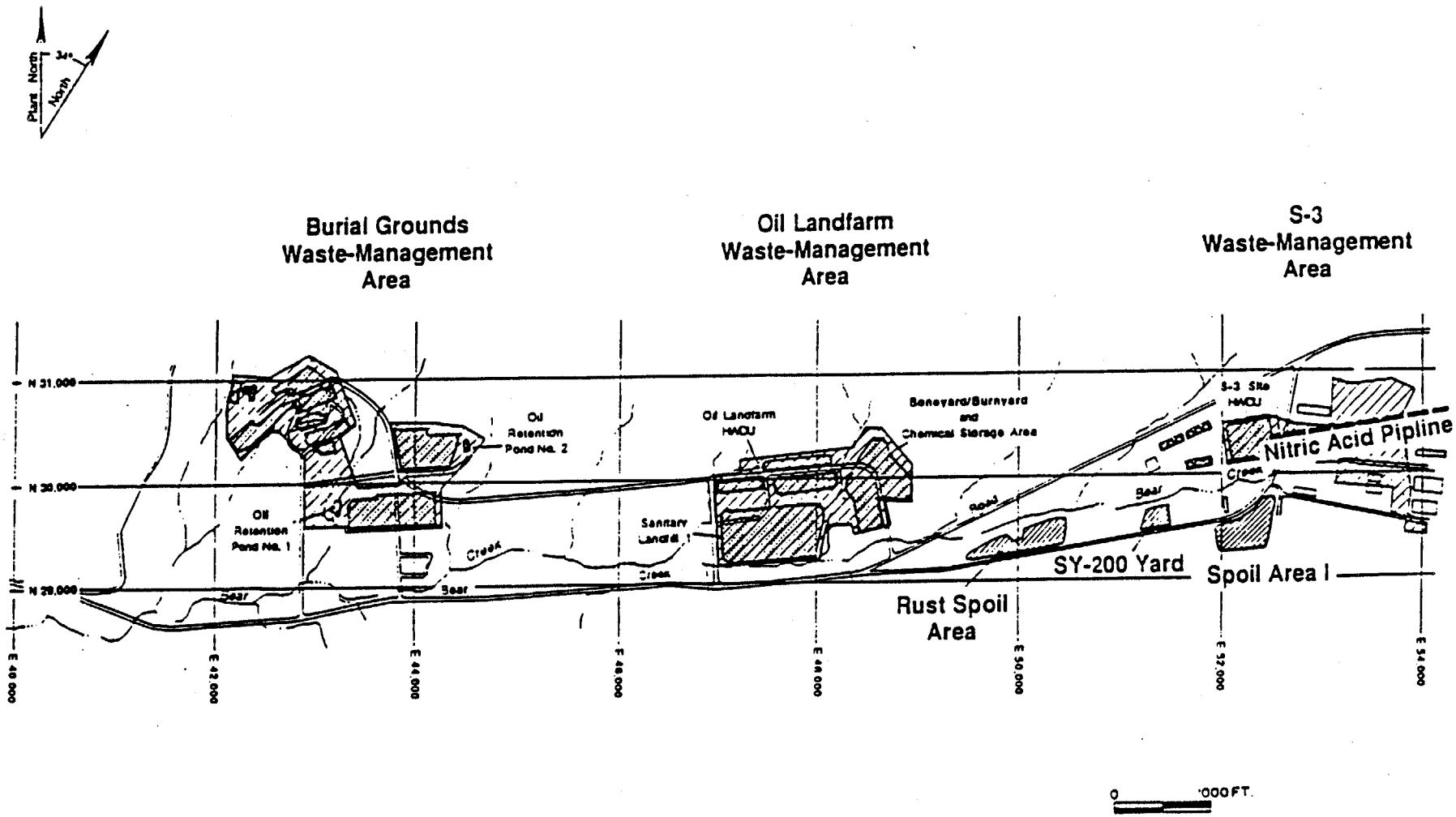
HYDROGEOLOGIC REGIMES
AT THE Y-12 PLANT

Table 2-1. Regulatory Classification of Waste Sites Located in the Bear Creek Hydrogeologic Regime

SITE NAME	REGULATORY CLASSIFICATION[1]
S-3 Site	RCRA T/S/D Unit
Oil Landfarm Waste-Management Area	
Oil Landfarm	RCRA T/S/D Unit
Burnyard/Boneyard	SWMU
Chemical Storage Area	SWMU
Sanitary Landfill I	SWDU
Bear Creek Burial Grounds Waste-Management Area	
Burial Grounds A and C	RCRA T/S/D Unit
Burial Grounds B,D,E,J	SWDU
Oil Retention Ponds Nos.1 and 2	SWMU
SY-200 Yard	SWMU
Rust Spoil Area	SWMU
Spoil Area I	SWMU

NOTE:

1. RCRA T/S/D Unit - RCRA regulated land-based treatment, storage, or disposal unit.
   SWMU - Solid Waste Management Unit
   SWDU - Solid Waste Disposal Unit (non-hazardous waste)



EXPLANATION

Waste-Management Area

Solid Waste-Management Unit

MODIFIED FROM: G&M 1990

FIGURE 2-2

BEAR CREEK VALLEY WASTE DISPOSAL SITES

Y-12 PLANT, OAK RIDGE, TENNESSEE

OA3018

contamination that were suspected during the 1989 sampling program.

An ambitious monitor-well installation program was proposed for 1990 to finalize delineation of contaminant plume boundaries. However, installation of many of these wells was delayed until a categorical exclusion from the National Environmental Policy Act (NEPA) was obtained. Categorical exclusion from NEPA was received from DOE Oak Ridge Operations on August 10, 1990 (Personal Communication, H. King, May 1991). However, because of the delay, some wells that were installed were not sampled until the first quarter of 1991. Installation of the remaining wells is currently in progress.

An "Exit-Pathway" monitoring program for obtaining data on the quality of groundwater and surface water exiting the BCHR was also initiated in 1990. Groundwater quality is monitored in a network of wells screened at various depths in the Maynardville Limestone, the formation considered to be the primary groundwater exit pathway. This well network is being expanded by the installation of several monitor-well clusters along parallel traverses that cut across the Maynardville Limestone. Screened or open intervals in these wells will intercept specific stratigraphic zones containing features (e.g. solution cavities) which provide the principal groundwater flow paths. Installation of these wells is currently underway. Surface-water quality is monitored at springs and other stations located along Bear Creek (including a background location in a Bear Creek tributary).

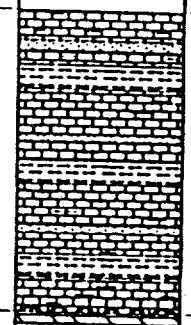
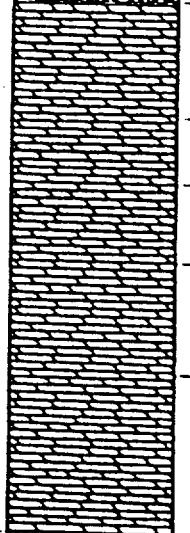
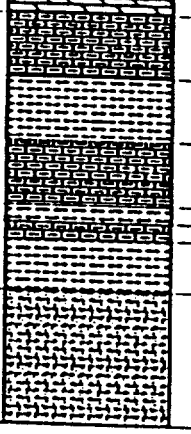
3.0 HYDROLOGIC FRAMEWORK

The following overview of the hydrology in the BCHR is intended to provide the reader with a basic understanding of the geology and groundwater system in the area. The hydrogeologic system in the BCHR is highly complex and this overview should not be considered comprehensive. More detailed presentations of the stratigraphy, structure, and groundwater flow characteristics in the vicinity of the sites located within the BCHR may be found in a variety of reports generated by different investigators; many of these reports are listed in the Reference section of this document and Part I of the 1990 GWQAR (HSW Environmental Consultants, Inc. 1991).

3.1 GROUNDWATER SYSTEM

The groundwater system in the BCHR generally consists of two zones: an upper zone composed of unconsolidated materials and a lower bedrock zone consisting of the six formations of the Conasauga Group. These formations are, from youngest to oldest, the Maynardville Limestone, Nolichucky Shale, Maryville Limestone, Rogersville Shale, Rutledge Limestone, and Pumpkin Valley Shale (Figure 3-1). The bedrock geology of the BCHR is shown on Figure 3-2, and the overall geologic framework of the Y-12 Plant area is illustrated on Figure 3-3.

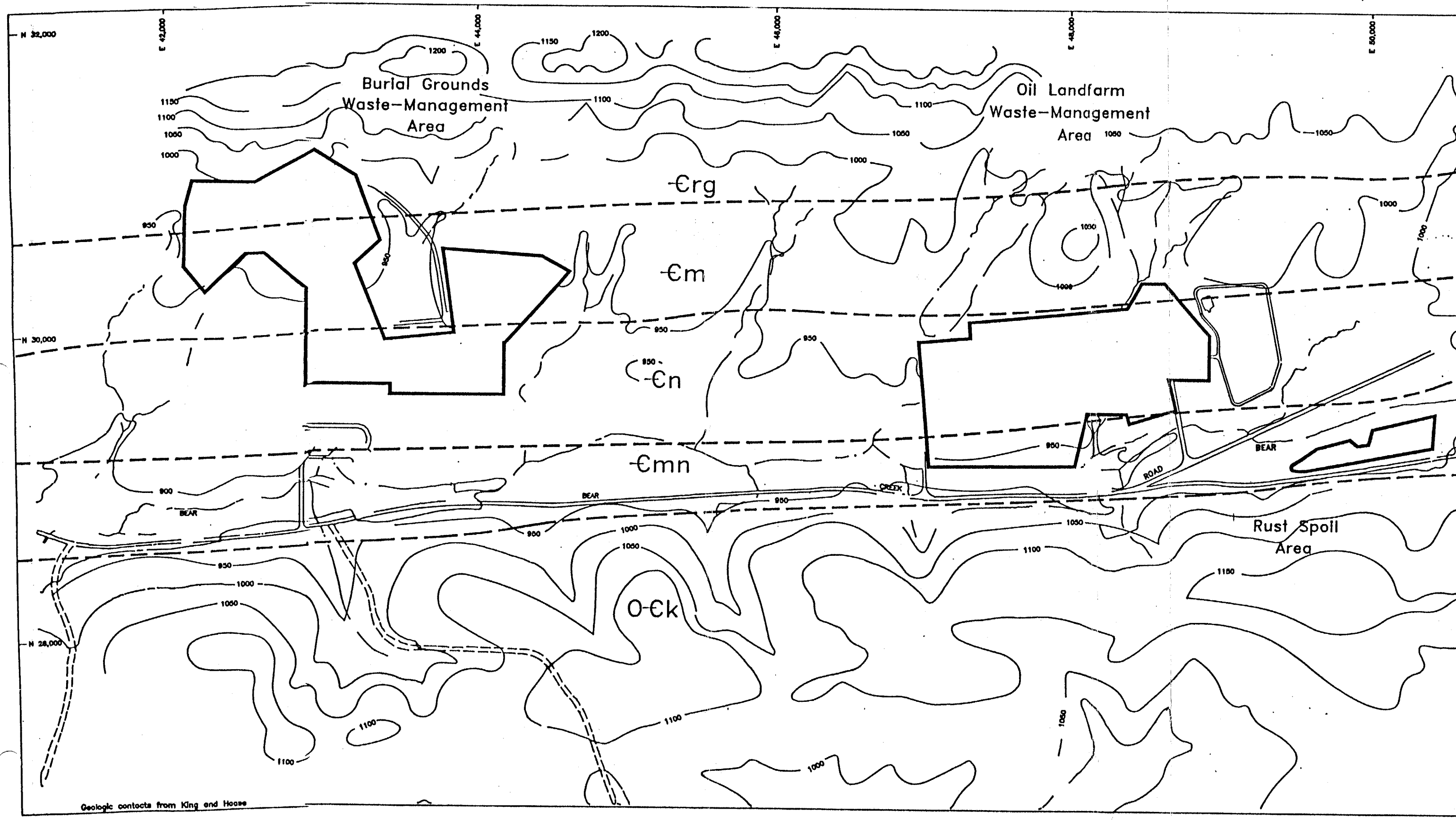
The unconsolidated and bedrock zones in the BCHR can be considered as a single aquifer (i.e. no distinct confining layer separates the two zones). Unconsolidated materials in the BCHR are of varying thickness and consist of manmade fill, alluvium, colluvium, and residuum from the weathering of the underlying bedrock. Groundwater in the unconsolidated zone occurs under unconfined (water-table) conditions. The movement of groundwater in the bedrock zone is restricted to structures such as bedding planes, joints, fractures, and solution cavities. Consequently, groundwater movement in the bedrock is strongly controlled by the orientation and distribution of these features. Strike and dip of the strata in the BCHR is generally N 55° E and 45° SE, respectively (King and Haase 1987). However, small scale folds in

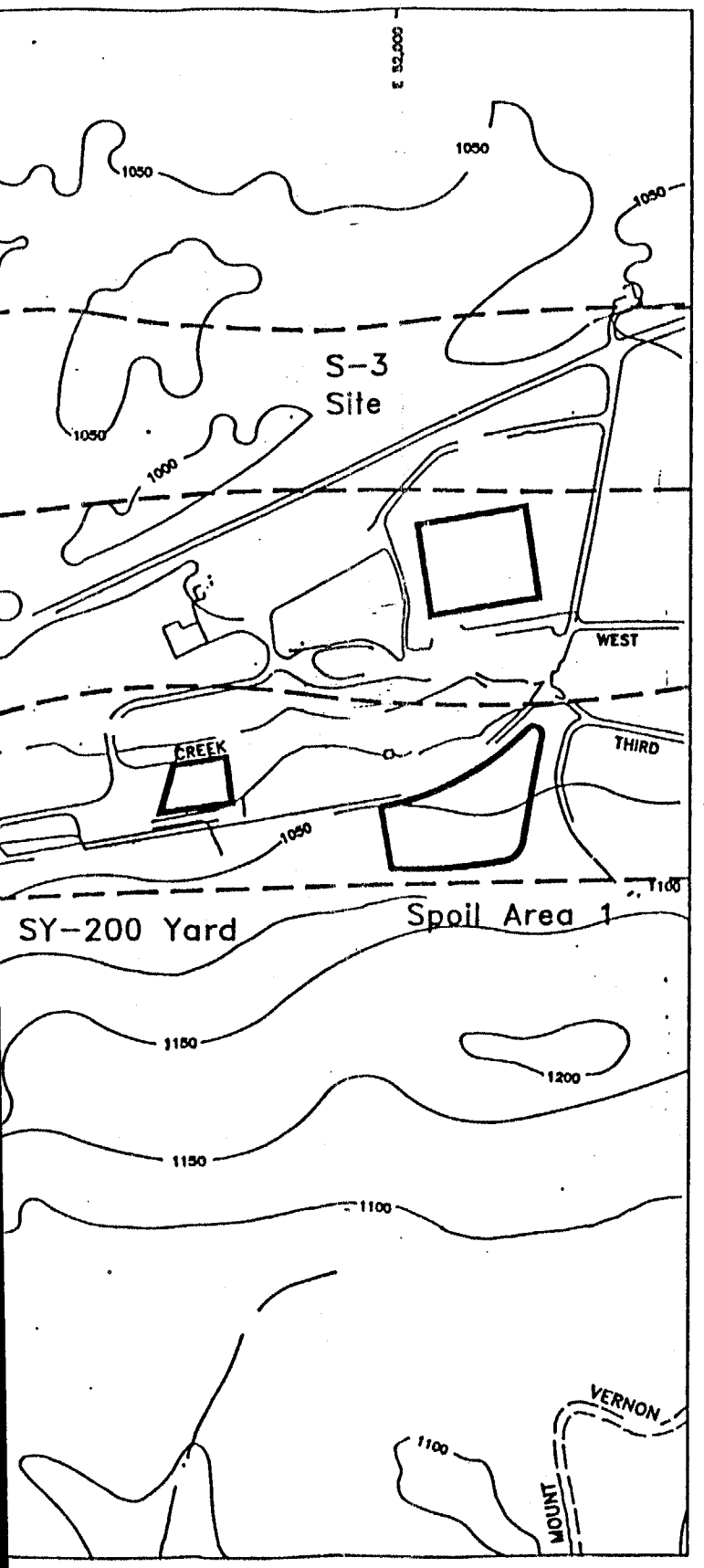
Age	Group	Lithology	Formation	Approximate Thickness (ft)		
				King and Haase 1987	Milici 1973	McMaster 1963
Middle Ordovician	Chickamauga		Undivided	Not Determined	Not Determined	1,750 (undivided)
Lower Ordovician	Knox		Mascot Formation	Not Determined	400-800	3,000 (undivided)
			Kingsport Formation		200-320	
			Longview Dolomite		250-450	
			Chepultepec Dolomite		725-880	
Middle & Upper Cambrian			Copper Ridge Dolomite		900-1000	
	Conasauga		Maynardville Limestone	418 - 450	Not Determined	1,500 (undivided)
			Nolichucky Shale	422 - 550		
			Maryville Limestone	346 - 445		
			Rogersville Shale	90 - 120		
			Rutledge Limestone	90 - 120		
			Pumpkin Valley Shale	260 - 320		
Lower Cambrian			Rome	Not Determined	Not Determined	800 +

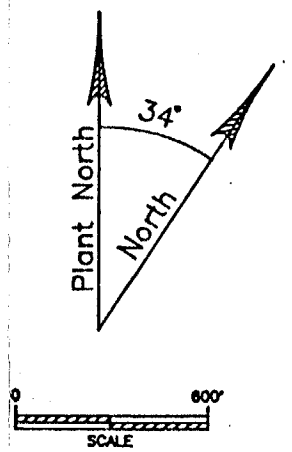
MODIFIED FROM: G&M 1990b

FIGURE 3-1

STRATIGRAPHIC COLUMN OF BEDROCK UNITS AT THE Y-12 PLANT


N 32,000
E 42,000
E 44,000
E 46,000
E 48,000
E 50,000
Burial Grounds
Waste-Management
Area
Oil Landfarm
Waste-Management
Area
Ꞓrg
Ꞓm
Ꞓn
Ꞓmn
O-Ꞓk
N 30,000
N 28,000
BEAR
CREEK
ROAD
Rust Spoil
Area
Geologic contacts from King and Hoare





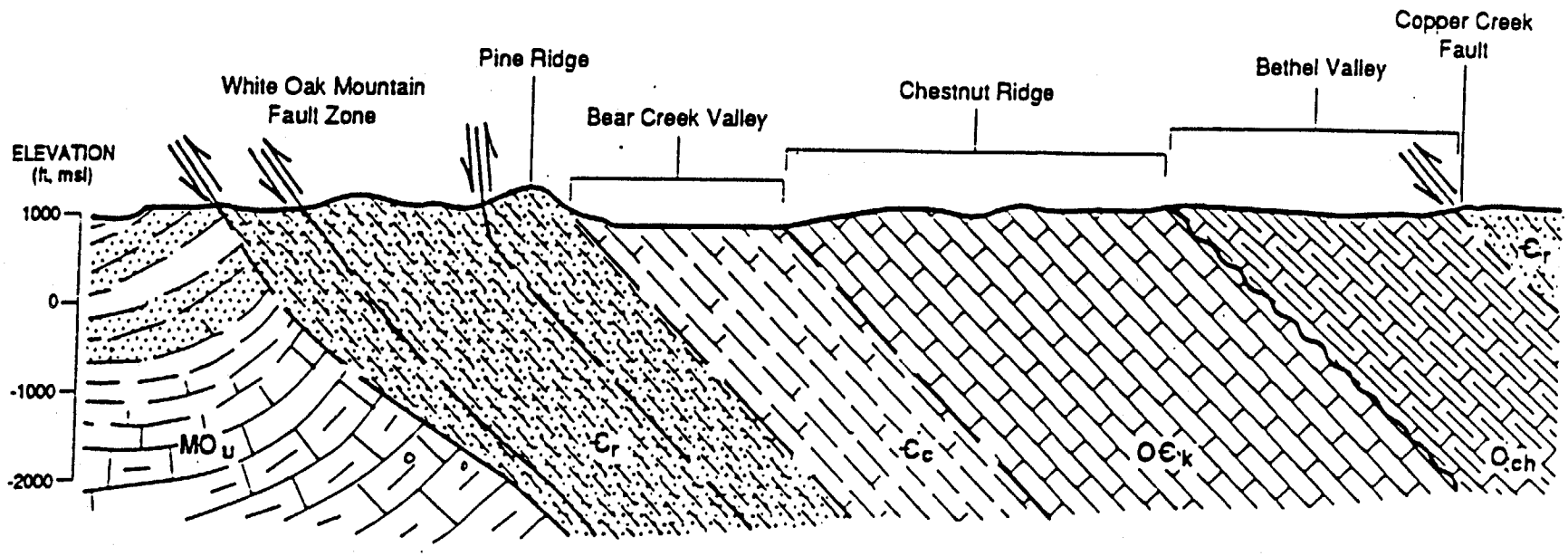
0 600'
SCALE

Topographic Contour Interval: 50 ft.

EXPLANATION

▬▬▬	Boundary of Site or Waste – Management Area
▬ ▬ ▬	Approximate Geologic Contact
OCk	Knox Group
Cmn	Maynardville Limestone
Cn	Nolichucky Shale
Cm	Maryville Limestone
Crg	Rogersville Shale

FIGURE 3-2
BEDROCK GEOLOGY IN THE
BEAR CREEK
HYDROGEOLOGIC REGIME



EXPLANATION

MO u	Mississippian to Ordovician Undivided	Ꞓc	Conasauga Group
Och	Chickamauga Group	Ꞓr	Rome Formation
OꞒk	Knox Group		Disconformity
			Fault

0 2000 ft
APPROXIMATE SCALE

MODIFIED FROM: G&M 1990b

FIGURE 3-3
REGIONAL GEOLOGIC CROSS-SECTION
AT THE Y-12 PLANT

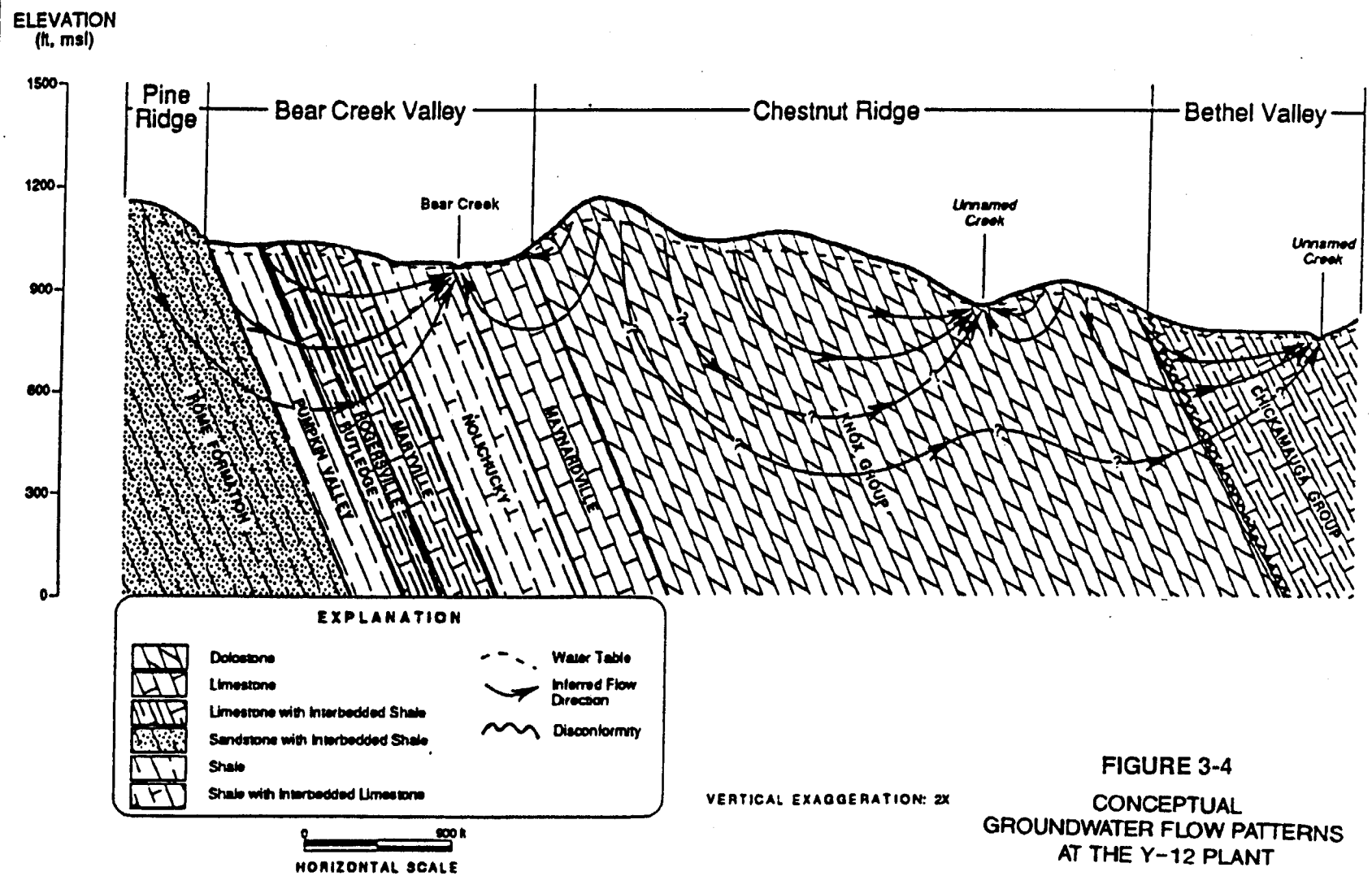
the Conasauga Group produce a variety of local bedding orientations. Joint sets are the most common structural features observed in the BCHR and several studies have identified one major joint set that roughly parallels the strike and dip of bedding, and a second steeply dipping joint set that strikes approximately N 10° W (Rothschild, Turner, et. al. 1984). Dissolution along joints, fractures, and bedding planes in the carbonate units of the Conasauga Group, in particular the Maynardville Limestone, has produced solution cavities that have greatly increased the permeability of these units. Solution cavities most commonly occur in the upper part of the saturated zone, and range in thickness from a fraction of an inch to several feet (Geraghty & Miller, Inc. 1985).

The lithologic composition of the Conasauga Group formations also plays an important role in the occurrence and movement of groundwater in the BCHR. The Maynardville Limestone is comprised of about 440 ft of fine to coarse grained, thin-bedded to massive limestones and dolostones (King and Haase 1987). The hydraulic conductivity of the Maynardville Limestone averages about 13 ft per day (ft/day) (Geraghty & Miller, Inc. 1989a), which is higher than that of any other Conasauga Group formation. For this reason, the Maynardville Limestone is considered the primary conduit for lateral solute transport in the BCHR. The Nolichucky Shale, which underlies the Maynardville Limestone, is comprised of approximately 500 ft of massive to thinly bedded siltstones with interbedded limestones (King and Haase 1987). In comparison with the Maynardville Limestone, the hydraulic conductivity of the Nolichucky Shale is low, averaging about 1.2 ft/day (Geraghty & Miller, Inc. 1989a). In general, the lithologic composition of the Nolichucky Shale differs very little from that of the underlying Maryville Limestone, which is composed of 340 to 415 ft of thin to medium-bedded limestones interbedded with calcareous mudstones and siltstones (King and Haase 1987). The average hydraulic conductivity of the Maryville Limestone is very low (0.3 ft/day; Geraghty & Miller, Inc. 1989a). Beneath the Maryville are the massive mudstones of the Rogersville Shale (105 to 140 ft thick) and the interbedded limestones and shales of the Rutledge

Limestone (85 to 105 ft thick) (King and Haase 1987). There is little information regarding the hydrologic properties of these formations in the BCHR. The oldest Conasauga Group member, the Pumpkin Valley Shale, is comprised of 290 to 330 ft of massive shale and mudstone with thin beds of siltstone (King and Haase 1987). This is a very tight formation that is considered one of the poorest aquifers in East Tennessee (DeBuchananne and Richardson 1956).

Groundwater in the bedrock zone occurs under unconfined conditions, but it becomes increasingly confined with depth. The general pattern of groundwater flow in the bedrock zone is illustrated on Figure 3-4. Downward recharge to the groundwater system occurs along Pine Ridge and Chestnut Ridge. Water then flows laterally toward the axis of BCV and discharges upward into Bear Creek and its tributaries. This conceptualization of groundwater movement is supported by water-level data from monitor-well pairs and clusters in the BCHR, which indicate upward vertical hydraulic gradients (generally less than 0.07) along the axis of BCV (Geraghty & Miller, Inc. 1985).

A contour map of the potentiometric surface in the BCHR based on water levels in wells recorded on April 16-19, 1990, is presented on Figure 3-5. It appears that a groundwater divide is located just east of the S-3 Site which roughly coincides with the topographic divide between the BCHR and the UEFPCHR. Southerly and southeasterly directions of groundwater movement are indicated along the slope of Pine Ridge north of Bear Creek. In the zone underlying Bear Creek, the direction of groundwater movement is southwest along the valley axis. Furthermore, the potentiometric contours only indicate the general direction of groundwater movement because the orientation and distribution of bedding planes, joints, fractures, and solution cavities impart a high degree of anisotropy to the bedrock zone. Although the water table in the BCHR fluctuates throughout the year, the pattern of fluctuation is similar in all wells and the slope of the water table remains essentially unchanged.

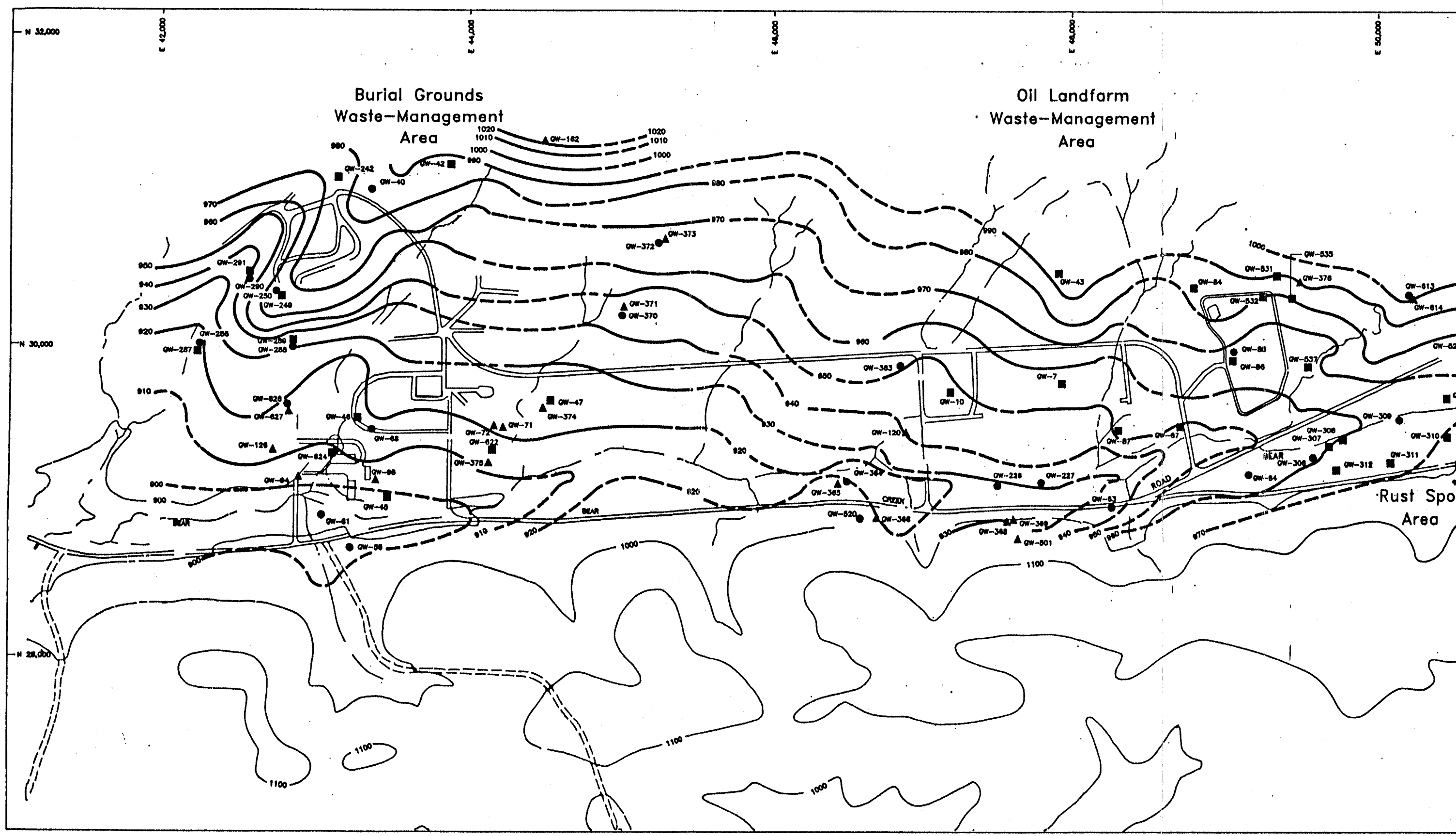


MODIFIED FROM: G&M 1990b

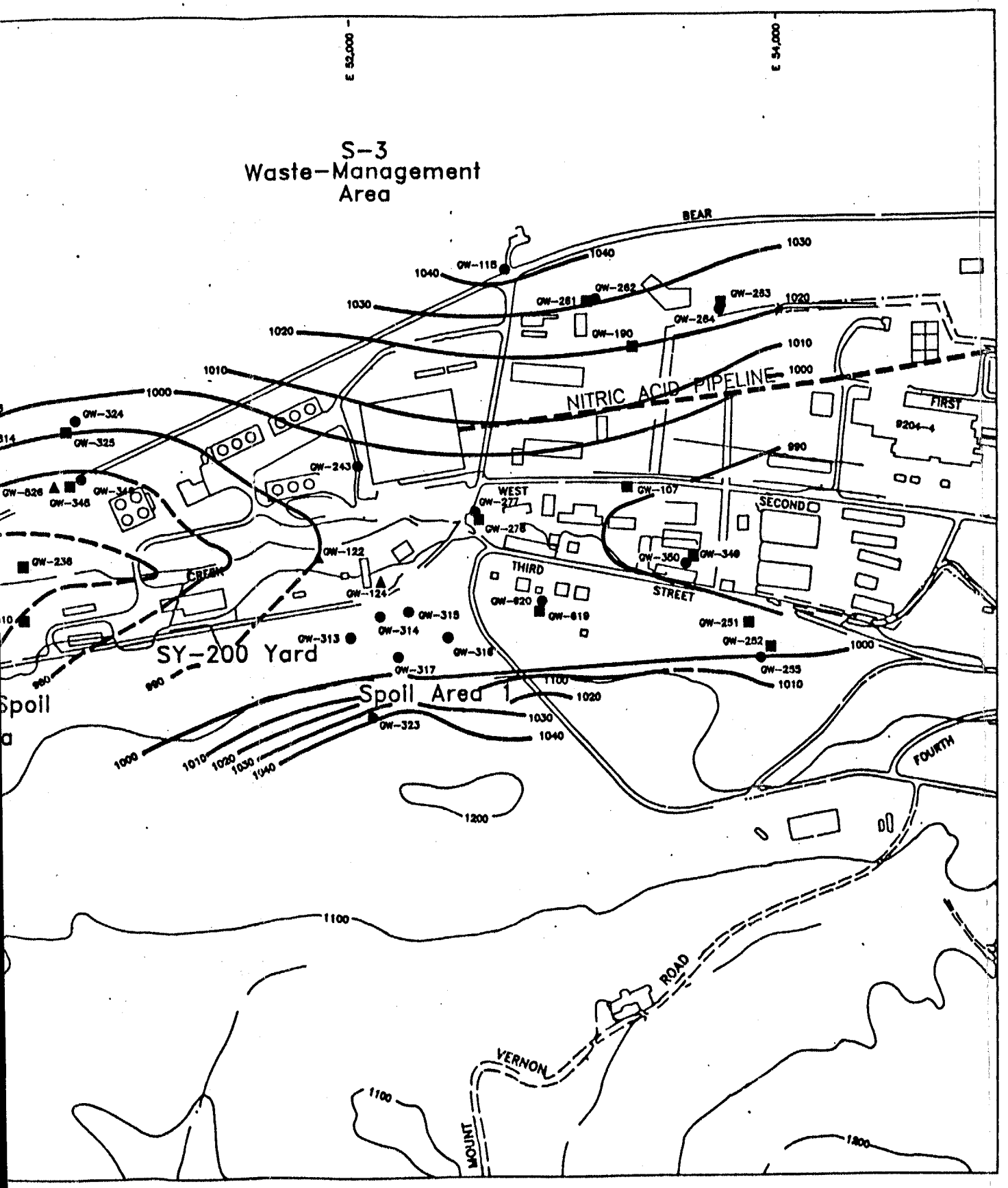
FIGURE 3-4

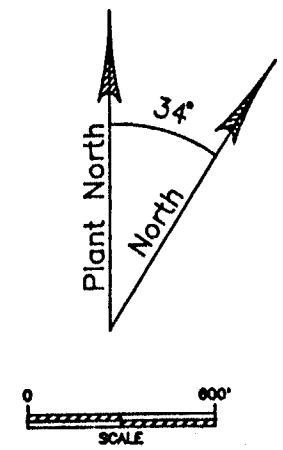
CONCEPTUAL GROUNDWATER FLOW PATTERNS AT THE Y-12 PLANT

Y-12 PLANT, OAK RIDGE, TENNESSEE



Y-12 PLANT, OAK RIDGE, TENNESSEE





EXPLANATION

GW-276 ■ Unconsolidated Zone Monitor Well

GW-277 ● Shallow Bedrock Zone Monitor Well (Unc – 85')

