Energy Systems Environmental Restoration Program
Y-12 Environmental Restoration Program

**Remedial Investigation Work Plan for Bear Creek Valley
Operable Unit 4 (Shallow Groundwater in Bear Creek Valley)
at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee**

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OAK RIDGE Y-12 PLANT
Oak Ridge, Tennessee 37831-8169
managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
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under contract DE-AC05-84OR21400

MASTER

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ACRONYMS

AAS	atomic absorption spectroscopy
ACLs	alternate concentration limits
AEA	Atomic Energy Act
ALARA	as low as reasonably achievable
ANSI/ASME	American National Standards Institute/American Society of Mechanical Engineers
APR	average or mean percent recovery
ARARs	applicable and relevant or appropriate requirements
ARPA	Archaeological Resources Protection Act
ASC	Analytical Services Coordinator
BCK	Bear Creek Kilometer
BCV	Bear Creek Valley
BLS	Below Land Surface
BMAP	Biological Monitoring and Abatement Program
BRA	baseline risk assessment
CAA	Clean Air Act
CAR	Corrective Action Report
CCC	criterion continuous concentration
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	<i>Code of Federal Regulations</i>
CLP	Contract Laboratory Program
CM	corrective measures
CMC	criterion maximum concentration
CMS	Corrective Measures Study
CSF	carcinogenic slope factors
C _v	coefficient of variation
CWA	Clean Water Act
DCA	dichloroethane
DCE	dichloroethene
DNAPL	dense nonaqueous phase liquid
DOE	U.S. Department of Energy
DOE-OR	DOE Oak Ridge Field Office
DOI	U.S. Department of the Interior
EA	environmental assessment
EFPC	East Fork Poplar Creek
Energy Systems	Martin Marietta Energy Systems, Inc.
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration
ESD	Environmental Sciences Division
FDA	U.S. Food and Drug Administration
FFA	Federal Facility Agreement
FID	flame ionization detector
FR	<i>Federal Register</i>
FS	Feasibility Study

FSP	field sampling plan
FWS	Fish and Wildlife Service
GWQAR	Groundwater Quality Assessment Report
HAs	Health Advisories
HPD	Health Physics Department
HSWA	Hazardous and Solid Waste Amendments
ICP	inductively coupled plasma
IDW	investigation-derived waste
IP	integration point
IROD	Interim Record of Decision
LCS	Laboratory Control Sample
LLW	low-level waste
LLWDDD	Low-Level Waste Disposal, Development, and Demonstration
MCL	maximum contaminant level
MCLGs	maximum contaminant level goals
MDL	method detection limit
MLE	most likely exposure
MS	matrix spikes
MSD	matrix spike duplicate
MSL	mean sea level
NAs	Natural Areas
NCP	National Contingency Plan
NCR	Nonconformance Report
NEPA	National Environmental Policy Act
NERP	National Environmental Research Park
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NMFS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NPRM	Notice of Proposed Rulemaking
NRC	Nuclear Regulatory Commission
NRDA	Natural Resource Damage Assessment
NSDWS	National Secondary Drinking Water Standards
ODW	Office of Drinking Water
OREIS	Oak Ridge Environmental Information System
ORNL	Oak Ridge National Laboratory
ORP	Oil Retention Pond
ORR	Oak Ridge Reservation
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
OU	operable unit
PA	Preliminary Assessment
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PCE	perchloroethene (or tetrachlorethene)
PGDP	Paducah Gaseous Diffusion Plant
PID	photoionization detector

PPE	Personal Protective Equipment
ppm	parts per million
PSS	Plant Shift Superintendent
QA	quality assurance
QAMS	Quality Assurance Management Staff
QAPP	quality assurance project plan
QAS	quality assurance specialist
QC	quality control
RAs	Reference Areas
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RfC	reference concentration
RfD	reference dose
RFI/RI	RCRA Facility Investigation/Remedial Investigation
RI	Remedial Investigation
RME	reasonable maximum exposure
ROD	Record of Decision
RPD	relative percent difference
RSA	Research Areas
S&A	sampling and analysis
SARA	Superfund Amendments and Reauthorization Act
SD	standard deviation
SDWA	Safe Drinking Water Act
SEG	Scientific Ecology Group
SEN	Secretary of Energy Notice
SHSO	site safety and health officer
SI	Site Investigation
SMCLs	secondary maximum contaminant levels
SNA	State Natural Area
SOW	statement of work
SRA	screening risk assessment
SWMU	solid waste management unit
TBC	to be considered
TC	toxicity characteristic
TCA	trichloroethane
TCA	Tennessee Code Annotated
TCE	trichloroethene
TDEC	Tennessee Department of Environment and Conservation
TDHE	Tennessee Department of Health and Environment
TDS	total dissolved solids
TPH	total petroleum hydrocarbons
TSCA	Toxic Substances Control Act
TSD	treatment, storage, and disposal
TSS	total suspended solids
TVA	Tennessee Valley Authority
TWRA	Tennessee Wildlife Resources Agency
UEFPC	Upper East Fork Poplar Creek

USC
USGS
VOCs
WOM
WQC

United States Code
U.S. Geological Survey
volatile organic compounds
White Oak Mountain
water quality criteria

EXECUTIVE SUMMARY

The enactment of the Resource Conservation and Recovery Act (RCRA) in 1976 and the Hazardous and Solid Waste Amendments to RCRA in 1984 created management requirements for hazardous waste facilities. The facilities within the Oak Ridge Reservation (ORR) were in the process of meeting the RCRA requirements when ORR was placed on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) National Priorities List on November 21, 1989. Under RCRA, the actions typically follow the RCRA Facility Assessment/RCRA Facility Investigation/Corrective Measures Study/Corrective Measures Implementation process. Under CERCLA, the actions follow the Preliminary Assessment/Site Investigation/Remedial Investigation (RI) Feasibility Study (FS)/Remedial Design/Remedial Action process. The development of this document will incorporate requirements under both RCRA and CERCLA into an RI work plan for the first phase of characterization of Bear Creek Valley (BCV) Operable Unit (OU) 4.

To effectively evaluate the cumulative impact of releases from multiple sources of contamination, a structured approach has been adopted for ORR based on studies of the groundwater and surface water separate from studies of the sources. Based on the realization of the complexity of the hydrogeologic regime of the ORR, together with the fact that there are numerous sources contributing to groundwater contamination within a geographical area, it was agreed that more timely investigations, at perhaps less cost, could be achieved by separating the sources of contamination from the groundwater and surface water for investigation and remediation. The result will be more immediate attention [Records of Decision (RODs) for interim measures or removal actions] for the source OUs while longer-term remediation investigations continue for the hydrogeologic regimes, which are labeled as integrator OUs.

OUs designated as both source and groundwater OUs are projected to reach a final ROD. Those identified as source OUs only will be addressed initially in interim action RODs. Upon completion of all proposed source OU interim actions, sufficient monitoring data of the integrator OUs will be available to determine if the interim actions have been effective, and, if not, further remediation would be undertaken in the integrator OU final ROD.

BCV OU 4 is the groundwater/surface water integrator unit in the valley. This work plan represents the first phase of a two-phase investigation of the integrator unit. Phase I addresses the shallow groundwater and surface water component of BCV OU 4. This phase is designed to investigate migration pathways in the active conduit flow in the aquifer in BCV and the connections between groundwater and surface water, which have been identified as the main data gaps in understanding BCV Hydraulic Regime. Phase II will address the intermediate groundwater and the deeper flow system. Data from the investigations on the dense nonaqueous phase liquid plume and the Maynardville Exit Pathway study will be included in Phase II. The scope of this work plan is further limited to addressing the shallow groundwater and surface water in a narrow belt of the Bear Creek watershed underlain by the Nolichucky Shale (which underlies the major sources) and the Maynardville/Knox carbonate aquifer.

Extensive compliance monitoring programs have been conducted in the BCV groundwater, and the results of those analyses have identified major source areas, the horizontal and, to some extent, vertical bounds of a contaminant plume. Analyses of the historical monitoring data have identified contaminants of concern in BCV shallow groundwater [e.g., radiological species (uranium), nitrate, barium, volatile organic compounds (VOCs)].

Subsurface geological, hydrogeological, and surface water data collected in conjunction with compliance monitoring and special studies have identified the Maynardville Limestone as the focus of groundwater flow in the valley. Groundwater flow within the valley and, in particular, within the Maynardville occurs preferentially along bedding and joint planes that have been enlarged by solution. This "conduit" flow system appears to predominate in shallow bedrock, communicate directly with the surface water system via springs and seeps, and become less effective at depths ~200 ft below ground surface.

Extensive studies in the valley have identified major source areas and areas of interaction between the shallow groundwater and the surface water system. Major source areas have undergone some form of remedial action (e.g., removal and capping, capping in place). Recent analyses of historical groundwater and surface water quality data have identified trends of decreasing contaminant concentrations that may reflect the implementation of source control measures.

Application of the observational approach to the development of the RI work plan entailed development of a site conceptual model and development of a list of likely remedial alternatives that includes the following:

1. no action and monitoring of the effects of ongoing source control measures in surface water and groundwater;
2. prevention of Maynardville contamination by instituting appropriate containment controls within the Nolichucky Shale (soil and/or bedrock);
3. surface water interception of contaminants downstream of all sources at springs and/or within Bear Creek and treatment;
4. Maynardville groundwater interception and treatment using the following technologies:
 - interception at wells in the conduit flow system;
 - reaction barrier; and
 - french drain collection and treatment; and
5. in-situ treatment of groundwater in source areas.

The observational approach is intended to focus the design of data collection activities to support the likely alternatives. The FS will assess all likely remedial alternatives (including treatment alternatives) based on the existing data and data collected during the RI. Based on the conceptual model and the preliminary results of historical data analyses, data collection, and analysis activities described in the work plan are designed to support continued

groundwater and surface water monitoring, with additional activities designed to gather data to support alternatives 3 and 4. Therefore, site characterization activities that address the conceptual model for this site focus on

- identifying flow paths within the shallow groundwater of BCV OU 4 between major source areas (in the Nolichucky) and surface water, and
- sampling and analysis of shallow groundwater and surface water within identified flow paths.

This RI work plan contains summaries of geographical, historical, operational, geological, and hydrological information specific to the unit. Taking advantage of the historical data base and ongoing monitoring activities and applying the observational approach to focus data gathering activities will allow the FS to evaluate all probable or likely alternatives.

Data from Phase I of the site characterization activities will be used in conjunction with data from ongoing ORR site-wide BCV monitoring programs (i.e., groundwater, surface water, source OU soil sampling, and biological monitoring) to provide input for integration point assessments, reasonable maximum exposure assessments (RME), and most likely exposure assessments. These risk assessments will address current and future on-source-OU and off-source-OU exposures and will support (1) RODs for interim actions and (2) removal actions. For further remediation in the integrator OU and for final action RODs, data from both Phases I and II will be used to support a baseline risk assessment for each source OU and for the integrator OU (BCV OU 4); these assessments will be combined and evaluated in terms of a BCV site-wide baseline risk assessment/RME risk assessment (future source-OU and integrator-OU RME risk assessments).

1. INTRODUCTION

1.1 REGULATORY INITIATIVE

The Oak Ridge Reservation (ORR) is composed of three major installations: the Oak Ridge National Laboratory (ORNL), the Oak Ridge Y-12 Plant, and the Oak Ridge K-25 Site [formerly referred to as the Oak Ridge Gaseous Diffusion Plant (ORGDP)]. These installations were constructed in the early to mid-1940s by the Atomic Energy Commission [predecessor of the U.S. Department of Energy (DOE)] as research, development, and process facilities in support of the Manhattan Project. These installations, along with the Paducah Gaseous Diffusion Plant (PGDP) in Paducah, Kentucky, and the Portsmouth Gaseous Diffusion Plant (PORTS) in Piketon, Ohio, are currently administered by the DOE Oak Ridge Operations Office (DOE-ORO) in Oak Ridge, Tennessee.

During the construction and operation of these research, development, and process facilities, the associated decontamination, maintenance, and fabrication processes resulted in the generation of various hazardous and radioactive waste by-products. Hazardous waste treatment, storage, and disposal (TSD) facilities were created at each of the DOE-ORO facilities to handle such by-products. Some of these facilities continue to receive hazardous wastes while others have been decommissioned. All DOE-ORO TSD facilities are currently subject to the requirements of several laws:

- **Resource Conservation and Recovery Act (RCRA)**—created in 1976 as a management system for hazardous wastes that mandates permitting currently operating TSD facilities. Under RCRA, these TSD facilities are referred to as solid waste management units (SWMUs). RCRA defines an SWMU as any discernible waste management unit at a RCRA facility from which hazardous waste or hazardous constituents might migrate, irrespective of whether the unit was intended for the management of solid or hazardous waste. Such units include any area at a facility at which hazardous waste or hazardous constituents have been routinely and systematically released.
- **Hazardous and Solid Waste Amendments (HSWA)**—amendments to RCRA (1984) that provide the U.S. Environmental Protection Agency (EPA) with the authority to enforce corrective actions by broadening the scope of the RCRA Corrective Action Program. In addition to evaluating and correcting releases to the uppermost aquifer from regulated RCRA units, HSWA promotes the cleanup of continuing releases to any media resulting from waste management units and practices at RCRA facilities. Among the most significant provisions of the HSWA are the following.
 - **Section 3004(u): Corrective Action for Continuing Releases.** Section 3004(u) states that for permits issued after November 8, 1984, corrective action is required for releases of hazardous waste or constituents from any SWMU at any TSD facility seeking permit for permanent operation, regardless of when waste was placed in the unit. Thus, corrective actions apply to releases presently occurring as well as past releases.

- **Section 3004(v): Corrective Action Beyond the Facility Boundary.** Section 3004(v) authorized EPA to require that corrective action be taken by the facility owner or operator for releases that have migrated beyond the facility boundary (off site). Such action should be taken where necessary to protect human health and the environment unless the owner/operator demonstrates to the satisfaction of the administrator that permission to undertake such action was denied.
- **Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, also referred to as Superfund)**—created in 1980 to establish a program to identify sites [operable units (OUs)] from which environmental releases of hazardous substances might occur or have occurred. At such sites, Superfund promotes the evaluation of damage to natural resources, ensures cleanup by the responsible party or the government, and creates a claims procedure for parties involved in site cleanup and natural resource reclamation. Sites identified by CERCLA are evaluated and then placed on the National Priorities List (NPL), if appropriate. The ORR was listed on the NPL in the December 1989 *Federal Register* (54 FR 48184).
- **Superfund Amendments and Reauthorization Act (SARA)**—created in 1986 as a 5-year extension of the Superfund/CERCLA program to clean up hazardous releases at uncontrolled or abandoned hazardous waste sites.
- **National Environmental Policy Act (NEPA)**—created in 1968, directed federal agencies to consider the impacts of their actions (e.g., construction, remediation) on the environment as a part of all decision-making processes.

In anticipation of the ORR being listed on the NPL, DOE, the Tennessee Department of Environment and Conservation (TDEC), and EPA formulated a Federal Facility Agreement (FFA) for ORR. The FFA was designed to ensure that all necessary steps were undertaken to protect the public health and the environment during the investigation, evaluation, and remediation of all SWMUs/OUs. The FFA also outlines all deliverables, review times, and schedules to ensure that activities are undertaken in a timely manner.

DOE and TDEC have formulated an oversight agreement/agreement-in-principle. As stated in this agreement, TDEC is the lead agency for the state of Tennessee. The purposes of this agreement are to (1) ensure compliance with applicable federal, state, and local environmental laws and (2) assure the citizens of Tennessee that their health, safety, and environment are being protected through a program of independent monitoring and oversight by the state.

Each of these agreements provides a measure of oversight for all environmental restoration at the ORR installations. PGDP and PORTS are not listed on the NPL and as such have no FFA. (They do however have agreements-in-principle with their respective states.)

1.2 DOE-ORO ENVIRONMENTAL RESTORATION (ER) PROGRAM

The mission of the DOE-ORO ER Program is "to eliminate or reduce to prescribed safe levels the risks to the environment or to human health and safety posed by inactive and surplus ORO-managed sites and facilities that have been contaminated by radioactive, hazardous, or mixed wastes" (Energy Systems 1991a). As a result of ORR's placement on the NPL in December 1989, all remedial activities including characterization, alternative selection, and implementation must meet the requirements of RCRA, CERCLA, and NEPA. Therefore, the DOE ER Program decided to address the requirements of all applicable laws in a series of "integrated" documentation for each SWMU.

To facilitate consistency in the preparation of these integrated documents at all DOE-ORO facilities, the managing and operating contractor for DOE-ORO facilities established an ER Division. Along with central staff that serve to oversee the main program areas, ER site program managers were appointed at each of the DOE-ORO facilities. These site program managers oversee the day-to-day operations of the facility-specific programs and interface with the central ER Division staff.

1.3 SITE ER PROGRAM

A major objective of CERCLA investigations is to characterize the nature and extent of contamination at uncontrolled hazardous waste sites. HSWA requires assessments to be conducted at all former and current SWMUs at RCRA-permitted facilities. Descriptions of the individual SWMUs at the Y-12 Plant are provided in a report titled *Solid Waste Management Unit Information for the Y-12 Plant RCRA 3004(u) Facility Assessment* and its supplements (Welch et al. 1987, Welch 1987a, Welch and Poore 1987, Wiggins and Welch 1988, Murphy 1989). For SWMUs that are suspected to be the source of contaminant release to the environment, a RCRA Facility Investigation (RFI) is required to define the nature and extent of the release.

The RCRA Facility Assessment (RFA) that was conducted for the Y-12 Plant (Welch et al. 1987) resulted in the decision to perform RFIs or initiate closures for SWMUs that have received liquid plant discharges and/or solid wastes containing hazardous, or potentially hazardous, constituents (listed in Table 1.1).

Under RCRA, actions typically follow the RFA/RFI/Corrective Measures Study (CMS) implementation process. Under CERCLA, actions typically follow the Preliminary Assessment (PA)/Site Investigation (SI)/Remedial Investigation (RI)/Feasibility Study (FS)/remedial design/remedial action process. The development of this document incorporates the requirements under both RCRA and CERCLA into an RI work plan.

Table 1.1. SWMUs for RFI or closure

SWMU	Unit No.	RFI Plan Schedule
S-3 Ponds	T-004	Closed 1988
Oil Retention Ponds	T-008, T-009	Closed 1989
Oil Landfarm	T-014	Closed 1982
Bear Creek Burial Grounds	D-024	Closure continuing
Sanitary Landfill I	D-101	Closed 1982
Rust Spoil Area	D-106	Interim closure, 1987
Spoil Area I	D-107	Interim closure, 1987
Hazardous Chemical Disposal Area-Burnyard/Boneyard	D-024-HC	Plan issued December 1990

1.4 FACILITY OU STRATEGY

To effectively evaluate the cumulative impact of releases from multiple sources of contamination, a structured approach has been adopted for ORR based on studies of the groundwater and surface water separate from studies of the sources. Based on the realization of the complexity of the hydrogeologic regime of the ORR, together with the fact that there are numerous sources contributing to groundwater contamination within a geographical area, it was agreed that more timely investigations, at perhaps less cost, can be achieved by separating the sources of contamination from the groundwater and surface water for investigation and remediation.

The Y-12 Plant OUs have been grouped not only by their proximity but also by common physical and hydrogeological parameters. Extensive study of groundwater movement and its relation to contaminant transport at the Y-12 Plant indicates that groundwater can be subdivided into two distinct hydrogeological regimes: Upper East Fork Poplar Creek (UEFPC) and Bear Creek. This subdivision is based on topography, surface water drainage, and groundwater flow patterns. It offers the advantages of providing a basis for unifying monitoring efforts at the Y-12 Plant and for tailoring monitoring efforts to the hydrogeologic characterization of each regime. The strategy used to delineate boundaries of each regime is included in *Comprehensive Groundwater Monitoring Plan for the DOE Y-12 Plant, Oak Ridge, Tennessee* (Geraghty and Miller 1990). The Bear Creek Hydrogeologic Regime (BCHR), in general, and specifically the shallow groundwater flow component of Bear Creek Valley (BCV) OU 4 and, in particular flow within the Maynardville, is the focus of this RI work plan (Fig. 1.1).

LEGEND:

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1" = 4000'

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Science Applications
International Corporation

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FIG. 1.1 93044\DWGS\422BC4-2 0
FIGURE # CAD FILE # ROT. ANGLE

Source OUs identified within BCV are listed below:

- BCV OU 1—comprising the major contaminant source areas (e.g., S-3 Ponds, Oil Landfarm, Boneyard/Burnyard, Bear Creek Burial Grounds, and Sanitary Landfill 1).
- BCV OU 2—comprising the Rust Spoil Area, Spoil Area 1, and the SY-200 Yard.

The initial aim of source OU investigations is to develop Records of Decision (RODs) for interim measures that reduce the risk to human health and the environment via direct contact pathways from soil (e.g., inhalation). In addition, interim measures at source OUs are intended to reduce source contaminant contributions to groundwater and surface water and thereby reduce contaminant levels in the media of OU 4 (groundwater, surface water, sediment, and floodplain soils).

For BCV the human health risk assessment approach is divided into two land-use scenarios (current and future) for on-site and off-site exposure assessments. To support RODs for interim actions (risk-based removal actions), the current-land-use scenario will be based on a most likely exposure (MLE) risk assessment, and source OU sites will be prioritized with an integration point (IP) assessment (see Chap. 4). For final action RODs, a future-land-use scenario will be used (this land use will be agreed upon by the regulators) for a baseline risk assessment (BRA) for human health [a reasonable maximum exposure (RME) assessment] for each source OU and the integrator OU.

Ecological risk assessment will follow an approach similar to the human health risk assessment in order to reduce duplication of effort. Ecological MLE assessments will be carried out on an indicator-by-indicator basis for each source site, in conjunction with an IP assessment in the integrator. In addition to the abiotic integration points used in the human health IP assessment, biota integrators will be defined and evaluated. This will support RODs for interim measures at the source OUs. A baseline ecological risk assessment (RME) will be carried out to support the final ROD and will be based on data obtained by the source OU RIs and the integrator OU RI.

The advantage of this approach is that it allows the MLE and the IP assessments to be updated as remedial actions are carried out at source OUs or as additional data are acquired in the BRA process. The IP assessment provides a dynamic approach that will allow the effects of source control actions to be evaluated year by year in the integrator OU. In summary, an IP assessment can be used to establish a reference point (or many reference points) for evaluating risk within the integrator, to identify and prioritize contaminant sources, and to monitor and document the degree of risk reduction achieved by source control actions.

These two approaches (MLE and IP assessments) will provide an understanding of the risk posed to on-site receptors (MLE assessment) and will give an indication of the relative contribution of risk from each source OU to off-site receptors (IP assessment). The result is more immediate attention to source OUs, with continuing investigation for long-term remediation of both source and integrator OUs. Upon completion of all source OU interim actions, continued monitoring data from the integrator OUs will be used to determine if the interim actions have been effective; depending on these monitoring results, further remediation may be necessary in the integrator OU ROD.

Data acquisition for source OUs in BCV will be carried out in three stages that meet the OU strategy for the ORR outlined in Sect. 1.4 (Fig. 1.2). The three stages are as follows.

Stage 1: Assemble sufficient data concerning the source OUs to support decisions such as the need for immediate removal actions, whether to continue with the RI process for source OUs, or whether no further action is required

If the decision is made to continue the RI/FS process, then the following stages apply.

Stage 2: Assemble sufficient data for source OUs to allow for a ROD for interim measures (data for the MLE assessment)

Stage 3: Provide input (e.g., monitoring data) from the source OU that allows a final ROD to be issued for all OUs in the BCV hydrologic regime (RME assessment)

Stage 4: Remove the Y-12 Plant from the NPL

Each stage supports a different level of decision making and thus would require different types and amounts of data. A goal of the source OU RI work plans will be to ensure that sampling operations required for the initial stage are not repeated at later stages. Ideally, the interim measures taken at the end of the second stage will be sufficient for the final ROD; therefore, it is anticipated that the third stage of the process will rely on postremediation performance monitoring data collected at the source.

For the OU 4 integrator unit, data acquisition will be carried out in two phases. Figure 1.2 outlines the relationship between the two-phase approach of the integrator RI and the three-stage approach for the source OU RIs. In Phase 1 sufficient data will be assembled concerning groundwater contamination and pathways in the integrator media to support RODs for interim measures for the source OUs in Bear Creek and to carry out the IP assessment. This phase will address the shallow groundwater (defined as the zone of active conduit flow that is ~200 ft deep) and surface water in BCV and will be carried out concurrently with the first two stages of the source OU RI process (Fig 1.2).

Phase 2 of the integrator OU RI is concurrent with Stage 3 of the source OU RIs and will be carried out after RODs for interim measures have been issued for the source OUs in BCV. In this phase sufficient data will be assembled to allow the BCV human health and ecological BRA (MLE assessment). At this time the complete database for Bear Creek environmental data will be evaluated for data gaps that affect the BRA. The objective of any sampling in Phase 2 will be to complete the database for the purposes of performing the BRA. This phase will address all environmental media (e.g., groundwater, surface water, sediments, and floodplain soils) in BCV. Ideally all data required for the BCV BRA concerning soils at source OUs will be available from the source OU RIs. In addition, data will be available from Phase 1 of the OU 4 RI and other groundwater studies in BCV [i.e., the Maynardville Exit Pathway Program and investigations being carried out on the dense nonaqueous phase liquid (DNAPL) plume].

1.5 INTENT AND SCOPE OF THE RI WORK PLAN

BCV OU 4, the integrator OU for BCV, comprises groundwater, surface water, sediment, and floodplain soils within BCV and is the focus of this work plan. The schedule of RI/FS activities in BCV OU 4 will follow the overall facility OU strategy for the Y-12 Plant outlined

Fig. 1.2. The relationship between the three-stage source OU RI process and the two-phase integrator OU RI process.

in Sect. 1.4. The ultimate goal is to develop a final ROD for all the OUs in BCV. The aim of the OU 4 RI in Phase 1 is to delineate pathways for contaminant migration in the BCHR, to define contaminant fate and transport after contaminants exit from the source OUs, and to carry out an IP risk assessment that can be used to prioritize the cleanup operations at source OUs. The scope of this work plan is further limited to addressing the shallow groundwater and surface water in a narrow belt of the Bear Creek watershed underlain by the Nolichucky Shale (which underlies the major sources) and the Maynardville/Knox carbonate aquifer. The intent of this RI work plan is to:

- summarize the existing data on the extent of contamination in the BCV groundwater system,
- describe the current understanding of the physical flow system, especially the interaction between the groundwater system and the surface water system, and
- describe a combination of historical data analyses and proposed field activities that will result in a definition of the BCV shallow groundwater (based on physical and chemical lines of evidence) that supports a remedial alternative selection.

Extensive studies in the valley have identified major source areas (Table 1.1) and areas of interaction between the shallow groundwater and the surface water system. Major source areas are being closed or have undergone some form of remedial action (e.g., removal and capping, capping in place). Valley-wide groundwater and surface water monitoring programs provide a significant source of data that can now be used to begin assessing the impacts of source control measures on the concentrations of contaminants in the shallow groundwater and Bear Creek surface water. Preliminary results of these analyses suggest that contaminant concentrations in groundwater and surface water near one major source area (S-3 Ponds) are decreasing.

Application of the observational approach to the development of the RI work plan entailed development of a site conceptual model and development of a focused list of likely remedial alternatives that include the following:

1. no action and monitoring of the effects of ongoing source control measures in surface water and groundwater;
2. prevention of Maynardville contamination by instituting appropriate containment controls within the Nolichucky Shale (soil and/or bedrock);
3. surface water interception of contaminants downstream of all sources at springs and/or within Bear Creek and treatment;
4. Maynardville groundwater interception and treatment using the following technologies:
 - interception at wells in the conduit flow system;
 - reaction barrier; and
 - french drain collection and treatment; and
5. in-situ treatment of groundwater in source areas.

The observational approach entails design of data collection activities to support the primary alternative with additional data requirements of the remaining alternatives. Based on the conceptual model and the preliminary results of historical data analyses, data collection and analysis activities described in the work plan are designed to support all likely alternatives.

1.6 SPECIAL PROBLEMS

The following special problems have been defined for BCV OU 4:

- **Karst geology.** The karst geology of aquifers in BCV strongly influences groundwater flow and contaminant migration patterns. An important aspect of Phase 1 of the OU 4 RI will be to define flow paths in the groundwater system.
- **DNAPLs.** The presence of large quantities of DNAPLs in the formations below source sites poses a unique problem to groundwater remediation. DNAPLs are being addressed as part of an ongoing DNAPL study of the Nolichucky Shale.

1.7 OVERALL PROJECT OBJECTIVES

The overall RI/FS goal for BCV OU 4 is to select remediation alternatives at reasonable cost that are protective of human health and the environment, that maintain protection over time, and that minimize the volume of untreated waste. The objective of the RI is to provide sufficient information to assess the risks to human health and the environment and to support the development, evaluation, and selection of appropriate response alternatives. This work plan provides justifiable rationale and guidance for the collection and analysis of the data required to fulfill the objectives of Phase 1 of the RI.

BCV shallow and intermediate groundwaters have been the subject of extensive sampling and special studies that have produced a wide range of historical data types. Ongoing compliance monitoring programs and planned environmental studies are designed to provide data for the immediate needs of monitoring program design. An objective of this work plan is to provide the base of information necessary to evaluate the most probable remedial alternative by making full use of the existing data, the results of ongoing data collection programs. The remaining data gaps will be filled with focused sampling and analysis activities.

1.8 DATA QUALITY OBJECTIVES

1.8.1 State the Problem to be Resolved

Groundwater contamination in BCV groundwater has been recognized, and the major source areas are being remediated. The problem to be solved is to determine the horizontal and vertical extent of contamination using existing data if possible, in order to support a baseline risk assessment and feasibility study, which include cleanup alternatives and an evaluation of attenuation over the next 100 years. Monitoring the effects of source control and closure on the concentrations of groundwater contamination is the focus of Phase 1 of

this investigation. If active remediation of the shallow, actively flowing groundwater in the conduit flow system underlying BCV is required (reflecting a contingency alternative in the observational approach), the dynamics of the flow system must be investigated further. Specifically, the depth of the active flow system and its interactions with Bear Creek and its springs must be resolved.

1.8.2 Identify the Decisions to be Made

The data collected in Phase 1 of the OU 4 RI will serve to support the human health and ecological MLE and IP risk assessments. The results of the risk assessments will be used to prioritize cleanup of source OUs and clarify the necessity for immediate remedial actions on groundwater. If groundwater remedial actions are indicated, the data from this RI will support the selection of the most appropriate alternative.

1.8.3 Identify Inputs to the Decision

The inputs to the decision process include the data, historical and newly collected, described in this work plan. The data will be interpreted to document the effects of source control measures and, as necessary, to define the physical dimensions of the shallow groundwater component of the OU, the physical flow of the shallow groundwater, the interaction of the groundwater and surface water systems, and the flux of contaminants within the system. Subsets of the data (e.g., water quality data, contaminant fluxes at springs) will be used to calculate human health and ecological screening risk assessments and to test the feasibility of the most probable remedial alternative.

The approach taken to provide needed quantitative data on concentration levels is based on collecting and analyzing samples from representative locations. The determination that sample collection locations are representative was made by assimilating information from relevant disciplines. Those disciplines included site history, geology, hydrogeology, statistics, and analytical chemistry. To provide defensible laboratory analyses upon which to base statistical analysis and the resulting conclusions, the RI team determined that EPA Level III quality control (QC) and documentation would be required. The role of BCV OU 4 as an integrator unit, and thereby the focus of a BRA, further indicates that Level III data are preferred.

1.8.4 Narrow the Boundaries of the Study

The physical boundaries of this study were narrowed in scoping meetings held with DOE and EPA. After defining the problem to be resolved and the decisions to be made from project data, the boundaries of the study were narrowed in three ways: (1) appropriate locations for sample collection were determined, (2) analytical parameters were agreed upon, and (3) statistical analytical procedures designed. From these decisions, the appropriate levels of quality assurance (QA) documentation required from field sampling and laboratory activities were established. The process for selecting sample collection sites is discussed in detail in Chap. 6 of this plan, as are the analytical parameters of interest, for both the field and laboratory activities. The associated QA documentation requirements for each are discussed in Chaps. 8 and 9.

In accordance with the observational approach, the focus of RI activities will be to evaluate data that test the hypothesis that source control measures are reducing contaminant concentrations. A contingent objective of the RI is to define the boundaries of the BCV shallow groundwater OU and its interactions with the surface water system. The site conceptual model is presented in Sect. 3.8 and is based on the results of extensive studies of the groundwater/surface water system in BCV. Despite extensive studies in the valley, there are insufficient details on the functioning of the conduit flow system to support selection of a contingency remedial alternative. Better definition of the boundaries of the active flow system and the interactions of the active flow system with the surface water/springs will aid contingency alternative selection.