GW-124 ▲ Intermediate Bedrock Zone Monitor Well (85' – 300')

990 Water Level Isopleth (ft msl)

FIGURE 3-5

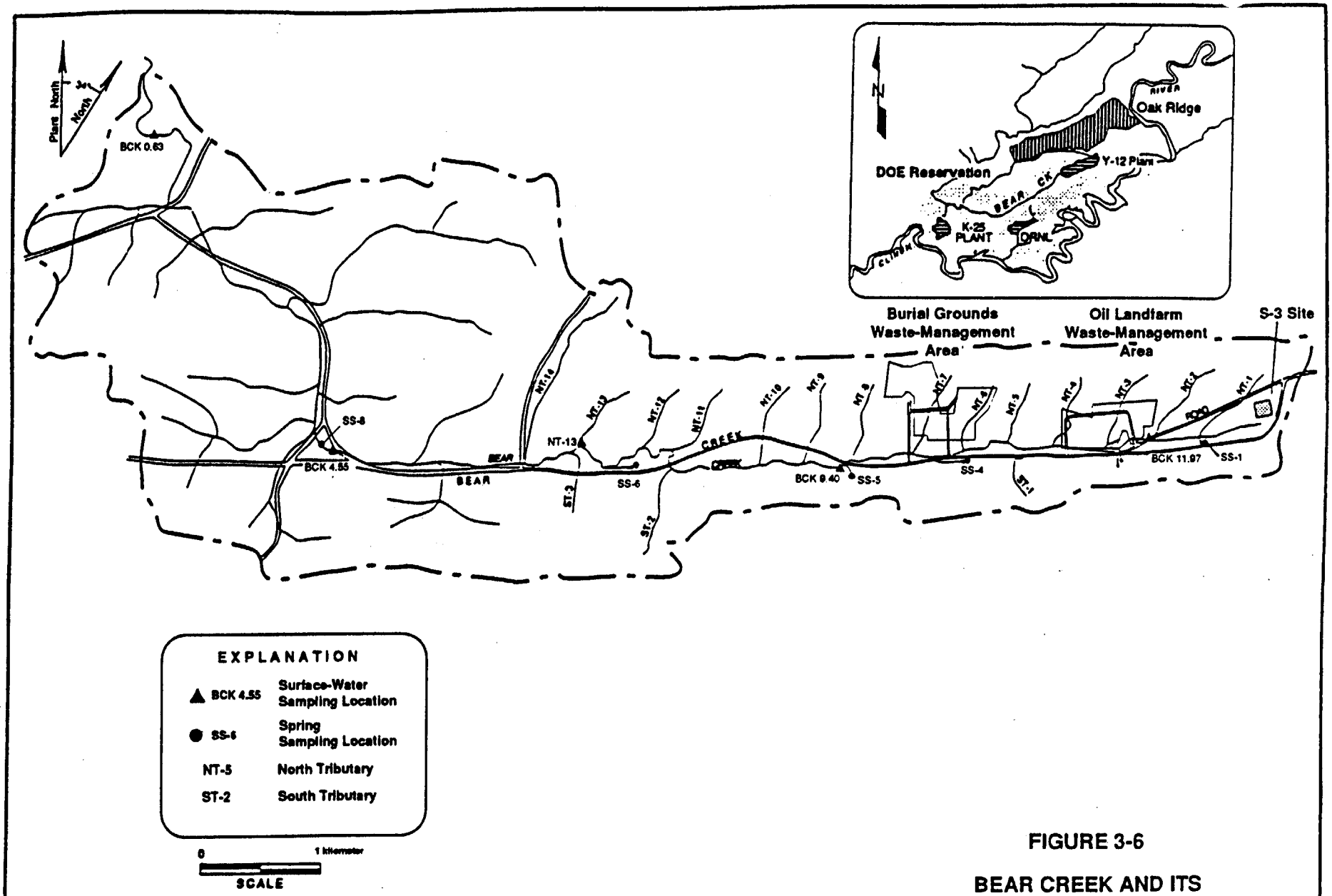
WATER-TABLE SURFACE IN THE
BEAR CREEK HYDROGEOLOGIC REGIME
APRIL 16-19, 1990

3.2 SURFACE-WATER SYSTEM

The surface water system in the BCHR is comprised of Bear Creek and its tributaries. The parallel alignment of the tributaries located on the shale units in BCV is believed to represent the surface expression of joint and fracture patterns in the bedrock (Geraghty & Miller, Inc. 1985). Headwaters of Bear Creek are located at the west end of the Y-12 Plant near the S-3 Site (Figure 3-6). In its upper reaches, Bear Creek follows a relatively straight course along geologic strike that lies very close to the contact between the Conasauga and Knox groups. Approximately 4-1/2 miles downstream of its headwaters, Bear Creek turns northward through a gap in Pine Ridge and empties into East Fork Poplar Creek about 6 miles upstream of the Clinch River.

The channel of Bear Creek along much of its course through BCV is formed in the shallow alluvium overlying the Maynardville Limestone. Drilling activities in areas proximal to Bear Creek have indicated that a zone of potentially interconnected solution cavities is present in the upper part of the saturated zone in this formation (Geraghty & Miller, Inc. 1985). Because of the hydrologic interaction between the creek and this solution cavity system, the Bear Creek channel contains influent (losing) reaches where surface water discharges from the creek to the groundwater system, and effluent (gaining) reaches where groundwater discharges to the creek.

A dye-tracer test was performed in 1989 to evaluate the hydrologic interactions between Bear Creek and the Maynardville Limestone (Geraghty & Miller, Inc. 1989b). During this study, a review of historical stream-flow data for Bear Creek was performed. Results of this review indicated that Bear Creek loses flow to the groundwater system during extreme low-flow conditions over much of its length from near the S-3 Site to a spring located at Bear Creek Kilometer (BCK) 4.56. During normal flow conditions, Bear Creek loses flow to the groundwater system in its upper reaches and gains flow in its lower reaches downstream of BCK 9.41 (Geraghty & Miller, Inc. 1989b). It was concluded from the dye-tracer test that there is strong evidence indicating that surface water lost in influent reaches of Bear Creek between BCK 11.64 and BCK 9.41 is



MODIFIED FROM: G&M 1990b

FIGURE 3-6

BEAR CREEK AND ITS TRIBUTARIES IN BEAR CREEK VALLEY

discharged back into Bear Creek from spring SS-5 (Geraghty & Miller, Inc. 1989b).

4.0 GROUNDWATER QUALITY ASSESSMENT

This section contains a description of groundwater quality in the BCHR based on results of the 1990 and previous annual assessments. Groundwater and surface-water samples collected during the 1990 assessment monitoring program in the BCHR were analyzed for the parameters and constituents shown on Table 4-1 and in Appendix A to Part I of the 1990 GWQAR (HSW Environmental Consultants, Inc. 1991a). Locations of the monitor wells included in the 1990 assessment are shown on Figure 4-1. Data regarding the screened or open-hole interval depths, and the aquifer zone monitored by each well are provided on Table 4-2. Locations of springs and surface-water sampling points are shown on Figure 3-6.

4.1 INTERPRETIVE ASSUMPTIONS

The interpretations presented in this report were based primarily on the assessment monitoring data collected during 1990, evaluated with respect to historical (1986-1989) assessment data. Descriptions of the interpretive assumptions associated with each category of data (e.g., metals) are provided in the following sections.

4.1.1 Nitrate

Evaluation of the extent of nitrate in groundwater in the BCHR was based on average annual concentrations in excess of the maximum contaminant level (MCL) for nitrate as N (10 mg/L). Individual nitrate concentrations were used for wells sampled only once in 1990.

4.1.2 Metals

The extent of trace metal contamination in the BCHR was evaluated with respect to MCLs or background levels. Metals for which the highest concentration was below the MCL or background levels were not considered groundwater contaminants. Conversely, metals having concentrations that exceeded background levels or MCLs were considered groundwater contaminants.

Interpretations of the analytical results for trace metals

Table 4-1. Groundwater Quality Assessment Parameters, 1990

METALS[1]

ICP

Aluminum	Boron	Iron	Silver
Antimony	Cadmium	Molybdenum	Strontium
Arsenic	Chromium	Nickel	Thorium
Barium	Cobalt	Selenium	Vanadium
Beryllium	Copper	Silicon	Zinc

AAS
Cadmium, Chromium, and Lead

CVAA
Mercury

FLUOR
Uranium

MAJOR CATIONS AND ANIONS

Alkalinity (HCO_3)	Manganese
Alkalinity (CO_3)	Nitrate
Calcium	Potassium
Chloride	Sodium
Fluoride	Sulfate
Magnesium	

VOLATILE ORGANIC COMPOUNDS

Acetone	1,2-Dichloropropane
Benzene	cis-1,3-Dichloropropene
Bromodichloromethane	trans-1,3-Dichloropropene
Bromoform	Ethylbenzene
Bromomethane	2-Hexanone
2-Butanone	4-Methyl-2-pentanone
Carbon disulfide	Methylene chloride
Carbon tetrachloride	Styrene
Chlorobenzene	1,1,2-2-Tetrachloroethane
Chlorodibromomethane	Tetrachloroethene
Chloroethane	Toluene
Chloroform	1,1,1-Trichloroethane
Chloromethane	1,1,2-Trichloroethane
1,1-Dichloroethane	Trichloroethene
1,2-Dichloroethane	Vinyl acetate
1,1-Dichloroethene	Vinyl chloride
1,2-Dichloroethene	Xylenes

Table 4-1. (cont'd)

RADIOCHEMICAL

- Gross Alpha Activity
- Gross Beta Activity
- Radionuclides:
  - Cesium 137[a]
  - Iodine 129 and 125
  - Protactinium[a]
  - Radium (Total)
  - Radium 228[a]
  - Strontium - 89 + 90
  - Technetium - 99
  - Thorium - 231[a] + 234[a]
  - Tritium
  - Uranium - 234, 235, and 238

FIELD

- Conductivity
- Dissolved Oxygen
- Redox
- Ph
- Depth to Water
- Water Temperature

MISCELLANEOUS

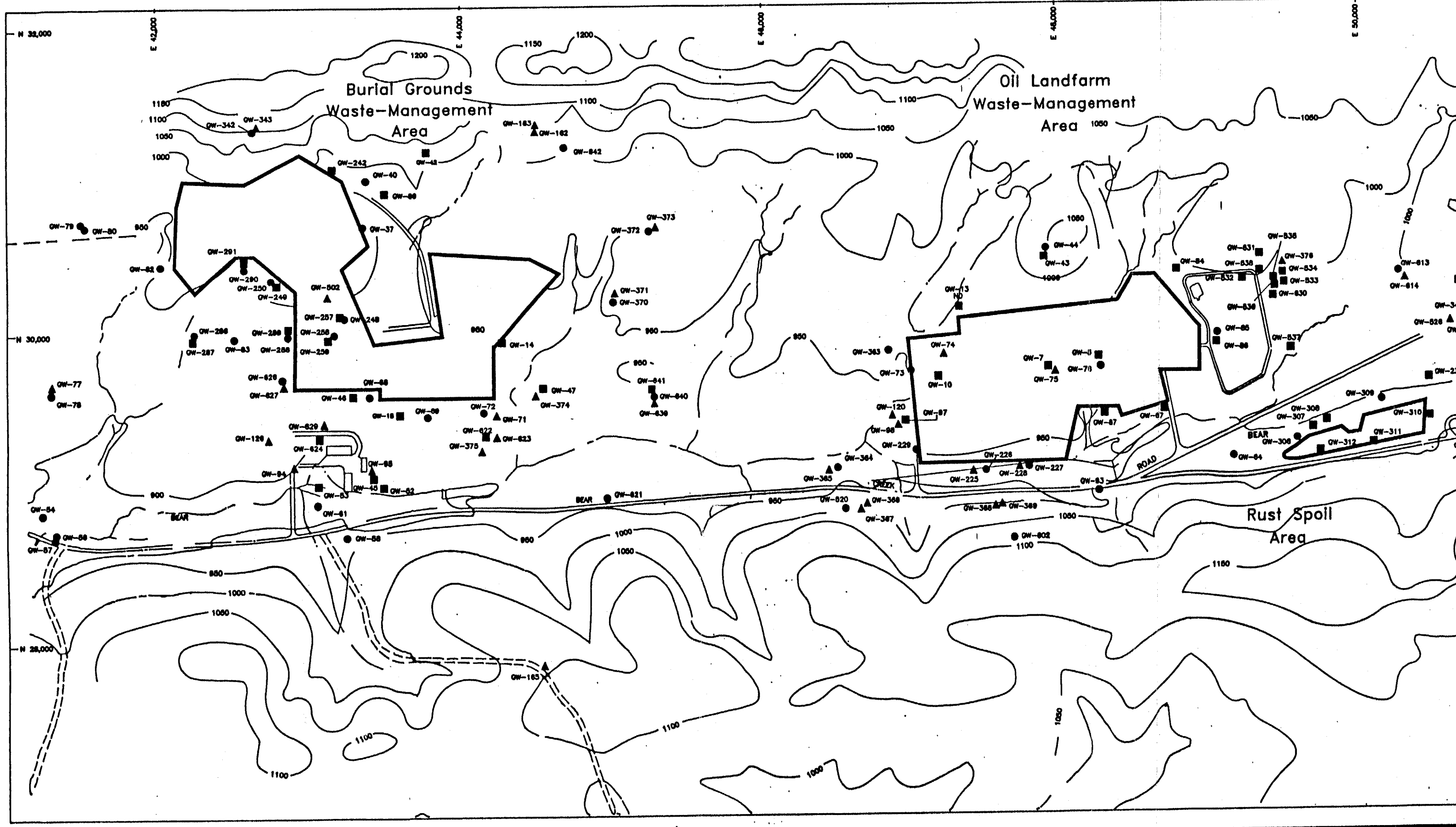
- Specific Conductivity
- Dissolved Solids
- Ph
- Phenols
- Turbidity
- Total Organic Carbon
- Total Organic Halogens
- Total Suspended Solids

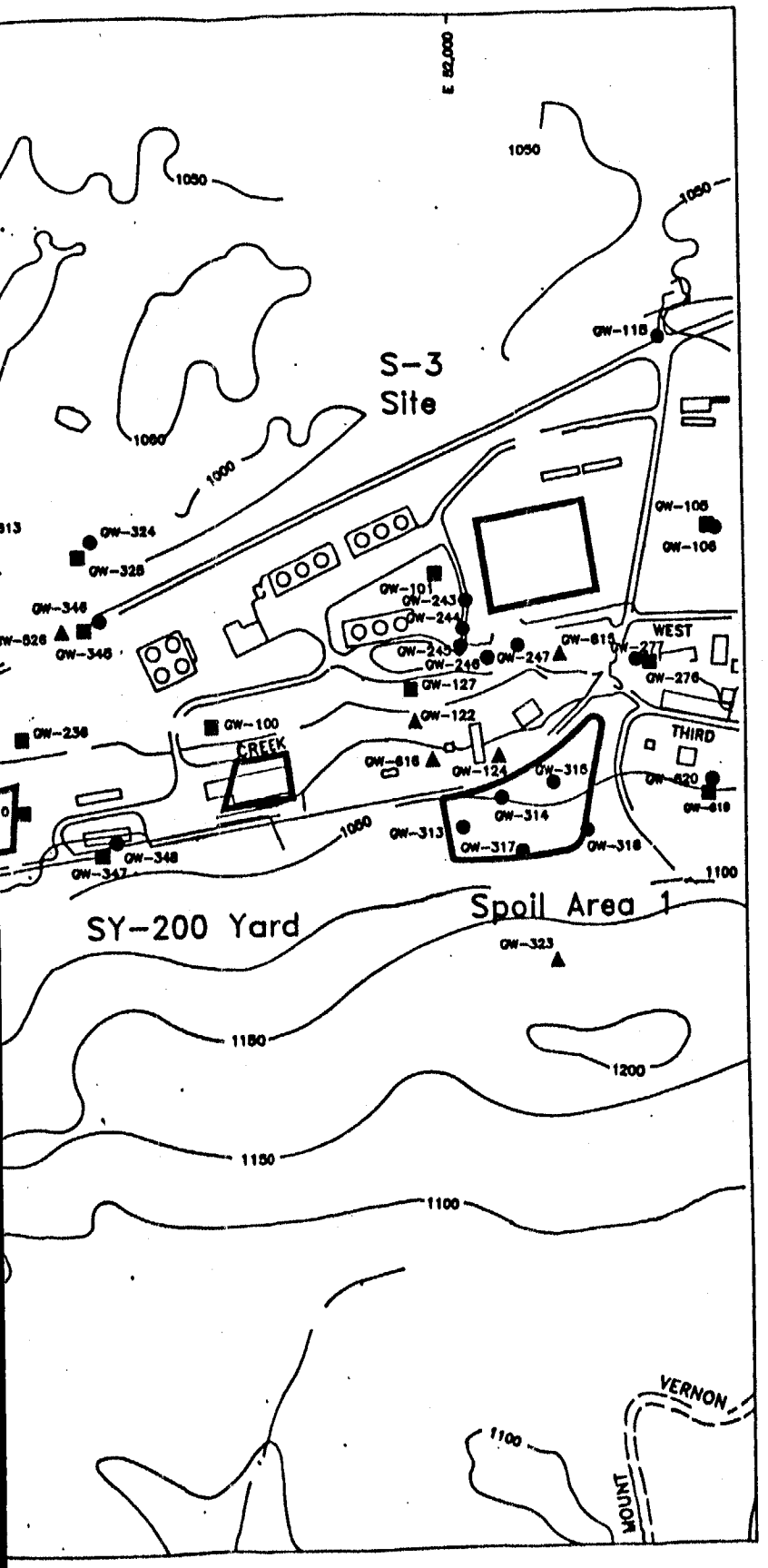
NOTE:

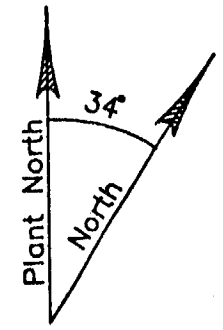
1. ICP - Inductively-Coupled Plasma (Spectroscopy)
   AAS - Atomic Absorption Spectroscopy
   CVAA - Cold Vapor Atomic Absorption
   FLUOR - Fluorometric

a. Radionuclides analyzed in first quarter 1990 samples from:

GW-108	GW-246	GW-87
GW-115	GW-247	GW-225
GW-243	GW-274	GW-227
GW-244	GW-275	GW-367
GW-245	GW-64	GW-58


Burial Grounds
Waste-Management
Area
Oil Landfarm
Waste-Management
Area
Rust Spoil
Area
BEAR
CREEK
ROAD
N 32,000
N 30,000
N 28,000
E 42,000
E 44,000
E 46,000
E 48,000
E 50,000





0 600'
SCALE

Topographic Contour Interval: 50 ft.

EXPLANATION

GW-97	■	Unconsolidated Zone Monitor Well
GW-226	●	Shallow Bedrock Zone Monitor Well (Unc – 85')
GW-120	▲	Intermediate Bedrock Zone Monitor Well (85' – 300')
GW-119	▼	Deep Bedrock Zone Monitor Well (300'+)
	▬	Boundary of Site or Waste – Management Area

FIGURE 4-1
WELL NETWORK USED IN THE
1990 ASSESSMENT PROGRAM

Table 4-2. Screened and Open Interval Depths, and Aquifer Zones Monitored by the 1990 Assessment Wells

WELL NUMBER	MONITORED INTERVAL (depth, ft)	SCREEN/ OPEN	AQUIFER ZONE[1]	BDR UNIT[2]
S-3 Site WMA				
GW-100 (a)	3.8 - 20.7	Screen	UNC	----
GW-101	10.1 - 17.5	Screen	UNC	----
GW-105 (a)	9.5 - 17.0	Screen	UNC	----
GW-106 (a)	53.3 - 75.0	Screen	BDR	Cn
GW-115 (b)	42.0 - 52.0	Screen	BDR	Cm
GW-122	92.0 - 142.0	Open	BDR	Cn
GW-123	522.0 - 572.0	Open	BDR	Cn
GW-124 (a)	100.0 - 150.0	Open	BDR	Cmn
GW-125	502.0 - 552.0	Open	BDR	Cn
GW-127 (a)	14.0 - 24.0	Screen	UNC	----
GW-236 (a)	13.0 - 18.0	Screen	UNC	----
GW-243	43.2 - 77.0	Screen	BDR	Cn
GW-244 (a)	43.0 - 77.0	Screen	BDR	Cn
GW-245 (a)	25.3 - 76.0	Screen	BDR	Cn
GW-246 (a)	34.2 - 76.0	Screen	BDR	Cn
GW-247 (a)	46.9 - 74.9	Screen	BDR	Cn
GW-276	11.3 - 18.5	Screen	UNC	----
GW-277	62.2 - 77.4	Screen	BDR	Cn
GW-324 (b)	68.5 - 79.0	Screen	BDR	Cn
GW-325 (b)	7.3 - 17.9	Screen	UNC	----
GW-345	16.0 - 26.0	Screen	UNC	----
GW-346 (a)	54.6 - 64.6	Screen	BDR	Cmn
GW-347	11.7 - 27.5	Screen	UNC	----
GW-348	70.2 - 80.6	Screen	BDR	Cmn
GW-526	101.0 - 123.0	Open	BDR	Cn
GW-613 (b)	31.7 - 75.2	Screen	BDR	Cn
GW-614 (b)	42.0 - 90.2	Screen	BDR	Cn
GW-615	222.5 - 245.0	Open	BDR	Cn
GW-616	219.7 - 269.0	Open	BDR	Cn
GW-619	26.8 - 40.8	Screen	UNC	----
GW-620	61.7 - 75.0	Screen	BDR	Cmn
Spoil Area I				
GW-313	98.2 - 113.0	Screen	BDR	Cmn
GW-314	101.0 - 115.0	Screen	BDR	Cmn
GW-315	90.0 - 104.0	Screen	BDR	Cmn
GW-316	67.5 - 80.0	Screen	BDR	Cmn
GW-317	117.0 - 132.0	Screen	BDR	OCk
GW-323	94.0 - 108.0	Screen	BDR	Ock
Rust Spoil Area I				
GW-306	48.1 - 58.1	Screen	BDR	Cmn
GW-307	28.7 - 41.6	Screen	UNC	----
GW-308	22.0 - 37.7	Screen	UNC	----
GW-309	27.0 - 37.0	Screen	BDR	Cmn

Table 4-2. (Cont'd)

WELL NUMBER	MONITORED INTERVAL (depth, ft)	SCREEN/ OPEN	AQUIFER ZONE[1]	BDR UNIT[2]
Rust Spoil Area				
GW-310	21.8 - 27.1	Screen	UNC	----
GW-311	25.6 - 40.3	Screen	UNC	----
GW-312	29.6 - 41.0	Screen	UNC	----
Oil Landfarm WMA				
GW-005	3.0 - 12.5	Screen	UNC	----
GW-007 (a)	8.7 - 16.5	Screen	UNC	----
GW-010 (a)	5.3 - 15.0	Screen	UNC	----
GW-013	6.0 - 14.0	Screen	UNC	----
GW-043 (b)	22.8 - 32.8	Screen	UNC	----
GW-044 (b)	42.5 - 70	Screen	BDR	Cm
GW-063	27.7 - 32.7	Screen	BDR	Cmn
GW-064	50.7 - 52.7	Screen	BDR	Cmn
GW-067 (a)	7.6 - 16.2	Screen	UNC	----
GW-073 (a)	66.9 - 79.8	Screen	BDR	Cn
GW-074	176.5 - 200.6	Screen	BDR	Cn
GW-075	176.5 - 199.6	Screen	BDR	Cn
GW-076	67.8 - 80.3	Screen	BDR	Cn
GW-084 (b)	46.8 - 52.7	Screen	UNC	----
GW-085	53.8 - 58.8	Screen	BDR	Cn
GW-086	21.0 - 29.6	Screen	UNC	----
GW-087 (a)	7.5 - 19.0	Screen	UNC	----
GW-097 (a)	11.8 - 16.8	Screen	UNC	----
GW-098 (a)	82.4 - 103.4	Screen	BDR	Cn
GW-120 (a)	130.0 - 180.0	Open	BDR	Cn
GW-225	150.0 - 200.0	Open	BDR	Cmn
GW-226	45.0 - 55.0	Open	BDR	Cmn
GW-227	30.0 - 40.0	Open	BDR	Cmn
GW-228 (a)	80.0 - 100.0	Open	BDR	Cmn
GW-229 (a)	40.0 - 55.0	Open	BDR	Cmn
GW-363 (a)	50.0 - 75.0	Open	BDR	Cn
GW-364	49.8 - 59.8	Screen	BDR	Cmn
GW-365	126.7 - 150.0	Open	BDR	Cmn
GW-366	90.5 - 100.5	Screen	BDR	Cmn
GW-367	125.0 - 150.0	Open	BDR	Cmn
GW-368 (a)	225.0 - 245.0	Open	BDR	Cmn
GW-369 (a)	115.8 - 150.2	Open	BDR	Cmn
GW-376 (a)	63.0 - 218.0	Open	BDR	Cn
GW-520	68.0 - 80.3	Screen	BDR	Ock
GW-531	22.0 - 38.5	Screen	UNC	----
GW-532	11.0 - 28.7	Screen	UNC	----
GW-533	18.0 - 30.1	Screen	UNC	----
GW-534	29.4 - 46.3	Screen	UNC	----
GW-535	3.0 - 19.5	Screen	UNC	----
GW-536	3.2 - 19.7			

Table 4-2. (Cont'd)

WELL NUMBER	MONITORED INTERVAL (depth, ft)	SCREEN/ OPEN	AQUIFER ZONE[1]	BDR UNIT[2]
Oil Landfarm WMA				
GW-537	4.8 - 23.3	Screen	UNC	----
GW-538	25.5 - 42.2	Screen	UNC	----
GW-601	318.5 - 194.3	Open	BDR	Cmn
GW-602	356.0 - 212.0	Open	BDR	Cmn
GW-630	14.8- 28.6	Screen	UNC	----
Bear Creek Burial Grounds WMA				
GW-014(a)	5.0 - 13.2	Screen	UNC	----
GW-037	42.0 - 68.7	Screen	BDR	Cm
GW-040(a)(b)	21.0 - 29.0	Screen	BDR	Cpv
GW-042(b)	13.4 - 28.7	Screen	UNC	----
GW-045(a)	3.0 - 13.0	Screen	UNC	----
GW-046(a)	5.0 - 20.3	Screen	UNC	----
GW-047(a)	18.5 - 23.5	Screen	UNC	----
GW-052	4.0 - 19.5	Screen	UNC	----
GW-053	11.4 - 32.8	Screen	UNC	----
GW-054	31.1 - 37.2	Screen	BDR	Cmn
GW-056	49.1 - 55.2	Screen	BDR	Cmn
GW-057	17.5 - 22.8	Screen	BDR	Cmn
GW-058	42.2 - 44.2	Screen	BDR	Cmn
GW-061	19.6 - 24.6	Screen	BDR	Cmn
GW-068(a)	70.0 - 83.6	Screen	BDR	Cn
GW-069	79.0 - 99.2	Screen	BDR	Cn
GW-071	195.1 - 219.0	Screen	BDR	Cn
GW-072	84.5 - 98.4	Screen	BDR	Cn
GW-077	87.4 - 100.3	Screen	BDR	Cn
GW-078	11.7 - 21.1	Screen	BDR	Cn
GW-079(b)	49.9 - 64.9	Screen	BDR	Crg
GW-080(b)	20.8 - 29.7	Screen	BDR	Crg
GW-082	29.4 - 34.4	Screen	BDR	Cm
GW-083	19.9 - 29.5	Screen	BDR	Cn
GW-089	20.0 - 25.0	Screen	UNC	----
GW-094(a)	93.8 - 114.8	Screen	BDR	Cmn
GW-095	134.8 - 155.8	Screen	BDR	Cmn
GW-117	480.0 - 530.0	Open	BDR	Cn
GW-118	525.0 - 575.0	Open	BDR	Cn
GW-119	460.0 - 510.0	Open	BDR	Cn
GW-126(a)	105.0 - 155.0	Open	BDR	Cn
GW-162(b)	92.0 - 125.0	Open	BDR	Cpv
GW-163	201.0 - 225.0	Open	BDR	Rome
GW-164	370.0 - 405.0	Open	BDR	Rome
GW-242(a)	9.0 - 17.0	Screen	UNC	----
GW-248(a)	49.1 - 62.0	Screen	BDR	Cn
GW-249(a)	28.5 - 35.1	Screen	UNC	----
GW-250(a)	49.5 - 61.7	Screen	BDR	Cn

Table 4-2. (Cont'd)

WELL NUMBER	MONITORED INTERVAL (depth, ft)	SCREEN/ OPEN	AQUIFER ZONE[1]	BDR UNIT[2]
Bear Creek Burial Grounds WMA				
GW-257 (a)	19.0 - 33.7	Open	BDR	Cm
GW-258 (a)	37.0 - 50.0	Screen	BDR	Cn
GW-259 (a)	21.1 - 33.5	Screen	UNC	----
GW-286 (a)	22.0 - 32.0	Screen	BDR	Cn
GW-287 (a)	7.3 - 12.3	Screen	UNC	----
GW-288 (a)	49.1 - 59.1	Screen	BDR	Cn
GW-289 (a)	30.6 - 40.6	Screen	UNC	----
GW-290 (a)	19.3 - 32.5	Screen	BDR	Cm
GW-291 (a)	6.7 - 14.2	Screen	UNC	----
GW-342 (b)	65.0 - 75.0	Screen	BDR	Cpv
GW-343	170.0 - 185.0	Open	BDR	Rome
GW-344	301.0 - 316.0	Open	BDR	Rome
GW-370	22.5 - 32.5	Screen	BDR	Cm
GW-371	110.0 - 125.0	Open	BDR	Cm
GW-372 (b)	41.0 - 51.0	Screen	BDR	Cm
GW-373 (b)	123.0 - 158.0	Open	BDR	Cm
GW-374 (a)	124.6 - 150.1	Open	BDR	Cn
GW-375 (a)	125.0 - 161.5	Open	BDR	Cn
GW-502 (a)	223.7 - 260.0	Open	BDR	Cm
GW-621	24.8 - 40.5	Screen	BDR	Cmn
GW-622	8.6 - 18.7	Screen	UNC	----
GW-623	219.0 - 349.0	Open	BDR	Cn
GW-624	16.9 - 27.2	Screen	UNC	----
GW-626	67.7 - 254.0	Screen	BDR	Cn
GW-627	77.7 - 270.0	Open	BDR	Cn
GW-629	262.3 - 312.0	Open	BDR	Cn
GW-639	95.5 - 125.5	Open	BDR	Cn
GW-640	35.0 - 47.4	Screen	BDR	Cn
GW-641	20.0 - 25.0	Screen	UNC	----
GW-642 (b)	18.5 - 36.9	Screen	BDR	Crg

NOTE:

1. BDR - Bedrock Zone
   UNC - Unconsolidated Zone

2. Ock - Knox Group
   Cmn - Maynardville Limestone
   Cn - Nolichucky Shale
   Cm - Maryville Limestone
   Crg - Rogersville Shale
   Cpv - Pumpkin Valley Shale
   Rome - Rome Formation

a. 1989 Assessment well sampled First Quarter 1991

b. Background Well

were based on the following: (1) comparison of total to dissolved metal concentrations, (2) a review of the analytical methods used in the metals analyses, and (3) a comparison of the highest metal concentration reported for each monitor well with background levels or applicable MCLs.