1.8.5 Develop a Decision Rule

The shallow groundwater is a subdivision of OU 4, the BCV groundwater integrator unit and, as such, the results of the RI will include an RI report, an MLE and IP risk assessment, and a ROD for interim measures. Remedial actions may be implemented for BCV shallow groundwater OU while RIs are conducted on the deeper groundwater components of the groundwater integrator unit.

The effectiveness of any remedial action will depend on the level of system understanding derived from this RI. Several possible decision rules can be developed by considering the range of likely remedial actions, such as the following.

- If temporal contaminant concentration trends show systematic decline and concentrations of contaminants reaching the Maynardville do not pose health threats, then no remedial action will be taken at this time. Groundwater remediation will only be addressed after RODs for interim measures have been accomplished for the source OUs.
- If the concentration of contaminants in the Maynardville does not show a decreasing trend and pose a threat to human health and the environment, then shallow groundwater may be captured near source areas.
- If contaminant migration to the Maynardville cannot be reduced by applying likely alternatives near source areas, then contaminant capture in Bear Creek and/or at springs in the Maynardville may be effective.
- If springs are ineffective in capturing the contaminant plume and if source control is preferable, then data gathered in this RI will aid in the design of a hydraulic capture alternative.

1.8.6 Develop Uncertainty Constraints

All data collected for this RI and for use in the decision-making process will be of defensible quality to minimize uncertainty. To achieve the lowest uncertainty in the statistical analysis conducted as a part of this project, high quality data are required. The project team decided that analytical data used in this phase of the OU investigation should require EPA Level III QC documentation to ensure high quality data and to support the BRA for the integrator OU. Field screening analyses were assigned EPA Level II QC documentation. To ensure that sample collection and field observations were done in such a way as to ensure technically accurate and legally defensible information, these activities will be conducted

according to procedures that have been reviewed and approved and are subject to appropriate QA oversight (Chap. 8). The details of the laboratory QA requirements are described in Chap. 9. Data other than laboratory analyses will be collected in such a way as to be fully documented (i.e., by field notes, field forms, surveyed locations) and defensible.

1.8.7 Optimize Design for Obtaining Data

The data collection design for this project is described in Chap. 6. The design optimizes the use of historical data analysis and ongoing monitoring programs. Analysis of historical data from BCV shallow groundwater will identify any temporal trends in water quality or physical characteristics (e.g., seasonal water levels). The results of these analyses will be used to determine whether representative samples have been and are being obtained from BCV OU 4. The design of any modifications to ongoing or planned sampling will derive from these analyses.

1.9 SCHEDULE

The schedule of the BCV OU 4 RI sampling and analysis activities is provided in Fig. 1.3.

1.10 QA

1.10.1 Program Planning and Implementation

The overall planning and implementation of QA and QC activities for the OU 4 RI are described in Chaps. 7 and 8 and are governed by the *Environmental Restoration Quality Program Plan*, ES/ER/TM-4/R2 (Energy Systems 1992a), which incorporates the guidance in *Interim Guidelines and Specification for Preparing Quality Assurance Project Plans—QAMS-005/80* (EPA 1980) and the specification of the Energy Systems Quality Procedures Manual, the American Society of Mechanical Engineers document *Quality Assurance Program Requirements for Nuclear Facilities, NQA-1* (ANSI/ASME 1986) and applicable DOE orders.

1.10.2 Project-Specific Planning

Project-specific QA planning is described in detail in Chaps. 7 and 8. All QAMS-005/80 QA/QC and ER Division QA Program Plan requirements are addressed in this work plan, either in Chaps. 7 and 8 or within other sections of the work plan. A project-specific locator page is included at the beginning of Chaps. 7 and 8.

2. HISTORY AND CURRENT CONDITIONS

As part of the groundwater integrator unit, contaminants within BCV OU 4 reflect the contributions from source areas, throughout BCV, to surface water, soil/sediment, and groundwater. This chapter will summarize the available information on the nature, quantity, and concentration of contaminants in each of the source areas (formerly identified as SWMUs) located in Bear Creek watershed. In the absence of direct evidence (measurements) of the contents of each source area, the nature and concentration of contaminants in receiving media (surface water, soil/sediment, groundwater) immediately adjacent to each source area will be summarized. The purpose is to identify those contaminants that have, or may have, been released from each source area.

2.1 GEOGRAPHIC INFORMATION

The DOE ORR is located within the corporate limits of the city of Oak Ridge in eastern Tennessee, ~16 km (10 miles) southeast of the Cumberland Mountains and 113 km (70 miles) northwest of the Great Smoky Mountains. Figure 2.1 shows the city's location approximately midway between Nashville, Tennessee and Asheville, North Carolina on an east-west line and between Lexington, Kentucky and Atlanta, Georgia on a north-south line. The area is serviced by Interstates 40 and 75, which intersect in nearby Knoxville, Tennessee, east of Oak Ridge. The reservation, 14,300 ha (35,300 acres) of federally owned land, houses three facilities (the K-25 Site, ORNL, and the Y-12 Plant) which are managed by Martin Marietta Energy Systems, Inc. (Energy Systems).

The Y-12 Plant contains ~800 acres and is located adjacent to the corporate center of the city of Oak Ridge between Chestnut Ridge, located to the south, and Pine Ridge, located north of the plant. The plant complex, built predominantly in the mid-1940s, is roughly divided into two portions; the western portion was previously devoted to DOE weapons-manufacturing activities, and the eastern portion is devoted to ORNL research programs, general plant operations, and maintenance activities.

Extensive geographical information concerning the Y-12 Plant, its facilities within Bear Creek watershed, and the surrounding area is given in Welch (1989). The Bear Creek watershed is located entirely within the boundaries of the DOE ORR (Fig. 2.2) and contains no privately owned lands. The watershed occupies portions of both Roane County and Anderson County. The creek originates at the western margin of the Y-12 Plant. The hydrologic divide between Bear Creek and UEFPC is just east of the S-3 Ponds.

The Bear Creek watershed has a drainage area of 18.3 km² (7.4 miles²). The stream channel is characterized by steep banks, and cuts up to 5 ft into the unconsolidated clays and silty soils of the floodplain. Underlying shale and limestone beds are visible as outcrops along the mainstream of Bear Creek and its tributaries. The average gradient of the creek from the headwaters at mile 8.0 to the confluence with East Fork Poplar Creek (EFPC) is 30 ft/mile (5.7 m/km). Most of the drainage area is bounded by Pine Ridge on the northwest and Chestnut Ridge on the southeast.

Fig. 2.2. General location of Bear Creek watershed within the ORR.

Table 2.1 provides a listing of creek landmarks referenced to kilometers or miles above the confluence of Bear Creek with EFPC. The use of creek kilometers to describe monitoring and sampling sites along the creek and its tributaries is applied throughout this document. Tennessee Valley Authority (TVA) maps showing mile markings were used originally to establish the kilometer locations. Sites are designated as "BCK," for "Bear Creek kilometer," plus the kilometer value, e.g., BCK-4.55. As indicated in the footnote to Table 2.1, tributaries are designated as NT, ST, WT or ET plus a value representing the tributary number counting from the headwaters. Thus, NT-14 is the 14th tributary originating on the north side of Bear Creek. Tributaries can also have a second identifier that shows the direction off the main tributary and the distance from the confluence with Bear Creek. For example, BCK-6.23 NO.32 refers to a point that is 0.32 km up a tributary that enters Bear Creek at kilometer 6.23 from the north. This site also has the common name NT-14. Springs follow an identical naming convention. Figures 2.3 and 2.4 show some important localities using this site naming system.

2.2 BACKGROUND INFORMATION

2.2.1 Engineered Modifications

Engineered modifications of Bear Creek have included road crossings, channel relocations, and small impoundments. A comparison of modern photographs with the trace of Bear Creek on 1939 aerial photographs revealed at least three sections of the creek channel that were relocated since 1939. Construction of a sanitary landfill adjacent to the reach between BCK-11.15 and BCK-11.83 resulted in relocation of the creek channel to the south of its original location. Improvements to Bear Creek Road and construction of a utility corridor adjacent to Bear Creek Road resulted in relocation of the reach of Bear Creek between BCK-10.14 and BCK-10.36 to the north of its original location.

In 1970 a concrete and steel weir was constructed at BCK-4.55 to serve as a discharge monitoring station for Bear Creek. This structure permanently flooded a small upstream area.

In 1972 two lagoons were dug in the channel of Bear Creek near BCK-12.46 to collect sufficient water contaminated with nitrate for an experimental forest fertilization project. In 1988 these lagoons were again excavated to remove contaminated sediments that had accumulated since their construction. The lagoons were then stabilized with stone riprap (Y-12 HSEAD 1988).

In 1978 the intersection of State Routes 58 and 95 was improved by construction of an overpass and ramps. This activity necessitated some disturbance and minor relocation of the channel of Bear Creek in this area (near BCK-2.01).

In 1986 the Bear Creek Road crossing at BCK-9.42 was improved by installing new steel culverts in the existing wood-roofed concrete culvert and grouting. This operation resulted in the removal of sediment in the original culverts and minor disturbance of the adjacent floodplain.

Table 2.1. Bear Creek kilometer (mile) locations

Kilometer	Mile	Landmark ^a
12.87	8.00	Headwaters near S-3 Ponds
12.46	7.74	Road (gravel) crossing between "lagoons"
12.39	7.70	Confluence with tributary NT-1
12.38	7.69	Confluence with spring SS-1
11.97	7.44	Bear Creek Road crossing
11.96	7.43	Confluence with tributary NT-2
11.84	7.36	Road (gravel) crossing at east end of Oil Landfarm
11.68	7.26	Confluence with spring SS-2
11.67	7.25	Confluence with spring SS-3
11.59	7.20	Confluence with tributary NT-3
11.28	7.01	Road (gravel) crossing at west end of Oil Landfarm
11.15	6.93	Confluence with tributary NT-4
10.94	6.80	Confluence with tributary ST-1
10.78	6.70	Confluence with tributary NT-5
10.40	6.46	Confluence with tributary NT-6
10.27	6.38	Road (gravel) crossing at entrance to Burial Grounds
10.14	6.30	Confluence with spring SS-4
9.99	6.21	Confluence with tributary NT-7
9.98	6.20	Road (gravel) crossing at west end of Burial Grounds
9.45	5.87	Confluence with tributary NT-8
9.42	5.86	Road (asphalt) crossing (Bear Creek Rd)
9.41	5.85	Confluence with spring SS-5
9.06	5.63	Confluence with tributary NT-9
8.67	5.39	Confluence with tributary NT-10
7.92	4.92	Confluence with tributary ST-2
7.89	4.90	Road (asphalt) crossing (Bear Creek Rd)
7.77	4.83	Confluence with tributary NT-11
7.44	4.62	Confluence with tributary NT-12
7.11	4.42	Confluence with spring SS-6
6.89	4.28	Road (gravel crossing)
6.76	4.20	Confluence with tributary NT-13

Table 2.1 (continued)

Kilometer	Mile	Landmark ^a
6.66	4.14	Confluence with tributary ST-3
6.23	3.87	Confluence with tributary NT-14 (Gum Hollow Branch)
6.21	3.86	Road (gravel) crossing
5.54	3.44	Confluence with tributary ST-4
5.33	3.31	Confluence with tributary NT-15
4.68	2.91	Road (asphalt) crossing east of S.R. 95 (White Wing Rd)
4.65	2.89	Confluence with spring SS-7
4.56	2.84	Confluence with spring SS-8
4.55	2.83	Cipolletti weir (NPDES ^b monitoring site)
4.47	2.78	Road (asphalt) crossing at S.R. 95
4.44	2.76	Confluence with tributary ST-5
4.38	2.72	Confluence with tributary WT-1
4.09	2.54	Confluence with tributary ET-1
4.06	2.52	Confluence with tributary WT-2
3.60	2.24	Confluence with tributary ET-2 (McNew Hollow)
3.30	2.05	Confluence with tributary ET-3
2.41	1.50	Road (asphalt) crossing east of junction S.R. 95 and S.R. 58
2.27	1.41	Confluence with tributary WT-3 and ET-4
2.01	1.25	Road (asphalt) crossing at junction of S.R. 95 and S.R. 58
1.82	1.13	Confluence with tributary WT-4
1.74	1.08	Road (gravel) crossing
1.48	0.92	Road (gravel) crossing
0.88	0.55	Road (gravel) crossing
0.63	0.39	Road (gravel) crossing
0.0	0.0	Confluence with EFPC

^aNaming convention: ET = eastern tributary, WT = western tributary, NT = northern tributary, ST = southern tributary, SS = south side spring, NS = north side spring.

^bNational Pollutant Discharge Elimination System.

Fig. 2.3. Upper Bear Creek hydrologic system.

Fig. 2.4. Lower Bear Creek hydrologic system.

In 1988 a 100-m reach of Bear Creek at BCK-6.89 was temporarily relocated to allow construction of an improved road crossing for a haul road associated with closure of the waste disposal areas. Although Bear Creek was returned to its original channel, the channel was widened and stabilized with stone riprap.

2.2.2 Sources of Contamination

For the purpose of this RI Plan, the Y-12 Plant waste disposal facilities located in the Bear Creek watershed are considered to be the primary contaminant sources. The Y-12 RFA listed nine source areas within defined OUs associated with the Y-12 Plant located in BCV, including two construction spoil areas, liquid-waste percolation ponds, a sanitary landfill, an oil landfarm, a hazardous-chemical disposal/storage area, a solid-waste burial area, and two ponds used to capture any oil that might seep from the burial grounds (Fig. 2.5).

The source areas and the possible contaminant types associated with each are summarized in Table 2.2. The general contaminant types are based on a combination of disposal records, knowledge of administrative disposal practices, and site-specific sampling. Where data collected as part of this RI or another RI in BCV (OU 1 or OU 2) indicate sources of contamination in groundwater other than those listed in Table 2.2, groundwater at these sites will be included in this RI.

While the facilities are, or were, the original sources of contamination, secondary sources now exist in the soils and regolith and in the sediments and floodplain deposits of Bear Creek. These secondary sources may continue to release contaminants into Bear Creek surface water and groundwater even after upstream releases from the source areas are eliminated.

2.3 OPERATIONAL INFORMATION

The following sections contain descriptions of the wastes managed in each source area as well as information about their generation, disposal methods, and any subsequent treatment or cleanup activities at the source area. Where monitoring data have been obtained that are site-specific to a source area, those results are also included.

2.3.1 S-3 Ponds

The S-3 Ponds were located adjacent to the west end of the Y-12 Plant (Fig. 2.5). Constructed in 1951, these were four unlined impoundments covering an area of roughly 400 by 400 ft. The original pond excavations penetrated residual soil and fill materials but did not extend down to bedrock. Before closure in 1988, the ponds were approximately 17-ft deep and contained variable amounts of sludge ranging from 2-ft to 5-ft thick. The sludges were produced by the neutralization and in situ denitrification of wastewater in the ponds. While in operation, each pond had a storage capacity of 2.5 million gal.

Accurate records of the types and amounts of waste disposed of in the S-3 Ponds are not available. However, three different sources of waste, generally classified as toxic, corrosive, and radioactive, are known to have been disposed of in the S-3 Ponds. The three sources are (1) liquid wastes generated from Y-12 Plant operations and other facilities, (2) sludges generated from the in situ neutralization and bionitrification of the pond waters and sludges generated from the treatment of acid raffinate, and (3) contaminated sediments from upper

T-004
 T-008
 T-009
 T-014
 D-101
 D-106
 D-107
 D-024
 D-024-HC
 S-3 Ponds
 Oil Retention Pond #1
 Oil Retention Pond #2
 Oil Land Farm
 Sanitary Landfill 1
 Rust Spoil Area
 Spoil Area 1
 Burial Grounds
 Hazardous Chemical Disposal
 Area - Boneyard/Burnyard

Fig. 2.5. Location of source areas in Bear Creek watershed.

Table 2.2. Summary of possible contaminant types from BCV source areas

Source Areas	Possible Contaminants
S-3	Metals—Ba, Pb, Cr
	Radionuclides—U, Pu, Tc
	Nitrate
	Volatile organic compounds (VOCs)
Rust Spoil Area	Metals—Hg
	Radionuclides—U
	VOCs
Spoil Area 1	Metals—Be, Hg
	Radionuclides—U, Th
	VOCs
Hazardous Chemical	Metals—Be, Hg
Disposal Area - Bone/Burnyard	Radionuclides—U
	VOCs
	Pesticides/polychlorinated biphenyls (PCBs)
Oil Landfarm	Metals—Be, Cr, As, Pb, Hg
	Radionuclides—U
	VOCs
	PCBs
Sanitary Landfill I	Unknown
Oil Retention Ponds 1 and 2	Metals—As, Cr, Pb
	Radionuclides—U
	VOCs
	PCBs
Burial Grounds	Metals—Be
	Radionuclides—U, Th
	VOCs
	PCBs

Bear Creek. Table 2.3 is a generic summary of the waste materials known to have been disposed of in the S-3 Ponds, not all of which are hazardous.

Table 2.3. Waste disposed of in the S-3 Ponds^{a,b}

Substance	Classification
Liquid waste:	
Nitrate wastes	Corrosive
Machine coolants	Toxic
Caustic solutions	Corrosive
Pickling wastes	Toxic
Plating wastes	Toxic
Mop water	Toxic
Nitric acid	Corrosive
Miscellaneous dilute acids	Corrosive
Miscellaneous acids (pH<2)	Corrosive
Depleted uranium (in nitrate solutions)	Radioactive
Plutonium (in uranyl nitrate solutions)	Radioactive
Technetium (in raffinate and condensate)	Radioactive
Biodenitrification sludges	Toxic
Contaminated Bear Creek sediments	Toxic

^aAnnual volume of waste was 2.7 million gallons in 1983. This volume is reduced from pre-1976 quantities.

^bPonds operated from 1951 to 1984.

Waste products were discharged into the ponds from tank trucks, small containers, and an underground pipeline, which was abandoned and plugged in 1983. The wastes consisted primarily of nitric acid, nitrate waste, pickling and plating wastes, and miscellaneous liquid wastes associated with routine cleanup operations (e.g., mop water). Other wastes included dilute acid, machine coolants, caustic solutions, biodenitrification sludges, and acids with a pH of less than 2.0. During the mid-1950s, uranyl nitrate solutions containing small amounts of plutonium were discharged into the ponds. Depleted uranium in nitric acid solution and technetium contained in raffinate and condensate also may have been placed in the ponds while they remained in operation. All waste discharges into the ponds terminated in March 1983.

Water and sludges in the S-3 Ponds have been extensively characterized on several occasions (Jeter 1983; Kimbrough and Turner 1987). Although the pond water chemistry varied from pond to pond and from year to year, in general, pond water chemistry remained highly acidic, dominated by nitrate anion, with extremely high concentrations of the major cationic constituents (Ca, Mg, K, Mg, Al) and moderately high concentrations of trace metals. The few organics analyses available for the pond waters indicate that concentrations of organics could have been highly variable over the period of operation. Sludges in the ponds were characterized both before and following neutralization/biodenitrification (Jeter 1983; Kimbrough and Turner 1987). Appendix B in Turner et al. (1991) gives selected results of investigations of the composition of water and sludges in the S-3 Ponds.

Influent discharge rates varied throughout the period of operation, but the amount of waste was significantly reduced when a nitric-acid recovery system became operational in 1976. In 1983, the annual quantity of liquid waste entering the ponds was reported to be about 2.7 million gal. The annual loss from the ponds caused by evaporation was estimated to be one-half to two-thirds the annual input from direct rainfall, or about 3 million gal (Y-12 HSEAD 1987).

In situ treatment of wastewater in the S-3 Ponds began in 1983 and continued until September 1984. Between May and November 1983, liquids in all four of the ponds were neutralized. Biodenitrification of the liquids occurred from May 1983 to September 1984, causing nitrate levels in the pond water to decrease to ~100 parts per million (ppm). Nutrients continued to be added to the ponds to maintain the bioreaction and aerators agitated the sludge to denitrify the residuals. Subsequently, nitrate levels were maintained below 50 ppm in the pond water.

After denitrification, the contents of the ponds were allowed to settle and the supernatant was pumped to the S-3 Ponds Treatment Facility for removal of trace metals and organics. A flexible hose attached to the suction side of the pump allowed decanting of remaining small pockets of liquid on the surface of the sludge. The treatment steps for the supernatant included pH adjustment, precipitation, coagulation, flocculation, carbon adsorption, filtration, and chlorination. Treated effluent was discharged to EFPC in accordance with an National Pollutant Discharge Elimination System (NPDES) permit. The supernatant treatment began in 1985 and was completed by the spring of 1986.

Immediately before structural stabilization and filling for closure of the S-3 Ponds in 1988 (Y-12 HSEAD 1988), sediment that had accumulated in two "lagoons" in upper Bear Creek adjacent to the S-3 Ponds was placed in the southwest cell of the S-3 Ponds. Turner and Kamp (1984) characterized this material in place and each truckload of sediment placed in the ponds was also characterized by sampling and laboratory analyses. The data from the 1988 sampling and characterization have been tabulated by McMahon (1988).

2.3.2 Rust Spoil Area

Rust Engineering, a former DOE prime contractor, conducted various renovation, maintenance, and construction operations at the Y-12 Plant. Solid waste (spoil material) generated during these operations was disposed of in an area on the ORR known as the Rust

Spoil Area (Fig. 2.5). The Rust Spoil Area was operated from 1975 to 1983. The 5.4-acre site measures approximately 300 by 900 ft in area and 10 ft in depth (Welch 1987b).

The Rust Spoil Area was operated as a dump with periodic grading (typically once per month) to promote positive drainage. Dumping progressed northward from Old Bear Creek Road. As dumping occurred, the natural topography was elevated and a portion of the Bear Creek Channel was filled. Eventually, the stream channel course was relocated to the north to compensate for the outslope progression. Based on a review of maps depicting the topography before and after the disposal operations, it is estimated that less than 100,000 yd³ of construction debris and spoil were disposed of at the site. The spoil material apparently was not covered with soil. Because routine compaction of the soil was not intended but occurred only as grading took place, it is likely that the compaction operations at the site were somewhat deficient.

The RFI Plan for this source area (Welch 1987b) indicates that no formal design plans were developed for the disposal area, and that no detailed disposal records are available for the wastes disposed of there. The bulk of the waste is reported to consist of demolition debris, including soil, masonry materials and metal (steel rebar in concrete). The RFI Plan also indicated the possibility that minor amounts of solvent-contaminated material, and material containing asbestos, mercury, and uranium, may have been disposed of in this area.

Site closure activities began in the fall of 1983 with the preparation of the site's closure plan. The plan called for grading and shaping the existing fill, capping the entire fill area with a minimum of 2 ft of soil, and establishing vegetative growth over all the disturbed areas. The specifications of the capping plan called for a minimum of 1.5 ft of compacted clay and 0.5 ft of topsoil to be placed over the site. The clay layer would be compacted in maximum 8-in. lifts. Closure began in late 1983 and was completed in mid-1984 (Welch 1987b).

The RFI Plan for the Rust Spoil Area includes soil core sampling and chemical analysis to characterize material in the fill. The results of a Phase I RI are summarized in Table 2.4 and in the RI work plan for Bear Creek Valley OU 2 (Rust Spoil Area, SY-200 Yard, Spoil Area 1) (DOE 1992). In general elevated concentrations of metals (e.g., barium, beryllium, cadmium, lead) were observed.

2.3.3 Spoil Area 1

Spoil Area 1 is located west of the Y-12 Plant on Old Bear Creek Road near the junction with West Patrol Road (Fig. 2.5). Various renovation, maintenance, and construction operations at the Y-12 Plant produced construction debris that includes concrete, asphalt, brick, brush, rock, and tile. Solid waste (spoil material) generated during these operations has been disposed of in Spoil Area 1 since about 1980, but the RFI Plan for this SWMU (Welch 1987c) indicates that no detailed disposal records are available. The site is approximately 5 acres. Since 1985, Spoil Area 1 has had a permit from the TDEC as a landfill for rubble and noncombustible, nonputrescible solid waste. It is estimated that roughly 100,000 yd³ of nonuranium-contaminated construction debris have been disposed of at the site (Welch 1987c). The waste was determined to be nonradioactively contaminated according to health physics requirements established for the Y-12 Plant, although construction material disposed of in this area may have contained minor amounts of asbestos, mercury, beryllium, uranium,

Table 2.4. Summary of soil chemical data, Rust Spoil Area soil borings

Chemical/element	Number of detects/analyses	Detected minimum ^a (mg/kg)	Detected maximum ^a (mg/kg)	BCV soil background levels (ppm) ^b
<i>Volatile organic compounds</i>				
Acetone	9/24	0.16	0.49	
Tetrachloroethene (PCE)	1/24		0.072	
<i>Metals</i>				
Arsenic	24/24	2.8	26	5.145
Barium	24/24	24	820	94.861
Beryllium	23/24	0.67	2.1	1.006
Cadmium	23/24	2.4	7.3	0.2453 ^c
Chromium	23/24	17	41	20.812
Cobalt	23/24	9.4	66	34.81 ^c
Copper	24/24	14	740	21.22 ^c
Lead	24/24	13	150	42.28 ^c
Mercury	5/24	1.1	7.5	0.2003
Nickel	23/24	15	55	20.61
Uranium	24/24	2	14.5	2.30 ^c
Vanadium	23/24	20	70	34.962
Zinc	24/24	44	230	43.487
<i>Radiological</i>				
Gross alpha, pCi/g	24/24	1.45	4.37	<i>d</i>
Gross beta, pCi/g	24/24	1.87	5.07	<i>d</i>
Uranium-235, wt %	3/3	0.04	1.18	0.0855

^aConcentration units are mg/kg unless otherwise indicated.

^bUpper 95% confidence bound on the median concentration from Phase I of the ORR Background Soil Characterization Project (Energy Systems 1993).

^cFrom Turner et al. 1991.

^dNo background levels available. Phase I of the ORR Background Soil Characterization Project (Energy Systems 1991) contains background values for individual radionuclides.

thorium, and other contaminants, according to the RFI Plan. This area ceased receiving waste in 1987 and underwent an interim closure (clay cover) in 1988.

Soil borings were completed in September 1990 at various locations within Spoil Area 1. Subsurface soil samples were collected and analyzed for metals, organics, and selected radiologicals. The results of these investigations are summarized in Table 2.5 and in the BCV OU 2 RI work plan (DOE 1992).

2.3.4 Hazardous Chemical Disposal Area—Bone/Burnyard

The Hazardous Chemical Disposal Area is directly southwest of the Boneyard and is on top of the Burnyard (Fig. 2.5). The site received solid, liquid, and gaseous waste materials from 1975 to 1981. It is estimated that during this period less than 5 tons of waste per year were deposited. The material was broadly characterized as ignitable, reactive, corrosive, toxic, highly flammable, or, in some instances, inert (Y-12 HSEAD 1987b).

Generally, the Hazardous Chemical Disposal Area received wastes that posed safety hazards within the Y-12 Plant. The material came from two sources: gas cylinders with leaking or damaged valves, and lab chemicals considered to be reactive or explosive. Gas cylinders containing noncorrosive gases were allowed to leak into the atmosphere or were bled off to expedite the process. Those containing corrosive gases were bled through neutralizing slurries. Empty gas cylinders then were either destroyed or transported to another location for repair. The lab chemicals included acids, bases, organics, water-reactive compounds, and explosive compounds such as picric acid, benzoyl peroxide, and ether. Bottles of chemicals were broken under water spray in a concrete vessel open to the atmosphere. After the explosion or chemical reaction had taken place, the effluent was discharged into a small unlined surface impoundment and allowed to percolate through the soil. The chemical residue remaining in the concrete vessel was removed periodically and transported to the Bear Creek Burial Grounds (Y-12 HSEAD 1987b).

The Boneyard is located east of the Oil Landfarm (Fig. 2.5). This area was an active waste-disposal site from 1943 to 1970. The wastes have been characterized as ranging from ignitable and possibly radioactive to inert. They are known to have included organics, metals, debris, acids, and beryllium; the total quantity of material is unknown.

Magnesium chips were disposed of in the southwest corner of the Boneyard, south of the gravel road. The metal chips were placed in burn pans in unlined earthen trenches. Ignitable solvents were used to initiate the burn. The residue remaining in the trench was covered with soil and compacted until the trench was filled. The trench then was covered with topsoil and seeded with grass. The remaining land in the Boneyard was used to dispose of construction spoil material such as concrete and rebar. Neither a leachate-collection system nor a treatment system (other than the burning described above) was installed at the site (Y-12 HSEAD 1987b).

Data from an investigation carried out by Bechtel National Inc. for several grab samples of sediment collected downstream of the Boneyard area show elevated levels of mercury (6.7 to 140 $\mu\text{g/g}$), uranium (18 to 200 pCi/g), several polynuclear aromatic hydrocarbons, and phthalates. Analytical results for groundwater downgradient of the area have also indicated

Table 2.5. Chemical summary, Spoil Area-1 soil borings

Chemical/element	Number of detects/analyses	Detected minimum ^a (mg/kg)	Detected maximum ^a (mg/kg)
<i>Semivolatile organic compounds</i>			
Acenaphthene	4/53	0.079	0.41
Acenaphthylene	1/53	0.11	0.11
Anthracene	7/53	0.14	0.85
Benzo(a)anthracene	12/53	0.14	1.7
Benzo(a)pyrene	11/53	0.12	1.3
Benzo(a)fluoranthene	10/53	0.11	1.4
Benzo(ghi)perylene	9/53	0.085	0.8
Benzo(k)fluoranthene	11/53	0.15	1.4
Chrysene	12/53	0.16	1.7
Dibenzofuran	3/53	0.17	0.25
Fluoranthene	13/53	0.07	4.1
Fluorene	6/53	0.18	0.45
Indeno(1,2,3-cd)pyrene	8/53	0.099	0.77
Naphthalene	3/53	0.12	0.21
Phenanthrene	13/53	0.059	3.6
Pyrene	13/53	0.055	3.1
<i>Metals</i>			
Arsenic	44/51	1.9	45.7
Barium	51/51	15.3	385
Beryllium	50/51	0.27	11
Cadmium	50/51	1.1	10.9
Chromium	50/51	6.4	54.2
Cobalt	50/51	1.7	110
Copper	50/51	13.3	109
Lead	51/51	6.5	670
Mercury	38/51	0.05	31.5
Nickel	51/51	4.7	173
Uranium	51/51	2	80
Vanadium	50/51	6.8	128
Zinc	51/51	26.4	591
<i>Radiological</i>			
Gross alpha, pCi/g	50/51	0.03	12
Gross beta, pCi/g	48/51	1.56	37.4
Total radium, pCi/g	51/51	0.973	7.568
Uranium-235, wt%	21/57	0.29	1

^aConcentration units are milligrams per kilogram unless otherwise noted.

the possibility of migration of a number of contaminants from the Hazardous Chemical Disposal Area—Bone/Burnyard, including organic compounds and uranium (Turner et al. 1991).

The Burnyard consists of two trenches approximately 300 ft long and 40 ft wide. The site is no longer visible because the Chemical Storage Area was built on top of it (Fig. 2.5). The Burnyard functioned as an active waste site from 1943 to 1968. It is estimated that the site received approximately 350 tons per month (4000 tons per year) of sanitary refuse from plant operations, including solids, liquids, and sludges. The waste materials may have contained empty pesticide containers, metal shavings, solvents, oils, and lab chemicals. The wastes were placed in unlined earthen trenches and burned. Oils and other flammable liquids, possibly transformer oils containing PCBs, were used to start and sustain combustion. Therefore dioxin/furan contamination is a possibility because they are produced when PCBs are burned at relatively low temperatures. When filled, the trenches were covered with soil. No collection or treatment systems other than burning have been used on this site (Y-12 HSEAD 1987b).

2.3.5 Oil Landfarm

The Oil Landfarm is located north of the Sanitary Landfill as shown on Fig. 2.5. Disposal activity ended in 1982 after 9 years of operation during which approximately 1 million gal of liquid wastes were disposed (Turner et al. 1991). The facility was used for the biological degradation of waste oil and machine coolants via landfarming, a process involving the application of waste oils and coolants to nutrient-adjusted soil during the dry months of the year (April to October). After application, the plots were cultivated frequently to maintain aerobic conditions to enhance biodegradation of the wastes. Waste was not applied immediately before or after periods of precipitation.

2.3.5.1 Disposal of contaminants

Wastes placed in the Oil Landfarm included the following:

- waste oils,
- beryllium-contaminated oils,
- coolants,
- mop waters,
- tanker oils from the K-25 Site,
- wastes from cooling towers and the Burial Grounds, and
- unidentified miscellaneous liquid wastes.