Trace metal concentrations were reported by the K-25 Site Analytical Chemistry Department for unfiltered groundwater samples (total metal concentrations) and filtered groundwater samples (dissolved metal concentrations) from each well. As required by the TDC, the evaluation of potential trace metal contamination in the BCHR was based upon total metal concentrations. However, unfiltered groundwater samples may contain significant amounts of suspended solids (e.g., clay particles). These samples may reflect actual groundwater conditions monitored by some wells (e.g., wells screened in the Maynardville Limestone) or simply the disturbance of sediment in the bottom of the well (e.g., unconsolidated zone wells). This distinction is important because total metal concentrations determined from turbid samples may be biased if metals are desorbed from the suspended solids and mobilized into solution when the ph of the sample is reduced during sample preservation. In cases where the turbid unfiltered samples may not reflect groundwater conditions (i.e., in the unconsolidated zone), total metals concentrations may be reported and lead to erroneous interpretations regarding groundwater quality with respect to trace metal concentrations.

A review of the historical assessment data for the BCHR was performed to identify the relationship between total suspended solids (TSS) and total and dissolved metals concentrations (see Section 4.3.2). The objective of this review was to determine if fluctuations in TSS were accompanied by corresponding fluctuations in total and dissolved metal concentrations. If the total metal concentrations fluctuated with TSS, and a similar pattern was not evident with dissolved metal concentrations, the total metal concentrations were assumed to have been affected by desorption from the suspended materials.

Several methods are available for the analysis of trace metals in groundwater samples. The most common methods involve

inductively-coupled plasma spectroscopy (ICP), and flame or flameless atomic absorption spectroscopy (AAS). When the ICP method is used, certain interferences inherent to the method may cause inaccurate results to be reported for antimony, arsenic, lead, and selenium (U.S. Environmental Protection Agency 1986). These interferences are usually caused by high concentrations of iron and aluminum; metals that are ubiquitous in soil and rock and naturally present in most groundwaters. To avoid using inaccurate data in the assessment of trace metal contamination, ICP results were considered unusable for those metals prone to interferences. The AAS method was used for cadmium, chromium, and lead analyses as specified in Part II of the 1989 GWQAR (Geraghty & Miller, Inc. 1990b).

4.1.3 Volatile Organic Compounds

Evaluation of the concentration and distribution of volatile organic compounds (VOCs) in groundwater in the BCHR was based upon historical data and summed average concentrations of VOCs detected in samples from the 1990 assessment wells. Summed average VOC concentrations were determined by summing the average concentration of each VOC detected in samples collected from each well during 1990. For the purposes of calculating average concentrations, results identified as false positives or anomalous values, and VOC concentrations reported as less than the analytical quantitation limit (i.e., not detected), were assumed to be zero. In cases where elevated detection limits (i.e., above the contract required quantitation limit) were reported, the data were considered qualitative only and were not used to calculate averages. In Section 4.3.3 describing VOCs in groundwater in the BCHR, references to "total VOCs" represents a sum of the average concentration of each VOC detected in a sample.

Data screening procedures were used to identify false positive results and anomalous values. Use of the procedures in evaluating VOC concentration data provides a more representative (and repeatable) delineation of VOC plume boundaries. These procedures, which are summarized below, are described in detail in Geraghty & Miller, Inc. (1990a) and are based on procedures established by the

U.S. Environmental Protection Agency (EPA), (1988).

False positive VOC concentrations are defined as results that are probable artifacts of the sampling or analysis procedures. Identification of these results is accomplished through a detailed evaluation of analytical results for the laboratory blank, trip blank, and equipment rinsate sample associated with each groundwater sample. The maximum concentration of each VOC detected in the associated blanks or rinsate sample is multiplied by a qualification factor to determine the blank-qualification results (BQRs). A factor of 5 is used for most VOCs, and a factor of 10 is used for common laboratory reagents such as methylene chloride, acetone, 2-butanone, and toluene (U.S. Environmental Protection Agency 1988). Groundwater sample results for VOCs detected in the quality control samples are then compared to their respective BQRs. If a constituent is detected in the groundwater sample at or below the BQR for the constituent, the result is considered a false positive. The BQRs and false positive results determined for the 1990 VOC data are presented in Appendix D and E, respectively, to Part I of the 1990 GWQAR for the BCHR (HSW Environmental Consultants, Inc. 1991).

Anomalous VOC results were identified by examining the frequency of occurrence of each VOC in groundwater samples collected from each well during 1990. Historical assessment data were used to identify anomalous results for those wells which were not sampled during each 1990 quarterly sampling event. If a VOC was detected in only one of at least four consecutive sampling events for a particular well, that occurrence was considered to be anomalous and not indicative of actual groundwater conditions.

Use of this method to identify anomalous results for samples from wells located at or near the VOC plume boundary may negate a result indicative of plume migration. This could occur if an anomalous value is identified in a fourth quarter sample from a plume boundary well. However, wells used to delineate plume boundaries are included in the monitor-well network used during each annual assessment. Further migration of the plume would be confirmed if the suspect compound is detected in the sample collected from the well during the first quarter of the following

year. If the VOC is not detected in the sample, interpretation of the previous fourth quarter result as anomalous would be substantiated.

4.1.4 Radiochemical Parameters

The radiochemical quality of groundwater in the BCHR was evaluated through a review of results for gross alpha and gross beta activity and isotopic data for selected radionuclides. Delineation of radiochemical plume boundaries was based on annual average gross alpha and gross beta activities in excess of 15 and 50 picoCuries per liter (Pci/L), respectively. These values represent the MCL for gross alpha activity and a threshold limit for gross beta activity above which a total body or critical organ dose equivalent of 4 millirems per year (mrem/yr) (the MCL for gross beta activity) would be expected. Results of uranium and other radionuclide analyses were used to identify the source of gross alpha and gross beta activities.

A degree of uncertainty is associated with the determination of gross alpha and gross beta activities, and is expressed by the counting error reported for each result. In some instances, the counting error exceeds the reported activity. The measured activity is nonetheless valid; the high counting errors imply only that there is a higher degree of uncertainty associated with the value. In addition, some gross alpha and gross beta activities are reported as negative values. This is because the activity reported for a particular sample represents the total activity minus the background activity, so that negative values represent activities below background.

The annual average gross alpha and beta activities for 1990 were determined primarily from quarterly 1990 data. However, for wells which were not sampled during each quarter of 1990, it was necessary to calculate average annual activities using 1989 and 1990 data. Mean annual counting errors were calculated using the

following formula from Evans (1955):

$$\text{Mean counting error} = (E_1^2/N^2 + E_2^2/N^2 + E_3^2/N^2..)^{1/2}$$

where: E_1, E_2, etc. are the individual errors, and N is the number of observations.

This formula is appropriate for calculating the mean error of a series of errors (Geraghty & Miller, Inc. 1990b).

4.2 BACKGROUND CONDITIONS

A description of groundwater geochemistry in the BCHR, based on primary anion and cation data reported for each well during 1990, is provided in this section. Background groundwater and surface-water quality also is discussed.

4.2.1 Inorganic Geochemistry

The geochemistry of groundwater at the Y-12 Plant varies with depth and rock type. Haase and King (1990) noted distinct changes in groundwater chemistry with depth at the Bear Creek Burial Grounds WMA. These changes were interpreted to represent a chemical evolution of groundwater from a calcium-magnesium-bicarbonate groundwater at shallow depths (less than 85 feet [ft] below ground surface), through a sodium-bicarbonate groundwater at intermediate depths (85 to 300 ft), to a sodium-chloride-bicarbonate groundwater at depths of greater than 500 ft (Haase and King 1990). Results of the 1989 assessment indicate that this geochemical zonation was generally evident at the other waste sites in the BCHR (Geraghty & Miller, Inc. 1990b).

Groundwater geochemistry in the BCHR was evaluated through review of the major ion data reported for each well. Primary cations are calcium, magnesium, sodium, and potassium and the principal anions are bicarbonate, chloride, and sulfate. The accuracy of major ion data was checked by computing a relative percent difference (RPD) in the charge balance between the cations

and anions using the following formula:

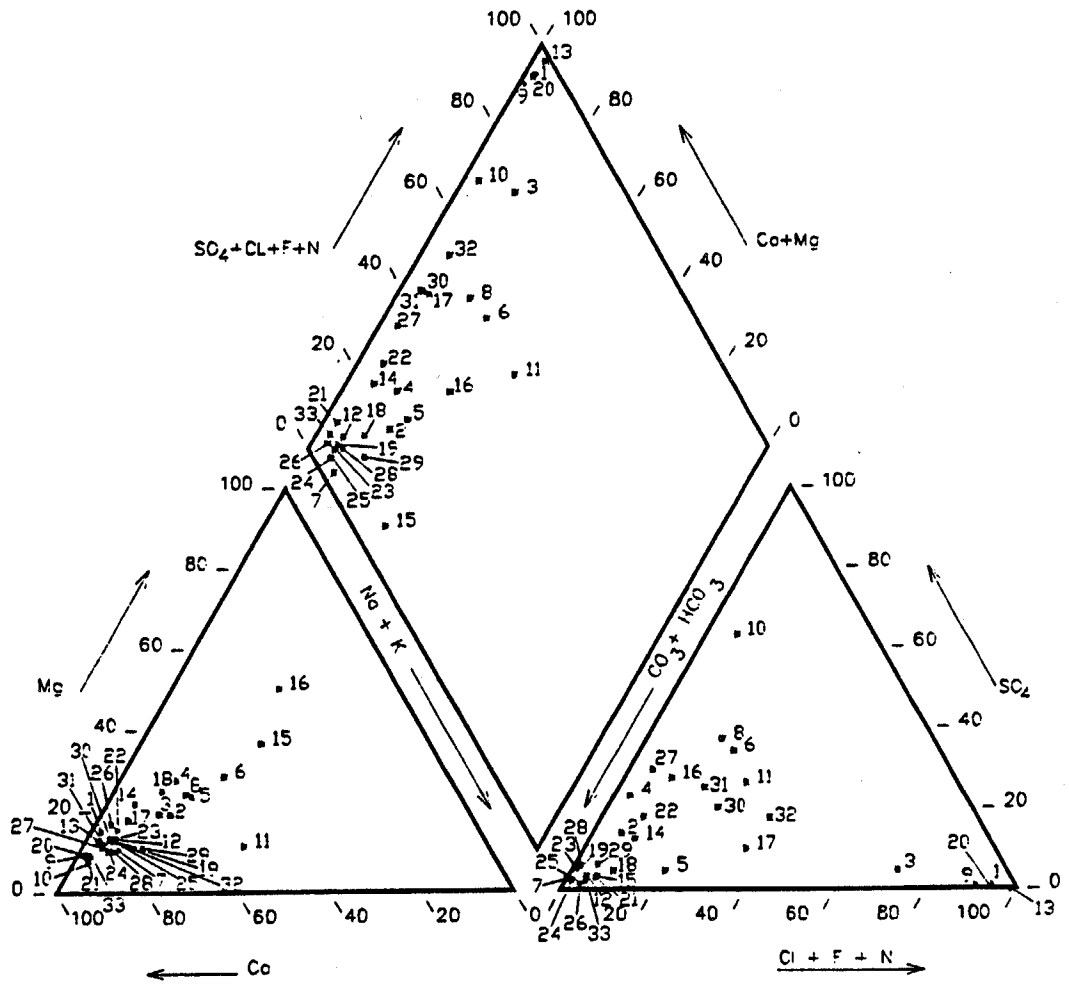
$$RPD = \frac{[\text{Total Cations}] - [\text{Total Anions}]}{[\text{Total Cations}] + [\text{Total Anions}]} \times 100$$

Samples for which the RPD in the anion-cation balance exceeded 10 percent were excluded from further evaluation.

For the purposes of evaluating groundwater geochemistry in the BCHR, wells included in the 1990 assessment were grouped into three categories: (1) unconsolidated zone wells, (2) bedrock wells completed in the Maryville Limestone or the Maynardville Limestone, and (3) bedrock wells completed in the shale formations of the Conasauga Group (Pumpkin Valley, Rogersville, and Nolichucky). Based on the geochemical changes in the composition of groundwater described by Haase and King (1990), the two categories of bedrock wells were further subdivided into : (1) shallow bedrock wells (top of bedrock to 85 ft), (2) intermediate depth bedrock wells (85 ft to 300 ft), and deep bedrock wells (<500 ft).

Groundwater in the unconsolidated zone (Figure 4-2), and at shallow and intermediate depths in the Maryville and Maynardville limestones is primarily of the calcium-magnesium-bicarbonate type (Figure 4-3 and Figure 4-4). Nitrate levels above background levels are evident in groundwater from wells located near the S-3 Site and the eastern boundary of the Oil Landfarm WMA. The ratio of calcium to magnesium varies from 10:1 to 1:1 in groundwater from the bedrock zones. The intermediate limestones have small areas of sodium bicarbonate waters (Figure 4-4). A calcium-magnesium-chloride type groundwater occurs in well GW-601, a deep bedrock well open to the Maynardville Limestone south of the Oil Landfarm WMA.

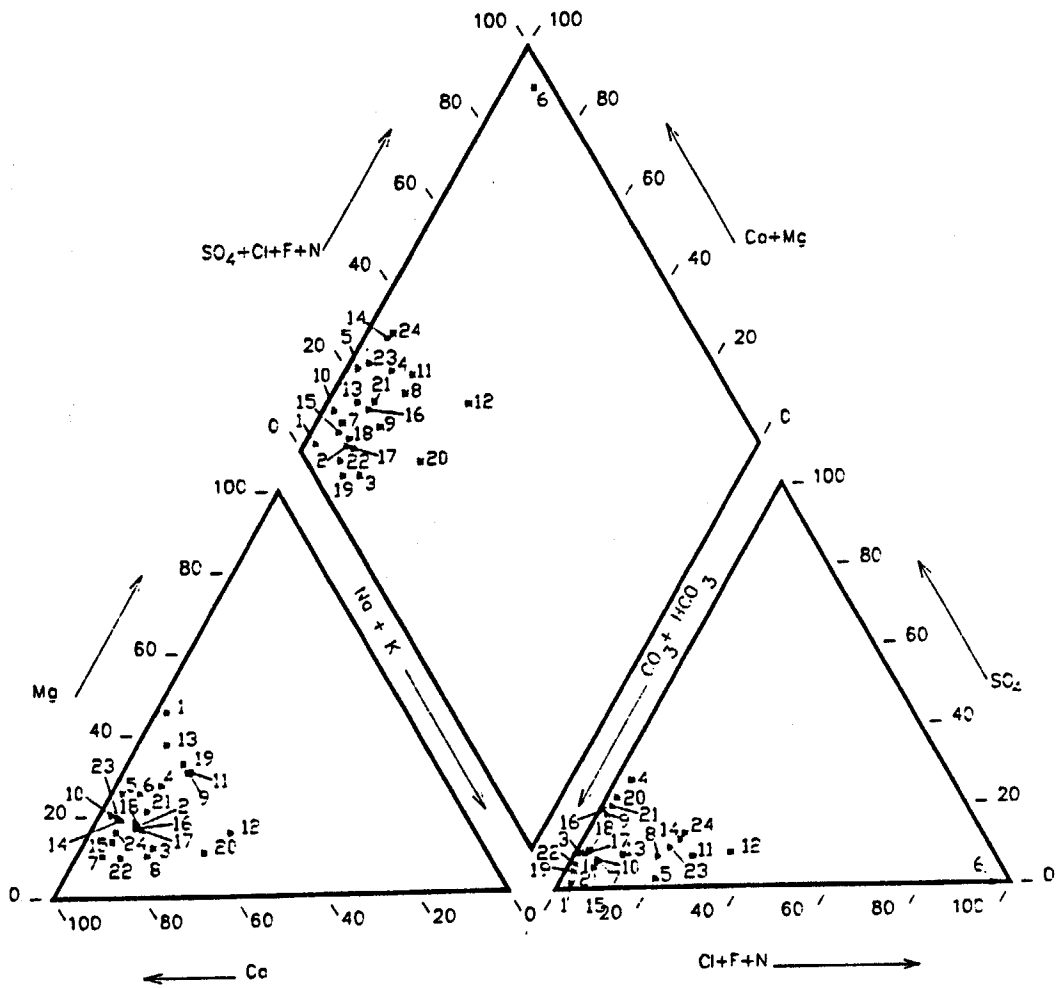
The calcium-magnesium-bicarbonate groundwaters typical of shallow bedrock zones in the Maryville and Maynardville limestones are also common at shallow depths in the Conasauga shales (Figure 4-5). However, wells screened at the intermediate depths in the Conasauga shales monitor two distinct groundwater types: a calcium-magnesium-bicarbonate groundwater and sodium-bicarbonate groundwater (Figure 4-6). The change from the calcium-magnesium-



1	GW-101
2	GW-190
3	GW-251
4	GW-261
5	GW-263
6	GW-325
7	GW-347
8	GW-617
9	GW-100
10	GW-107
11	GW-127
12	GW-349
13	GW-274
14	GW-272
15	GW-252
16	GW-042
17	GW-053
18	GW-089
19	GW-535
20	GW-537
21	GW-622
22	GW-624
23	GW-630
24	GW-532
25	GW-534
26	GW-013
27	GW-067
28	GW-084
29	GW-086
30	GW-307
31	GW-308
32	GW-310
33	GW-311

FIGURE 4-2. GROUNDWATER GEOCHEMISTRY IN THE UNCONSOLIDATED ZONE

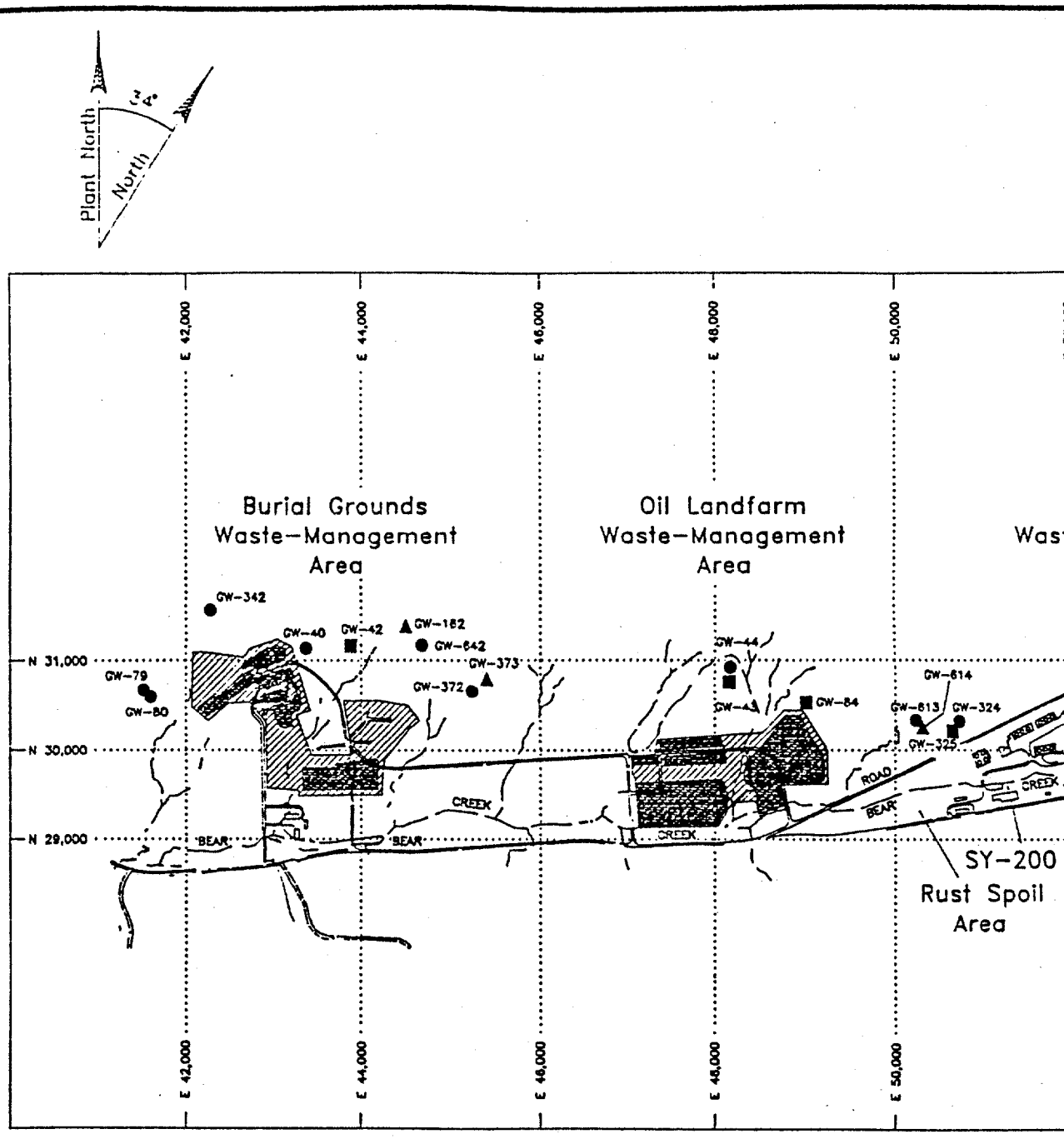
2E200105\XFIG4-2.DWG



1	GW-316
2	GW-115
3	GW-262
4	GW-264
5	GW-348
6	GW-346
7	GW-350
8	GW-618
9	GW-037
10	GW-054
11	GW-056
12	GW-057
13	GW-058
14	GW-061
15	GW-082
16	GW-248
17	GW-258
18	GW-290
19	GW-342
20	GW-370
21	GW-372
22	GW-044
23	GW-064
24	GW-309

FIGURE 4-3. GROUNDWATER GEOCHEMISTRY AT SHALLOW DEPTHS IN THE CONASAUGA GROUP LIMESTONES

2E20[redacted]\XFIG4-3.DWG



EXPLANATION

Waste-Management Area

Solid Waste-Management Unit

Monitor Well Location and Number

GW-42 ■ Unconsolidated Zone

GW-372 ● Shallow Bedrock (Unc-85 ft)

GW-373 ▲ Intermediate Depth Bedrock (85 ft-300 ft)

0 1000'

SCALE

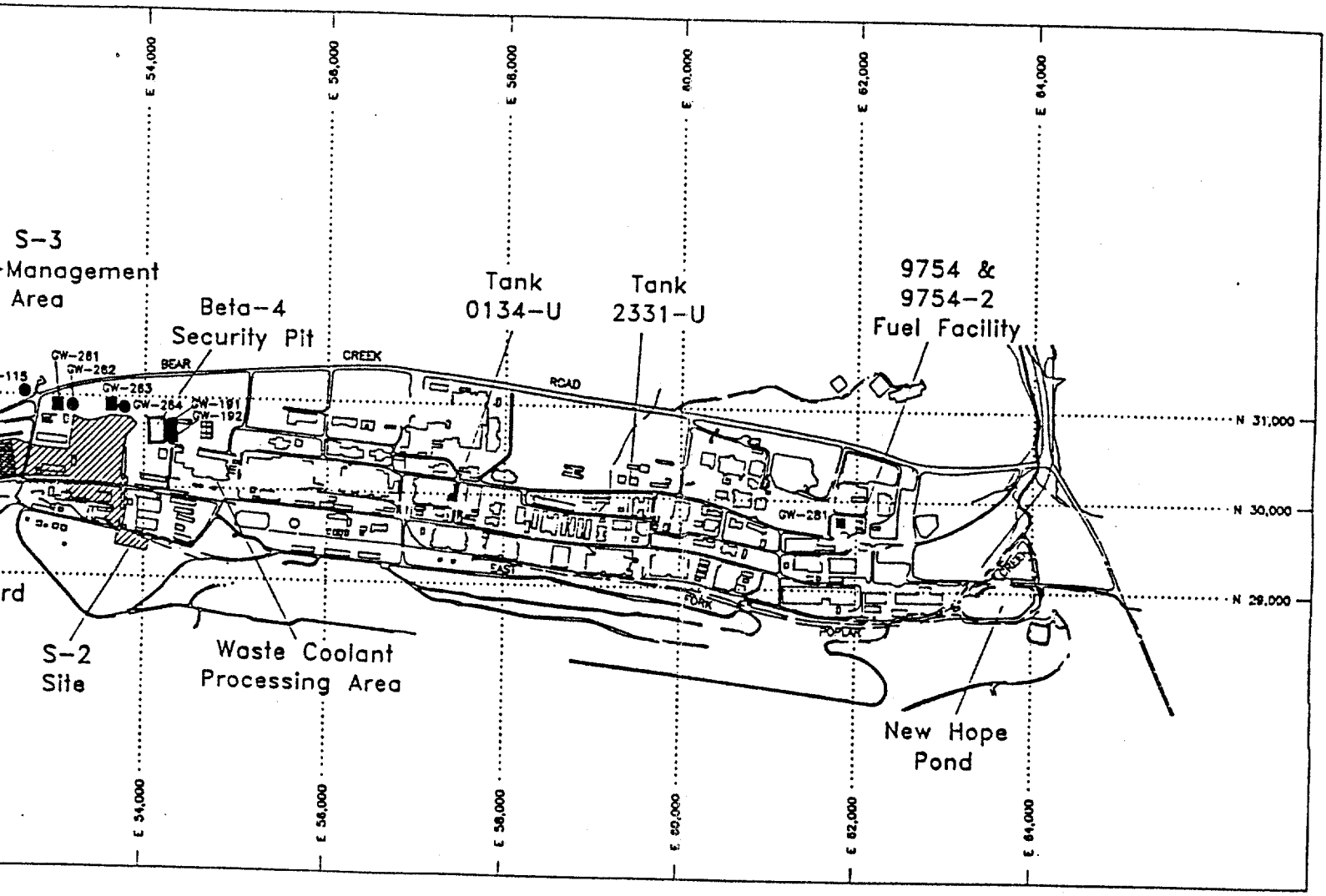


FIGURE 4-7

WELLS USED TO DETERMINE BACKGROUND GROUNDWATER QUALITY

Table 4-4. Background Groundwater Quality in the Bear Creek Valley, 1990

CONSTITUENT[1]	RANGE OF TOTAL CONCENTRATIONS		RANGE OF DISSOLVED CONCENTRATIONS	
GROUNDWATER METALS[2] (mg/L)				
ALUMINUM	<0.02	15	<0.02	0.27
BERYLLIUM	<0.0003	0.0017	<0.0003	0.00037
BORON	<0.004	1.2	<0.004	1
COBALT	<0.005	0.011	<0.005	0.01
COPPER	<0.004	0.094	<0.004	0.039
IRON	0.0051	31	<0.004	4.7
MANGANESE	0.0013	3.6	<0.001	4
MOLYBDENUM	<0.01	0.024	<0.01	0.011
NICKEL	<0.01	0.98	<0.01	1.1
SILICON	1.7	19	0.59	19
STRONTIUM	0.0095	0.88	0.0095	0.89
URANIUM (FLUOR)	<0.001	0.028	<0.001	0.002
VANADIUM	<0.005	0.016	<0.005	0.0053
ZINC	<0.001	0.43	<0.001	0.078
MAJOR ANIONS AND CATIONS (mg/L)				
ALKALINITY-CO^3	<1	36		
ALKALINITY-HCO_3	<1	418		
CALCIUM	1.7	150	1.1	150
CHLORIDE	0.8	30		
FLUORIDE	0.1	1.6		
MAGNESIUM	0.17	45	0.1	43
NITRATE NITROGEN	<0.2	0.6		
POTASSIUM	0.64	5.9	0.64	3.9
SODIUM	1.4	110	1.3	110
SULFATE	2	178		
MISCELLANEOUS PARAMETERS[3]				
SP.COND. (umhos/cm)	33	1143		
DO (ppm)	0.4	10.7		
PH (pH units)	4.9	9.5		
REDOX (mV)	-90	400		
TOC (mg/L)	1	4		
TOX (ug/L)	65	65		
TSS (mg/L)	<1	653		
TURBIDITY (NTU)	0.4	2200		
DISSOLVED SOLIDS	22	708		

Table 4-4. (cont'd.)

Constituent[1]	Minimum Activity	Counting Error (+/-)	Maximum Activity	Counting Error (+/-)
RADIOCHEMICAL PARAMETERS (pCi/L)				
GROSS ALPHA	-1.51	1.5	11.43	2.5
GROSS BETA	-4.29	3.6	29.54	4.4
RADIUM (Bq/L)	0.021	0.042	0.16	0.07
STRONTIUM	57.1	45	57.1	45
228-RADIUM (Bq/L)	0.1	1.4	0.8	1.1
231+234-THORIUM	22.26	13	22.26	13
234-URANIUM	-9.49	38	40.54	36.3
235-URANIUM	-0.95	1.3	16.22	22.9
238-URANIUM	-1.23	1.64	18.98	26.8

NOTE:

Groundwater constituents not detected at minimum attainable detection limit:

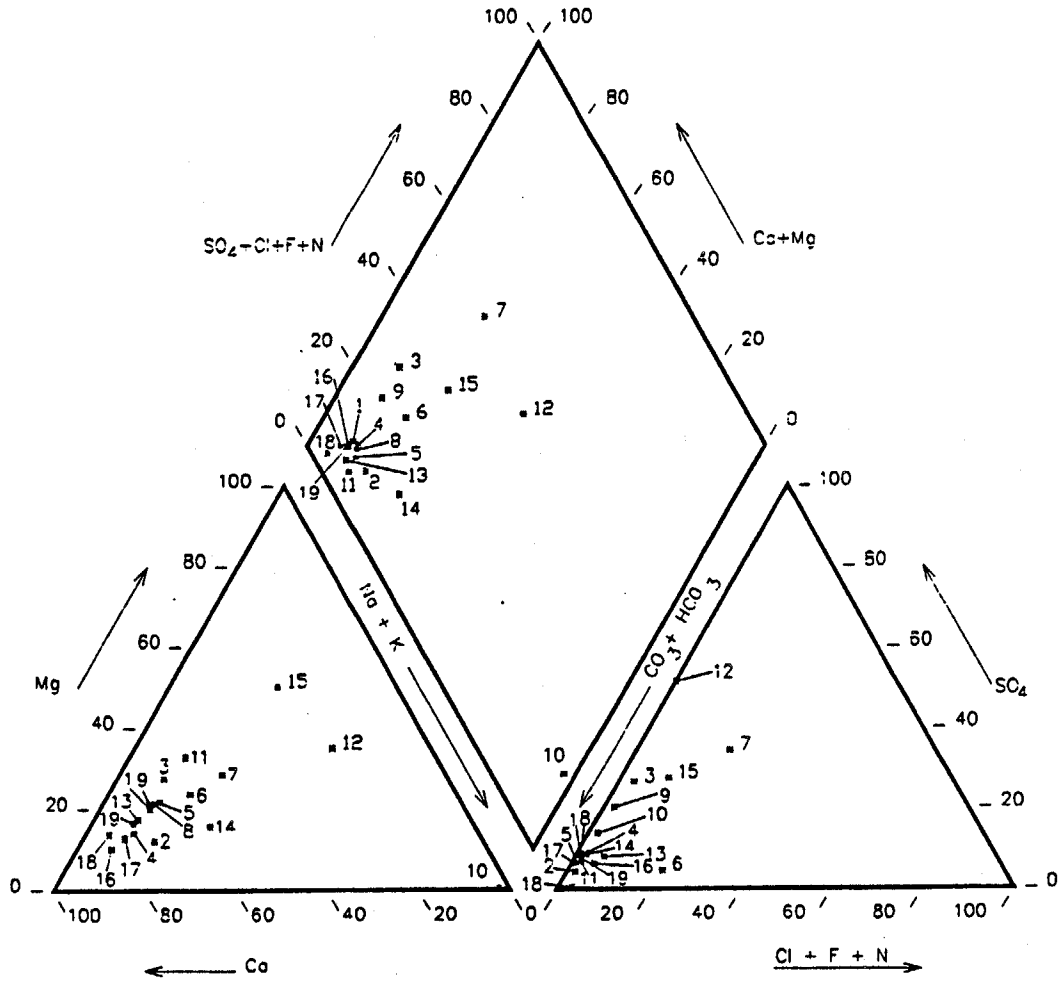
Antimony	Silver	Ammonia Nitrogen
Arsenic	Thorium	Nitrite Nitrogen
Selenium	Thallium	Phenols

1. Metals analyzed using Inductively Coupled Plasma Spectroscopy unless otherwise noted.

   Units:
   - mg/L - Milligrams per liter
   - umhos/cm - Micromhos per centimeter
   - NTU - Nephelometric turbidity unit
   - mV - Millivolts
   - pCi/L - PicoCuries per liter
   - Bq/L - Becquerel per liter

2. Range for metals represents 1989 and 1990 data.
   FLUOR - Fluorometric

3. SP. COND. - Specific Conductance
   DO - Dissolved Oxygen
   TOC - Total Organic Carbon
   TOX - Total Organic Halide
   TSS - Total Suspended Solids



1	GW-115
2	GW-262
3	GW-264
4	GW-613
5	GW-614
6	GW-263
7	GW-325
8	GW-324
9	GW-372
10	GW-373
11	GW-342
12	GW-080
13	GW-079
14	GW-162
15	GW-042
16	GW-084
17	GW-191
18	GW-192
19	GW-281

FIGURE 4-8. GEOCHEMISTRY OF GROUNDWATER IN BACKGROUND WELLS IN BEAR CREEK VALLEY

\2E200105\XFIG4-8.DWG

Table 4-5. Background Surface-Water Quality in the Bear Creek Hydrogeologic Regime, 1990

CONSTITUENT[1]	RANGE OF TOTAL CONCENTRATIONS		RANGE OF DISSOLVED CONCENTRATIONS	
METALS (mg/L)				
ALUMINUM	0.18	7.4	0.3	0.7
BERYLLIUM	<0.0003	0.00072	<0.003	
BORON	0.0043	0.18	0.015	0.016
COBALT	<0.005	0.016	<0.005	
COPPER	<0.004	0.0063	<0.004	
IRON	0.85	29	0.036	0.62
MANGANESE	0.24	6.1	0.23	2.7
SILICON	4.3	19	4.4	6.3
STRONTIUM	0.047	0.11	0.047	0.1
VANADIUM	<0.005	0.013	<0.005	
ZINC	<0.001	0.062	<0.001	0.0082
MAJOR ANIONS AND CATIONS (mg/L)				
ALKALINITY-HCO_3	38	115		
CALCIUM	11	36	11	34
CHLORIDE	1	1		
MAGNESIUM	2.2	7.2	2.2	6.2
POTASSIUM	1.5	3.5	1.4	2.1
SODIUM	2.3	4.6	2.2	4.8
SULFATE	5	7		
MISCELLANEOUS PARAMETERS[2]				
SP. COND. (umhos/cm)	95	370		
DO (ppm)	6	6.4		
pH (pH units)	7.6	7.6		
TSS (mg/L)	3	165		
TURBIDITY (NTU)	8	220		
DISSOLVED SOLIDS	50	136		

Table 4-5. (cont'd.)