Because operating instructions called for different types of oils to be applied to different plots, both the composition and volume of liquid waste applied varied from plot to plot. Thus, over 50% of the total amount of beryllium-contaminated oil disposed of over the lifetime of the Oil Landfarm was administered to Plot 1/2, with most of the remainder being divided nearly equally between Plots 7/8 and 9/10. Tanker oils were applied most heavily to Plots 3/4 and 5/6; coolants were applied most heavily to Plots 3/4, 5/6, 11/12, 13/14, and 15/16 (Bechtel

1983). In general the east plots received more total liquid waste application than the west, which in turn received more than the north plots.

Summaries have been compiled for the types and amounts of waste oils (Table 2.6) and waste coolants (Table 2.7) disposed of in the plots during the operating period. While waste oils typically consisted of crankcase, hydraulic, gear, vacuum pump, mineral, and machine coolant oils, the totals for 1974 and 1975 included approximately 15,000 gal of oil skimmed from the surface of the two Oil Retention Ponds located in the Y-12 Plant Burial Ground A. The machine coolants included nonsoluble oils and water-soluble mixtures consisting of approximately 5% oil and 95% water.

Table 2.6. Summary of waste oil disposals at the Y-12 Plant Oil Landfarm

Calendar year	Origin	No. of disposals	Volume (gal)	Active plots (acres)	Description
1973	Y-12	11	42,800	0.4	Waste oil
1974	Y-12	14	53,300	1.0	Waste oil
1975	Y-12	4	14,600	1.0	Waste oil
1976	Y-12	9	25,600	1.0	Waste oil
	NR	5	17,700	1.0	No record
1977	NR	5	14,000	1.4	No record
1978	Y-12	12	36,000	1.7	Waste oil
	ORGDP	1	1,000	1.7	Mineral oil
1979	Y-12	4	16,500	2.6	Waste oil
	ORGDP	16	63,900	2.6	Waste oil
1980	Y-12	22	72,400	2.6	Waste oil
	Y-12	5	17,800	2.6	Mineral oil
	ORGDP	7	22,300	2.6	Waste oil
1981				2.6	No disposals
1982	Y-12	9	32,900	2.6	Waste oil
Total		124	430,800		

^aNR = no record.

Source: Union Carbide 1984 (*Inventory of Existing Contamination in the Y-12 Plant Bear Creek Valley Oil Landfarm Area*).

Table 2.7. Summary of waste coolant disposals at the Y-12 Plant Oil Landfarm

Calendar year	No. of disposals	Volume (gal)	Active plots (acres)	Description
1973	12	34,800	0.9	Coolants
	8	22,500	0.9	Coolants and mop waters
	2	9,700	0.9	Water contaminated with nitrate
1974	22	104,000	1.6	Coolants
	6	21,000	1.6	Coolants and mop waters
1975	21	97,500	2.0	Coolants
1976	25	107,000	2.0	Coolants
	3	9,400	2.0	Water
1977	23	114,000	1.6	Coolants
1978	15	62,600	1.4	Coolants
1979			1.4	No disposals
1980	1	1,000	1.4	Dye penetrant
1981			1.4	No disposals
1982			1.4	No disposals
TOTAL	138	583,500		

^aFrom Union Carbide 1984 (*Inventory of Existing Contamination in the Y-12 Plant Bear Creek Valley Oil Landfarm Area*).

The typical composition of waste oils and coolants generated at the Y-12 Plant is summarized in Turner et al. (1992) Appendix B. The values are considered to be representative of the oily wastes disposed of in the Oil Landfarm plots. As expected, the waste oils exhibit lower densities and higher carbon contents than the oil/water coolant mixtures. Uranium contents of the oily wastes ranged from approximately 5 to 50 $\mu\text{g/g}$. The data further indicate that waste oils contained high levels of calcium, iron, sodium, silicon, phosphorous, chlorine, zinc, and lead. Analyses of machine coolants show a similar composition with the exception of barium, which is present in the coolants at levels 10 to 50 times higher than in the oils.

Before 1979, waste oils and coolants were not specifically analyzed for contaminants before application to the Oil Landfarm. In 1979, analytical results for oil samples collected from the surface of one of the ponds in the Burial Grounds indicated the presence of PCBs.

Thereafter, oils were analyzed for uranium, beryllium, thorium, and PCBs. A maximum permissible concentration level of 5 mg/L was established by the Y-12 Plant for PCBs in waste oils to be landfarmed. Oils containing >5 mg/L of PCBs were shipped for commercial disposal if uranium concentrations were less than permissible limits established for release to the public. If uranium concentrations were greater than permissible limits established for release to the public, waste oils containing greater than 5 mg/L of PCBs were placed in storage for future incineration at the K-25 Toxic Substances Control Act (TSCA) Incinerator.

In December 1981, the analyses of wastes were expanded to include chlorinated hydrocarbons. A maximum permissible concentration of 3% was established for concentrations of chlorinated solvents in the waste oils. Experience gained since 1981 in sampling and analysis of waste oils for chlorinated solvents has shown that waste oils contain concentrations of <3% chlorinated hydrocarbons.

2.3.5.2 Soil contaminants

Because of concerns about levels of PCBs that may have been present in the Oil Landfarm from disposal of contaminated oils, several rounds of sampling for PCBs in Oil Landfarm soils have occurred since 1981. The highest level detected in Oil Landfarm soil during this period was 110 $\mu\text{g/g}$ (Bechtel 1983). A total of 200 samples was collected in 1985 in a randomized block design with the objective of delineating areas containing PCB levels >25 $\mu\text{g/g}$. Several portions of plots were identified over this action level; the highest concentration measured was 60.5 $\mu\text{g/g}$. PCB contamination was principally confined to the upper 6 in. of the soil; concentrations declined by more than 90% between the surface (0-6 in. interval) and the 12-18 in. interval in ten depth profiles. Highest concentrations were found in the east and west plots (Herbes 1988).

Soil samples collected in the 1985 study were also analyzed for uranium. Concentrations of uranium were similarly highest in the east and west plots. The highest mean uranium concentration observed was 204 $\mu\text{g/g}$ (in Plot 7/8). Lowest concentrations were between 13 and 27 $\mu\text{g/g}$ in the north plot group. As was observed for PCBs, uranium concentrations declined rapidly with soil depth.

Forty-eight soil samples were collected and analyzed by the Y-12 Plant Analytical Laboratory for total carbon, PCBs, and a series of metals. Results are summarized in the Bechtel (1983) report. Maximum levels (in micrograms per gram) for the metals analyzed were arsenic (73), barium (340), beryllium (290), cadmium (6), chromium (88), lead (550), mercury (55), selenium (0.4), silver (8), thorium (20), and uranium (273). As would be expected from the historical pattern of oil application, contaminant concentrations were uniformly lowest in the north plots. Concentrations of beryllium were highest in plots 1/2 (mean of four analyses: 213 $\mu\text{g/g}$), 5/6 (112), and 9/10 (75). Beryllium levels in the West plots averaged 32 $\mu\text{g/g}$, and in the North plots, 8 $\mu\text{g/g}$. With the exception of one sample from plot 1/2, all mercury and lead concentrations were less than 4 $\mu\text{g/g}$ and 75 $\mu\text{g/g}$, respectively.

Composite samples were obtained in September 1983 from "light" and "dark" areas (differentiated visually) of Plots 1-12, 13-18, and 19-24 (east, west, and north areas, respectively). The five samples (no "dark" area was identified in the north plots) were analyzed for volatile organic compounds (VOCs), acid- and base-neutral extractables,

inductively coupled plasma (ICP)-analyzable metals, and pesticides/polychlorinated biphenyls (PCBs). Results are summarized in the Bechtel (1983) report. In general, the Plot 1-12 (east) "dark" sample contained the highest concentrations of contaminants. Major organic contaminants found, and maximum concentrations (in micrograms per gram), were tetrachloroethylene (8.4), trans-1,2-dichloroethylene (2.7), trichloroethylene (0.75), 1,1,1-trichloroethane (0.50), bis(2-ethylhexyl) phthalate (520), fluoranthene (140), phenanthrene (13), phenol (29), and 2,4-dimethylphenol (31).

A number of cores from monitoring wells installed around the perimeter of the Oil Landfarm in 1983 by Bechtel were analyzed for the organic contaminants listed above. Principal organic contaminants identified, and the highest levels quantified (in micrograms per gram), included toluene (1.6), methylene chloride (0.96), tetrachloroethylene (1.1), and trans-1,2-dichloroethylene (0.40). PCBs were found in three core segments from well GW-5, located east of the Oil Landfarm, at total concentrations of 1.6 $\mu\text{g/g}$ to 2.8 $\mu\text{g/g}$ at depths of 0-5 ft (Bechtel 1983).

2.3.5.3 Groundwater contaminants

Since 1982, groundwater wells that encircle the Oil Landfarm have been sampled for waterborne contaminants. The wells have consistently shown the presence of VOCs at total concentrations ranging from 0.01 to 3.1 mg/L. Principal contaminants observed include 1,1-dichloroethane, 1,1,1-trichloroethane, 1,1-dichloroethylene, trans-1,2-dichloroethylene, trichloroethylene, and tetrachloroethylene; chloroethane and vinyl chloride have also been detected (HSW Environmental Consultants 1992).

During 1986 and 1987, as part of the Groundwater Quality Assessment Plan groundwater samples from three monitoring wells that border the Oil Landfarm were analyzed for total and dissolved toxic metals and gross radioactivity. Cadmium, chromium, and lead were detected in several samples at levels slightly exceeding drinking-water standards. Levels of arsenic, mercury, lead, selenium, and gross alpha and beta radioactivity did not exceed drinking-water standards on any occasion (Y-12 HSEAD 1988).

2.3.5.4 Surface water and sediment analyses

Several water and sediment samples were collected by Bechtel near the confluences of tributaries NT-3 and NT-4 with Bear Creek during 1983 and 1984 (Turner et al. 1991). Levels of VOCs, phenols, and beryllium were all below detection limits (0.01, 0.001, and 0.001 mg/L, respectively) in these samples. Both dissolved and particulate PCBs were also below the detection limit (0.0003 mg/L) in single samples collected in 1983.

PCBs were undetectable ($<0.05 \mu\text{g/g}$) both in tributary and in Bear Creek sediments. Concentrations of beryllium, heavy metals (cadmium, chromium, cobalt, copper, lead, nickel, uranium, and mercury), and phenols showed no increases in the tributary sediments above upstream Bear Creek levels (Turner et al. 1991).

2.3.5.5 Summary

Based on soil analyses, at least some of the Oil Landfarm plots contain elevated levels of beryllium, uranium, several heavy metals, VOCs, and PCBs. VOCs have been detected in groundwater from wells bordering the Oil Landfarm. Detection of PCBs in soil cores from a boring east of the Oil Landfarm suggests that PCB transport across the surface or through the shallow subsurface has occurred in the past and may still be occurring. Contaminant levels in water and sediment samples collected from the tributaries that drain the Oil Landfarm are no greater than in Bear Creek, which suggests that transport through surface water from the Oil Landfarm is not now a major source of contaminants to either Bear Creek or the shallow groundwater.

2.3.6 Sanitary Landfill I

The Sanitary Landfill I is located approximately 0.8 mile west of the Y-12 Plant just north of Bear Creek and immediately south of the Oil Landfarm as shown on Fig. 2.5. The site was used between 1968 and 1980 for the disposal of combustible and decomposable solid wastes. The landfill was permitted for materials such as paper and cardboard, plastics, rubber, wood, brush, animal bedding, organic garbage, textile products, and asphalt roofing materials. Although administrative controls were used to exclude the disposal of toxic chemicals and other contaminated materials, it is likely that some of these materials were disposed of in the landfill (Y-12 HSEAD 1987b).

Trenches were excavated to depths of ~20 ft and backfilled to ~15 ft above grade. Approximately 105,000 tons of refuse were disposed of at the landfill. The landfill was closed in 1983 by grading to promote drainage, capping with 2 ft of clay and topsoil, and establishing a vegetative stand (Y-12 HSEAD 1987b).

2.3.7 Burial Grounds

The Burial Grounds are located ~2 miles west of the Y-12 Plant (Fig. 2.5). The Burial Grounds consist of several principal waste-disposal units designated as BG-A, B, C, D, E, and J. Collectively, these units are referred to in this document as the Burial Grounds.

Each waste-disposal unit consists of a series of trenches used for disposal of liquid and solid wastes. The trenches are between 14 and 25 ft deep. Perforated standpipes were installed vertically into some trenches for liquid-waste disposal; rock and gravel were backfilled around the standpipes for support and maximum rate of drainage.

Table 2.8 provides a chronological list of events and summarizes the available information concerning wastes deposited in the Burial Grounds. The first trench in BG-A was excavated in August 1955 for the disposal of solid wastes. In July 1959, the Y-12 Plant began using this facility for the disposal of certain types of liquid waste. Before 1959, liquids generated at the Y-12 Plant from floor-cleaning operations, known as mop waters, had been placed in the burial facilities at ORNL. Since that time, several types of wastes have been disposed of in the Burial Grounds; Table 2.9 provides a summary of the major types of wastes. The actual quantity and identity of materials is uncertain, and other materials may have been disposed of that are not listed in any inventory (Turner et al. 1991).

Table 2.8. Chronological list of events at the Burial Grounds

Year	Event	Reference
August 1955	Disposal at Burial Grounds began with the disposal of solid waste in Unit A. The Burial Grounds consisted of waste disposal units A, B, C, D, E, and J. Each unit consisted of a series of trenches, 4.3 to 7.6 m (14 to 25 ft) deep, that were used for the disposal of liquid and solid wastes.	Turner et al. 1991
July 1959	Burial Grounds used to dispose of certain types of liquid wastes.	Turner et al. 1991
1959	Large volumes of solvent-contaminated water and oils began being disposed of in BG-A.	
1961	Surface tank installed in BG-A to hold waste oils and coolants; accumulations were burned. Liquids that did not burn were drained into trenches. An estimated 684,000 L (180,000 gal) of oil and coolants were disposed of by this method.	
1962	BG-B opened and used for disposal of depleted uranium metal and oxides.	Turner et al. 1991
1962	BG-C opened for the disposal of beryllium, beryllium oxide, thorium, and solid waste contaminated with these materials. Other materials contaminated with enriched uranium were also disposed of in BG-C.	Turner et al. 1991
1966	Walk-In Pits established in the Burial Grounds. Area used to dispose of chemicals and uranium metal saw fines.	Turner et al. 1991
1968	Burning of waste oils and coolants terminated in BG-A.	
1968	BG-B reached waste disposal capacity.	
1968	BG-D opened. The area was used to replace BG-B and received depleted uranium metals and oxides waste.	
1969-1971	Oil was first observed seeping from the ends of trenches in BG-A into Tributary NT-7 and from the soil surface above the oil disposal pits.	
January 1969	Oil and coolants were poured into standpipes that were installed in the trenches.	
1970-1981	Approximately 380,000 L (100,000 gal) of waste solvents were poured into rock piles and into waste filled trenches in the southern part of BG-A.	Turner et al. 1991
1971-1978	Estimated 2.3 million L (600,000 gal) of mop water were disposed of annually in BG-A.	Turner et al. 1991
May 1971	ORP 1 was constructed with dimensions of 55 m (180 ft) long, 34 m (110 ft) wide, and 2 m (6 ft) deep.	Bailey 1979

Table 2.8 (continued)

Year	Event	Reference
May 1972	ORP 2 was constructed on Tributary NT-6 at the northeast corner of BG-A.	Bailey 1979
1974-1975	Approximately 57,000 L (15,000 gal) of oil were skimmed and removed from the surfaces of both oil retention ponds for disposal on the Oil Landfarm.	
1975	Since 1975, no significant accumulation of oil has occurred on surface of ORP 2.	
1975-1987	Historical monitoring at site as part of program to identify groundwater contamination sources at Y-12 Plant.	
1979	68,400 L (18,000 gal) of oil removed from ORP 1.	
1979	Disposal of mop water in BG-A terminated.	Turner et al. 1991
1979	Oil disposal ceased in the Burial Grounds.	
1980	Trenches and disposal areas in the Burial Grounds that received hazardous wastes were designated and given interim status.	
1980, 1982	Series of soil cores was collected along transects from the perimeter of ORP 1 for PCB analysis.	
1981	After 1981, Walk-in Pits used solely for disposal of uranium metal saw-fines.	
1983-1986	Characterization monitoring in response to the MOU signed by DOE, EPA and TDEC.	
1983	Water and sediment samples collected from sites in NT-6 and NT-7 analyzed for VOCs, metals, cyanide, phenols, and a number of conventional water quality parameters. Several VOCs principally including 1,1-dichloroethane, tetrachloroethylene (PCE), trans-1,2-dichloroethylene, and trichloroethylene (TCE) found in sediments of ORP 1 and in both water and sediments of NT-7 downstream of the pond. VOCs were not detected in a water sample collected north of ORP 1, which indicates VOC source differs from that of PCBs.	Turner et al. 1991
September 1983	Sediment samples collected from ORP 1 and NT-7 downstream of pond did not show elevated levels of toxic metals, cyanide or phenols in comparison to control site on NT-7 upstream from Burial Grounds.	
September 1983	Samples from ORP 1 contained PCBs ranging from 3 to 31 mg/L.	