Constituent[1]	Minimum Activity	Counting Error (+/-)	Maximum Activity	Counting Error (+/-)
RADIOCHEMICAL PARAMETERS (pCi/L)				
GROSS ALPHA	-0.57	1.5	2.11	1.8
GROSS BETA	1.68	3.5	2.91	3.6
234-URANIUM	-0.95	1.9	0	1.7
235-URANIUM	0	1.3	0.42	1.5
238-URANIUM	-0.47	1.6	0	1.5

NOTE:

Surface water constituents not detected at minimum attainable detection limit:

Alkalinity-CO_3	Molybdenum	Silver
Antimony	Nickel	Thorium
Arsenic	Nitrate Nitrogen	
Fluoride	Uranium (Fluorometric)	

1. Metals analyzed using Inductively Coupled Plasma Spectroscopy unless otherwise noted.

Units:
- mg/L - Milligrams per liter
- umhos/cm - Micromhos per centimeter
- NTU - Nephelometric turbidity unit
- mV - Millivolts
- pCi/L - PicoCuries per liter
- Bq/L - Becquerel per liter

2. SP. COND. - Specific Conductance
   DO - Dissolved Oxygen
   TSS - Total Suspended Solids

maximum total concentration of 0.11 mg/L was reported for strontium.

4.3 GROUNDWATER QUALITY

The principal constituents of concern in groundwater in the BCHR are nitrate, metals, VOCs, and radionuclides. The primary sources of VOCs in the BCHR include the S-3 Site, the Rust Spoil Area, the Oil Landfarm WMA, and the Bear Creek Burial Grounds WMA. The primary source of nitrates, metals, and radionuclides is the S-3 Site, which is also a principal source of these compounds in the UEFPCHR. Although the S-3 Site lies west of a groundwater divide that now separates the BCHR from the UEFPCHR, a mound in the water table present below the site during its operational period enabled migration to occur east of the current divide (Geraghty & Miller, Inc. 1985). Since the termination of waste disposal at the S-3 Site in 1984, the mound in the water table gradually abated and is no longer present (see Figure 3-5). However, because contaminants released from the S-3 Site have migrated into the UEFPCHR, detailed descriptions of the plumes to the east of the site are contained in Part II of the 1990 GWQAR for the UEFPCHR (HSW Environmental Consultants, Inc. 1991b).

4.3.1 Nitrate

As noted in Section 4.1.1, nitrate plume boundaries were based on nitrate (as N) concentrations exceeding 10 mg/L. The extent of the nitrate plume in unconsolidated, shallow bedrock, and intermediate depth bedrock zones in the BCHR is illustrated on Plate 1. Nitrate source areas are indicated by the irregular geometry of the plumes in the unconsolidated zone and shallow bedrock zone. Additionally, the elongated shape of the plume in the shallow bedrock zone reflects a preferred migration pathway through the Maynardville Limestone. Down-valley (along strike) transport through the Maynardville Limestone is further illustrated by the nitrate plume geometry in the intermediate depth aquifer zone.

The nitrate plume in the unconsolidated zone is essentially defined (Plate 1) and the S-3 Site appears to be the principal

nitrate source area. The plume extends from the S-3 Site to the west for about 1,800 ft, then trends sharply southward toward Bear Creek, and southwest along a relatively narrow band paralleling the creek for about 6,000 ft downstream. The sharp southward trend along the western plume boundary may be the result of preferred migration through fill material in a buried tributary of the original Bear Creek drainage system. In the eastern section of the Oil Landfarm WMA, a second nitrate source area is indicated by a lobe of the unconsolidated zone plume extending to the north of Bear Creek along tributary NT-2 (Plate 1). Evidence for a nitrate source in this area is provided by data reported for well GW-537. Nitrate concentrations in samples from well GW-537 averaged 819 mg/L, which is substantially higher than nitrate concentrations in samples from other unconsolidated zone wells located between well GW-537 and the S-3 Site.

Nitrate concentrations exceeded the 10 mg/L MCL in only one unconsolidated zone well (GW-52) at the Bear Creek Burial Grounds WMA (Plate 1). Well GW-52 is located approximately 100 ft north of Bear Creek and a nitrate concentration of 28 mg/L was reported for the first quarter 1990 sample collected from the well. Although the well was sampled only once during 1990, this result is supported by historical data for the well.

Elevated nitrate concentrations in well GW-52 may indicate a local nitrate source area, or may demonstrate a hydraulic connection between the well and Bear Creek. Spring SS-4 discharges groundwater to Bear Creek about 700 ft upstream of GW-52, and nitrate concentrations of 52 mg/L and 29 mg/L were reported for the third and fourth quarter samples from the spring. The reach of Bear Creek upstream of GW-52 and downstream of spring SS-4 loses flow to the groundwater system during both normal and extreme low flow conditions (Geraghty & Miller, Inc. 1989b). It is possible that groundwater quality in well GW-52 is affected by the infiltration of nitrate-bearing surface water from Bear Creek.

The nitrate plume in the shallow bedrock aquifer zone is well defined (Plate 1), and also implicates the S-3 Site as the primary source area. The plume extends about 1,600 ft along strike in the Nolichucky Shale to the west of the S-3 Site. In addition, the

plume extends into the Maynardville Limestone directly south (down-dip) of the site. Nitrate in the Maynardville Limestone has migrated much farther along strike than in the Nolichucky Shale. As shown on Plate 1, the nitrate plume in the Maynardville Limestone extends approximately 9,000 ft to the west of the S-3 site to an area south of the Bear Creek Burial Grounds WMA. Moreover, it appears that nitrate migration in the Maynardville Limestone may be somewhat limited to a relatively discrete stratigraphic interval. This stratigraphic influence on nitrate migration may account for the narrow shape of the shallow bedrock plume in the Maynardville Limestone between the Oil Landfarm WMA and the Bear Creek Burial Grounds WMA.

As in the unconsolidated zone, a northward trending lobe in the shape of the nitrate plume in the shallow bedrock zone indicates the presence of a second nitrate source area located near the eastern boundary of the Oil Landfarm WMA. Nitrate concentrations reported for samples collected from well GW-85, which averaged 185 mg/L, are significantly higher than the nitrate concentrations in any other shallow bedrock well within 1,000 ft west of the S-3 Site. However, the average nitrate concentration in samples collected from the unconsolidated zone well (GW-86) clustered with GW-85 was only 2 mg/L. The low nitrate levels in samples from well GW-85 indicate that the high nitrate concentrations in well GW-86 may reflect westward migration along-strike in the Nolichucky Shale from a nitrate source area located in the vicinity of unconsolidated zone well GW-537.

Although well control is more limited, the extent of the nitrate plume in the intermediate depth bedrock zone is essentially defined. The nitrate plume in the intermediate bedrock aquifer zone extends along strike in the Nolichucky Shale west of the S-3 Site for approximately 1,600 ft, and about 5,200 ft along strike in the Maynardville Limestone to the southwestern corner of the Oil Landfarm WMA (Plate 1). Data reported for samples collected from wells GW-615 and GW-616 indicate that high (i.e., >100 mg/L) nitrate concentrations extend deeper into bedrock than previously known. Both of these wells were completed with open intervals between 200 ft and 260 ft below ground surface. Samples from well

GW-615, which monitors a stratigraphic interval in the Nolichucky Shale directly down-dip (south) of the S-3 Site, contained a maximum nitrate level in excess of 13,000 mg/L. Groundwater monitored by well GW-616, located about 500 ft south and open to the Maynardville Limestone about 200 ft along strike to the west of the S-3 Site, was found to contain nitrate concentrations ranging between 200 mg/L and 400 mg/L.

The nitrate plume in the deep bedrock zone in the BCHR is limited to the general vicinity of the S-3 Site. Six deep bedrock wells are located downgradient of potential source areas in the BCHR: GW-123 and GW-125 at the S-3 Site, GW-601 at the Oil Landfarm WMA, and GW-117, GW-118, and GW-119 at the Bear Creek Burial Grounds WMA (Figure 4-1). Only samples collected from deep well GW-125 located at the S-3 Site contained nitrate concentrations above the 10 mg/L MCL. Well GW-125 monitors a stratigraphic interval in the Nolichucky Shale directly down-dip of the S-3 Site, and nitrate concentrations in groundwater samples from the well averaged about 28 mg/L. In contrast, nitrate was not detected in samples from well GW-123, which monitors a stratigraphic interval in the Nolichucky Shale about 300 ft along strike to the west of the S-3 Site. The difference between the nitrate concentrations in the two wells may indicate that nitrate migration is somewhat limited along strike in deep zones in the Nolichucky Shale.

4.3.2 Metals

As discussed in Section 4.1.2, evaluation of groundwater quality in the BCHR with respect to trace metals was based on total metal concentrations which exceeded MCLs established by the EPA for the eight primary drinking-water metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver), or background levels of other metals for which MCLs have not been promulgated. The following discussion has been divided into subsections describing results of the 1990 assessment for these two major groups of metals.

4.3.2.1 Primary Drinking-Water Metals

Total concentrations of arsenic, barium, cadmium, chromium, lead, mercury, and selenium exceeded their respective MCLs in groundwater samples from one or more wells in the BCHR. Results for arsenic and selenium were considered unreliable because of inherent analytical interferences associated with the ICP procedure used in the analyses for these metals (see Section 4.1.2). However, because total arsenic and selenium concentrations above the MCLs obtained with the AAS procedure before 1990 were sporadic this loss of quantitative data was not critical. In addition, what were considered anomalous concentrations exceeding MCLs for some metals were reported for samples from several wells (Table 4-6). These results were considered anomalous because they were inconsistent with the results reported for the other 1990 samples from the wells or they were not supported by historical assessment data for the wells. The 1990 results for all other metals exceeding MCLs (excluding arsenic, selenium, and anomalous results) are summarized on Table 4-7. Locations of the wells for which elevated concentrations of these metals were reported are shown on Figure 4-9.

Results of previous assessments have identified the S-3 Site as a source of elevated concentrations of barium, cadmium, chromium, lead, and mercury in groundwater in the BCHR. Data obtained during 1990 support this conclusion (Table 4-7); groundwater containing trace metal concentrations which exceeded MCLs was found mainly within 500 ft of the S-3 Site. This is the only area in the BCHR where an actual "plume" of elevated trace metal concentrations may be present.

Elsewhere in the BCHR, only isolated occurrences of elevated concentrations are evident. One well at the Rust Spoil Area (GW-308) contained elevated concentrations of chromium in the third and fourth quarter samples from the well (Table 4-7). At the Oil Landfarm WMA, elevated concentrations of barium, cadmium, chromium, lead, and mercury were reported. These concentrations were reported for samples from only three wells at the site: unconsolidated zone wells GW-5 and GW-537, and shallow bedrock well GW-63. Total metal concentrations exceeded MCLs in only three

Table 4-6. Trace Metal Concentrations Considered Anomalous

METAL	WELL NUMBER	AQUIFER ZONE[1]	1989[a] 1	2	3	4	1990[a] 1	2	3	4
S-3 Site										
Lead	GW-345	U	0.012	0.013	ND	0.0065	ND	ND	0.3*	0.0057
Spoil Area I										
Lead	GW-313	S	NS	NS	NS	NS	ND	ND	0.0067	0.12*
Rust Spoil Area										
Chromium	GW-307	U	NS	NS	NS	NS	ND	ND	ND	0.16*
Oil Landfarm WMA										
Lead	GW- 43	U	NS	NS	NS	NS	0.012	0.022	0.054*	0.0087
	GW- 63	S	0.031	0.025	0.019	0.02	0.027	0.14*	0.022	0.018
Bear Creek Burial Grounds WMA										
Cadmium	GW- 80	S	NS	NS	NS	NS	NS	0.022*	0.0032	0.0026
Chromium	GW- 54	S	NS	NS	NS	NS	NS	0.068*	ND	ND
	GW- 57	S	NS	NS	NS	NS	NS	0.1*	0.036	0.012
	GW- 58	S	0.12	ND	ND	ND	ND	0.19*	0.013	ND
Lead	GW- 46	U	NS	ND	NS	ND	0.257*	NS	NS	NS
	GW- 58	S	0.64	0.0042	0.0052	ND	0.058*	0.013	0.019	ND
	GW- 80	S	NS	NS	NS	NS	NS	0.093*	0.024	0.0062
	GW- 89	U	NS	NS	NS	NS	NS	0.031	0.128*	ND

Note: 1. U - Uncosolidated Zone
S - Shallow Bedrock Zone
I - Intermediate Bedrock Zone

a. Total Concentrations (mg/L)
ND - Not Detected
NS - Not Sampled
* - Anomalous Result

Table 4-7. Trace Metal Concentrations Which Exceeded Maximum Contaminant Levels

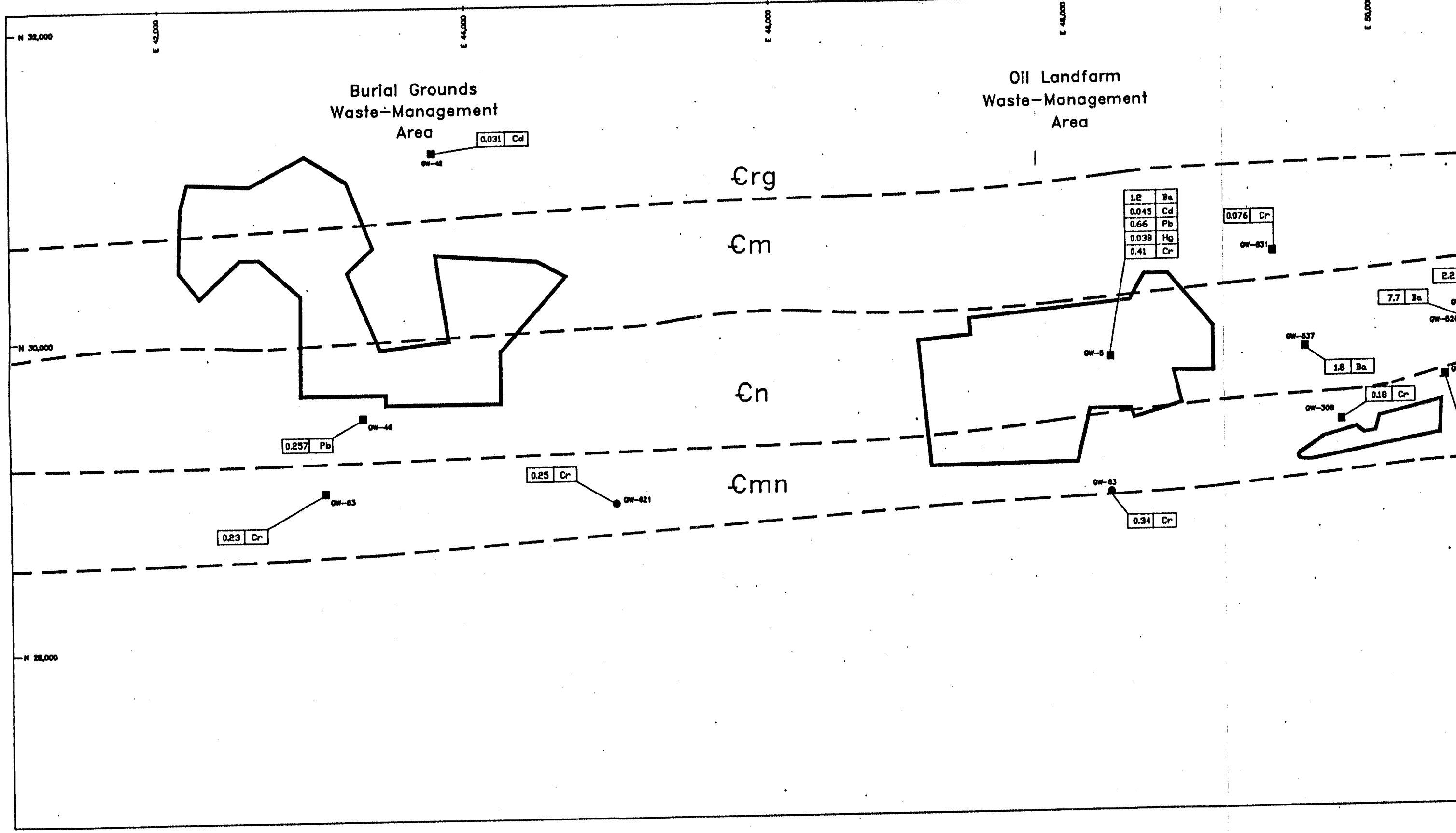
METAL[1]	WELL NUMBER	AQUIFER ZONE[2]	1990 QUARTER[3] 1	2	3	4
S-3 SITE WMA						
Barium						
	GW-100	U	1.2	NS	NS	NS
	GW-101	U	NS	10	5.9	6.3
	GW-236	U	1.1	NS	NS	NS
	GW-345	U	1.4	<MCL	1.3	1.2
	GW-243	S	NS	NS	NS	6.2
	GW-245	S	16	NS	NS	NS
	GW-246	S	25	NS	NS	NS
	GW-247	S	29	NS	NS	NS
	GW-346	S	2.2	NS	NS	NS
	GW-122	I	9.9	10	8.7	9.1
	GW-526	I	7	6.6	7	7.7
	GW-615	I	NS	320	330	350
Cadmium						
	GW-101	U	NS	0.06	1.4	0.0052
	GW-236	U	0.013	NS	NS	NS
	GW-243	S	NS	NS	NS	1.9
	GW-245	S	0.12	NS	NS	NS
	GW-246	S	0.38	NS	NS	NS
	GW-247	S	0.081	NS	NS	NS
	GW-615	I	NS	0.16	0.13	0.20
Chromium						
	GW-243	S	NS	NS	NS	0.22
Lead						
	GW-100	U	0.13	NS	NS	NS
	GW-245	S	0.32	NS	NS	NS
	GW-246	S	0.66	NS	NS	NS
	GW-247	S	0.66	NS	NS	NS
Mercury						
	GW-101	U	NS	0.0065	0.0067	0.012
	GW-243	S	NS	NS	NS	0.042
	GW-246	S	0.0026	NS	NS	NS
	GW-124	I	0.00034	NS	NS	NS

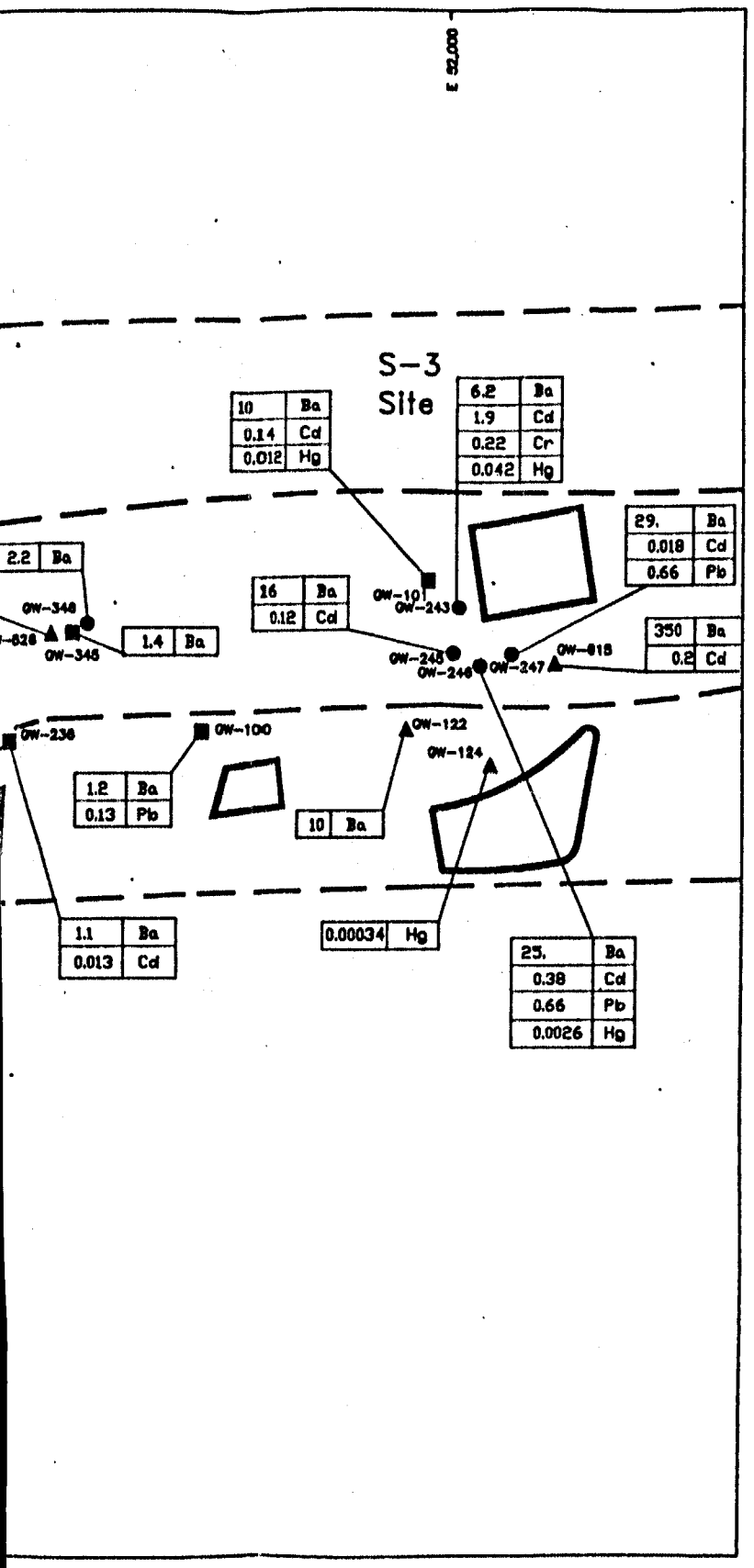
Table 4-7. (Cont'd)

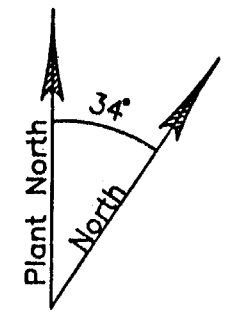
METAL[1]	WELL NUMBER	AQUIFER ZONE[2]	1990 QUARTER[3] 1	2	3	4
RUST SPOIL AREA						
Chromium						
	GW-308	U	ND	ND	0.059	0.18
OIL LANDFARM WMA						
Barium						
	GW-5	U	NS	<MCL	1.2	<MCL
	GW-537	U	1.7	1.7	1.6	1.8
Cadmium						
	GW-5	U	NS	0.011	0.045	<MCL
Chromium						
	GW-5	U	NS	0.11	0.41	<MCL
	GW-63	S	0.089	0.34	<MCL	0.096
Lead						
	GW-5	U	NS	0.27	0.66	0.086
Mercury						
	GW-5	U	NS	0.016	0.038	0.0084
	GW-531	U	ND	0.076	<MCL	<MCL
BEAR CREEK BURIAL GROUNDS WMA						
Cadmium						
	GW-42	U	29	<MCL	0.031	0.018
Chromium						
	GW-621	S	ND	0.25	0.082	0.089
	GW-53	U	NS	0.23	0.011	ND
	GW-46	U	0.257	NS	NS	NS

Note:

1. Maximum Contaminant Levels (mg/L):
   - Barium 1.0
   - Cadmium 0.01
   - Chromium 0.05
   - Lead 0.05
   - Mercury 0.002
2. U - Unconsolidated Zone
   S - Shallow Bedrock Zone
   I - Intermediate Bedrock Zone
3. Total Concentrations (mg/L)
   - ND - Not detected
   - NS - Not sampled
   - <MCL - Below Maximum Contaminant Level


N 32,000
E 42,000
E 44,000
E 46,000
E 48,000
E 50,000
Burial Grounds
Waste-Management
Area
Oil Landfarm
Waste-Management
Area
0.031 Cd
GW-42
Ꞓrg
Ꞓm
Ꞓn
Ꞓmn
1.2 Ba
0.045 Cd
0.66 Pb
0.038 Hg
0.41 Cr
0.076 Cr
GW-631
GW-5
7.7 Ba
GW-637
1.8 Ba
0.18 Cr
GW-306
N 30,000
GW-46
0.257 Pb
0.25 Cr
GW-621
GW-63
0.23 Cr
0.34 Cr
N 28,000





0 600'
SCALE

EXPLANATION

GW-101	■	Unconsolidated Zone Monitor Well
GW-243	●	Shallow Bedrock Zone Monitor Well (Unc-85')
GW-615	▲	Intermediate Bedrock Zone Monitor Well (85'-300')
		Approximate Geologic Contact
		Boundary of Site or Waste Management Area
OCk		Knox Group
-Cmn		Maynardville Limestone
-Cn		Nolichucky Shale
-Cm		Maryville Limestone
-Crg		Rogersville Shale
Ba		Barium
Cd		Cadmium
Cr		Chromium
Hg		Mercury
Pb		Lead

Note: 1990 Maximum metal concentrations are in mg/L

FIGURE 4-9
OCCURRENCE OF MAXIMUM TRACE METAL CONCENTRATIONS IN 1990 EXCEEDING MAXIMUM CONTAMINANT LEVELS

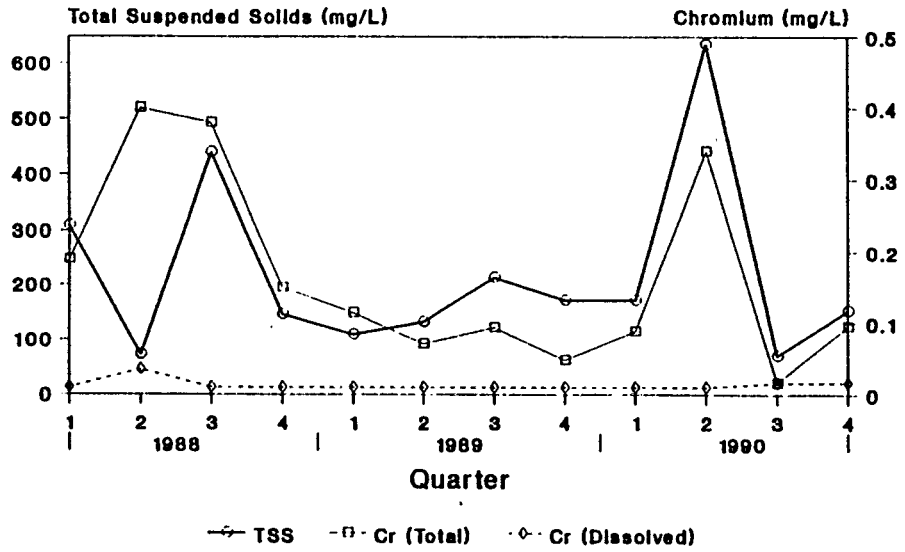
wells at the Bear Creek Burial Grounds WMA: unconsolidated zone wells GW-42 and GW-531, and shallow bedrock well GW-621.

As shown on Table 4-7, elevated metal concentrations were most commonly reported for groundwater samples collected from unconsolidated zone wells. Aside from one well at the Oil Landfarm (GW-63) and one well at the Bear Creek Burial Grounds WMA (GW-621), metal concentrations which exceeded MCLs in groundwater in the shallow bedrock zone were reported only for samples from wells located near the S-3 Site. Moreover, the only intermediate depth bedrock wells (GW-122, GW-526, and GW-615) with elevated metal concentrations were also located near the S-3 Site. This finding may indicate that the acidic wastes disposed in the S-3 Site locally reduced the pH in groundwater in the underlying bedrock enabling greater down-dip migration of the metal ions (i.e., near field effect).

A review of the 1990 and historical data indicates a strong relationship between the total chromium concentrations and the TSS in the unfiltered samples from wells GW-63 and GW-621. As illustrated on Figure 4-10, fluctuations in total chromium concentrations in the two wells are coincident with fluctuations in TSS, but dissolved chromium concentrations in both wells have consistently remained below the method detection limit of 0.01 mg/L. Moreover, the concentration trends in both wells during 1990 are very similar with the maximum TSS and total chromium concentration in both wells occurring in the second quarter 1990 samples from the wells. Both wells are screened in the Maynardville Limestone and the synchronous fluctuations in TSS may indicate that the two wells monitor the same flow system. A relationship is also evident between TSS and total lead concentrations in shallow bedrock wells GW-58 and GW-226 (Figure 4-11). Both wells are screened in the Maynardville Limestone; GW-226 is located just south of the Oil Landfarm WMA and GW-58 is located south of the Bear Creek Burial Grounds WMA. Data reported for the wells since 1988 show strong correlations between TSS and total lead concentrations in samples from the wells.

It is possible that groundwater containing elevated dissolved chromium concentrations has at some time migrated through the

GW-63



GW-621

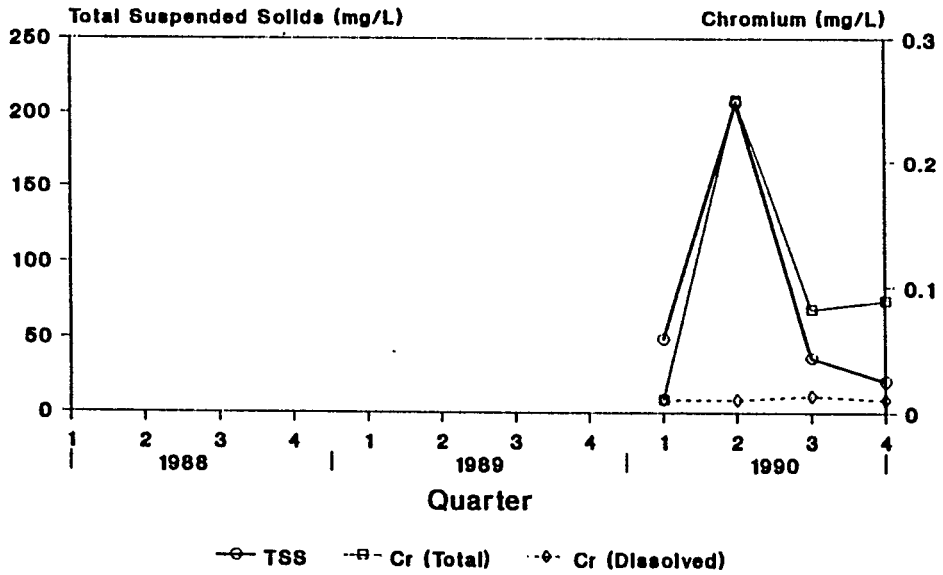
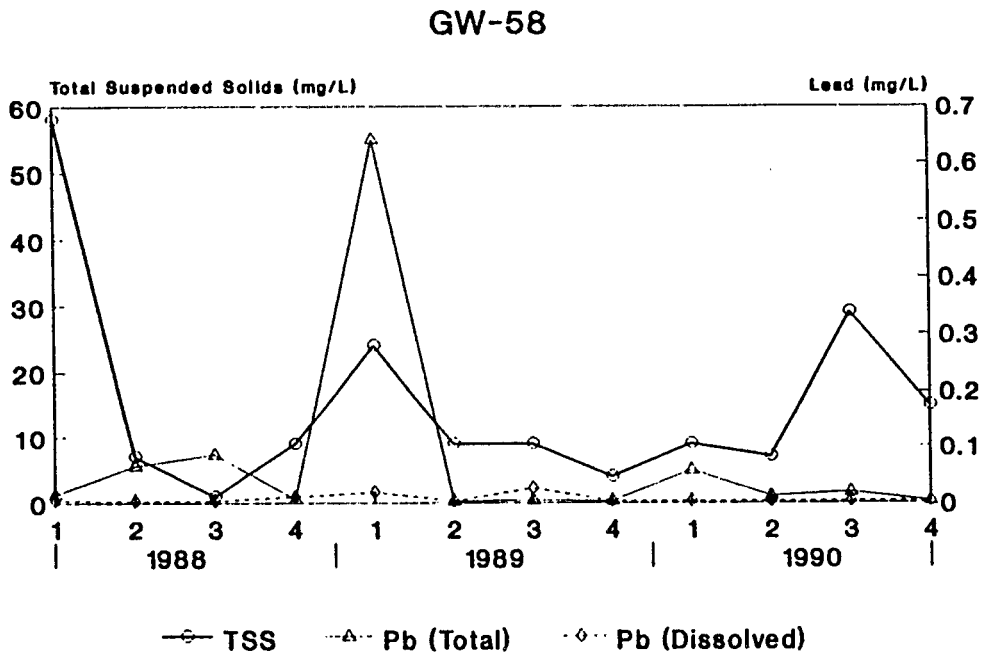


FIGURE 4-10

RELATIONSHIP BETWEEN TSS AND CHROMIUM CONCENTRATIONS IN WELLS GW-63 AND GW-621



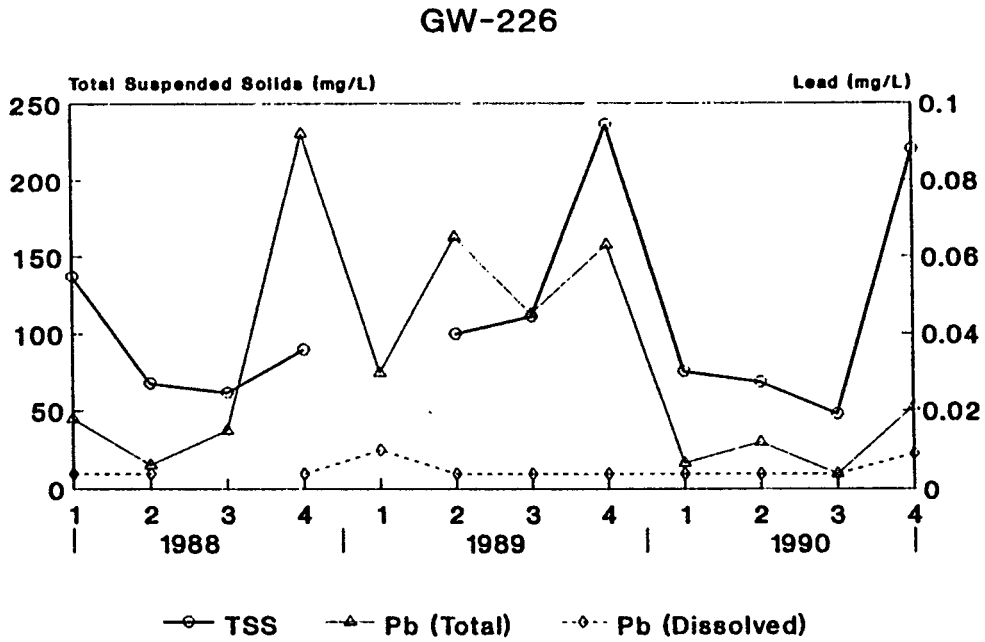


FIGURE 4-11
RELATIONSHIP BETWEEN TSS AND LEAD CONCENTRATIONS IN WELLS GW-58 AND GW-226

stratigraphic zones in the Maynardville Limestone monitored by wells GW-63 and GW-621. Similarly, groundwater containing high dissolved lead concentrations may have migrated the stratigraphic zones monitored by wells GW-58 and GW-226. Chromium and lead ions in the groundwater may have sorbed onto residual clays present in fractures or solution cavities in the rock. A turbid unfiltered groundwater sample could be collected if these sediments are suspended into the water column in each well when they are purged prior to sampling, or if the wells are sampled shortly after a precipitation event when a pulse of turbid groundwater may move through the flow system in the Maynardville Limestone. In either case, chromium or lead sorbed onto the suspended materials may be mobilized into solution when the pH of the samples is reduced during preservation. This may explain the close relationship between TSS and total chromium concentrationsand in samples from GW-63 and GW-621, and total lead concentrations in samples from GW-58 and GW-226.

4.3.2.2 Other Trace Metals

Total concentrations of trace metals for which MCLs have not been promulgated exceeded maximum background levels only in groundwater near the S-3 Site. Concentrations of aluminum beryllium, boron, copper, cobalt, nickel, strontium, and uranium exceeded background levels in samples from wells at the S-3 Site. Of these, elevated concentrations of strontium and uranium were most frequently reported.

In samples from unconsolidated zone well GW-101, total strontium ranged from 12 mg/L to 23 mg/L and total uranium ranged from 0.043 mg/L to 0.062 mg/L. Total uranium concentrations also exceeded background levels in samples from unconsolidated well GW-127 (0.434 mg/L). Well GW-101 is located adjacent to the S-3 Site, and well GW-127 is located near Bear Creek about 300 ft downstream of the S-3 Site.

The only occurrences of elevated strontium and uranium concentrations in shallow bedrock wells were reported for samples from wells located adjacent to the S-3 Site. Total uranium concentrations exceeded background levels in samples from shallow

bedrock wells GW-246 (0.552 mg/L) and GW-247 (0.027 mg/L). Total strontium and uranium concentrations were reported to be 9.7 mg/L and 34.9 mg/L, respectively, in shallow bedrock well GW-243. The sample from well GW-243 also contained elevated concentrations of aluminum (730 mg/L), beryllium (0.07 mg/L), boron (1.3 mg/L), cobalt (1.2 mg/L), copper (1.4 mg/L), and nickel (16 mg/L).

Total strontium ranged from 300 mg/L to 310 mg/L and total uranium ranged from 0.396 mg/L to 0.653 in intermediate depth well GW-615 monitoring groundwater in the Nolichucky Shale directly down-dip of the S-3 Site. Samples from GW-615 also contained elevated concentrations of copper (0.45 mg/L to 0.98 mg/L) and cobalt (0.13 mg/L to 0.2 mg/L). Total strontium concentration also exceed background levels in samples from intermediate depth wells GW-122 (19 mg/L to 23 mg/L) and GW-526 (8.5 mg/L to 9.7 mg/L).

4.3.3 Volatile Organic Compounds

The extent of VOCs in groundwater in the BCHR is illustrated on Plate 2. Sources of VOCs include the Bear Creek Burial Grounds WMA, Oil Landfarm, Rust Spoil Area, Spoil Area I, and the S-3 Site. Dissolved VOC plumes in the unconsolidated zone generally occur only in the immediate vicinity of the VOC source areas. In contrast, at shallow bedrock depths, an apparently continuous dissolved VOC plume extends from the S-3 Site westward for about 6,000 ft to just west of the Oil Landfarm. Additionally, what is believed to be a continuous VOC plume at intermediate bedrock depths extends from the S-3 Site south to the Maynardville Limestone, and along strike in the Maynardville Limestone to an area just west of the Oil Landfarm.

West of the Oil Landfarm WMA, separate dissolved VOC plumes occur in the groundwater underlying the Bear Creek Burial Grounds WMA. Additionally, a review of monitoring data suggests that VOCs are present in deep bedrock zones at the Bear Creek Burial Grounds WMA, but are not present in groundwater in deep bedrock zones in the eastern portion of the BCHR.

The types of VOCs present in the unconsolidated zone, shallow bedrock zone, and intermediate depth bedrock zone in the BCHR are

tetrachloroethene (PCE), trichloroethene (TCE), 1,2-dichloroethene (1,2-DCE), 1,1,1-trichloroethane (1,1,1-TCA), and 1,1-dichloroethane (1,1-DCA) (Plate 3). Acetone and chloroform are also present, but generally only in groundwater in the vicinity of the S-3 Site.

4.3.3.1 S-3 Site

Although VOCs have been released to the groundwater system at the S-3 Site, it is not the primary source of these compounds in the BCHR. Plume boundaries in the unconsolidated zone, shallow bedrock zone, and intermediate bedrock zone have essentially been defined, but delineation of these boundaries to the east of the S-3 Site is complicated by the effect of VOC contributions from other source areas in the UEFPCHR; a detailed description of the VOC plume to the east of the site is provided in Part II of the 1990 GWQAR for the UEFPCHR (HSW Environmental Consultants, Inc. 1990b). Similarly, the southern extent of the VOC plume probably reflects releases from another source area (possibly Spoil Area I). Summed concentrations of VOCs in groundwater at the S-3 Site are highest in samples collected from shallow bedrock wells located adjacent to the site (e.g., GW-243; 4,452 ug/L).

The VOC plume in the unconsolidated zone at the S-3 Site extends only to the south and east of the site; VOCs are not present in groundwater immediately west of the site as indicated by the absence of these compounds in samples collected from wells GW-101 and GW-127 (Plate 2). Concentrations of VOCs in groundwater in the unconsolidated zone within 400 ft south and west of the S-3 Site are generally less than 200 ug/L.

The horizontal extent of the VOC plume at shallow bedrock depths underlying the S-3 Site is greater than that in the unconsolidated zone. As shown on Plate 2, the VOC plume in the shallow bedrock zone extends along strike in the Nolichucky Shale about 300 ft west of the S-3 Site. Additionally, VOCs originating from the site may have entered the Maynardville Limestone south (down-dip) of the site. However, the extensive VOC plume in this formation downgradient of the S-3 Site probably reflects VOC releases from additional source areas (Plate 2).

As shown on Plate 2, VOCs have also been detected in groundwater at intermediate bedrock depths south of the S-3 Site. A summed average total VOC concentration of 230 ug/L was determined for samples collected from well GW-615, which is screened in the Nolichucky Shale directly down-dip of the site. However, the migration of VOCs along strike at intermediate depths in the Nolichucky Shale may be minimal as indicated by the absence of VOCs in groundwater samples collected from well GW-122, which is located about 450 ft west of GW-615. Data reported during 1990 for well GW-124 suggests that VOCs from the S-3 Site may have migrated to intermediate depths in the Maynardville Limestone south of the site and intermingled with VOCs released from other source areas, possibly Spoil Area I.

Although there are few deep bedrock wells at the site, the data obtained to date do not indicate an extensive VOC plume in the deep bedrock zone. The 1990 data for wells GW-123 and GW-125, which monitor deep bedrock zones down-dip of the S-3 Site, indicate trace concentrations (<1 ug/L) of benzene and toluene; however, based upon a review of the 1989 and 1990 assessment data, the pattern of detection of benzene and toluene in samples from these deep wells is somewhat inconsistent.

The types of VOCs present in groundwater at the S-3 Site are illustrated on Plate 3. Tetrachloroethene, chloroform, and acetone are the primary VOCs, comprising at least 90 percent of the total VOCs detected in samples collected from unconsolidated zone and shallow bedrock wells located within 400 ft south and west of the site. At intermediate bedrock depths, average concentrations of acetone (193 ug/L) and 2-butanone (32 ug/L) constitute 98 percent of the total VOCs detected in samples from well GW-615. Other VOCs less commonly detected in samples from wells at the site include 1,1,1-TCA, 1,1-dichloroethene (1,1-DCE), carbon tetrachloride, and methylene chloride.

The absence of 1,2-DCE in groundwater adjacent to the S-3 Site in contrast to the relative abundance of this compound in groundwater in the Maynardville Limestone directly south of the site strongly indicate a separate VOC source area (Plate 3). Data obtained during 1990 indicate that Spoil Area I may be the source

of 1,2-DCE in groundwater in the Maynardville Limestone south of the S-3 Site.

4.3.3.2 Spoil Area I

As shown on Plate 2, relatively low summed concentrations of VOCs were detected in ground samples from three of the five shallow bedrock wells at Spoil Area I: GW-313, GW-314, and GW-315. Summed VOC concentrations in these wells ranged from 20 ug/L in well GW-313 to 71 ug/L in well GW-315. Constituents detected in samples from the wells were PCE, 1,2-DCE, and TCE (Plate 3), with PCE and 1,2-DCE typically comprising greater than 80 percent of the total VOCs in samples from the wells.

The types and relative percentages of the VOCs detected in samples from wells at Spoil Area I are similar to those reported for wells located about 450 ft east at the Fire Training Facility, a newly identified potential VOC source area in the UEFPCHR. Both of these sites overly the Maynardville Limestone in the water-table "saddle" between the BCHR and UEFPCHR, and past variations in the slope of the water-table may have enabled constituents from one site to intermingle with compounds released from the other. However, substantially higher (>1,000 ug/L) VOC concentrations are reported for samples from wells at the Fire Training Facility, and it is possible that this site is the source of VOCs detected in groundwater samples from wells at Spoil Area I.

4.3.3.3 Rust Spoil Area

As shown on Plate 2, VOCs are present in groundwater in the unconsolidated and shallow bedrock zones beneath the Rust Spoil Area. The concentrations of VOCs in groundwater at the Rust Spoil Area are relatively low. Summed average VOC concentrations in samples from wells at the site ranged from 29 ug/L in upgradient unconsolidated zone well GW-236 to 92 ug/L in downgradient shallow bedrock well GW-306.

The extent of the plume in the unconsolidated zone is generally limited to within 200 ft of the site. In the shallow bedrock zone, data from downgradient wells GW-306 and GW-64 indicate that the VOC plume in the Maynardville Limestone is

continuous from the Rust Spoil Area to the Oil Landfarm WMA. There are insufficient data regarding the presence of VOCs in groundwater at intermediate depths beneath the site. However, data that will be obtained from several intermediate depth wells currently being installed as part of the exit-pathway monitoring network west (downgradient) of the site should enable delineation of plume boundaries in this zone.

As shown on Plate 3, TCE and 1,2-DCE are the predominant VOCs detected in groundwater at the site, and average about 69 percent and 26 percent, respectively, of the total VOCs detected in most wells. Trace concentrations (<2 ug/L) of carbon tetrachloride, PCE, 1,1,1-TCA, and 1,1-DCA were also reported for samples from Rust Spoil Area wells.

4.3.3.4 Oil Landfarm Waste-Management Area

As shown on Plate 2, VOCs are present in groundwater beneath the Oil Landfarm in the unconsolidated zone, and shallow and intermediate depth bedrock zones. The geometry of the plumes indicates that the VOCs have migrated generally southward (down-dip) through the Nolichucky Shale, then west along strike through the Maynardville Limestone. The highest summed average VOC concentrations (830 ug/L) in groundwater at the site were reported in samples from unconsolidated zone well GW-87. Based on historical data, VOC concentrations exceeding 1,000 ug/L are present in groundwater at shallow bedrock depths in Nolichucky Shale in the vicinity of the Oil Landfarm's northwestern plots. Summed average VOC concentrations exceeding 100 ug/L occur in groundwater at intermediate depths in the Maynardville Limestone south of the site.

The VOC plume in the unconsolidated zone underlies most of the WMA. Three unconsolidated zone wells (GW-645, GW-646, and GW-647) were installed during 1990 to complete delineation of the southern boundary of the VOC plume in the unconsolidated zone. No VOCs were detected in the first quarter 1991 samples collected from these wells, and this data indicates that the southern extent of the unconsolidated zone plume has been delineated.

Two shallow bedrock wells (GW-602 and GW-621) were installed

in 1990 to further define the southern and western VOC plume boundaries. The lack of VOCs in samples from well GW-602 delineates the southern plume boundary, and data reported for samples from well GW-621 indicate that the VOC plume originating from the Oil Landfarm may not extend as far west as the Burial Grounds (Plate 2).

Data from intermediate depth bedrock wells south of the Oil Landfarm WMA indicate that VOCs have migrated down-dip and entered the Maynardville Limestone. The intermediate depth VOC plume extends at least 400 ft south and 600 ft west of the Oil Landfarm WMA (Plate 2). The vertical extent of the VOC plume in the Maynardville Limestone south of the site is uncertain because summed average VOC concentrations in groundwater samples from deep well GW-601 was 162 ug/L. Exit-pathway monitor well clusters currently being installed to the east (upgradient) and west (downgradient) of the site may provide VOC plume definition at depth in the Maynardville Limestone.

Some vertical segregation of VOCs is indicated by the distribution of VOCs at the Oil Landfarm WMA (Plate 3). The unconsolidated zone VOC plume typically contains higher proportions of 1,2-DCE, PCE, and 1,1-DCA than the plume in the bedrock zones. Additionally, TCE is pervasive in groundwater in the bedrock zones but is generally not present in the unconsolidated zone. In samples from shallow and intermediate depth bedrock wells, TCE comprises about 49 percent and 28 percent, respectively of the total VOCs in the samples. Total VOCs in samples from only one unconsolidated zone well (GW-87) contained a substantial percentage (40 percent) of TCE.

4.3.3.5 Bear Creek Burial Grounds Waste-Management Area

Volatile organic compounds are essentially the only contaminants in the groundwater at the Bear Creek Burial Grounds WMA, and are present in groundwater in the unconsolidated zone, and in the shallow, intermediate, and deep bedrock zones in the underlying shales of the Conasauga Group. Summed VOC concentrations underlying the Bear Creek Burial Grounds WMA are among the highest reported in the BCHR, exceeding 10,000 ug/L in

the unconsolidated zone adjacent to waste trenches, and in the bedrock zone along the southern border of Burial Ground A South where dense nonaqueous phase liquids (DNAPLs) have been found. The DNAPLs were discovered at depths of about 270 ft in January 1990 and were found to consist primarily of PCE, TCE, and 1,1,1-TCA with high concentrations (19,000 ug/L) of polychlorinated biphenyls (PCBs), (Haase and King, 1990).

The horizontal extent and concentration distribution of the VOC plume in each zone at the Bear Creek Burial Grounds is illustrated on Plate 2, and the types of VOCs present in each zone are illustrated on Plate 3. In general, the lateral extent of the plumes below the site decrease with depth. As shown on Plate 3, the VOCs typically detected in groundwater in the unconsolidated zone, shallow bedrock zone, and intermediate depth bedrock zone are PCE, TCE, 1,2-DCE and 1,1-DCA. Vinyl chloride, 1,1-DCE, and 1,1,1-TCA have also been detected in samples from wells containing the highest summed VOC concentrations (e.g., unconsolidated zone wells GW-46 and GW-14, and shallow bedrock well GW-68). In 1990, the highest summed average VOCs concentrations in each zone were reported for samples from unconsoliated zone wells GW-46 (7,556 ug/L) and GW-624 (5,640 ug/L), shallow bedrock wells GW-68 (1,742 ug/L) and GW-288 (1,212 ug/L), intermediate bedrock well GW-71 (1,500 ug/L) and GW-623 (5,000 ug/L), and deep bedrock well GW-117 (24 ug/L).

Dissolved VOCs are most widespread in the unconsolidated zone at the Bear Creek Burial Grounds WMA and are present in an area that basically underlies the entire WMA (Plate 2). Five wells (GW-655, GW-654, GW-653, GW-651, and GW-643) were installed during 1990 to complete delineation of VOC plume boundaries in the unconsolidated zone. These wells were sampled during the first quarter 1991, and VOCs were detected only in the sample from well GW-653 at a summed concentration 17 ug/L. In addition, unconsolidated zone wells GW-18, GW-52, GW-53, and GW-83 were sampled in 1990 to confirm historical results which indicated that no VOCs were detectable in groundwater monitored by the wells. The 1990 data confirmed the absence of VOCs in all the wells except GW-53 and GW-89. Summed average VOCs in 1990 samples from GW-53

and GW-89 were 72 ug/L, and 40 ug/L, respectively. Either the historical data for these wells were in error, or further migration of the VOC plume in the unconsolidated zone at the site has occurred.

The VOC plume in the shallow bedrock zone is somewhat smaller than that in the unconsolidated zone, underlying only the eastern (Burial Grounds A-North) and southern (Burial Grounds A-South) portions of the WMA. Plume boundaries in the shallow bedrock zone have essentially been defined. One shallow bedrock well (GW-652) was installed during 1990 to further define the plume boundary to the southwest of the site. The well was sampled during the first quarter of 1991 and no VOCs were detected in the sample. Additionally, samples from shallow bedrock wells GW-60, GW-69, and GW-82 have historically not contained VOCs and the wells were re-sampled in 1990 to confirm these historical findings. Volatile organic compounds were detected only in samples from well GW-82 located near the northwest boundary of the WMA (Plate 2). Either the historical data for this well were in error, or further migration of the VOC plume at shallow bedrock depths has occurred to the northwest of the site.

As shown on Plate 2, the dissolved VOC plume in groundwater at intermediate bedrock depths is elliptical in shape and underlies only the southern most portions of the Bear Creek Burial Grounds WMA. The highest dissolved VOC concentrations in groundwater at intermediate depths were reported in 1989 for wells GW-625 and GW-628. Both wells intercepted DNAPL at depths below 200 ft and summed dissolved VOC concentration exceeded several hundred mg/L in samples from the two wells (Haase and King, 1990). Neither of these wells have been sampled since the initial investigation of the DNAPL in January 1990 because it is possible that purging or bailing the wells may disturb and remobilize the DNAPL.

Previous annual assessment reports have indicated the presence of VOCs in the deep (>500 ft) bedrock zone south of Burial Grounds A-South. However, the VOCs detected in groundwater in the deep bedrock zone are not believed to originate from the down-dip migration of VOCs from the surfical disposal areas. The dissolved VOCs in the deep bedrock probably originate from dissolution of

DNAPLs at depth. This supposition is based on three primary factors: (1) samples from deep bedrock well GW-117 have been reported to contain PCBs (1.5 ug/L to 2.6 ug/L), which may be a unique indicator of the DNAPL at the site (Haase and King 1990) (2) the upward vertical hydraulic gradients which characterize the deep bedrock zone would tend to inhibit down-dip migration of dissolved VOCs, and (3) the hydraulic conductivity in the deep bedrock zone of the Nolichucky Shale is extremely low (0.0002 ft/day; Geraghty & Miller, Inc. 1987).

Samples from deep bedrock well GW-117 have historically contained constituents characteristic of the DNAPL at the site (PCE and TCE). However, concentrations of PCE and TCE in samples from GW-117 have significantly decreased since 1987. This decrease may be related to changes in the sampling technique used for the well. Before August 1988, GW-117 was not purged prior to sampling because the low well yield resulted in prolonged delays between pruging and sampling. Summed VOC concentrations in samples from well GW-117 averaged about 1,000 ug/L when the well was not purged prior to sampling, but have averaged less than 25 ug/L since August 1988 when partial purging of the well prior to sampling was initiated.

The VOCs characteristic of the DNAPL (PCE and TCE) were detected for the first time in samples from deep bedrock well GW-119 (11 ug/L) during 1990. The discovery and subsequent investigation of the DNAPL in 1989 may have resulted in the remobilization of the DNAPL such that the stratigraphic interval monitored by GW-119 is now in the flow path of VOCs dissolved from the DNAPL.

Results reported for VOC concentrations in samples from GW-118 have been inconsistent since 1987. During 1987 and 1988, benzene was sporadically detected at low concentrations (generally <10 ug/L). In 1989, only acetone was detected (average 5 ug/L) in samples from the well, and during 1990 estimated concentrations (<1 ug/L) of toluene and benzene were reported. These constituents are not characteristic of the VOC plume in the shallow and intermediate bedrock zone or the DNAPL below the site and are believed to be artifacts of sampling and analyses.

4.3.4 Radionuclides

As discussed in Section 4.1.4, radiochemical quality of groundwater in the BCHR was evaluated with respect to the MCL for gross alpha activity (15 pCi/L) and a threshold value (50 pCi/L) for gross beta activity. The horizontal and vertical extent of gross alpha and gross beta activities in excess of these respective values is illustrated on Plates 4 and 5, respectively. As shown, plume boundaries for the unconsolidated and shallow bedrock zones have essentially been defined. The gross beta plume appears to be more widespread in the two zones than is the gross alpha plume. Available data indicate that the gross alpha and gross beta plumes in groundwater in the intermediate and deep bedrock zones is not extensive.

4.3.4.1 Alpha Radioactivity

Groundwater samples from 17 wells in the BCHR exceeded the gross alpha MCL of 15 pCi/L during the 1990 assessment (Table 4-8); eleven wells located near the S-3 Site, five wells located at the Oil Landfarm WMA, and one well at the Bear Creek Burial Grounds WMA. The highest mean alpha activity was reported in samples from shallow bedrock well GW-243 (8,205$\pm$386 pCi/L) located adjacent to the S-3 Site. Gross alpha activities at the Oil Landfarm ranged from 20$\pm$2 pCi/L (GW-226) to 54$\pm$5 pCi/L (GW-87). A gross alpha activity of 40$\pm$4 pCi/L was reported for GW-52 at the Bear Creek Burial Grounds.

In 1990, samples from wells with gross alpha exceeding 15 pCi/L were not speciated for alpha-emitting radionuclides. However, data obtained in 1989 indicates that the primary alpha emitting radionuclide in the groundwater of the BCHR is most likely uranium. However, isotopes of radium (^{223}Ra, ^{224}Ra, ^{226}Ra), neptunium (^{237}Np), and americium (^{241}Am) may also contribute to the gross alpha activity in groundwater in the vicinity of the S-3 Site (Geraghty & Miller, Inc. 1990b).

The extent of the mean gross alpha activity plumes in unconsolidated, shallow bedrock, and intermediate depth bedrock aquifer zones in the BCHR are illustrated on Plate 4. Gross alpha activity is most extensive in the unconsolidated aquifer zone near

Table 4-8. Nitrate, Annual Mean Gross Alpha Activity, and Gross Beta Activity Exceeding MCLs, 1990

WELL NUMBER	AQUIFER ZONE[1]	NITRATE (AS N)[2] (mg/L)	GROSS ALPHA ACTIVITY[2] (pCi/L)	GROSS BETA ACTIVITY[2] (pCi/L)
S-3 SITE				
GW-100	U	388	<MCL[3]	<TL[4]
GW-101	U	2,200	96 +/- 49	<TL
GW-122	I	770	<MCL	<TL
GW-124	I	160	<MCL	556 +/- 15
GW-125	D	28	<MCL	<TL
GW-127	U	<MCL	267 +/- 35	308 +/- 46
GW-236	U	421	19 +/- 3	203 +/- 9
GW-243	S	6,230	8,205 +/-386	60,750 +/-1,345
GW-244	S	NA[5]	67 +/- 75	3,240 +/- 290
GW-245	S	4,545	79 +/-102[a]	2,765 +/- 270
GW-246	S	3,530	143 +/- 86	13,900 +/- 540
GW-247	S	7,380	56 +/- 64	4,240 +/- 370
GW-276	U	454	971 +/-160	4,110 +/- 320
GW-277	S	1,690	<MCL	2,900 +/- 290
GW-345	U	398	<MCL	244 +/- 6
GW-346	S	811	<MCL	<TL
GW-348	S	10	<MCL	<TL
GW-526	I	845	21 +/- 34	<TL
GW-615	I	9,690	307 +/- 79	554 +/- 173
GW-616	I	274	22 +/- 41	<TL
SPOIL AREA I				
GW-314	S	10	<MCL	<TL
GW-315	S	16	<MCL	55 +/- 3
RUST SPOIL AREA				
GW-306	S	11	<MCL	<TL
GW-307	U	18	<MCL	<TL
GW-308	U	15	<MCL	<TL
GW-309	S	18	<MCL	50 +/- 4
GW-310	U	23	<MCL	62 +/- 3
OIL LANDFARM WMA				
GW-005	U	BDL[6]	31 +/- 2	<TL
GW-064	S	10	<MCL	<TL
GW-085	S	185	<MCL	57 +/- 3
GW-087	U	BDL	54 +/- 5	<TL
GW-225	I	97	<MCL	<TL
GW-226	S	<MCL	20 +/- 2	<TL

Table 4-8. (Cont'd)

WELL NUMBER	AQUIFER ZONE[1]	NITRATE (AS N)[2] (mg/L)	GROSS ALPHA ACTIVITY[2] (pCi/L)	GROSS BETA ACTIVITY[2] (pCi/L)
OIL LANDFARM WMA				
GW-227	S	17	25 +/- 2	69 +/- 3
GW-228	I	37	<MCL	<TL
GW-369	I	11	<MCL	<TL
GW-537	U	819	40 +/- 16	354 +/- 48
GW-601	D	29	<MCL	<TL
BEAR CREEK BURIAL GROUNDS WMA				
GW-052	U	28	40 +/- 4	120 +/- 8
GW-061	S	11	<MCL	<TL
GW-621	S	12	<MCL	<TL

NOTE:

1. U - Unconsolidated Zone
   S - Shallow Bedrock Zone (Unc-85 ft)
   I - Intermediate Depth Bedrock Zone (85-300 ft)
   D - Deep Bedrock Zone (>300 ft)
2. mg/L - Milligrams per liter
   pCi/L - picoCuries per liter +/- Counting Error
3. <MCL - Results below the MCL:
   Nitrate (as N) - 10 mg/L
   Gross Alpha Activity - 15 pCi/L
4. <TL - Results less than 50 pCi/L Threshold Limit
5. NA - Not Analyzed
6. BDL - Below Detection Limit

a. Calculated mean activity including 1989 data.

the S-3 Site, and isolated pockets of elevated alpha activity are found in the unconsolidated zone at the Oil Landfarm WMA.

The irregular geometry of the gross alpha plume in the unconsolidated zone indicates three potential source areas. The S-3 Site appears to be the primary source, as gross alpha activity in excess of 15 pCi/L extends for about 1,900 ft west of the site, and exceeds 100 pCi/L in an area extending approximately 700 ft west and 300 ft south of the site. Moreover, virtually every well within 1,000 ft of the S-3 Site which contained elevated gross alpha activities also contained elevated concentrations of nitrate (Table 4-8), which may be considered the "signature" contaminant from the S-3 Site. A second potential source area is located at the Oil Landfarm WMA. Elevated gross alpha activity was detected in unconsolidated zone samples from wells GW-5 (31±2 pCi/L) and GW-87 (54±5) located in the east-central portion of the Oil Landfarm WMA. Because nitrate was not detected in samples from these wells, the source of alpha activity in these wells may not be the S-3 Site. Data for unconsolidated zone well GW-537 provides evidence for the third potential source area east of the Oil Landfarm WMA. Gross alpha activity in the well averaged 40±16 pCi/L, which is higher than alpha activities reported for wells closer to the S-3 Site source. South of the Burial Grounds WMA, the groundwater sample from well GW-52 had a reported gross alpha activity of 40±4 pCi/L. As previously discussed in the Section 4.3.1, the groundwater in the vicinity of this well may be hydraulically connected with Bear Creek. Spring SS-4 discharges groundwater to Bear Creek upstream of GW-52, and the mean gross alpha activity in 1990 samples from spring SS-4 was calculated to be 46±5 pCi/L.

The gross alpha activity plume in the shallow bedrock aquifer zone is well defined and clearly implicates the S-3 Site as the primary source area (Plate 4). However, south of the Oil Landfarm WMA, an isolated area of groundwater containing gross alpha activity slightly above 15 pCi/L is indicated by data for wells GW-227 (25±2 pCi/L) and GW-226 (20±2 pCi/L). These wells are completed at shallow depths in the Maynardville Limestone adjacent to an effluent reach of Bear Creek. Although the alpha activity in these wells may reflect continuation of the plume originating from

the S-3 Site, infiltration of surface water in Bear Creek, which has been reported to contain elevated levels of uranium (Turner 1988), may account for the elevated alpha activity in these wells.

The mean gross alpha plume in the intermediate depth bedrock zone generally occurs only in the vicinity of the S-3 Site. Gross alpha activity in intermediate depth well GW-615 located down-dip of the S-3 Site averaged 307±79 pCi/L. However, elevated gross alpha activity does not extend very far to the west along strike in the Nolichucky Shale; annual average gross alpha activity in well GW-124 was below the 15 pCi/L MCL (Plate 4). The plume appears to extend about 600 ft southwest from the S-3 Site into the Maynardville Limestone, as suggested by the annual average gross alpha activity of 22±14 pCi/L in samples from well GW-616.

Elevated levels of gross alpha activity do not appear to extend into the deep bedrock aquifer. Annual mean gross alpha activities did not exceed the MCL in samples from the six deep wells (GW-123, GW-125, GW-117, GW-118, GW-119 and GW-601) in the BCHR. Relatively high gross alpha activities were reported for the fourth quarter samples from wells GW-117 (40±148 pCi/L), GW-118 (104±157 pCi/L) and GW-119 (71±153 pCi/L), but a review of historical data for these wells indicates that these results probably reflect analytical errors.

4.3.4.2 Beta and Photon Radioactivity

The mean gross beta activity in groundwater samples from 19 wells located in the BCHR exceeded 50 pCi/L (Table 4-7). Twelve of these wells are located near the S-3 Site and three are located at the Oil Landfarm WMA. The highest mean gross beta activity was reported for shallow bedrock well GW-243 (60,750±1345 pCi/L) located adjacent to the S-3 Site. At the Oil Landfarm WMA, annual mean gross beta activities above 50 pCi/L ranged from 57±3 pCi/L in shallow bedrock well GW-85 to 354±48 pCi/L in unconsolidated zone well GW-537.

Technetium (^{99}Tc) has been identified as the primary beta emitting radionuclide present in the groundwater in the BCHR, although isotopes of strontium (^{89}Sr and ^{90}Sr) and tritium (^{3}H) may also contribute to gross beta activity in groundwater at the S-3

Site (Geraghty & Miller, Inc. 1990b). The 1990 data for beta-emitting radionuclides are consistent with the 1989 data. For samples which were speciated during 1990, mean activity and associated counting errors for these radionuclides have been plotted in data boxes on Plate 5, and demonstrate the relationship of the isotopic activities to the gross beta activity plume.

In the unconsolidated aquifer zone, the gross beta plume extends east from the S-3 Site approximately 3,100 ft to an area east of the Oil Landfarm WMA (Plate 5). Although the S-3 Site is clearly the primary source area, gross beta activity reported for samples from well GW-537 indicates that another possible source of beta emitting radionuclides exists east of the Oil Landfarm WMA. The groundwater samples from well GW-537 contained an annual mean gross beta activity of 354±48 pCi/L, which is the highest level in the unconsolidated zone west of the S-3 Site. Additionally, a gross beta activity of 120±8 pCi/L was reported for the groundwater sample collected from unconsolidated zone well GW-52, which is located adjacent to Bear Creek and south of the Bear Creek Burial Grounds WMA. The groundwater from this well also exceeded the MCL for nitrate and gross alpha activity. As discussed in Section 4.3.1 (Nitrate) and 4.3.4.1 (Alpha Radioactivity), groundwater quality in this well may be influenced by the infiltration of water discharged from spring SS-4 into Bear Creek upstream of the well. The gross beta activity in 1990 samples from this spring averaged 121±5 pCi/L.

The gross beta plume in the shallow bedrock aquifer zone extends approximately 2,000 ft west of the S-3 Site in the Nolichucky Shale. The plume also extends about 600 ft south into the Maynardville Limestone. The geometry of the plume indicates somewhat limited migration along strike in the Nolichucky Shale, but significant downgradient migration along strike in the Maynardville Limestone.

A mean gross beta activity of 60±3 pCi/L was reported for samples from shallow bedrock well GW-227, located adjacent to Bear Creek and south of the Oil Landfarm WMA (Plate 5). As was suggested for gross alpha activity in this well, the elevated gross beta activity in samples from well GW-227 may be caused by

infiltration of surface water in effluent reaches of Bear Creek upstream of the well; gross beta activities as high as 700 pCi/L in samples of Bear Creek surface water have been reported (Turner 1988). In addition to well GW-227, elevated gross beta activity was reported in samples collected from shallow bedrock well GW-85 (57±3 pCi/L), located along the eastern border of the Oil Landfarm WMA. Elevated levels of nitrate were also detected in samples from this well, and the potential nitrate, alpha activity, and beta activity source area located northeast of the Oil Landfarm WMA near unconsolidated zone well GW-537 may also be the source of beta emitting radionuclides in this well.

The geometry of the mean gross beta activity plume in the intermediate depth bedrock zone indicates southward migration from the S-3 Site approximately 600 ft into the Maynardville Limestone. As shown on Plate 5, gross beta activity exceeded 50 pCi/L in two of the four wells completed at intermediate depths near the S-3 Site: GW-615 (554±173 pCi/L) and GW-124 (556±15 pCi/L). The absence of beta activity in samples from GW-616 and GW-122 suggest minimal westward (along strike) migration of the plume.

4.3.4.3 Dose Equivalent Calculations

To determine compliance with the 4 mrem/yr MCL for gross beta and photon radioactivity, the dose equivalent to the critical organ affected or to the total body, assuming a 168 hr two-liter per day drinking water intake, was calculated using data for the beta-emitting isotopes ^{99}Tc, ^{90}Sr, and ^{3}H.

Although gross beta activity exceeded 50 pCi/L in samples from 19 wells in the BCHR, samples from only five wells (GW-243, GW-244, GW-245, GW-246, and GW-247) were speciated for the beta-emitting radionuclides during the 1990 assessment. To provide a more comprehensive evaluation, dose equivalent calculations were preformed using isotopic data obtained since 1988 (Table 4-9). Nevertheless, samples from seven of the 19 wells which exceeded 50 pCi/L have not beta-emitting isotopes thereby precluding dose equivalent calculations.

Samples from 11 wells exceed a cumulative dose of 4 mrem/yr; Technetium (^{99}Tc) is the primary beta emitter in most wells where

TABLE 4-9. Dose Equivalent Calculations, 1988-1990

WELL NUMBER	GROSS BETA (pCi/L)[1]	CUMULATIVE DOSE (mrem/yr)[2]	^{99}Tc MEAN ACTIVITY (pCi/L)	^{99}Tc IND. DOSE[3] (mrem/yr)	^{90}Sr MEAN ACTIVITY (pCi/L)	^{90}Sr IND. DOSE[3] (mrem/yr)	^{3}H MEAN ACTIVITY (pCi/L)	^{3}H IND. DOSE[3] (mrem/yr)
S-3 SITE								
GW-124	775.42	6.83	1,537.40	6.83	NA[4]		- 658.40	0.00
GW-236	253.05	5.11	1,150.40	5.11	NA		-1,188.00	0.00
GW-243	52,615.00	384.74	56,867.22	252.74	262.00	131.00	4,960.00	0.99
GW-244	3,226.67	58.29	4,571.11	20.32	75.45	37.73	1,252.00	0.25
GW-245	4,627.67	52.14	6,824.00	30.33	43.30	21.65	794.00	0.16
GW-246	13,749.50	146.54	23,801.50	105.78	80.20	40.10	3,294.00	0.66
GW-247	4,469.00	37.89	7,176.17	31.89	11.80	5.90	503.80	0.10
GW-276	6,404.98	41.71	9,364.25	41.62	NA		430.75	0.09
GW-277	1,704.44	13.34	2,990.50	13.29	NA		230.00	0.05
OIL LANDFARM								
GW-087	88	21.97	203.5	0.90	42.135	21.07	- 725	-0.15
GW-227	110.76	4.09	-169.30	0.00	8.17	4.09	-1916.60	0.00

NOTE:

1. pCi/L - picoCuries per liter
2. Mrem/yr - Millirems per year
3. Ind. Dose - (Mean Activity of isotope X 4)/Concentration yielding a dose of 4 Mrem/yr
4. NA - Not Analysed

the 4 mrem/yr gross beta MCL was exceeded. The 1990 data indicate that ^{90}Sr is the primary beta-emitter in samples from two wells at the Oil Landfarm (GW-87 and GW-227). Howver, uncertainty is associated with much of the ^{90}Sr data as evidenced by the 1990 samples from background well GW-115. This well lies upgradient of all known radionuclide source areas in the BCHR. The ^{90}Sr activity of 57±45 pCi/L was reported in a sample from the well while gross beta activity was 8±2 pCi/L. Because a ^{90}Sr activity of 8 pCi/L is equivalent to a 4 mrem/yr dose, the imprecision which may be associated with the ^{90}Sr analyses can have a significant impact on the cumulative dose calculations.