Table 2.8 (continued)

Year	Event	Reference
1983, 1984	Concentrations in NT-7 channel sediments at confluence with Bear Creek were reported to range from 5.2 to 28.2 mg/g.	McCauley 1984b
December 1984	Burial Grounds granted interim status and therefore subject to groundwater monitoring requirements described in TN Rule 1200-1-11-.05.	
1985-1988	Extensive sediment sampling throughout the tributary system has shown PCBs are present in concentrations of several hundred mg/g in surface sediments of NT-7 between ORP 1 and the visible area of oil seepage at west end of Burial Trench A-14 but decline below 25 mg/g by a depth of 60 cm (24 in.).	
October 1985	Five cores were collected from bottom of ORP 1 and subdivided into 15-cm (6-in.) intervals for analysis. Concentrations of PCBs in surface sediments ranged as high as 710 mg/g, but declined to 3 mg/g or less at a depth of 67.5 cm (27 in.).	Herbes 1988
1989	Both ORP 1 and ORP 2 were cleaned out and an engineered cap was constructed over each pond under an approved RCRA closure plan.	
1989	BG-A and BG-C west were closed in place as a landfill and covered with an engineered cap under RCRA.	
November 1990	TDEC granted approval for the final closure of BG-A.	

Table 2.9. Partial summary of waste materials deposited in the Burial Grounds

Constituent	Burial grounds ^a				
	A	B	C	D	Walk-in pits
Heavy metals ^b	P	P	P	P	P
Oils and coolants	P	P ^c	P	P ^c	P
Salts	P	NI	P	NI	P
Debris	P	NI	P	NI	P
Solvents	P	NI	P	NI	P
Ethylenediaminetetracetic acid (EDTA)	P ^d	NI	NI	NI	NI
Asbestos	P ^e	NI	P	NI	P
Material contaminated with radioisotopes	P	P	P	NI	P ^f
Mop water	P	NI	NI	NI	NI

^aP = listed in the records as having been deposited; NI = not identified in the records as having been deposited.

^bIncludes beryllium and uranium.

^cTrace quantities only.

^dIn A-South only.

^eIn A-North only.

^fIn northern walk-in pit only.

Source: McCauley 1985a.

An estimated 600,000 gal annually of mop water were disposed of in BG-A between 1971 and 1978; the quantities disposed of before 1971 were not recorded. Disposal of mop waters in BG-A was terminated in 1979; after that date, these waters were placed in the S-3 Ponds (Turner et al. 1991).

BG-A also was used for the disposal of oils and coolants. Before 1961, these wastes and solid wastes were placed in unlined trenches within the Burial Grounds. In 1961, a surface tank was installed in BG-A to hold waste oils and coolants; the accumulations then were burned, and liquids that did not burn were drained into adjacent trenches. An estimated 180,000 gal of oils and coolants were disposed of by this method between 1961 and 1968, when the practice was terminated. In January 1969, a new procedure was adopted; the oils and coolants were poured into standpipes installed in the trenches. By 1976, most of the waste oils and coolants were being disposed of at the Oil Landfarm, and in 1979, oil disposal ceased in the Burial Grounds (Turner et al. 1991).

Before July 1970, waste solvents were disposed of by burning in an open tank located east of BG-A. Between July 1970 and October 1981, ~100,000 gal of waste solvents were poured onto rock piles and into waste-filled trenches in the southern part of BG-A (Turner et al. 1991). Tables 2.10 and 2.11 show concentrations of contaminants in grab samples of waste oils and solvents deposited in the Burial Grounds.

BG-B was opened in 1962 for the disposal of depleted uranium metal and oxides. BG-C was opened in 1962 for the disposal of beryllium, beryllium oxide, thorium, and solid waste contaminated with these materials; other materials contaminated with enriched uranium were also disposed of in BG-C. BG-D was used after 1968 for the disposal of depleted uranium metals and oxides after BG-B had reached its capacity. An area of the Burial Grounds referred to as the Walk-In Pits was used from 1966 to 1981 for the disposal of chemicals and uranium metal saw fines. Since 1981, the Walk-In Pits have been used solely for the disposal of uranium metal saw fines (Turner et al. 1991).

BG-E and J were used primarily for the disposal of uranium. Through 1983, BG-E had received a total of 190.7 tons of uranium. In addition to the uranium, disposals to BG-J made by 1983 were estimated to include approximately 29 tons of debris and 14 tons of inorganic salts.

When RCRA Part A permit applications were submitted, trenches and disposal areas in the Burial Grounds that received hazardous waste after November 19, 1980, were designated and were given interim status.

A variety of wastes have been disposed of in the interim-status units in the Burial Grounds. They include:

- Walk-in Pits—miscellaneous laboratory chemicals;
- Isolation Area—solvents including alcohol, perchloroethylene, trichloroethylene, freon, and others;
- Trenches A-7 through A-12—mostly depleted uranium-contaminated solid waste, including wood, metal, paper, glass, debris, and others; smaller quantities of liquids including oils, machine coolants, and solvents;
- Rock Pits and Standpipes—some solvents and machine coolants; and
- Trenches C-18, C-20 and C-21—various types of solid wastes contaminated with beryllium, beryllium oxide, thorium, and enriched uranium, some contaminated with solvents; small quantities of acid.

The Burial Grounds are drained by Tributaries NT-6, -7, and -8. Seepage zones from adjacent burial areas have been observed on all three tributaries (Fig. 2.6); all three may thus serve as sources for contaminant entry into Bear Creek and BCV groundwater.

Contaminants detected in water and sediments from NT-6 and NT-7 are discussed in Sect. 2.3.8. Sediment sample analyses have been reported for NT-8 in Herbes (1988) and in Bogle and Turner (1991). Sediments from Seeps 3 and 4 on NT-8 (Fig. 2.6) have been shown to contain PCBs at concentrations up to 80 $\mu\text{g/g}$, and uranium levels up to 345 $\mu\text{g/g}$ (surface

Table 2.10. Spectrographic analyses of samples of oily wastes generated at the Y-12 Plant^a

Element	Waste oil composite (ppm)	Machine coolant composite (ppm)	Mixture machine coolant and mop water (ppm)	Waste oil from ponds (ppm)
Ag	<0.01	<0.1	<0.2	<20.
Al	2.	8.	10.	50.
Au		0.4	<0.8	<10.
B	0.2	0.8	10.	5.
Ba	0.4	20.	0.8	2.
Be	12.	0.4	0.04	<0.5
Bi		<0.2	0.4	<5.
Ca	25.	40.	200.	80.
Cd	0.2	<0.4	<2.	<20.
Co	<0.2	0.2	<0.2	<20.
Cr	2.	1.	2.	<5.
Cs		10.	<20.	<300.
Cu	0.5	2.	3.	<2.
Fe	9.	20.	70.	300
Ge				
Hf		<0.4	<0.8	<10.
K	50.	<400	800	<20.
Li	4.5	1.	2.	<10.
Mg	4.5	6.	20.	10.
Mn	0.5	0.4	0.8	10.
Mo	0.01	0.2	2.	<1.
Na	>200.	>400	800	10.
Nb		0.4	3.	<10.
Ni	<0.04	<0.2	0.8	<5.
P	<1.	200	<40.	500.
Pb	0.4	3.	3.	<5.
Pd		0.04		
Rb		3.	<60.	<80.
Sb		<0.8	<2.	<20.
Si	4.5	10.	50.	100
Sn	<0.01	10.	<0.2	<2.

Table 2.10 (continued)

Element	Waste oil composite (ppm)	Machine coolant composite (ppm)	Mixture machine coolant and mop water (ppm)	Waste oil from ponds (ppm)
Ta		<3.	60	<80.
Th		<0.8	<2.	<20.
Ti	0.2	0.8	2.	<5.
U	60.	20.	80.	<200
V	<0.01	0.1	0.2	<2.
W	<0.1	3.	6.	<40
Zn	2.	<2.	<3.	<40
Zr	1.5	0.2	2.	1.

Source: Turner et al. 1991.

^aAnalyses performed in 1974.

Table 2.11. Analysis of waste oils generated at the Y-12 Plant

	Concentration ($\mu\text{g/mL}$)				
	Vacuum pump oil		Crankcase oil	Surface oil-field Pond 2	
	Filtered	Unfiltered	Unfiltered	Filtered	Unfiltered
Be	<0.005	<0.01	<0.01	<0.01	<0.01
B	0.02	0.3	6.0	0.3	0.2
F	0.09	0.3	0.3	0.3	0.3
Na	100.0	20.0	500.0	50.0	20.0
Mg	0.3	11.0	10.0	1.0	1.0
Al	4.0	4.0	4.0	20.0	1.0
Si	10.0	10.0	80.0	80.0	1500.0
P	0.2	0.7	1500.0	6000.0	14500.0
S	2.0	10.0	40.0	20.0	7.0
Cl	200.0	650.0	1000.0	1000.0	2000.0
K	2.0	2.0	20.0	20.0	2.0
Ca	3.0	9.0	3000.0	9.0	3.0
Sc	0.6	<0.06	0.2	<0.06	<0.06
Cr	0.1	<0.09	0.9	<0.09	<0.09
Mn	0.1	0.1	0.8	<0.08	<0.08
Fe	80.0	40.0	80.0	10.0	30.0
Co	0.08	<0.08	<0.08	<0.08	<0.08
Ni	0.2	0.2	0.2	<0.1	<0.1
Cu	0.4	0.6	0.2	<0.1	<0.1
Zn	2.0	6.0	300.0	6.0	2.0
Cd	0.3	<0.5	<0.5	<0.5	<0.5
Sn	<0.2	<0.5	<0.5	<0.5	<0.5
Ba	0.3	<0.3	150.0	1.0	<0.3
Ta	0.8	<0.8	<0.3	<0.3	<0.3
W	0.4	<0.8	<0.8	<0.8	<0.8
Hg	<0.3	<0.9	<0.9	<0.9	<0.9
Pb	<0.2	<0.6	200.0	<0.6	<0.6
Bi	<0.1	<0.3	<0.3	<0.3	<0.3
Th	0.5	0.5	<0.3	<0.3	<0.3
U	<0.1	<0.3	<0.3	<0.3	<0.3
Mo	<0.6	<0.6	20.0	<0.6	<0.6

Source: Turner et al. 1991.

Fig. 2.6. Area of visible seepage into tributaries NT-6, NT-7

LEGEND:

- CAPPED DISPOSAL UNIT
- RCRA CAPPED DISPOSAL UNIT
- TSD FACILITY
- UNCAPPED DISPOSAL UNIT

SCALE
1" = 300'

SAIC

Science Applications
International Corporation

REVISION	DRAWN BY:	CHKD. BY:	DATE:
0	D. EVANS		7-1-93

XREFERENCES	PLOT FILES
93044/XREF/BASEMAP 93044/XREF/MANGAREA	93044/PL07/422BC4-1

FIG. 7	93044\DWGS\422BC4-1	0
FIGURE #	CAD FILE #	ROT. ANGLE

and NT-8 in the vicinity of the Y-12 Plant Burial Grounds. Scale: 1 in. = 600 ft.

sediments). Sediment samples from Seep 2, which serves as the source of NT-8, did not contain elevated PCBs ($<1 \mu\text{g/g}$) but contained uranium at levels up to $1349 \mu\text{g/g}$ (Herbes 1988). Lower uranium concentrations (maximum $260 \mu\text{g/g}$) were observed in surface sediments near Seep 2 in 1990 (Bogle and Turner 1991). Although sediment samples collected in 1983 from NT-7 near the confluence with Bear Creek did not contain detectable PCBs ($<0.05 \mu\text{g/g}$), subsequent samples collected in 1986 showed PCB levels up to $58 \mu\text{g/g}$ in sediments deposited in the floodplain near the confluence, with lower levels ($<0.1\text{--}19 \mu\text{g/g}$) at sites further upstream. Uranium concentrations were also elevated near the confluence with Bear Creek ($148\text{--}579 \mu\text{g/g}$) relative to concentrations at sites further upstream ($<1\text{--}315 \mu\text{g/g}$). The results indicate that both PCBs and uranium have been transported from sources in BG-C through NT-8, and have been deposited in the floodplain sediments at the confluence of NT-8 and Bear Creek. BG-C West was closed and capped in June 1991. BG-C East, BG-B, and the Walk-In Pits are undergoing RCRA closure and capping in 1993.

2.3.8 Oil Retention Ponds

2.3.8.1 Disposal of contaminants

From 1959 to 1979 large volumes of solvent-contaminated water and oils were disposed of in Burial Ground (BG) A (Fig. 2.6). Throughout the period of oil disposal, several million gallons of oil and mop waters were disposed of by discharge either directly into oil disposal pits in BG-A North and South or into standpipes in the burial trenches in BG-A South.

Between 1970 and 1981, volatile solvents were disposed of by pouring into a rock-covered area at the southeastern end of the BG-A South trenches. During this period approximately 100,000 gal of solvents were disposed of in this manner. Table 2.12 summarizes the solvents disposed of during the 12-year period.

Much of the oil disposed of in the BG-A South burial trenches during the 1970s is known to have been contaminated with PCBs (Bailey 1979). In addition, some of the coolants used in the Y-12 Plant during 1963-71 were reported to contain PCBs, although the means of disposal of these liquids is not known with certainty. PCB-contaminated oils are not known to have been disposed of in BG-B, C, or D. However, analyses of sediments from Tributary NT-8, which directly drains BG-C and may receive indirect discharges from BG-B and -D (Fig. 2.6), show the presence of PCBs (Sect. 2.3.7). Data on historical oil disposal patterns may therefore be incomplete.

Although overflow of mop waters from standpipes had occurred previously, oil was first observed seeping from the west ends of trenches in BG-A into Tributary NT-7, and from the soil surface above the oil disposal pits, in the 1969-71 period. At this time, oil addition to the BG-A South trenches was discontinued (Bailey 1979). To prevent oil transport down Tributary NT-7 to Bear Creek, Oil Retention Pond 1 (ORP-1), with maximum dimensions of 180 ft (55 m) in length, 110 ft (34 m) in width, and 6 ft (2 m) in depth, was constructed in May 1971. The pond was equipped with underflow pipes to permit water discharge while retaining floating oils in the impoundment. Simultaneously a drainage ditch was constructed about 60-100 ft (18-30 m) west of and parallel to the tributary, which rejoined Tributary NT-7

Table 2.12. Solvents discharged into isolation area (in gallons)

Solvent	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	Totals
Vythene	410		50	850	1,575	210		555	500	505	1,865	1,785	8,305
Varsol	245	410	1,000	720	490	650	615	1,000	900	560	810	661	8,061
Fuel and Water	450	500	700	110	15	680	1,165	2,500	400	250	790	205	7,765
Perchloroethylene	100			540	180	475	1,150	930	1,160	710	1,000	1,390	7,635
Freon	20	85	520		265	345					1,390	1,470	4,095
Alcohol	25	25	550	490	280	210	20	290	600	200	410	189	3,289
Solvents from Bldg. 9208 (Benzene, Toluene, Xylene, Alcohol)	40	265	210	125	50	50		110	125		190	5	1,170
Trichloroethylene		75	50		220				110	225		55	735
MEK			160		120				75	175			530
Miscellaneous	6,910	10,640	6,760	4,165	1,605	1,880	2,900	4,615	5,130	2,850	7,240	2,730	57,425
Gallons discharged	8,200	12,000	10,000	7,000	4,800	4,500	5,850	10,000	9,000	5,600	13,695	8,470	99,115

Source: McCauley 1984.

about 50 ft (15 m) south of the pond, to divert uncontaminated surface runoff around the pond. A sump was later dug at the western end of one of the trenches east of ORP-1 to collect oil, which was pumped into the pond; a pipe was also installed between the end of a second trench and the pond to permit direct oil transfer to the pond (Bailey 1979).