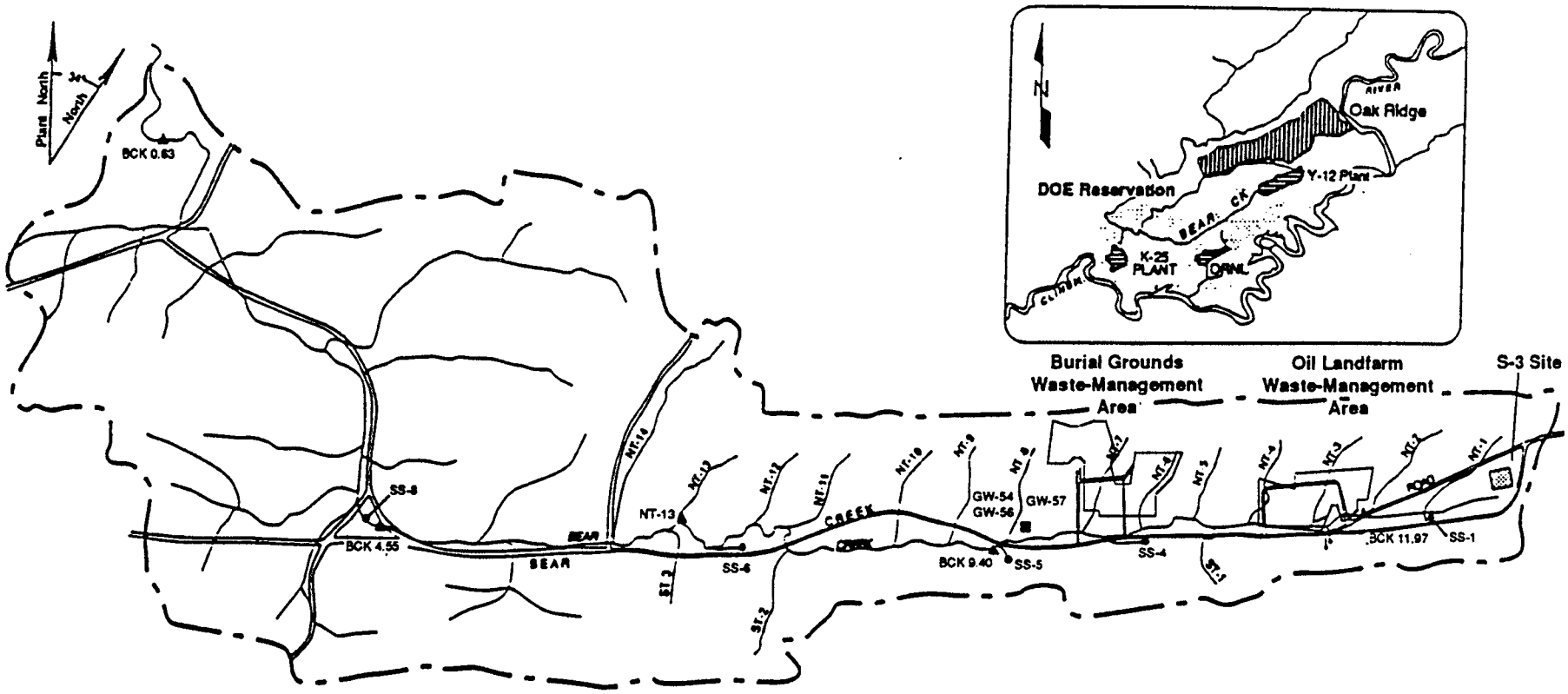
4.4 EXIT-PATHWAY MONITORING

Sampling of selected monitor wells completed in the Maynardville Limestone, springs, and surface-water sampling points along Bear Creek was performed in 1990 to evaluate the quality of groundwater and surface water moving through and eventually exiting the BCHR. Exit-pathway monitoring locations are shown on Figure 4-12 and include three monitor wells (GW-54, GW-56, and GW-57), five springs (SS-1, SS-4, SS-5, SS-6, and SS-8), and five surface-water sites (BCK 0.63, BCK 4.55, NT-13, BCK 9.40 and BCK 11.97). Monitor wells were sampled during the second, third, and fourth quarters of 1990, and surface water locations and springs were sampled during the third and fourth quarters of 1990. The 1990 exit-pathway water quality data are presented in Appendix C to the Part I 1990 GWQAR (HSW Environmental Consultants, Inc. 1991a).

4.4.1 Groundwater

Wells GW-54, GW-56, and GW-57 are completed at shallow bedrock depths (<85 ft) in the Maynardville Limestone about 1,200 ft west of the Bear Creek Burial Grounds WMA. Because of their location, these wells are well suited for determining groundwater quality in the primary exit pathway (the Maynardville Limestone) downgradient of all waste sources in the BCHR. The 1990 water quality data for samples from these wells generally reflect background water chemistry.

As discussed in Section 2.0, several monitor well clusters are



EXPLANATION

▲ BCK 4.55	Surface-Water Sampling Location
● SS-6	Spring Sampling Location
■ GW-57	Monitor - Well Cluster Sampling Location
NT-5	North Tributary
ST-2	South Tributary

0 — 1 kilometer
SCALE

MODIFIED FROM: G&M 1990b

FIGURE 4-12

EXIT-PATHWAY MONITORING LOCATIONS, 1990

being installed along parallel traverses that cut across the Maynardville Limestone. These proposed wells will target stratigraphic zones subject to solution activity. When completed, these well clusters will be incorporated in the 1991 assessment monitoring program, and will enable more comprehensive monitoring of groundwater quality exiting the BCHR.

The quality of groundwater discharged from springs located upstream of BCK 9.40 appears to have been impacted by contaminant releases from waste sites in the BCHR. Nitrate concentrations exceed the MCL in samples from SS-1, SS-4, and SS-5 (Table 4-10). The VOCs 1,2-DCE (37 ug/L) and TCE (26 ug/L) were also detected in samples from spring SS-4. Uranium concentrations, gross alpha activity and gross beta activity exceeded background levels or MCLs in samples from each of these springs. However, as shown on Table 4-10, gross alpha activity and uranium concentrations were lower in samples from the spring located closest to the S-3 Site (SS-1) than in samples from springs located much farther downstream (SS-4 and SS-5). This may indicate that water quality of samples from spring SS-1 reflect dilution from groundwater inputs from Chestnut Ridge. Additionally, the elevated concentrations of S-3 Site source constituents in springs SS-4 and SS-5 strongly suggest a hydraulic connection with the upper reaches of the Bear Creek watershed.

The quality of groundwater discharged from springs downstream of BCK 9.4 is characteristic of native groundwater. As shown on Table 4-10, the quality of water from SS-6 and SS-8 does not appear to have been impacted by waste disposal activities in the BCHR.

4.4.2 Surface Water

Numerous investigations of surface-water quality have been conducted in the Bear Creek watershed. Information obtained during these investigations is summarized in the RCRA Facility Investigation (RFI) Plan for Bear Creek (R. Turner, 1988).

Prior to neutralization of the S-3 Site, the upper reaches of Bear Creek were typically acidic (pH as low as 3.5) and contained high concentrations of inorganic and radioactive compounds (Turner 1988). However, concentrations of these compounds greatly decreased following neutralization and closure of the S-3 Site.

Table 4-10. Surface-Water Quality Downstream of the S-3 Site, 1990

	Spring SS-1	BCK 11.97	Spring SS-4	Spring SS-5	BCK 9.40	Spring SS-6	BCK 4.55	Spring SS-8	BCK 0.63
Approximate Distance from S-3 (miles)	0.3	0.6	1.6	2.1	2.2	3.2	5.1	5.1	7.8
Nitrate (mg/L)	89	308	52	29	31	<0.2	5	0.2	5
Strontium (mg/L)	0.71	1.2	0.33	0.23	0.27	0.045	0.11	0.053	0.18
Uranium (mg/L)	0.047	0.36	0.157	0.118	0.123	<0.001	0.042	0.001	0.027
Gross Alpha (pCi/L)	31 ± 4	77 ± 6	53 ± 5	53 ± 5	43 ± 5	1 ± 2	16 ± 3	1 ± 2	18 ± 3
Gross Beta (pCi/L)	177 ± 9	610 ± 16	125 ± 8	93 ± 7	159 ± 9	11 ± 4	32 ± 5	2 ± 4	20 ± 4
^{234}U (pCi/L)	7 ± 4	32 ± 7	8 ± 5	7 ± 4	13 ± 5	<BG[1]	7 ± 4	0 ± 1	1 ± 2
^{235}U (pCi/L)	<BG	3 ± 3	5 ± 3	1 ± 2	2 ± 2	0 ± 2	<BG	0 ± 1	1 ± 2
^{238}U (pCi/L)	10 ± 4	79 ± 12	15 ± 5	13 ± 5	32 ± 7	0 ± 2	11 ± 4	0.4 ± 1	3 ± 3

NOTE:

1. <BG - activity below instrument background

Moreover, the concentrations of inorganic and radiochemical compounds were noted to decrease downstream (Turner 1988).

The data obtained during 1990 support these findings. As shown on Table 4-10, background concentrations, MCLs, or radiological health criteria for uranium (.005 mg/L), strontium (0.17 mg/L), nitrate (10 mg/L), gross alpha activity (15 pCi/L), gross beta activity (50 pCi/L), and ^{234}U and ^{238}U activities (10 pCi/L) were exceeded in samples from surface water in Bear Creek and springs located in the upper reaches of the watershed near the S-3 Site, but their concentrations decrease with distance from the S-3 Site.

A review of the historical data presented in the Bear Creek RFI Plan show that 1,2-DCE, PCE, and TCE have been detected in Bear Creek and in two tributaries (NT-7 and NT-8) located near the Bear Creek Burial Grounds WMA. Summed VOC concentrations as high as 1,000 ug/L have been reported in samples from surface water collected near the Bear Creek Burial Grounds WMA. However, the concentrations of the compounds decrease to near detection limits within one-half kilometer downstream of the site (Turner, 1988). The 1990 data for surface-water quality in Bear Creek are consistent with historical data. At the confluence of tributary NT-8 (Figure 3-6) and Bear Creek, 1,2-DCE (108 ug/L) and trace concentrations (<3 ug/L) of PCE and TCE were detected at BCK 9.40. However, VOCs were not detected in samples collected at points downstream (BCK 4.55 and BCK 0.63) of BCK 9.4.

With the exception of gross alpha, gross beta, and uranium, surface-water quality in Bear Creek downstream of BCK 9.40 reflects background conditions. Gross alpha, gross beta, and uranium exceeded MCLs or background in samples collected from Bear Creek at BCK 4.55 and BCK 0.63.

5.0 SUMMARY

The primary groundwater contaminants in the BCHR are nitrate, VOCs, radionuclides, and to a lesser degree, trace metals. The S-3 Site is the primary source of nitrate although a separate, much smaller source located northeast of the Oil Landfarm WMA is suggested by the 1989 and 1990 monitoring data. Data obtained in 1990 further confirm that the S-3 Site, the Rust Spoil Area, the Oil Landfarm WMA, and Bear Creek Burial Grounds WMA are sources of VOCs. In addition, evidence of VOC sources upgradient of the Rust Spoil Area, possibly Spoil Area I, are also indicated. The S-3 Site is the primary source of trace metals and radionuclides. Although elevated concentrations of these constituents are found in wells at several waste sites in the BCHR, the bulk of the elevated trace metal concentrations and radionuclides generally occur in the immediate vicinity of this site.

The nitrate plume in the unconsolidated, shallow bedrock, and intermediate depths bedrock zones extends westward from the S-3 Site and for about 3,300 ft, 9,000 ft, and 5,100 ft, respectively. Plume boundaries in the unconsolidated zone, the shallow bedrock zone, and the intermediate depth bedrock zone have essentially been defined. Elevated concentrations of nitrate in deep bedrock wells is evident at this time in only one well located down-dip of the S-3 Site.

The occurrence of trace metal concentrations above MCLs or background levels generally occur in groundwater in the immediate vicinity of the S-3 Site. The principal trace metal contaminants are barium, cadmium, chromium, lead, mercury and uranium. The occurrence of metals above MCLs or background levels in wells at other sites in the BCHR is sporadic and somewhat inconsistent with respect to location, depth, and concentration.

Data obtained in 1990 indicate that VOCs are pervasive in groundwater in the BCHR, and source areas include the S-3 Site, the Rust Spoil Area, the Oil Landfarm WMA, the Bear Creek Burial Grounds WMA, and possibly Spoil Area I. In general, the primary VOCs in groundwater in the BCHR are PCE, TCE, 1,2-DCE, 1,1,1-TCA, 1,1-DCA. The dissolved VOC plume in the unconsolidated zone occurs

only in the general vicinity of the source areas. At shallow and intermediate bedrock depths, a continuous plume extends from the S-3 Site westward to an area just west of the Oil Landfarm WMA. In deep bedrock wells in the eastern portion of the BCHR, VOCs are detected in only one well.

Separate VOC plumes are present in groundwater at the Bear Creek Burial Grounds WMA. The extent of the VOC plume in the unconsolidated zone, and at shallow and intermediate bedrock depths is essentially defined. Dissolved VOCs are also found in groundwater at depths of about 500 ft below the site. However, the VOCs in the deep bedrock are believed to originate from DNAPLs discovered at depths of about 275 ft. Energy Systems and DOE are currently evaluating options for further investigation of the DNAPLs at the Burial Grounds, and this investigation will be conducted independent of the assessment monitoring program.

Groundwater with annual mean gross alpha activity in excess of the 15 pCi/L MCL was detected in 17 wells and annual average gross beta activity in excess of the 50 pCi/L threshold value was reported in samples from 19 wells in the BCHR. Most of these wells were located near the S-3 Site. Based on the 1989 data, isotopes of uranium, and ^{237}Np are the most probable alpha emitters. The primary beta emitter is ^{99}Tc although ^{90}Sr and to a lesser extent ^{3}H may also be contributors. The extent of the mean gross alpha and gross beta activity plumes has been defined in the unconsolidated zone, shallow bedrock zone, and intermediate depth bedrock zone in the BCHR. Elevated gross alpha and gross beta activities are not evident in the deep bedrock zones. Dose equivalent calculations were performed using 1988-1990 data on samples from thirteen wells which exceeded 50 pCi/L. The 4 mrem/yr primary drinking-water standard for gross beta activity was exceeded in eleven of these wells, most of which are located near the S-3 Site.

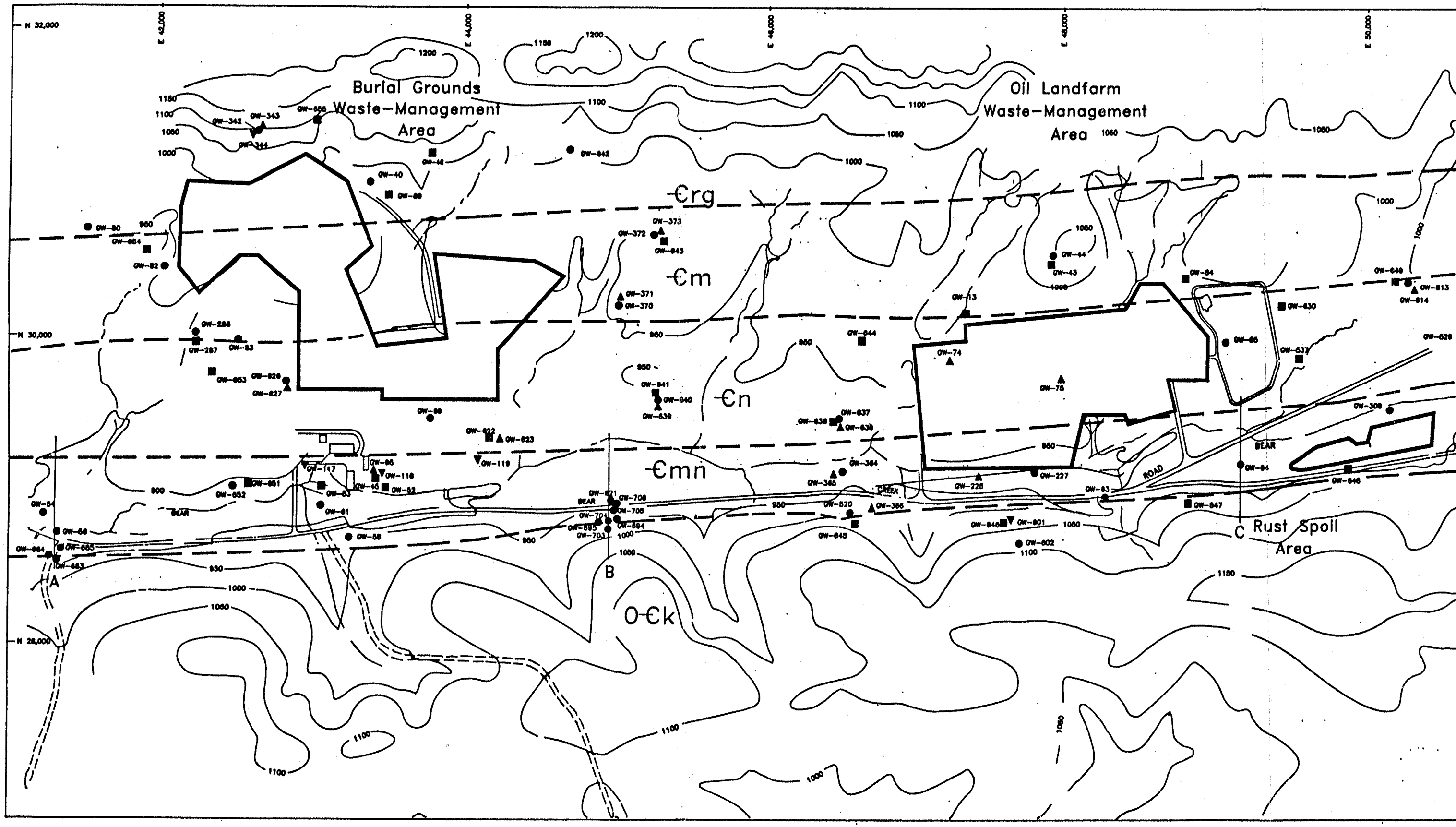
6.0 RECOMMENDATIONS

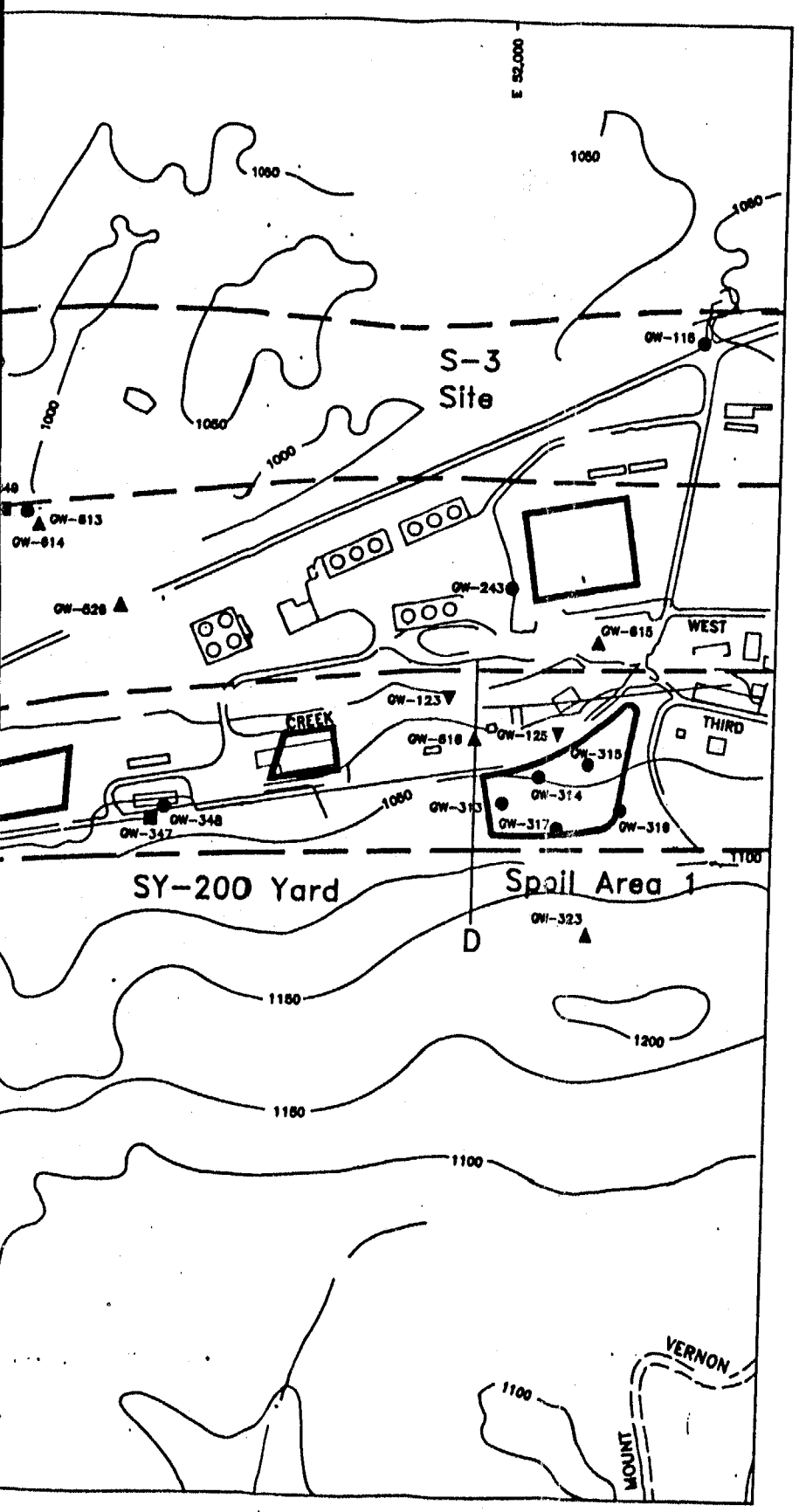
The following modifications to the groundwater quality assessment program in the BCHR are proposed for 1991.

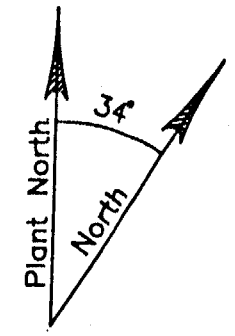
1. The monitor well network to be used for assessment monitoring in 1991 is presented on Figure 6-1. This well network reflects efforts to reduce the total number of wells by excluding "internal plume" wells which have been sampled for four consecutive quarters. The 1990 assessment monitor well network included 106 wells. The 1991 assessment well network includes a total of 95 wells, 24 of which are newly installed exit-pathway and plume delineation wells. The 1990 data indicate possible VOC plume migration in the northwest portion of the Bear Creek Burial Grounds. Therefore, two existing wells GW-286 and GW-287 will be added to the 1991 assessment program to monitor groundwater in the northwest portion of the Burial Grounds. Excluding the 24 new wells and the two existing wells, the 1991 proposed assessment well network represents a reduction of 37 wells.

2. Groundwater samples will be analyzed for the suite of parameters listed on Table 6-1. Included in the list are the primary groundwater contaminants, suspected contaminants which warrant further monitoring, and additional water-quality parameters, such as major ions, which are needed for a complete analyses of groundwater geochemistry in the BCHR.

3. As outlined in the Comprehensive Groundwater Monitoring Plan for the Y-12 Plant (Geraghty & Miller, 1990c), plume delineation and exit-pathway groundwater and surface water monitoring will be the focus of the 1991 assessment monitoring program. Installation of the exit-pathway monitor well network in the BCHR will be continued in 1991. Groundwater and surface water exit-pathway


Burial Grounds
Waste-Management
Area
Oil Landfarm
Waste-Management
Area
Rust Spoil
Area
Crg
Cm
Cn
Cmn
O-Ck
BEAR
CREEK
ROAD
A
B
C
N 32,000
N 30,000
N 28,000
E 42,000
E 44,000
E 46,000
E 48,000
E 50,000





0 600'
SCALE

Topographic Contour Interval: 50 ft.

EXPLANATION

GW-67	■	Unconsolidated Zone Monitor Well
GW-358	●	Shallow Bedrock Zone Monitor Well (Unc – 85')
GW-120	▲	Intermediate Bedrock Zone Monitor Well (85' – 300')
GW-119	▼	Deep Bedrock Zone Monitor Well (300'+)
	━━	Boundary of Site or Waste – Management Area
	— —	Approximate Geologic Contact
Ock		Knox Group
Cmn		Maynardville Limestone
Cn		Nolichucky Shale
Cm		Maryville Limestone
Crg		Rogersville Shale
A		Location of Maynardville Limestone Traverse For Exit-Pathway Monitoring

FIGURE 6-1
MONITOR WELL NETWORK PROPOSED
FOR ASSESSMENT MONITORING IN 1991

monitoring locations are presented on Figure 6-2. As shown on Figure 6-1, installation of exit-pathway monitor wells along traverse A (3 wells) and traverse B (6 wells) has been completed. Monitor wells are currently being installed along traverse C and completion of this exit-pathway cluster is expected by the end of 1991. Additionally, exit-pathway wells are currently being installed along a new traverse (traverse W) located about one mile west of traverse A. This cluster of wells will allow for a more complete investigation of the targeted (solution cavitydevelopment) stratigraphic intervals in the MaynardvilleLimestone.

Table 6-1. Sampling Sequence and Analytical Parameters Proposed for the 1991 Assessment Program

SITE[1]	WELL NUMBER	ANALYTICAL PARAMETERS[2]
S-3	GW-115[a]	STD
S-3	GW-613[a]	STD
S-3	GW-614[a]	STD
S-3	GW-649[a]	STD
S-3	GW-347	STD
S-3	GW-348	STD
RS	GW-648	STD
SPI	GW-323	STD
SPI	GW-317	STD
S-3	GW-123	STD
S-3	GW-125	STD
RINSATE SAMPLE		METALS, VOCs, NO_3, GROSS ALPHA, GROSS BETA
SPI	GW-316	STD
SPI	GW-315	STD
SPI	GW-314	STD
SPI	GW-313	STD
S-3/EXP	GW-616	STD
S-3	GW-526	STD, U, ^{241}Am, ^{237}Np, ^{3}H, ^{99}Tc, ^{90}Sr
S-3	GW-615	STD, U, ^{241}Am, ^{237}Np, ^{3}H, ^{99}Tc, ^{90}Sr
S-3	GW-243	STD, U, ^{241}Am, ^{237}Np, ^{3}H, ^{99}Tc, ^{90}Sr
RINSATE		METALS, VOCs, NO^3, GROSS ALPHA, GROSS BETA, ^{99}Tc
LD	GW-630[a]	STD
OL	GW- 84[a]	STD
OL	GW- 44[a]	STD
OL	GW- 43[a]	STD
OL	GW- 85	STD
RS	GW-309	STD
LD	GW-537	STD
OL/EXP	GW- 64	STD
OL	GW- 63	STD
RINSATE SAMPLE		METALS, VOCs, NO_3, GROSS ALPHA, GROSS BETA
OL	GW- 13	STD
OL	GW-644	STD
OL	GW-637	STD
OL	GW-638	STD
OL	GW-636	STD
OL	GW-645	STD
OL	GW-602	STD
OL	GW-646	STD
OL	GW-647	STD
OL	GW- 74	STD
OL	GW- 75	STD
OL	GW-520	STD
OL	GW-366	STD

Table 6-1. (Cont'd)

SITE[1]	WELL NUMBER	ANALYTICAL PARAMETERS[2]
RINSATE SAMPLE		METALS, VOCs, NO_3, GROSS ALPHA, GROSS BETA
OL	GW-364	STD
OL	GW-365	STD
OL	GW-601	STD
OL	GW-227	STD,U,^{241}Am,^{237}Np,^{3}H,^{99}Tc,^{90}Sr
OL	GW-225	STD
RINSATE SAMPLE		METALS, VOCs, GROSS ALPHA, GROSS BETA, ^{99}Tc
BG	GW-373[a]	STD
BG	GW-372[a]	STD
BG	GW-643[a]	STD
BG	GW-642[a]	STD
BG	GW- 42[a]	STD
BG	GW-655[a]	STD
BG	GW-342[a]	STD
BG	GW-343[a]	STD
BG	GW-344[a]	STD
BG	GW- 80	STD
BG	GW- 89	STD
RINSATE SAMPLE		METALS, VOCs
BG	GW-371	STD
BG	GW-370	STD
BG	GW-641	STD
BG	GW-640	STD
BG	GW-639	STD
BG/EXP	GW-621	STD
BG/EXP	GW-705	STD
BG/EXP	GW-704	STD
BG/EXP	GW-703	STD
BG/EXP	GW-706	STD
BG/EXP	GW-694	STD
BG/EXP	GW-695	STD
RINSATE SAMPLE		METALS, VOCs, N^{O3} GROSS ALPHA, GROSS BETA
BG	GW-654	STD
BG	GW-287	STD
BG	GW-286	STD
BG	GW- 83	STD
BG	GW-653	STD
BG	GW-652	STD
BG	GW-651	STD
BG/EXP	GW- 54	STD
BG/EXP	GW- 56	STD
BG/EXP	GW-685	STD
BG/EXP	GW-683	STD
BG/EXP	GW-684	STD

Table 6-1. (Cont'd)

SITE[1]	WELL NUMBER	ANALYTICAL PARAMETERS[2]
RINSATE SAMPLE		METALS, VOCs, N^{O3} GROSS ALPHA, GROSS BETA
BG	GW-627	STD
BG	GW- 95	STD
BG	GW-622	STD
BG	GW-118	STD
BG	GW- 69	STD
BG	GW- 82	STD
BG	GW- 52	STD
BG	GW-119	STD
BG	GW- 61	STD,U,^{241}Am,^{237}Np,^{3}H,^{99}Tc,^{90}Sr
BG	GW- 58	STD,U,^{241}Am,^{237}Np,^{3}H,^{99}Tc,^{90}Sr
BG	GW- 53	STD
BG	GW-626	STD
BG	GW-117	STD
BG	GW-623	STD
RINSATE SAMPLE		METALS, VOCs GROSS ALPHA, GROSS BETA

NOTE:

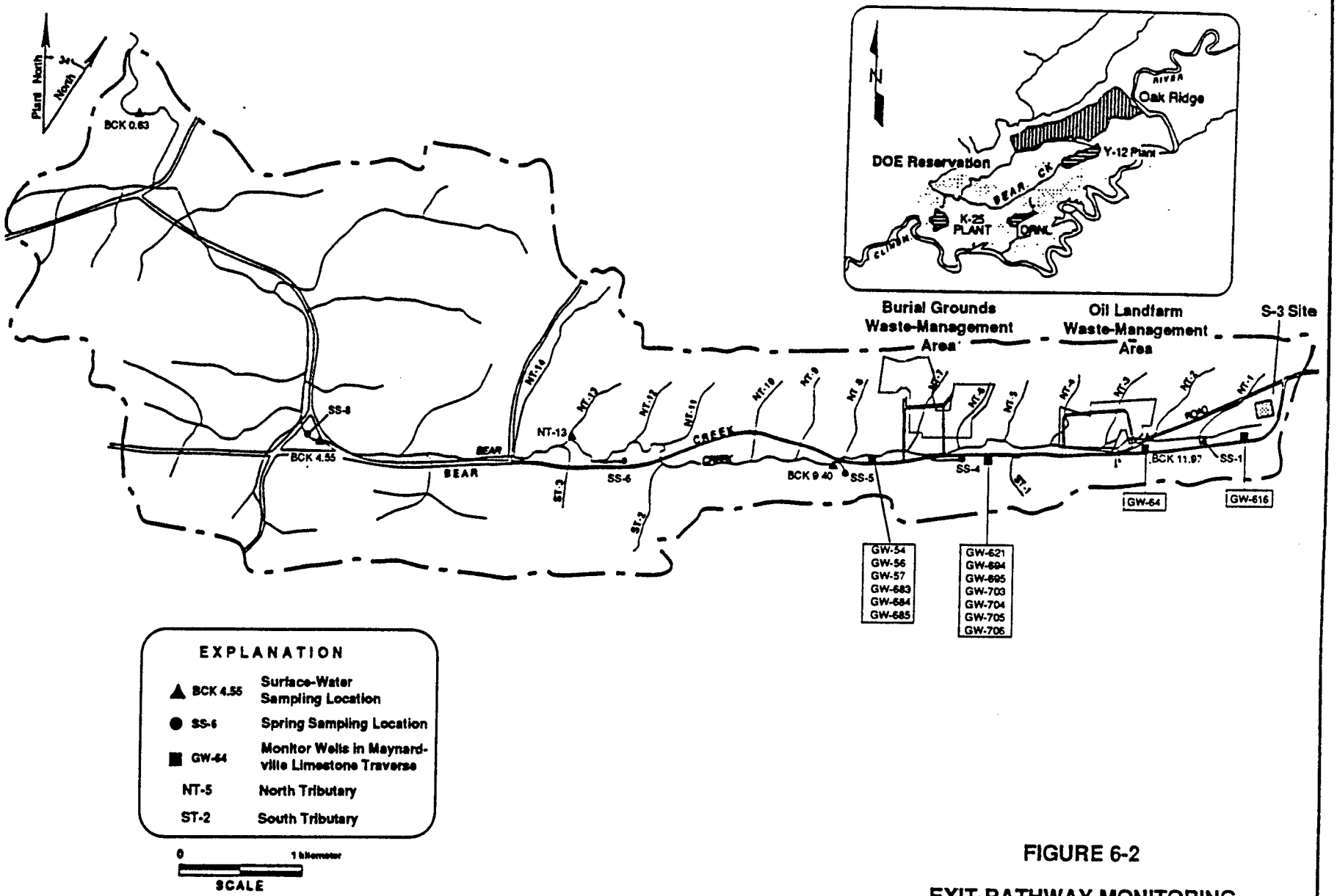
1. S-3 - S-3 Site
   RS - Rust Spoil Area
   SPI - Spoil Area I
   LD - Lysimeter Demonstration Site
   EXP - Exit-pathway
   OL - Oil Landfarm
   BG - Burial Grounds

2. STD - Standard Suite of Analytical Parameters
   * Cd, Cr, and Pb (AAS)
   * Mercury (CVAA)
   * Gross Alpha Activity
   * Volatile Organics
   * Nitrate (as N)
   * Metals Scan (ICP)
   * Uranium (Fluor.)
   * Gross Beta Activity
   * Major Ions

   * Field Parameters: Conductivity, Temperature, Dissolved Oxygen, Redox, Water Level

   * Others Parameters: pH, Conductivity, TSS, TDS, Turbidity
   U - Uranium (^{234}U, ^{235}U, and ^{238}U)
   ^{241}Am - Americium
   ^{237}Np - Neptunium
   3H - Tritium
   ^{99}Tc - Technetium
   ^{90}Sr - Strontium

a. Background Well



MODIFIED FROM: G&M 1990b

FIGURE 6-2

EXIT-PATHWAY MONITORING LOCATIONS PROPOSED FOR ASSESSMENT MONITORING IN 1991

7.0 REFERENCES

Brownlow, A.H. Geochemistry. 1979. Prantice-Hall, Inc., pg. 294.

DeBuchananne, G.D., and R.M. Richardson. 1956. Ground-Water Resources of East Tennessee. Tennessee Division of Geology, Bulletin 58, Part I.

Evans, R.D. 1955. The Atomic Nucleus McGraw-Hill, New York.

Geraghty & Miller, Inc. 1985. Remedial Alternatives for the Bear Creek Valley Waste Disposal Area. Prepared for Martin Marietta Energy Systems, Inc. (Y/SUB/85-00206C/3).

Geraghty & Miller, Inc. 1987. Preliminary Evaluation of the Hydrogeologic and Water-Quality Data from Phase IV wells located in the Bear Creek Valley Waste Disposal Area for the period Summer 1985-September 1986. Prepared for Martin Marietta Energy Systems, Inc. (Y/SUB/87-00206C/9).

Geraghty & Miller, Inc. 1989a. Development of Ground-Water Flow Models for the S-3 Waste-Management Area, Y-12 Plant, Oak Ridge, Tennessee. Prepared for Martin Marietta Energy Systems, Inc. (Y/SUB/89-00206C/1).

Geraghty & Miller, Inc. 1989b. Tracer Study of the Hydrologic System of Upper Bear Creek, Y-12 Facility, Oak Ridge, Tennessee. Prepared for Martin Marietta Energy Systems, Inc. (Draft)

Geraghty & Miller, Inc. 1990a. Data Evaluations Procedures for Contamination Assessment Programs at the Y-12 Plant, Oak Ridge, Tennessee. Prepared for Martin Marietta Energy Systems, Inc. (Draft)

Geraghty & Miller, Inc. 1990b. Groundwater Quality Assessment for the Bear Creek Hydrogeologic Regime at the Y-12 Plant, 1989: Data Interpretations and Proposed Modifications. Prepared for Martin Marietta Energy Systems, Inc. (Y/SUB/90-00206C/2/Part II).

Geraghty & Miller, Inc. 1990c. Comprehensive Groundwater Monitoring Plan for the Department of Energy Y-12 Plant. Prepared for Martin Marietta Energy Systems, Inc. (Y/SUB/90-00206C/5).

Haase, C.S., and H.L. King. 1990. Report and Preliminary Assessment of Occurrence of Dense, Nonaqueous Phase Liquids in the Bear Creek Burial Grounds Hazardous-Waste Disposal unit at the Oak Ridge Y-12 Plant. Martin Marietta Energy Systems (Y/TS-629).

HSW Environmental Consultants, Inc. 1991a. Groundwater Quality Assessment for the Bear Creek Hydrogeologic Regime at the Y-12 Plant 1990. Groundwater Quality Data and Calculated Rate of Contaminant Migration. Prepared for Martin Marietta Energy Systems, Inc. (Y/SUB/91-YP507C/1).

HSW Environmental Consultants, Inc. 1991b. Groundwater Quality Assessment for the Upper East Fork Poplar Creek Hydrogeologic Regime at the Y-12 Plant, 1990: Data Interpretations and Proposed Program Modifications. Prepared for Martin Marietta Energy Systems, Inc. (Y/SUB/91-YP507C/2 Part 2).

King, L.H., and C.S. Haase. 1987. Subsurface-Controlled Geological Maps for the Y-12 Plant and Adjacent Areas of Bear Creek Valley. Oak Ridge National Laboratory (ORNL/TM-10112).

Martin Marietta Energy Systems, Inc. 1988. Revised Closure Plan for New Hope Pond. Environmental Management Dept., Health, Safety, Environment and Accountability Division, Y-12 Plant (Y/TS-389).

Rothschild, E.R., R.R. Turner, S.H. Stow, M.A. Bogle, L.K. Hyder, O.M. Sealand, and H.J. Wyrick. 1984. Investigation of Subsurface Mercury at the Oak Ridge Y-12 Plant. Oak Ridge National Laboratory. (ORNL/TM-9092).

Turner, R.R. and T.M. Mercier. 1988. RCRA Facility Investigation Plan Bear Creek Oak Ridge Y-12 Plant Oak Ridge, Tennessee. Martin Marietta Energy Systems, Inc. Draft (Y/TS-417).

U.S. Environmental Protection Agency. 1986. Test Methods for Solid Waste Evaluation, Vol. 1A: Laboratory Manual Physical/Chemical Methods. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, SW-846, Third Edition.

U.S. Environmental Protection Agency. 1988. Laboratory Data Validation Functional Guidelines for Evaluating Organics Analyses.

Welch, S.H. 1989. RCRA Facility Investigation Plan for Bear Creek, U.S. DOE Y-12 Plant, Oak Ridge, Tennessee. Martin Marietta Energy Systems, Inc. (Y/TS-417).

PLATES

DISTRIBUTION

DEPARTMENT OF ENERGY

G. W. Bodenstein (5)
W. G. McMillan
W. C. Sidle
T. S. Tison

HEALTH, SAFETY, ENVIRONMENT AND ACCOUNTABILITY DIVISION

E. T. Collins
J. M. Eaton
C. C. Edwards
K. G. Hanzelka
J. B. Hunt
R. L. Johnson, Jr.
C. W. Kimbrough
H. L. King
L. W. McMahon (3)
J. E. Stone
L. O. Vaughan
S. W. Wiley

ENVIRONMENTAL AND SAFETY DIVISION

T. K. Cothron
M. E. Mitchell
T. P. A. Perry
C. L. Stair

ENGINEERING DIVISION

R. M. Hill
L. W. Little
W. E. Manrod
T. J. Read
J. K. Siberell

H&R TECHNICAL ASSOCIATES, INC.

T. M. Mercier

ENVIRONMENTAL SCIENCES DIVISION

R. B. Clapp
R. B. Dreier
T. O. Early
C. S. Haase
D. D. Huff
J. M. Loar
R. R. Turner

HEALTH AND SAFETY DIVISION

D. E. Bohrman
V. J. Brumback
R. K. White

ENERGY DIVISION

R. H. Ketelle

PRODUCTION SUPPORT MAINTENANCE DIVISION

K. D. Delius
I. W. Jeter
N. G. McRae

ENVIRONMENTAL RESTORATION DIVISION

M. J. Norris
G. L. Underburg
S. H. Welch (3)

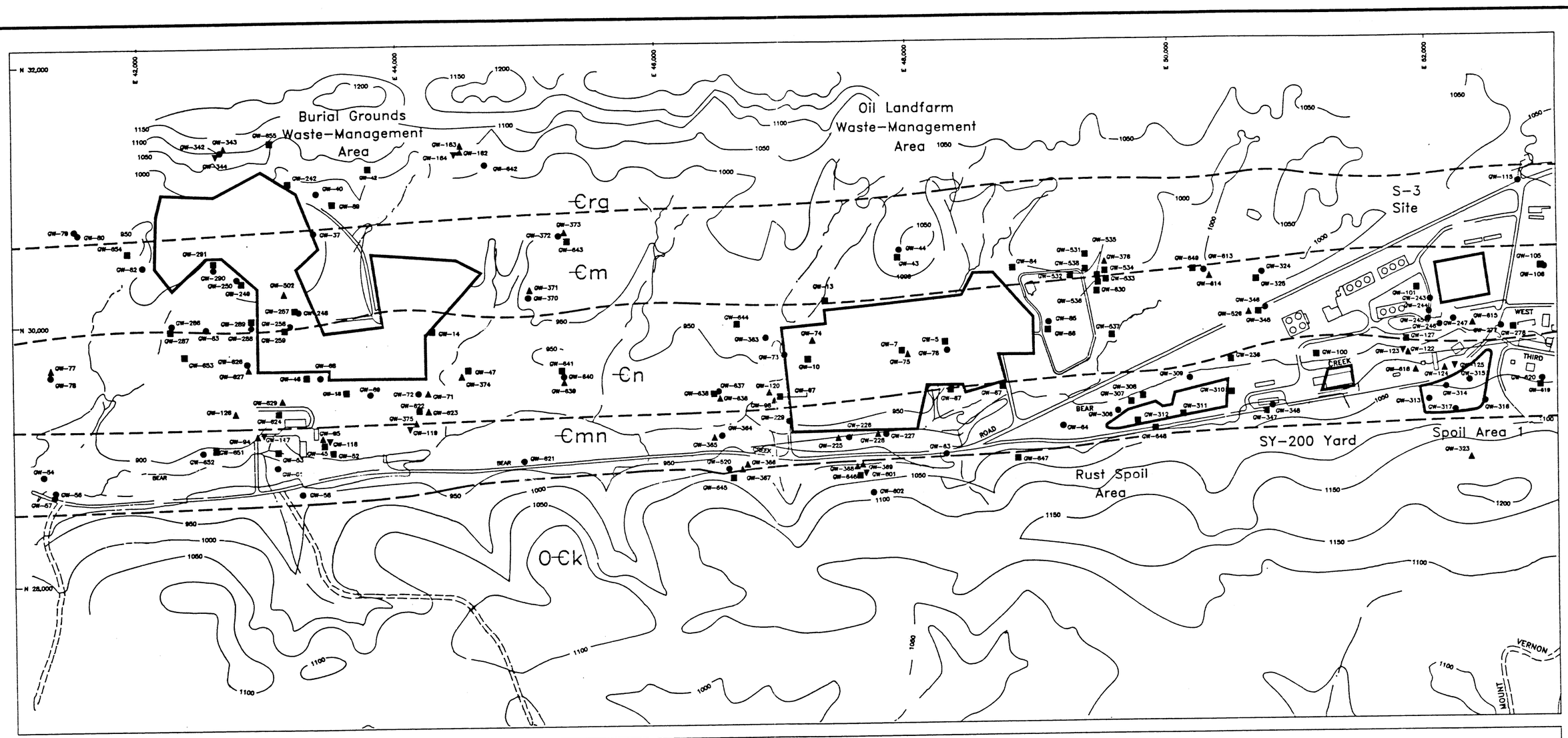
QUALITY AND TECHNICAL SERVICES DIVISION

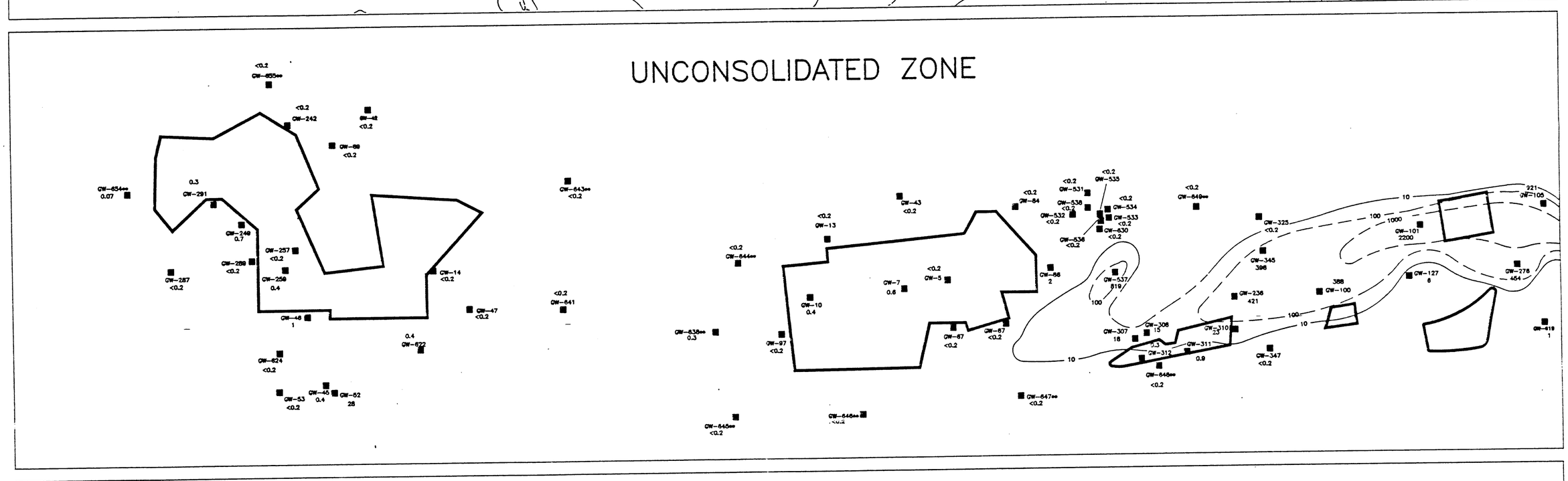
L. P. Burnett
G. S. Thurmer

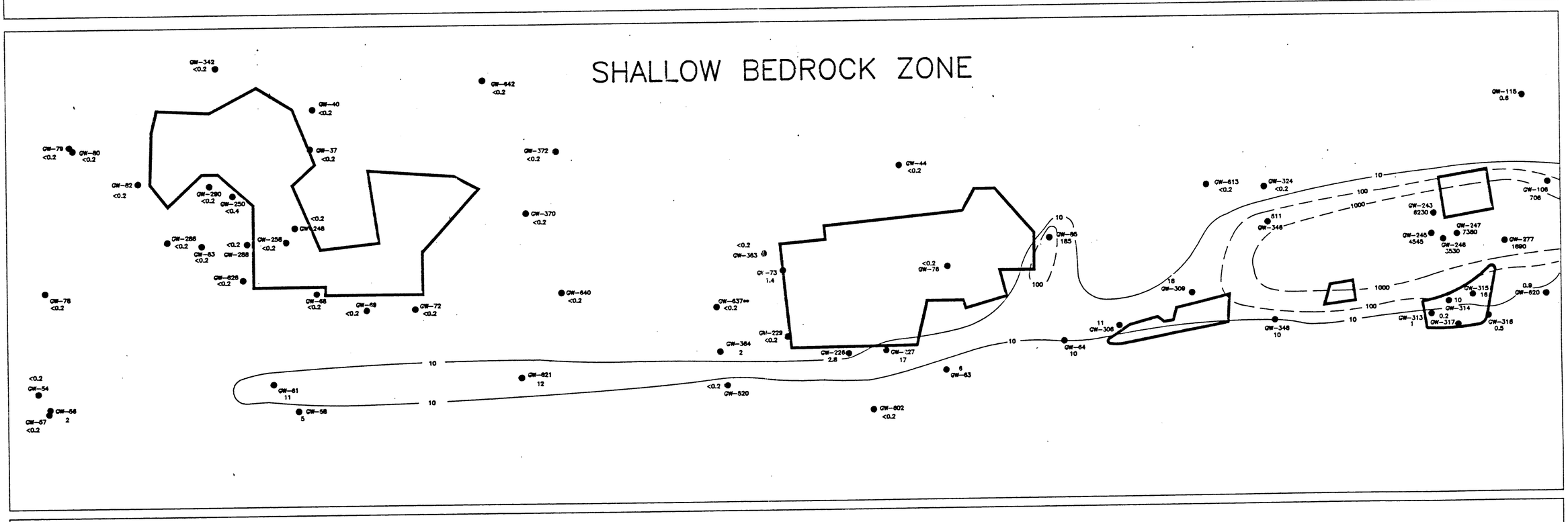
A. K. Lee/DOE-OSTI (4)
Y-12 Central Files - RC

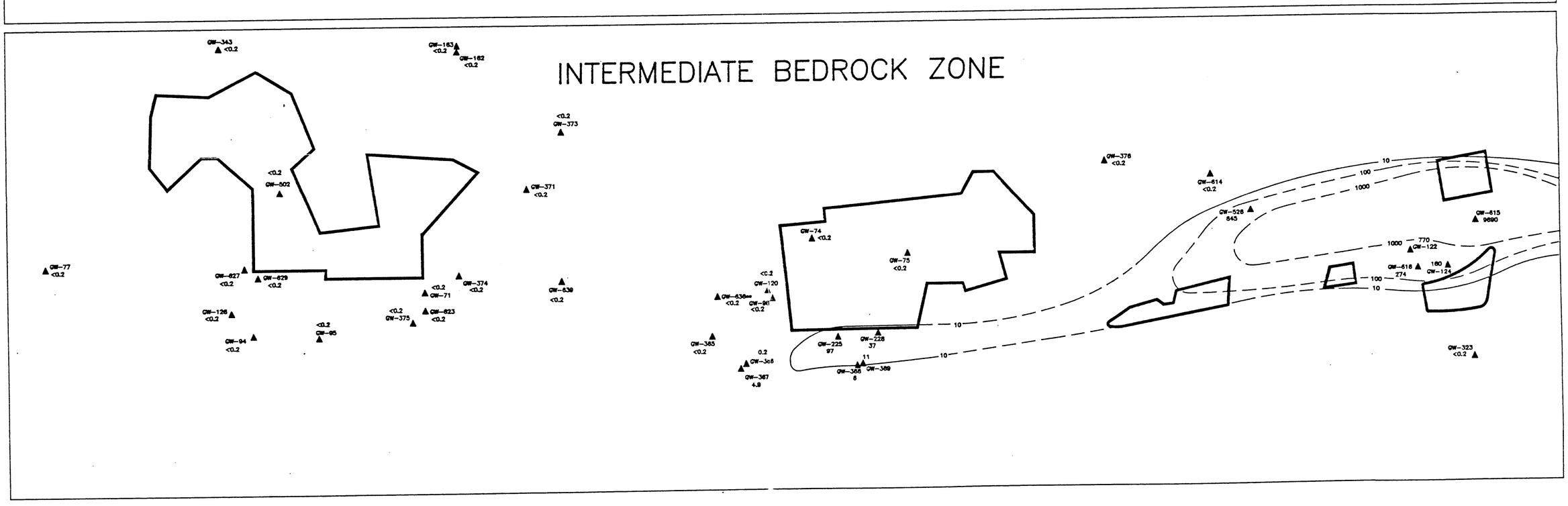
DISCLAIMER

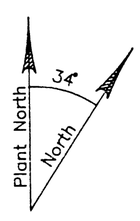
This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.











0 600'
SCALE

Topographic Contour Interval: 50 ft.

— — —	Approximate Geologic Contact	GW-52 ■	Unconsolidated Zone Monitor Well
OCk	Knox Group	GW-621 ●	Shallow Bedrock Zone Monitor Well (Unc – 85')
Cmn	Maynardville Limestone	GW-623 ▲	Intermediate Bedrock Zone Monitor Well (85' – 300')
Cn	Nolichucky Shale	GW-118 ▼	Deep Bedrock Zone Monitor Well (300'+)
Cm	Maryville Limestone	•	Indicates a Well sampled prior to 1990 (Data Qualitative)
Crg	Rogersville Shale	• •	Indicates a Well sampled in 1991 (Data Qualitative)

<0.2	Annual Average Nitrate (as N) Concentration (mg/L)
— 10 —	Line of Equal Concentration (dashed where approximate)
ND	Not Detected above Contract Required Quantitation Limit
▬▬	Boundary of Site or Waste – Management Area

PLATE 1

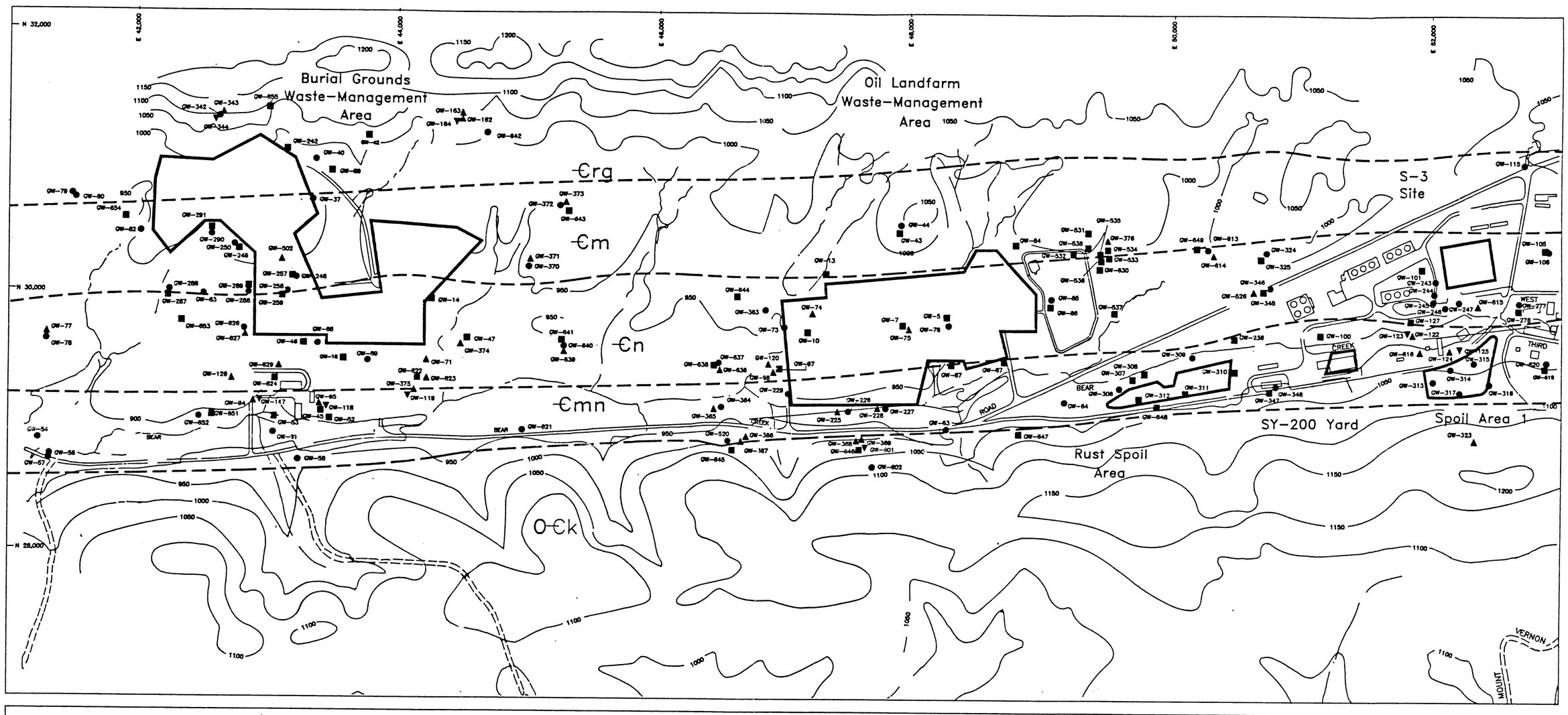
Prepared for: MARTIN MARIETTA ENERGY SYSTEMS, INC.

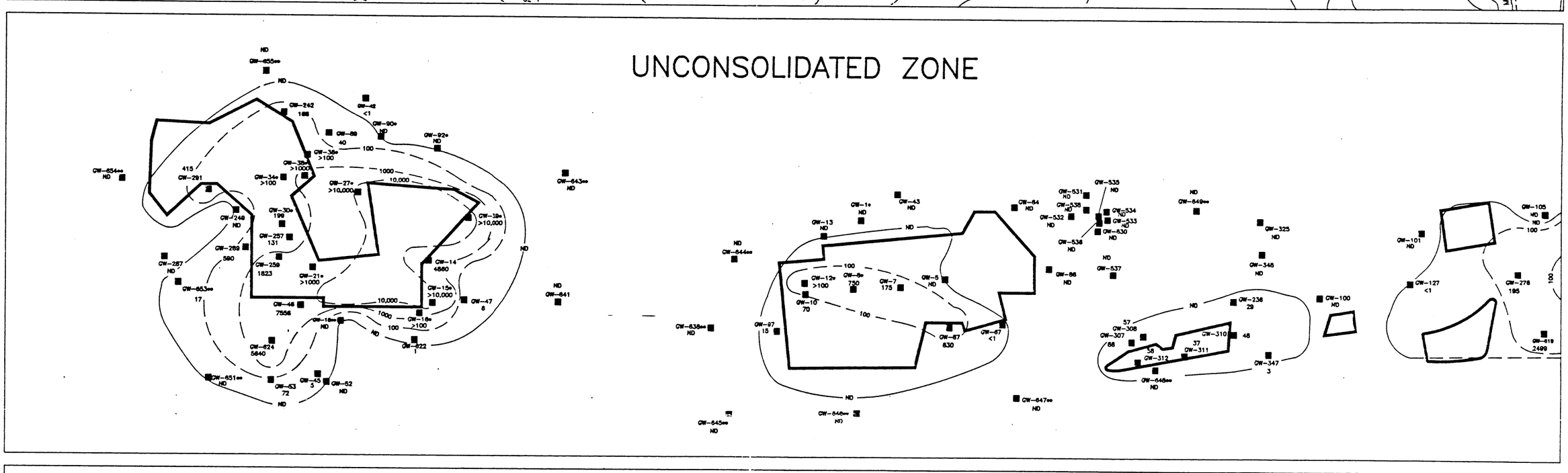
Title: Occurrence of Nitrate in Groundwater in the Bear Creek Hydrogeologic Regime

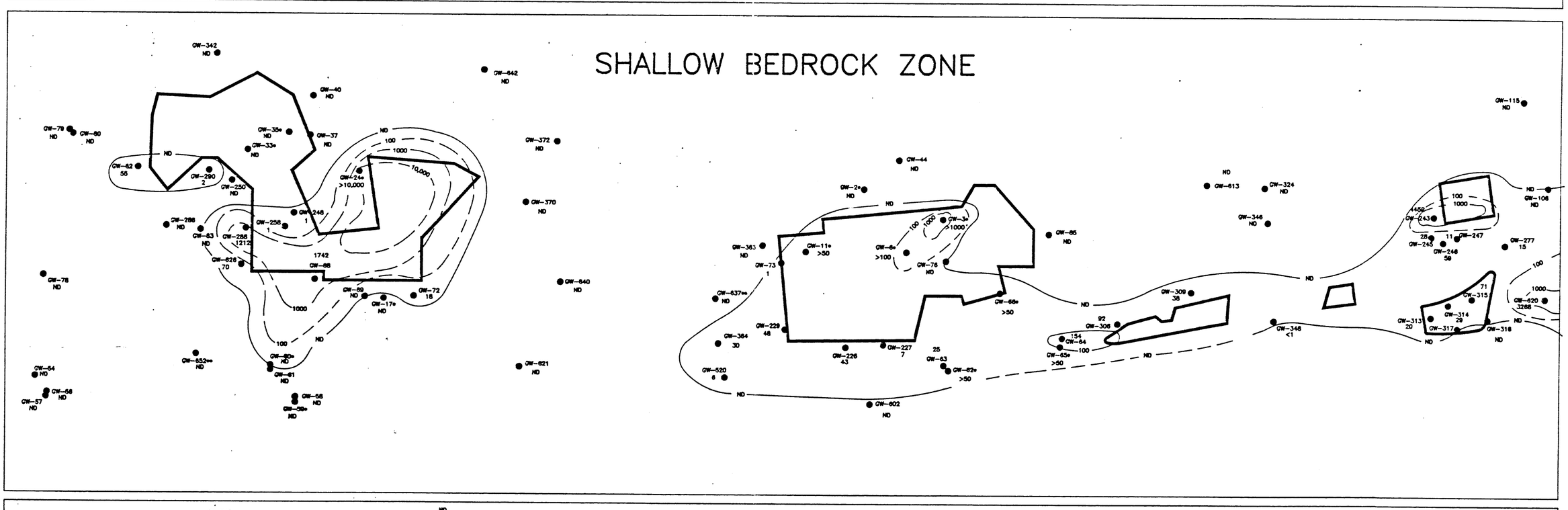
Compiled by: HSW ENVIRONMENTAL CONSULTANTS, INC.

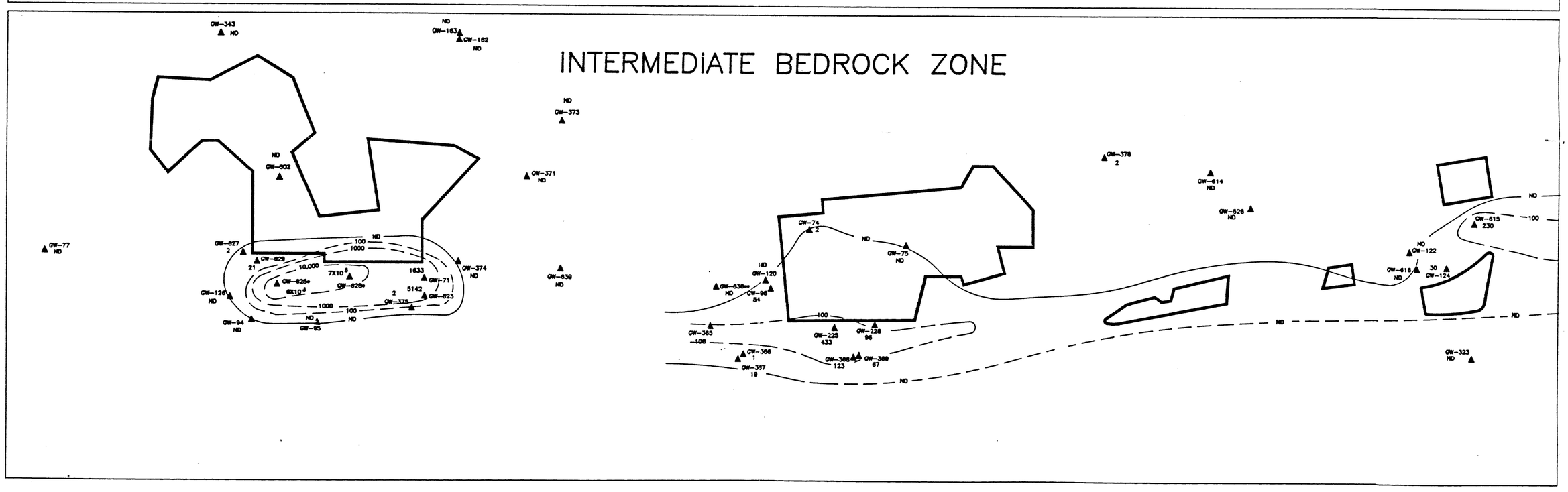
Date: JUNE 1991

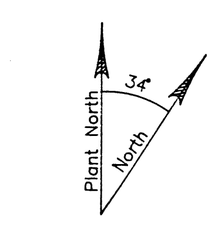
#1699











Topographic Contour Interval: 50 ft.

— — —	Approximate Geologic Contact	GW-52	■	Unconsolidated Zone Monitor Well	230		Summed Average VOC Concentration (µg/L)
OCk	Knox Group	GW-621	●	Shallow Bedrock Zone Monitor Well (Unc – 85')	— 100 —		Line of Equal Concentration (dashed where approximate)
Cmn	Maynardville Limestone	GW-623	▲	Intermediate Bedrock Zone Monitor Well (85' – 300')	ND		Not Detected above Contract Required Quantitation Limit
Cn	Nolichucky Shale	GW-118	▼	Deep Bedrock Zone Monitor Well (300'+)	▬▬		Boundary of Site or Waste – Management Area
Cm	Maryville Limestone	•		Indicates a Well sampled prior to 1990 (Data Qualitative)			
Crg	Rogersville Shale	• •		Indicates a Well sampled in 1991 (Data Qualitative)			

PLATE 2

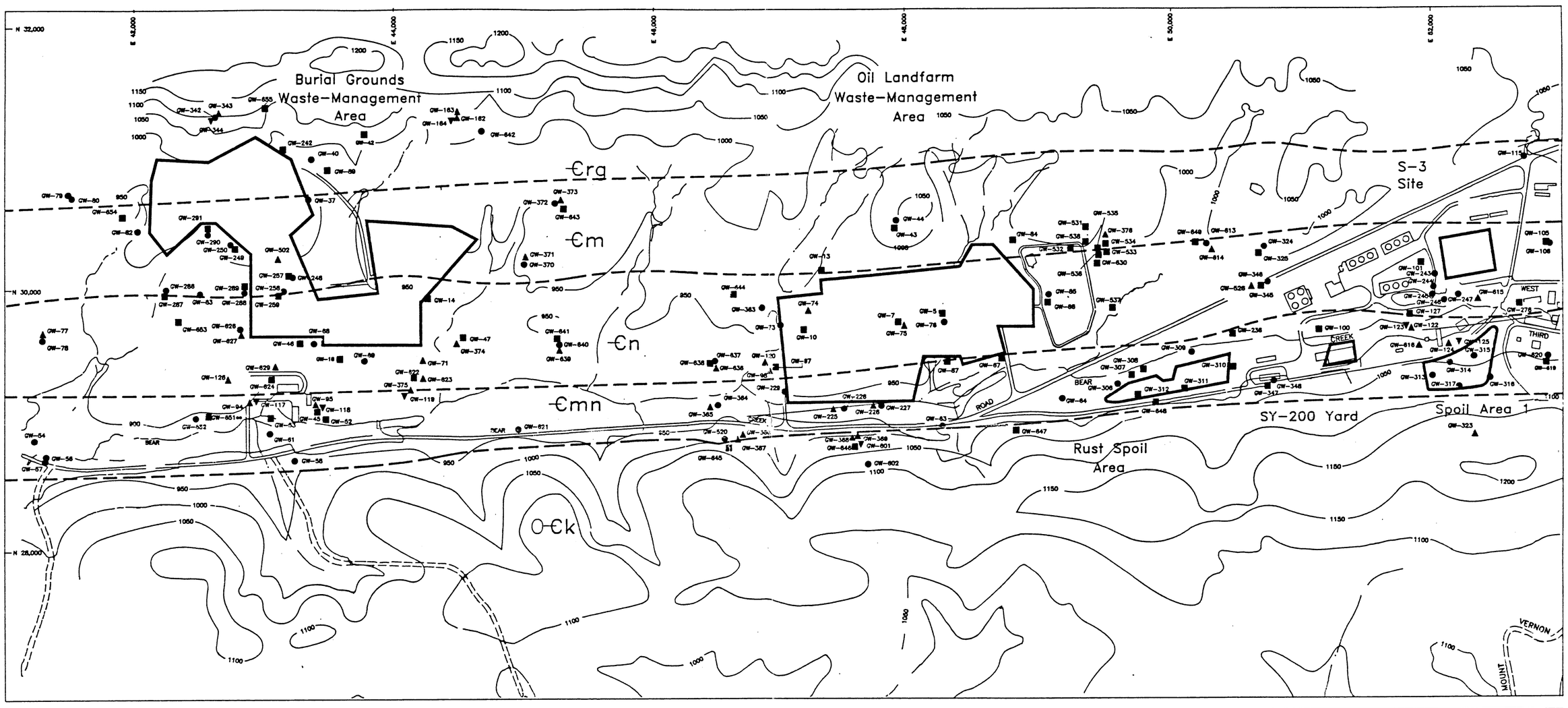
Prepared for: MARTIN MARIETTA ENERGY SYSTEMS, INC.