During the mid-1970s, oil seepage was observed from the west-facing slope west of trench A-14 into Tributary NT-7 (Bailey 1979). In 1974, ~15,000 gal (57,000 L) of oil were removed from the surface of ORP-1; an additional 5000 gal (19,000 L) were removed in early 1975. In 1979 an additional 18,000 gal (68,000 L) of oil were removed (Battelle 1986).

Oil seepage was observed on a steep slope above Tributary NT-6 at the eastern end of trenches A-14 and A-15 before 1972 (Bailey 1979), and in May 1972 a smaller impoundment, Oil Retention Pond 2 (ORP-2) was constructed on Tributary NT-6. No significant oil accumulation has been reported on the surface of this closed ORP-2 since 1975 (Battelle 1986).

2.3.8.2 Contaminant distributions

PCBs. Since 1982 several hundred soil and sediment samples have been collected from the Oil Retention Ponds and tributaries NT-6 and NT-7 and analyzed to determine contaminant concentrations. The principal contaminant analyzed for has been PCBs because of the known presence of these contaminants in oil disposed of in the Burial Grounds. These analyses have demonstrated the presence of PCBs at concentrations above 25 $\mu\text{g/g}$ throughout the sediments of both Oil Retention Ponds and much of Tributary NT-7.

In 1980 and 1982, a series of soil cores was collected along transects from the perimeter of ORP-1 for PCB analysis by the Y-12 Plant Analytical Laboratory. Concentrations of PCBs in six surface samples collected between 0 and 12 ft (3.7 m) from the pond perimeter ranged from 13 to 1448 $\mu\text{g/g}$. Several samples collected at a depth of 0.6 m (2 ft) contained 2.8 to 14 $\mu\text{g/g}$. Samples collected from the ORP-1 perimeter in July 1985 showed similar concentrations and distribution, while samples collected from ORP-2 showed levels as high as 174 $\mu\text{g/g}$ in surface sediment from the perimeter of the pond, and similarly declining with depth and distance from the pond. In October 1985 five cores were collected from the bottom of ORP-1 and subdivided into 6-in. intervals for analysis. Concentrations of PCBs in surface sediments ranged as high as 710 $\mu\text{g/g}$, but declined to 3 $\mu\text{g/g}$ or less at a depth of 27 in. (Herbes 1988).

Extensive sediment sampling throughout the tributary system conducted between 1985 and 1988 has shown that PCBs are present in concentrations of several hundred $\mu\text{g/g}$ in surface sediments of NT-7 between ORP-1 and the visible area of oil seepage at the west end of burial trench A-14 but decline below 25 $\mu\text{g/g}$ by a depth of 24 in. PCBs have been found in areas of the NT-7 floodplain south of ORP-1 at concentrations as high as 574 $\mu\text{g/g}$. Because PCBs sorb strongly to soil particles, elevated concentrations in the NT-7 floodplain appear to be caused by sediment transport from upstream areas. PCB levels in soils and sediments in NT-7 exceed 25 $\mu\text{g/g}$ (Herbes 1988). Concentrations in NT-7 channel sediments at the confluence with Bear Creek were reported to range from 5.2 to 28.2 $\mu\text{g/g}$ in 1983 and 1984 (McCauley 1984), and 2.1 to 14.1 $\mu\text{g/g}$ in 1986 (Herbes 1988).

A maximum PCB concentration of 33 $\mu\text{g/g}$ was found in sediment of the drainage ditch north of ORP-2. PCBs are present in NT-6 sediments at concentrations between 2.3 and 13.8 $\mu\text{g/g}$ throughout its length between the confluence with the intermittent stream draining ORP-2 and the confluence with Bear Creek.

Few analyses of PCBs in water from tributaries and Oil Retention Ponds are available. Samples of water obtained in September 1983 from ORP-1 contained PCBs ranging from 3 to 31 $\mu\text{g/L}$. Dissolved PCBs in water samples collected from NT-7 at the confluence with Bear Creek contained 2 $\mu\text{g/L}$ in 1983 (McCauley 1984), and less than 1.5 $\mu\text{g/L}$ in December 1987.

Uranium. Because large quantities of uranium were disposed of in the Burial Grounds, the soil and sediment sampling campaigns conducted in NT-6 and NT-7 since 1985 have included total uranium analyses. Concentrations measured in sediments north of the Burial Grounds generally range from 1 to 10 $\mu\text{g/g}$. These are areas of negligible contamination but are not being considered as background levels for this area. Background levels for sites in BCV will be obtained from results of Phase I of the Background Soil Characterization Project (Energy Systems 1993) (Table 2.4). In the lower reaches of both tributaries, concentrations range up to 225 $\mu\text{g/g}$. In contrast to PCBs, which are present at far higher levels in NT-7 sediments than in those of NT-6, uranium levels are similar in the two tributaries: the mean of nine samples collected at three locations from the stream channel and adjacent banks from NT-7 south of ORP-1 was 84 $\mu\text{g/g}$, while the mean of the same number of samples collected at three sites from NT-6 south of ORP-2 was 98 $\mu\text{g/g}$ (Herbes 1988). Uranium concentrations were not correlated with PCB concentrations.

Other Organic and Inorganic Contaminants. Water and sediment samples were collected in 1983 from the ponds and from several sites in NT-6 and NT-7, and analyzed for VOCs, metals, cyanide, phenols, and a number of conventional water quality parameters. Several VOCs, principally including 1,1-dichloroethane, tetrachloroethylene (PCE), trans-1,2-dichloroethylene, and trichloroethylene (TCE) were found in sediments of ORP-1, and in both water and sediments of NT-7 downstream from the pond. However, VOCs were not detected in a water sample collected north of ORP-1, which indicates that the VOC source differs from that of PCBs. The total VOC concentration in the NT-7 sample near the confluence with Bear Creek was 1.6 mg/L (Turner et al. 1991). A water sample collected at the same site in 1987 showed a similar VOC profile and similar concentrations (see Appendix C, Turner et al. 1991). The distribution of VOCs found in NT-7 water and sediment samples is similar to the contaminant distribution found in numerous groundwater monitoring wells located near the burial trenches, and suggests that subsurface flow is probably responsible for the contaminants detected in the tributary.

Sediment samples collected in September 1983 did not show elevated levels of toxic metals, cyanide, or phenols in ORP-1 or in NT-7 sediments downstream from the pond when compared to a control site on NT-7 upstream from the Burial Grounds. Sediment concentration ranges (in micrograms per gram) throughout the pond/NT-7 system were arsenic (40–140), beryllium (<1–3), cadmium (2–11), chromium (17–48), cobalt (2–20), copper (2–9), lead (30–80), nickel (6–68), silver (<1–2), zinc (21–100), cyanide (0.17–0.24), and total phenols (0.05–0.21). None of these contaminants was detected in water samples collected in September 1983 from the pond/NT-7 system except cyanide, which was detected north of the confluence with Bear Creek at the analytical detection limit (0.01 mg/L) (Turner et al. 1991).

A sample collected at this location in December 1987 gave similar results with the exception of nickel, which was detected at a concentration of 0.0619 mg/L (Appendix C, Turner et al. 1991).

No semivolatile contaminants were detected from NT-7 at the sampling point north of the confluence with Bear Creek in the December 1987 sampling (Appendix C, Turner et al. 1991). Both Ponds 1 and 2 were cleaned out, and an engineered cap was constructed over each pond in 1989.

Summary. PCBs, uranium, and VOCs are present at elevated levels in sediments from the Oil Retention Ponds and tributaries NT-6 and NT-7. The principal source of PCBs present is the visible seep north of ORP-1 on NT-7; PCB contamination is widespread south of this point throughout the tributary and pond sediments, and has been detected in groundwater and surface water samples as well. PCBs are found throughout the sediments of NT-6, although at lower levels. Although VOCs are also present in NT-7 water and sediments south of ORP-1, the source is different because VOCs are not detected between the pond and the visible seep to the north. Because the VOC profile in NT-7 water and sediments is similar to that of groundwater, elevated VOC concentrations in NT-7 may result from inflow to the stream of subsurface groundwater. Uranium is distributed throughout the sediments of both NT-6 and NT-7 in the reaches that flow past the Burial Grounds. Uranium in these tributary sediments may thus be caused by erosion of particles containing uranium from the soils covering the burial trenches and transport into the tributaries. Both ponds were closed and capped in 1989.

2.4 RELEASES

Releases from the Bear Creek source areas, as discussed in preceding sections, were the result of routine operations at land disposal units operating in a different regulatory environment.

3. CHARACTERIZATION OF THE ENVIRONMENTAL SETTING

3.1 GEOGRAPHY

A description of the geographic setting of Bear Creek is presented in Sect. 2.1.

3.2 CLIMATE

Detailed discussions of climate can be found in Sect. 4.4 of Vol. I of the General Document (Welch 1989) and in Sect. 3.1 of the *Clinch River RCRA Facility Investigation Plan* (Energy Systems 1990). The Oak Ridge area has a temperate climate that is moderated by the Blue Ridge Mountains to the east and the Cumberland Plateau to the west.

Weather patterns in Oak Ridge are generally temperate, with warm, humid summers and cool winters. The annual mean temperature is about 15°C (58°F), with a January mean of about 3.5°C (38°F) and a July mean of about 25°C (77°F). Relative humidity in mid-afternoon averages about 55%. At night humidity is higher, averaging 85% at dawn.

The mean annual rainfall is about 136 cm (Fig. 3.1), but during the drought of 1981-88 yearly precipitation was about 30-35 cm less than average. Winter months usually have the most rain, with another peak in July, when thunderstorms are common. Autumn is usually the season of lowest rainfall.

Prevailing winds in the area follow the general topography of the surrounding ridges (Fig. 3.2). The down-valley draft, coming from the northeast and identified with gravitational flow down local slopes and the Tennessee Valley, prevails during inversion conditions of late evening through mid-morning. Daytime up-valley flow is from the southwest when regional or synoptic flows aloft become strong enough to dominate the opposing local gravitational winds.

Oak Ridge is one of the country's calmest wind areas. Average wind speed for the Oak Ridge area is 4.4 mph. The Cumberland Plateau and the Smoky Mountains divert severe storms; local irregular ridges further minimize the air movement and wind impact.

3.3 DEMOGRAPHY

3.3.1 Population Information

The Y-12 Plant is located at the northeast boundary of ORR across Pine Ridge from the commercial center of Oak Ridge, which has a population of 27,310 (U.S. Department of Commerce 1991). The employment at the Y-12 Plant, as of January 1992, consisted of 6934 full-time Energy Systems employees and ~ 1000 on-site employees of M-K Ferguson, DOE,

Fig. 3.1 Annual precipitation record for the Oak Ridge area.
(Source: Energy Systems 1991)

Fig. 3.2 1990 wind rose for 10-m level at the west end of the Y-12 Plant. (Source: Energy Systems 1991)

and ORNL. A pumping station located on the north bank of Melton Hill Lake at Clinch River supplies water to the Y-12 Plant and the Oak Ridge water plant. The K-1515 water treatment plant which supplies water to the K-25 Site takes in ~2 million gallons of water per day from an intake located at K-1513 on the Clinch River.

3.3.2 Land Use

The East Tennessee Development District, which includes Oak Ridge, is rural in character. Knoxville is the district's regional center and the only city with a population in excess of 50,000. Oak Ridge and other cities in the district are within the 7500 to 50,000 population range, are incorporated, and have a definite central core that provides major employment and trade opportunities. Of the district's 1,700,010 ha (4,200,800 acres), ~80% is in agricultural and forest land use (Table 3.1).

In contrast to the district's general land use patterns, the city of Oak Ridge is an urban center with minimal agricultural activities. Land not owned by the federal government consists of 5510 ha (13,615 acres) and is divided into more than 9500 parcels. Table 3.2 categorizes urban land use data for the city of Oak Ridge. Most of this land is either residential or vacant, with over 1903 ha (4700 acres) of the vacant land suitable for housing (DOE 1982).

Several categories of land use are in close proximity to the ORR. The nearest privately owned residential properties are in the Poplar Springs, Sugar Grove Valley, Oak Ridge, and Scarboro communities. Oak Ridge and Scarboro are located on the northern boundary of the ORR. Poplar Springs is located 2 miles west across the Clinch River, and Sugar Grove Valley is located 1.5 miles north. Other residential areas include Bradbury, Edgewood, and Lawnville. Bradbury is located across the Clinch River ~5 miles to the south. Edgewood and Lawnville are located immediately west-northwest of the Poplar Springs community. Agricultural use includes limited-scale private gardening; raising of tobacco, corn, wheat, and soybeans as cash crops; raising of beef cattle; and dairy farming. Some areas are also used for commercial logging.

Industrial land use includes Phyton Technologies, Inc.; Scientific Ecology Group (SEG); and IT Corporation's Bear Creek Radiological Laboratory. SEG, Phyton, and the IT Corporation laboratory are within 2 miles of the Y-12 Plant. TVA facilities, including the Melton Hill Dam, the Bull Run Steam Plant, and the Kingston Steam Plant, are all greater than 6 miles from the Y-12 Plant.

Recreational areas in close proximity to ORR include the city of Oak Ridge parks (LaSalle, Cedar Hill, Al Bissell, Elm Grove, Milt Dickens, and Scarboro parks); the city of Oak Ridge swimming pools and sporting facilities; the Watts Bar Lake Embayment/Clinch River waterway, which is used as a recreational area by both pleasure boaters and fishermen; a number of small camping areas and boat launching ramps; a small dirt-surface racetrack located ~4 miles south which attracts several thousand spectators during the racing season; and a public swimming area 7 miles southeast at Melton Hill Dam. Sport hunting of gamebirds and game animals occurs seasonally in the region, and deer hunting is authorized on some parts of the ORR as a conservation measure.

Table 3.1. Land use data for the Eastern Tennessee Development District

Land use category	Hectares	Acres	Percent
Residential	35,074	86,670	2.1
Commercial	1,950	4,820	0.1
Industrial	20,700	51,150	1.2
Recreational	269,129	665,030	15.8
Agricultural	685,904	1,694,900	40.3
Public and quasi-public	28,430	70,250	1.7
Forest	658,823	1,627,980	38.8
Total	1,700,010	4,200,800	100.0

Source: DOE 1982.

Table 3.2. Urban land use data for the city of Oak Ridge, Tennessee*

Land use category	Hectares	Acres	Percent
Residential	1,640	4,050	28.9
Vacant	2,247	5,550	39.6
Recreational	749	1,850	13.2
Commercial	104	256	1.8
Industrial	47	115	0.8
Public transportation, Parking	480	1,185	8.5
Private transportation	33	82	0.6
Utilities and communications	52	129	0.9
Services	314	775	5.5
Total	5,666	13,992	99.9

* Excludes federally owned lands within the corporate city limits.

Source: DOE 1982.

The ORR lies within the corporate limits of the city of Oak Ridge. A buffer zone surrounds each of the facilities to provide security, space for expansion, and isolation from the general public. Tracts totaling about 5666 ha (14,000 acres) are allocated around operating reactors, waste disposal areas, and streams that receive routine waste releases and burial ground seepages. Acreage used for high-voltage transmission lines, pipelines, transportation corridors, and security fences amounts to about 2023 ha (5000 acres) (DOE 1982).

About 80% of the ORR is part of a comprehensive forest management program that divides the ORR into 27 compartments. These compartments range in size from 148 to 486 ha (365 to 1200 acres). Vegetational features unique to the area are excluded from timber harvest operations, and 40 individual sites are designated for environmental research.

The Y-12 Plant is situated at the eastern end of the ORR, adjacent to the commercial center of Oak Ridge and contains ~800 acres. Land uses associated with the Y-12 Plant facility include several waste storage or disposal areas, of which (1) a parcel of ~61 ha (150 acres) serves as a sanitary waste landfill for solid wastes; (2) ~26 ha (65 acres) located west of the main plant is used as a burial ground for low-level radioactively contaminated solid wastes generated by the Y-12 Plant; and (3) ~1.6 ha (4 acres) is an abandoned quarry formerly used as a disposal and dilution basin for selected nonradioactive chemical wastes, primarily sodium, lithium, and potassium from Y-12 Plant operations.

3.4 TOPOGRAPHY, GEOLOGY, AND SOILS

3.4.1 Topography and General Geology

The DOE ORR, which includes Bear Creek, is located in the Valley and Ridge physiographic province, part of the Appalachian fold and thrust belt. The area is characterized by a succession of northeast-trending ridges and valleys, which formed as a result of differential erosion of the clastic and carbonate lithologies (southeast dipping, locally 45° to vertical) that make up the individual thrust sheets.