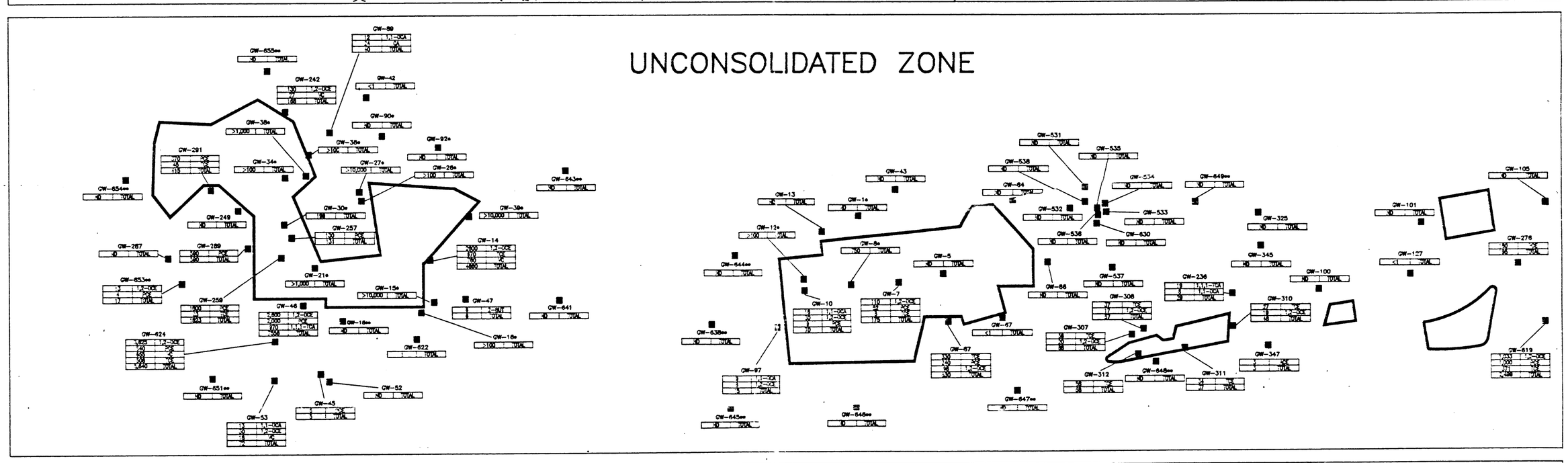
Title: Occurrence of Dissolved VOCs in Groundwater in the Bear Creek Hydrogeologic Regime

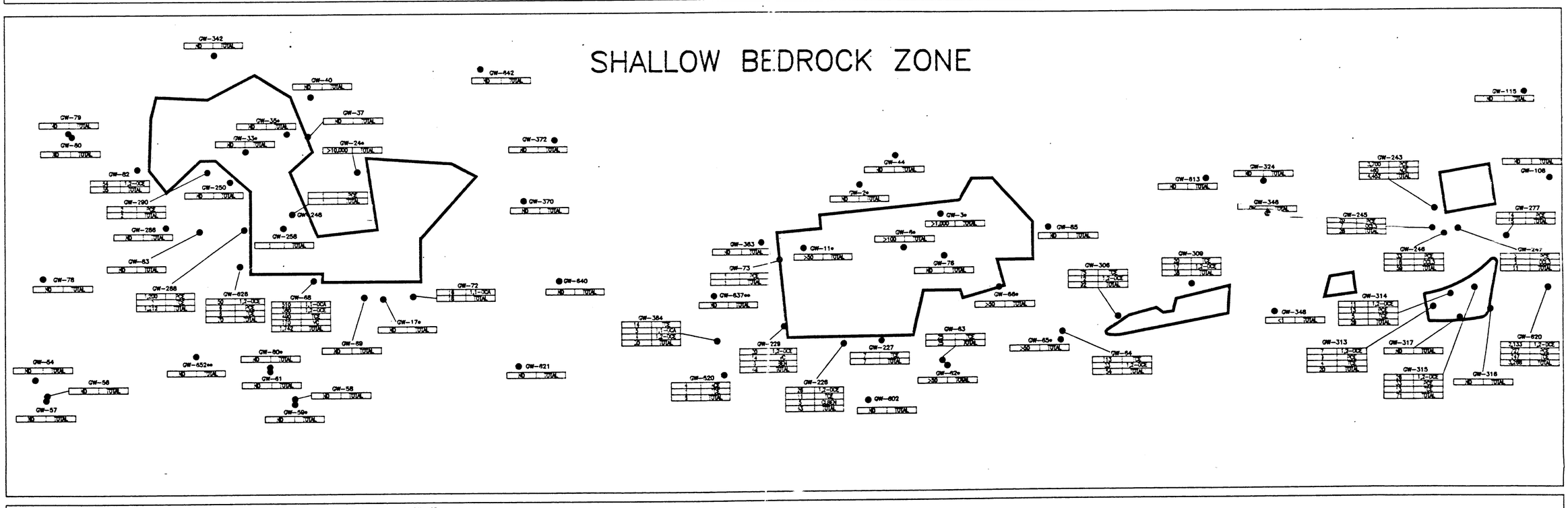
Compiled by: HSW ENVIRONMENTAL CONSULTANTS, INC.

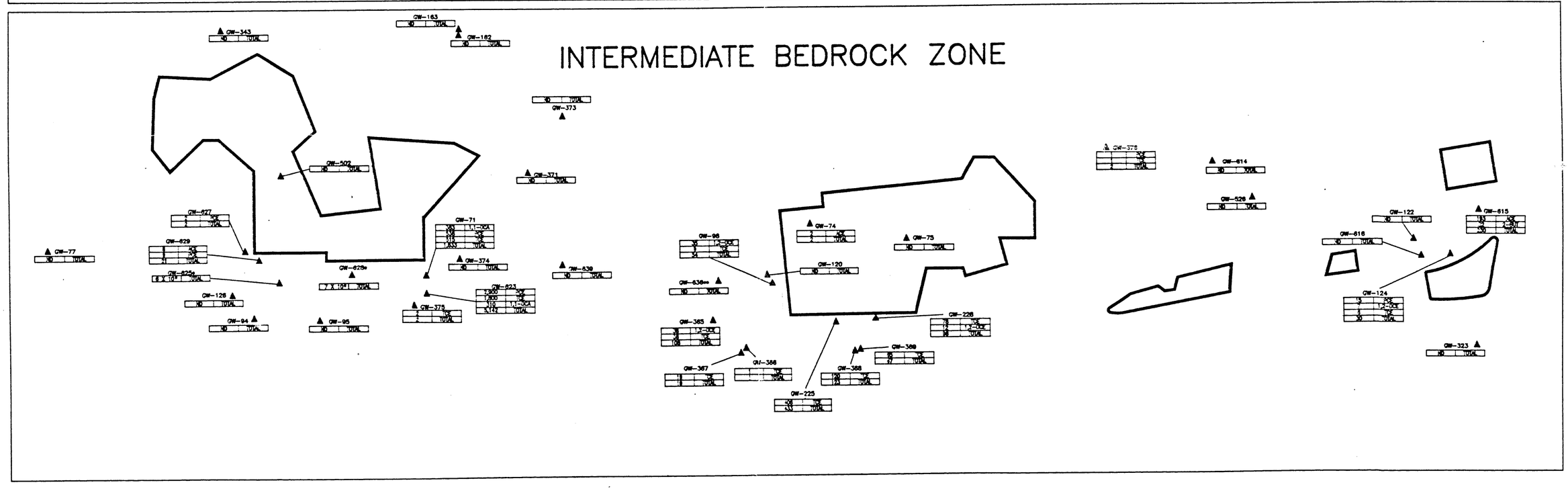
Date: JUNE 1991

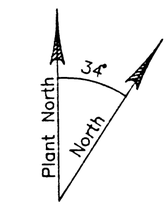
#1099











0 600'
SCALE

Topographic Contour Interval: 50 ft.

— — —	Approximate Geologic Contact	GW-52	■	Unconsolidated Zone Monitor Well	
OCk	Knox Group	GW-621	●	Shallow Bedrock Zone Monitor Well (Unc – 85')	
Cmn	Maynardville Limestone	GW-623	▲	Intermediate Bedrock Zone Monitor Well (85' – 300')	
Cn	Nolichucky Shale	GW-118	▼	Deep Bedrock Zone Monitor Well (300'+)	
Cm	Maryville Limestone		•	Indicates a Well sampled prior to 1990 (Data Qualitative)	
Crg	Rogersville Shale		• •	Indicates a Well sampled in 1991 (Data Qualitative)	

750	Average VOC Concentration (µg/L)
ND	Not Detected above Contract Required Quantitation Limit
▬▬	Boundary of Site or Waste – Management Area

1,1,1 – TCA	1,1,1 – Trichloroethane
1,1 – DCA	1,1 – Dichloroethane
1,2 – DCE	1,2 – Dichloroethene
2 – BUT	2 – Butanone
ACE	Acetone
BEN	Benzene
CA	Chloroethane
CCL3	Chloroform
CLBEN	Chlorobenzene
PCE	Tetrachloroethene
TCE	Trichloroethene
TOL	Toluene
VC	Vinyl Chloride
XYL	Xylenes
TOTAL	Summed Average VOCs

PLATE 3

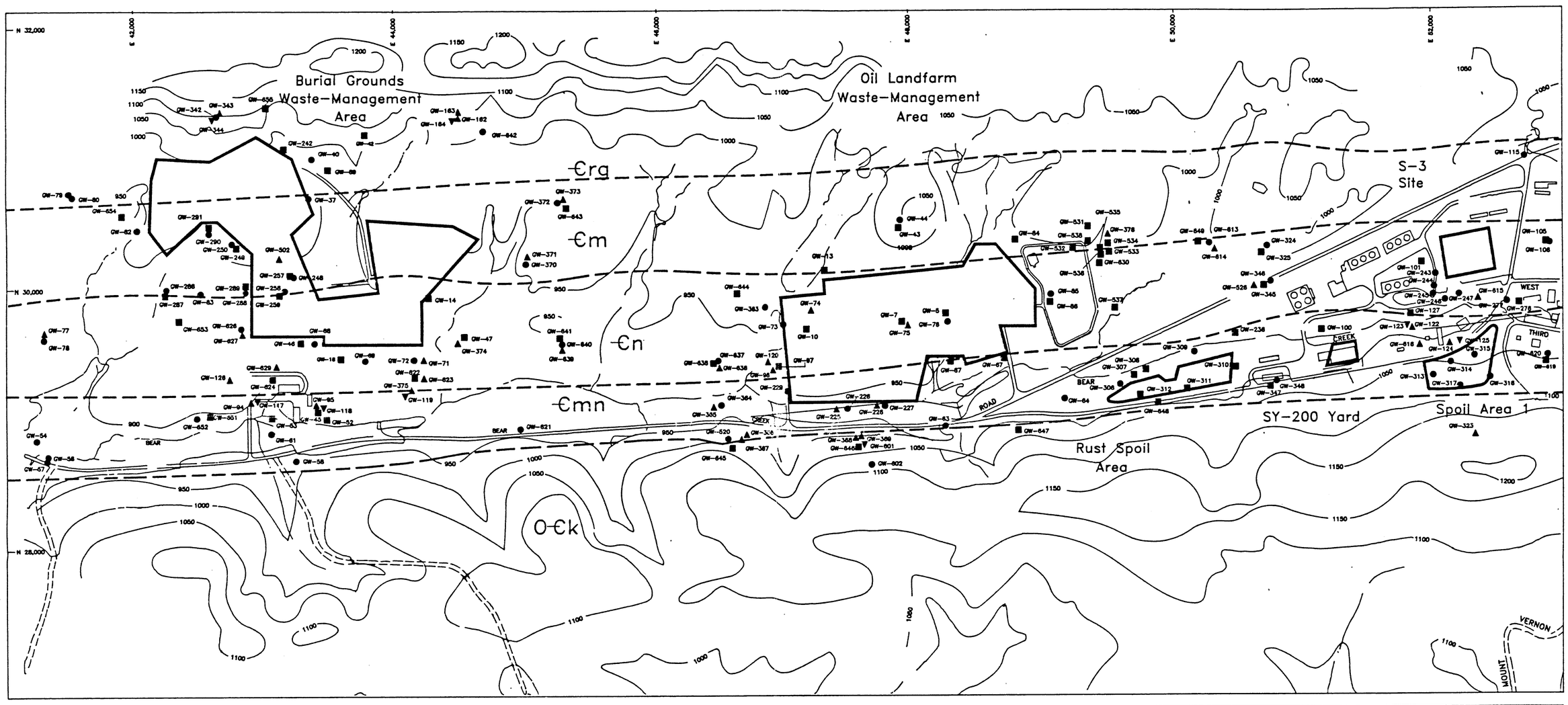
Prepared for: MARTIN MARIETTA ENERGY SYSTEMS, INC.

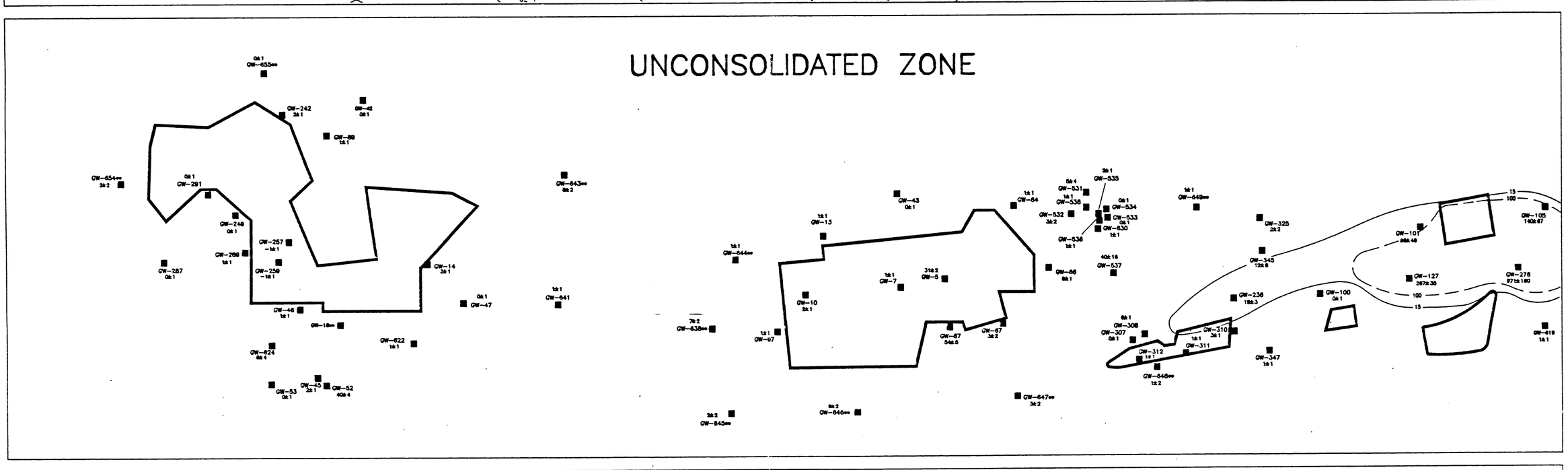
Title: Distribution and Summed Average Concentration of VOCs in Groundwater in the Bear Creek Hydrogeologic Regime

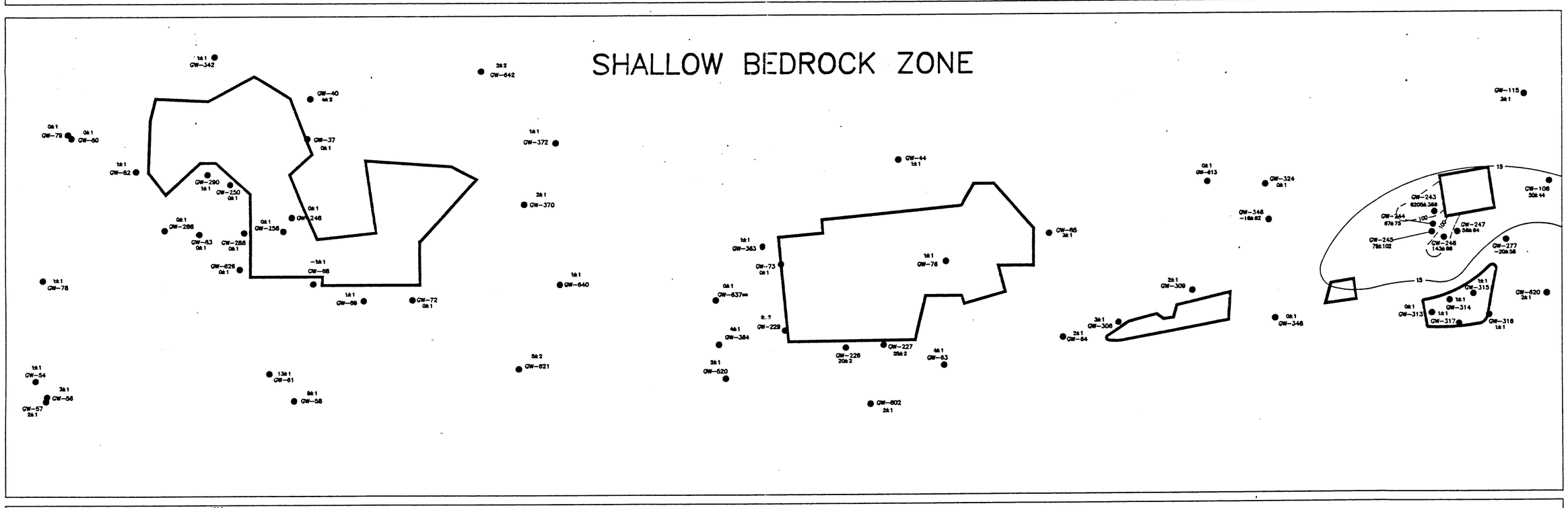
Compiled by: HSW ENVIRONMENTAL CONSULTANTS, INC.

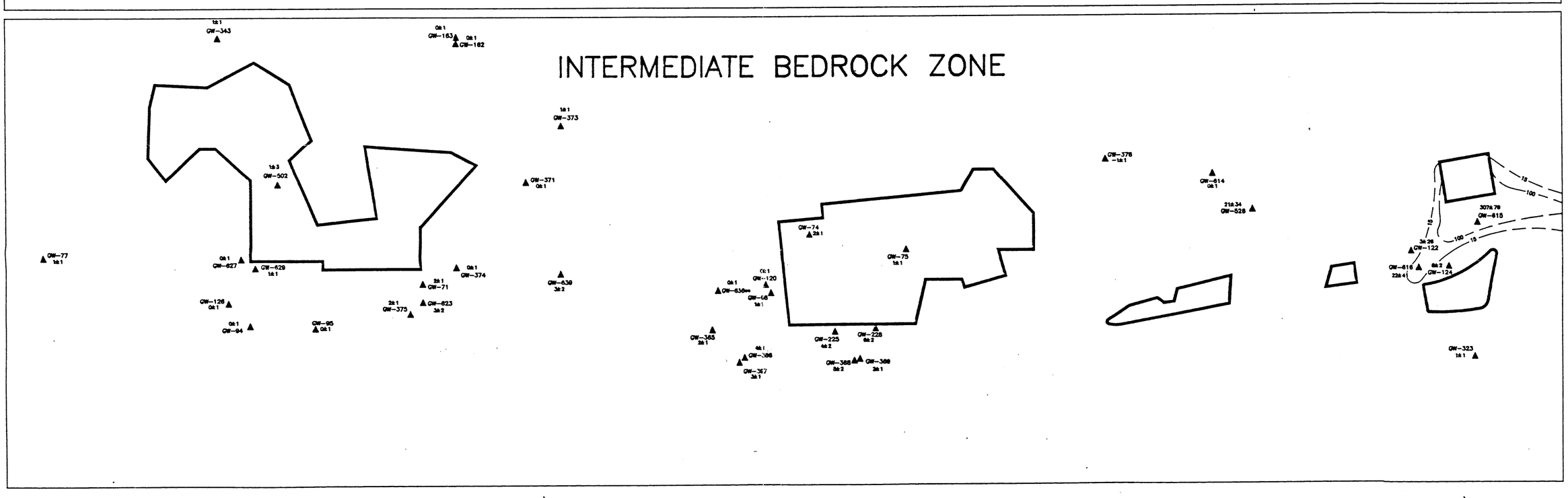
Date: JUNE 1991

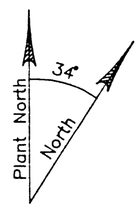
1099











0 800'
SCALE

Topographic Contour Interval: 50 ft.

— — —	Approximate Geologic Contact	GW-52	■ Unconsolidated Zone Monitor Well	12±6	Annual Average Gross Alpha Activity (pCi/L) and Mean Counting Error
ꞒCk	Knox Group	GW-621	● Shallow Bedrock Zone Monitor Well (Unc – 85')	— 15 —	Line of Equal Activity (dashed where approximate)
-Ꞓmn	Maynardville Limestone	GW-623	▲ Intermediate Bedrock Zone Monitor Well (85' – 300')	▬	Boundary of Site or Waste – Management Area
-Ꞓn	Nolichucky Shale	GW-118	▼ Deep Bedrock Zone Monitor Well (300'+)		
-Ꞓm	Maryville Limestone	•	indicates a Well sampled prior to 1990 (Data Qualitative)		
-Ꞓrg	Rogersville Shale	• •	indicates a Well sampled in 1991 (Data Qualitative)		

PLATE 4

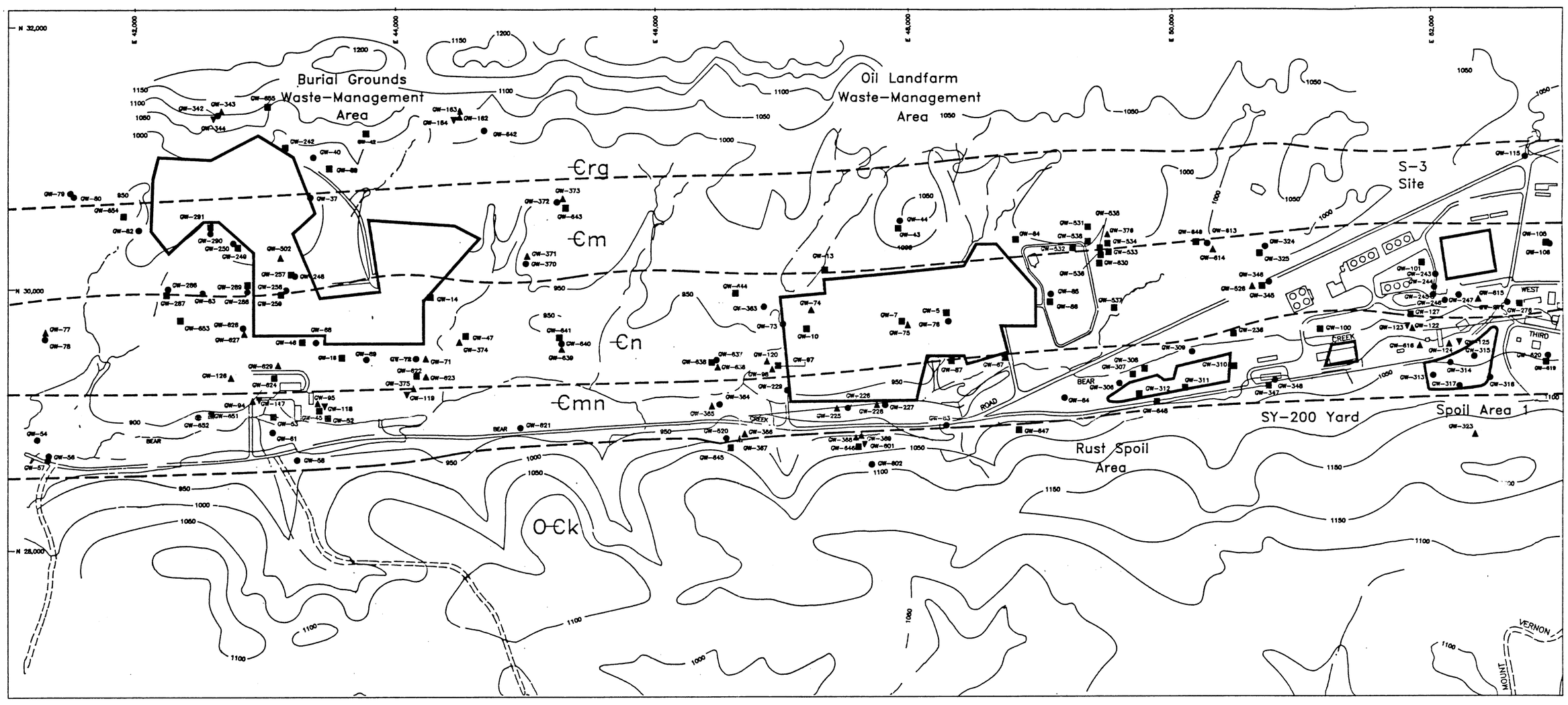
Prepared for: MARTIN MARIETTA ENERGY SYSTEMS, INC.

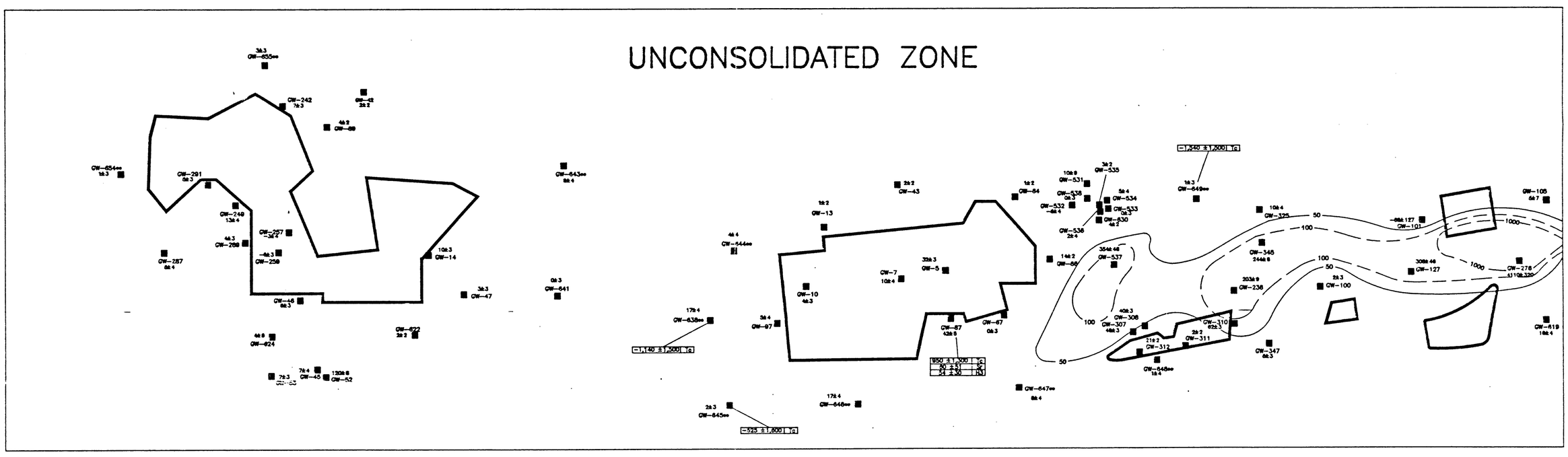
Title: Mean Gross Alpha Activity in Groundwater in the Bear Creek Hydrogeologic Regime

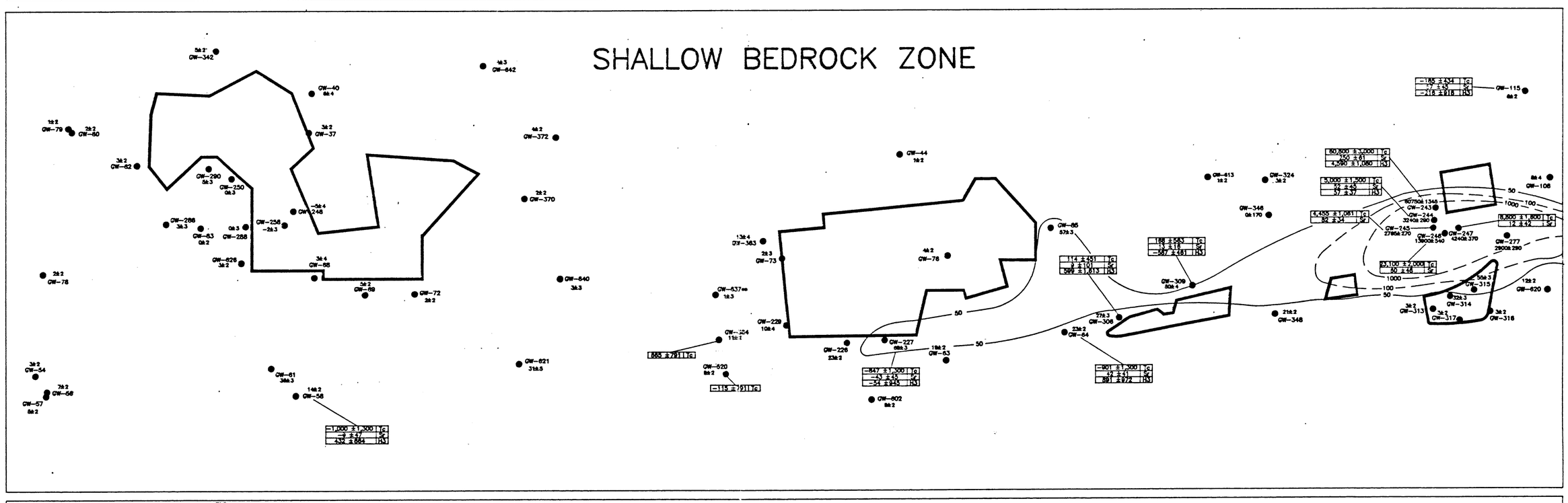
Compiled by: HSW ENVIRONMENTAL CONSULTANTS, INC.

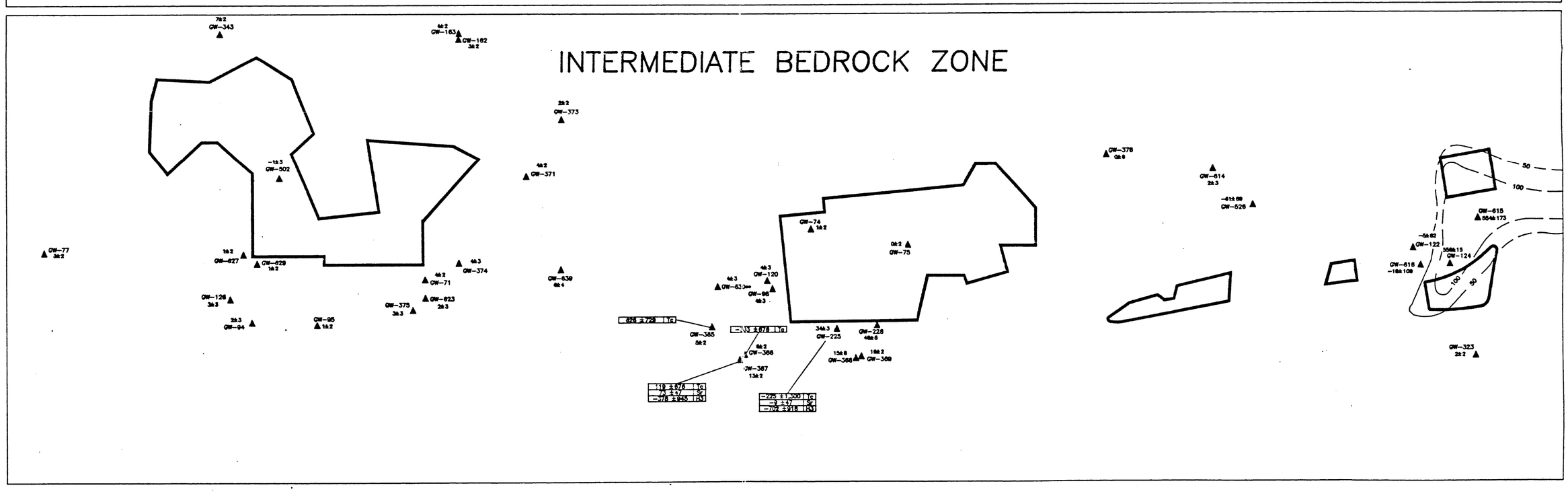
Date: JUNE 1991

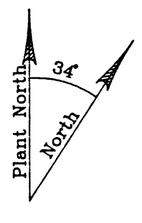
#1099











0 600'
SCALE

Topographic Contour Interval: 50 ft.

— — —	Approximate Geologic Contact	GW-52	■ Unconsolidated Zone Monitor Well	12±2	Annual Average Gross Beta Activity (pCi/L) and Mean Counting Error
OCk	Knox Group	GW-621	● Shallow Bedrock Zone Monitor Well (Unc – 85')	50	Line of Equal Activity (dashed where approximate)
-Cmn	Maynardville Limestone	GW-623	▲ Intermediate Bedrock Zone Monitor Well (85' – 300')	▬	Boundary of Site or Waste – Management Area
-Cn	Nolichucky Shale	GW-118	▼ Deep Bedrock Zone Monitor Well (300'+)	Tc	Technetium – 99
-Cm	Maryville Limestone	•	Indicates a Well sampled prior to 1990 (Data Qualitative)	Sr	Strontium – 90
-Crg	Rogersville Shale	• •	Indicates a Well sampled in 1991 (Data Qualitative)	H3	Tritium

PLATE 5

Prepared for: MARTIN MARIETTA ENERGY SYSTEMS, INC.

Title: Mean Gross Beta Activity in Groundwater in the Bear Creek Hydrogeologic Regime

Compiled by: HSW ENVIRONMENTAL CONSULTANTS, INC.

Date: JUNE 1991

1099