The major extent of Bear Creek is located in BCV, which is bounded to the north and south (plant grid directions, plant grid is ~34° W of true north) by Pine Ridge and Chestnut Ridge respectively. Maximum relief of the ridges is approximately 300 ft. These ridges and valley are part of the White Oak Mountain (WOM) thrust sheet, which exposes Lower Cambrian to Ordovician rock units in the immediate area (Fig. 3.3). The stratigraphy of the area, from oldest to youngest (and exposed from grid-north to grid-south), includes the Lower Cambrian Rome Formation (exposed on Pine Ridge), the Cambrian Conasauga Group (exposed in BCV), and the Knox Group (exposed on Chestnut Ridge).

The Conasauga Group is further divided into six formations of alternating shale and carbonate-rich lithologies. From oldest to youngest these are the Pumpkin Valley Shale, the Rutledge Limestone, the Rogersville Shale, the Maryville Limestone, the Nolichucky Shale, and the Maynardville Limestone (Table 3.3). At the immediate headwaters of Bear Creek south of the S-3 Ponds, the creek bed lies in the upper Nolichucky Shale. Within 400 ft to

Fig. 3.3 Bedrock geology for DOE-ORR.

02-120192-107

Table 3.3. Stratigraphy of the Y-12 area

Age	Group or formation	Thickness ^a (ft)	General comments
Upper Cambrian- Lower Cambrian	Knox Group		Only the lowermost formation, the Copper Ridge Dolomite, occurs in the Y-12 area on Chestnut Ridge. This formation consists mainly of siliceous dolomites.
Cambrian	Conasauga Group Maynardville Limestone Nolichucky Shale Maryville Limestone ^b Rogersville Shale Rutledge Limestone ^c Pumpkin Valley Shale	410-440 490-540 380-400 100-120 100-120 320	This group underlies BCV. Bear Creek flows along strike with the Maynardville Limestone.
Lower Cambrian	Rome Formation		This formation is exposed on Pine Ridge and consists predominately of sandstones and sandy shales.

^aOnly thicknesses of the formations of the Conasauga Group at the Y-12 Plant are given.

^bCorrectly referenced in the Oak Ridge area as the Dismal Gap Formation.

^cCorrectly referenced in the Oak Ridge area as the Friendship Formation.

Source: Energy Systems 1991.

the southwest, the creek crosses the contact of the Nolichucky Shale-Maynardville Limestone and remains in the Maynardville Limestone along much of BCV, flowing roughly parallel to regional geologic strike (N55E).

West of State Route 95 (White Wing Road), Bear Creek cuts north through BCV and Pine Ridge into the relatively gentle topographic depression that separates McKinney Ridge to the southwest from East Fork Ridge to the northeast. This region includes the WOM thrust fault zone, which exposes several slices of the Cambrian Rome Formation, and the Kingston Thrust Sheet, which exposes slices of the Cambro-Ordovician Knox Group with overlying Ordovician Chickamauga Group strata.

3.4.1.1 Stratigraphy

The strata of greatest interest, with respect to contaminant migration in BCV groundwater, include the Maynardville and Nolichucky Formations of the Conasauga Group. For general descriptions of the stratigraphy of other units in the ORR, the reader is referred to Haase, Walls, and Farmer (1985) (Conasauga Group and Rome Formation), Lee and Ketelle (1987) (Knox Group), and Lee and Ketelle (1988) (Chickamauga Group).

Maynardville Limestone. (Shevenell et al. 1992) The Maynardville Limestone is the youngest formation of the Conasauga Group and consists primarily of light-gray to tan, massive to thinly bedded limestone with subordinate amounts of dolostone. Data obtained from the Maynardville Exit Pathway Monitoring Program demonstrate that on the ORR, the

Maynardville is more uniformly dolomitic and exhibits more subtle vertical lithologic differentiation than that described in the type section. In BCV, the Maynardville Formation varies in vertical thickness from 320 to 600 ft and intratigraphic thickness from 230 to 445 ft. The Exit Pathways Program subdivided the Maynardville into six different informal lithologic zones and identified a seventh zone to mark the transition between the Maynardville Limestone and the overlying Copper Ridge Dolomite. The zones were divided based on the gamma log signatures of the individual zones. The following discussion provides descriptions for each of the seven lithologic zones.

The transition zone (zone 7) represents the contact between the Cooper Ridge Dolomite and the Maynardville Limestone. The dolomitic zone is approximately 20-ft thick and contains lithologies that are characteristic of both the Copper Ridge Dolomite and the Maynardville Limestone. The contact is gradational and is marked by a sudden appearance of chert in the Copper Ridge Dolomite and the appearance of vugs in the uppermost Maynardville Limestone. Zone 6 is as a dolostone with coarsely crystalline saccharoidal texture and contains and increase in vugs. The zone has an average thickness of 100 ft. Zone 5 is characterized by the presence of thin shale stringers that occur throughout the approximately 54-ft zone. Zone 4 has an average thickness of 105 ft and is recognized as a massive, light colored medium to coarsely crystalline spartie, with subordinate amounts of oosparite. Zone 3 is 79-ft thick and characterized by an increase in mottling. It is described as a continuation of zone 4 with a fine to medium-crystalline, massive to slightly mottled sparite. Zone 2 is characterized by a change from a mottled, stylolitic micrite and oosparite to a finely crystalline light colored sparite exhibiting thin, discontinuous, wisp-like, shale partings. Although the thickness can vary considerably, the average thickness is approximately 150 ft.

In BCV, the Maynardville Limestone occurs on the northern flanks of Chestnut Ridge and extends into the valley axis. Much of the flow through the Maynardville Limestone is controlled by solutionally enlarged fractures and joint sets. Three major joint sets have been identified within the Maynardville Limestone: (1) approximately parallel to geologic strike and along bedding planes; (2) geologic strike N10W and dips steeply; (3) parallel to strike and perpendicular to bedding planes (Rothschild et al. 1984; Dreier et al. 1987). Dissolution along joint, fractures, and bedding planes in the Maynardville Limestone has formed solutionally enlarged zones, and in some cases, relatively large cavities that have greatly increased the overall permeability of the unit. The larger solution cavities generally occur in the upper part of the saturated zone. A combination of factors, such as structure, depth, and lithology, affect the fracture and water interval distribution in the Maynardville Limestone. However, the greatest likelihood of intersecting a cavity in the Maynardville Limestone occurs within zone 6, whereas zone 3 appears to be the least likely to contain cavities. Most of the cavities in zones 6 through 2 were located at depths of <100 ft, suggesting the active karst system may be relatively shallow in the Maynardville Limestone.

Nolichucky Shale (Foreman et al. 1991, King and Haase 1987; Rothschild et al. 1984). In BCV, the Nolichucky Shale ranges in thickness from 422 to 550 ft (King and Haase 1987). Intraclastic limestone, thick fossiliferous limestone, and oolitic limestone interbedded with fissile shale are characteristic of the Nolichucky Shale in the WOM thrust sheet (Lincoln et al. 1991). The Nolichucky Shale can be subdivided into four zones based on dominant lithologies: (1) thrombotic limestone overlying oolitic limestone and lime mudstone occurs in the uppermost Nolichucky; (2) laminated peloidal packstone, lime mudstone, and shale are the most abundant lithologies toward the top of the Nolichucky Shale; (3) allochthonous oolitic and skeletal packstone and grainstone interbedded with shale are the dominant

lithologies in the middle Nolichucky Shale; and (4) intraclastic limestone interbedded with shale and calcareous siltstone are the dominant lithologies in the lower Nolichucky Shale (Foreman et al. 1991). The formation is massive to very thinly bedded and is characterized by a maroon-brown color. The interbedded limestones typically contain limestone-pebble conglomerates and oolite-rich beds similar to those occurring in the underlying Dismal Gap Formation. Throughout much of the Nolichucky Shale, mudstone/shale and limestone lithologies alternate on a scale of 1 to 3 ft, giving the formation a thickly bedded appearance.

During drilling at the Y-12 Plant, solution cavities, opened fractures, and iron precipitate were commonly observed up to downhole depths of 50 ft (Rothschild et al. 1984). Comparison of Maynardville Limestone and Nolichucky Shale descriptions suggests the solution cavity development is not as extensive in the Nolichucky Shale as it is in the Maynardville Limestone.

3.4.1.2 Structural geology

Faults. Pine Ridge, BCV, and Chestnut Ridge all are part of the WOM thrust sheet, which is floored by the WOM thrust fault. The WOM fault is a regional thrust fault of the Valley and Ridge, which shows at least several kilometers of displacement. The fault formed during the Permian-Pennsylvanian Alleghanian Orogeny and has not been historically active. At the ORR, the fault trends parallel to regional strike (N55E) and dips steeply (45°) to the southeast (King and Haase 1987). Bedding plane dip values measured in outcrops cluster around 45° but may steepen to vertical as a result of localized small-scale folding or faulting.

The WOM thrust fault north of Pine Ridge is very complex and is characterized by a sequence of cross-cutting imbricate splay faults that repeatedly stack the Rome Formation. In the vicinity of Bear Creek, this fault superposes the Cambrian Rome Formation over the younger Cambrian Copper Ridge Dolomite member of the Knox Group. In addition, north of the WOM thrust fault, in the underlying Kingston thrust sheet, Bear Creek flows over slices of the Knox Group and Chickamauga Group that have been complexly stacked and rotated as a result of footwall deformation associated with displacement along the WOM fault. Because of the complex deformation associated with the WOM thrust fault and the immediately underlying Kingston sheet, it is anticipated that this region contains numerous fault-related fracture zones of enhanced permeability.

BCV is characterized by numerous cross-strike streams with a consistent northwestern trend. Such a consistent orientation suggests that the location of these creek beds is controlled by a geological structural feature, either a minor tear fault or a prominent fracture trend. Both features are possible, and in Melton Valley the White Oak Creek Tear Fault shows a similar north trend. If these structures are faults, they show minor displacement but should have an associated fracture zone.

Fractures. Because of the large-scale faulting, all geologic units in the ORR are highly fractured. Recent detailed investigations of Conasauga Group core by Lutz and Dreier (1988) show that five fracture sets occur consistently throughout the core. One set is parallel to bedding, but the other four are generally perpendicular to bedding. The parallel bedding fractures are mainly release joints. Recent studies elsewhere in the Appalachians suggest that release joints can form at depths up to a kilometer (Engelder 1985). Assuming a regional strike of N55E, the strikes of the high angle sets are approximately N55E, N75W, N15E, and N20W.

Fracture density varies throughout the cores. The two variables that have the greatest effect on density are lithology and bedding thickness. Density is inversely proportional to bedding thickness. High fracture densities are found in shales and interbedded limestone and shale, whereas limestones exhibit lower densities. Mineralization is almost entirely confined to limestone beds. All fracture sets exhibit vein development; however, the N55E direction is most commonly mineralized.

3.4.2 General Soil Characteristics

Bedrock units in BCV are overlain by unconsolidated deposits of varying thicknesses consisting of residuum, which comprises the majority of the unconsolidated materials, man-made fill, alluvium, and colluvium (Petrich et al. 1984). Soils of particular importance to BCV OU 4 are those characteristic of the Conasauga Group. These soils include, but are not limited to, the Armuchee, Fullerton, Greendale, Hamblen, Jefferson, Leadvale, Newark, and Sequoia. Depth to bedrock varies from less than 10 ft to 30 ft, with the Montevallo series being the most shallow (Lietzke, Lee, and Lambert 1988). In general, these soils are classed as poor for crop growth or pasture. With the exception of a few areas that are suitable for pasture, the general classification of Y-12 Plant soils is for forestry. In BCV the Armuchee and Sequoia soil series are most prevalent. The Armuchee is a shaley, silty clay loam becoming more shaley with depth, and the Sequoia is a yellowish-brown silt loam overlying a residuum of acid shale. Chemical and physical properties of these soils are given in Tables 4.2 and 4.3 in Vol. I of the General Document (Welch 1989).

3.5 SURFACE WATER AND GROUNDWATER

3.5.1 Introduction

A substantial amount of sampling/analytical data (surface water, groundwater, and soil/sediment) exists for BCHR. In addition to monitoring activities such as NPDES monitoring conducted by Y-12 Plant staff at BCK-4.55, the Y-12 Plant contracted monitoring work to Bechtel National Inc. in 1983-84 and to Roy Weston Inc. in 1985-86. ORNL has performed monitoring for Y-12 as part of the Ecological Characterization of Bear Creek Program and for special studies. K-25 (formerly ORGDP) also performed soil and groundwater sampling and analysis for the Y-12 Plant. The U.S. Geological Survey (USGS) has installed groundwater wells and stream monitoring stations in the Bear Creek watershed, and conducted water quality sampling and analysis at these and other sites in the watershed. Environmental staff from the TVA sampled and analyzed water, sediment, and aquatic biota from Bear Creek in 1984 as part of an evaluation of contaminant releases from the Oak Ridge DOE facilities.

Although the bulk of the environmental monitoring data has been collected since 1982, some limited historical data prior to 1982 are available. This section will summarize and evaluate environmental monitoring data relevant to developing this document. Most of the data presented here have been published or were summarized in previous reports (e.g., Turner et al. 1991).

In discussing surface water and groundwater data in subsequent sections, references will be made to health and environmental assessment criteria. These include regulatory as well as guidance and advisory type criteria. For example, maximum contaminant levels (MCLs)

promulgated under the Safe Drinking Water Act (SDWA) represent one type of assessment criteria for use when evaluating monitoring data for surface water and groundwater. Concentrations of contaminants that are acutely or chronically toxic to aquatic life are another type of assessment criteria. Background concentrations of contaminants in an area of study represent yet another type of criteria. To prepare this document, information on a variety of assessment criteria was assembled for the purpose of determining whether a given contaminant in a particular medium needed further investigation. The same health and environmental assessment criteria may be used in the risk assessment for Bear Creek shallow groundwater. Initially a comprehensive list of contaminants was prepared that represented all contaminants that have been reported to have been disposed of in Bear Creek watershed or that have been found in surface water and groundwater, soil, or sediment in Bear Creek watershed at levels equal to or greater than analytical detection limits. This list was then compared with lists of health and environmental criteria given in the December 1987 RCRA Facility Investigation Guidance, Volume I (EPA 1987b) and in various other documents. Contaminants that appeared on both lists (occurrence and criteria) were designated "chemicals of potential concern" (COPC) for Bear Creek and BCV shallow groundwater. The health and environmental criteria for the COPC for Bear Creek are summarized in Appendix F of Turner et al. (1991). Appendix G in Turner et al. (1991) summarizes local background concentrations of a variety of contaminants in surface water and sediment. These background data were collected at site NT-2 upstream of all waste facilities and at two sites, GCK-1.4 and GCK-2.4, in the Grassy Creek watershed, which represents the westward continuation of BCV after Bear Creek turns north through Pine Ridge (Fig. 3.4).

3.5.1.1 Y-12 Plant monitoring

Y-12 Plant staff have performed compliance and special monitoring at several sites in the Bear Creek watershed. The Bear Creek site at BCK-4.55 has been monitored for stream discharge and selected constituents under an NPDES permit since 1971. Some contaminants not on the NPDES permit have also been analyzed at this site as part of the radiological and PCB monitoring plans for the Y-12 Plant. NPDES monitoring of the effluent from the two Oil Retention Ponds in the Burial Grounds has also been conducted. In response to requirements of the Memorandum of Understanding signed on May 26, 1983, by DOE, EPA and TDEC, Y-12 Plant staff began weekly monitoring of a site in Upper Bear Creek (BCK-12.46) for a variety of water quality parameters in July 1983. When the "lagoons" located in Upper Bear Creek were excavated in summer 1988, Y-12 staff performed the characterization of both the material removed from the two lagoons, and that left behind in the two lagoons. Although others have performed most of the recent groundwater level and quality monitoring, Y-12 Plant staff have conducted some of this work. Y-12 Plant staff operate the local ambient air monitoring station (No. 8) at the eastern margin of the Bear Creek watershed, while others (ORNL) operate the perimeter air monitoring station near BCK-11.09.

Aside from some special studies with limited sampling, the Y-12 Plant staff have not routinely performed any soil or sediment monitoring in Bear Creek watershed. Instead, this responsibility has been delegated to contractors and staff from K-25 and ORNL.

Fig. 3.4. Location of previously sampled surface water monitoring sites.

3.5.1.2 ORNL monitoring

ORNL staff, mainly from the Environmental Sciences Division (ESD), but also from the Health and Safety Research Division and Energy Division, have performed a variety of environmental monitoring tasks and special investigations on behalf of the Y-12 Plant. ESD staff established and monitored 19 hydrologic monitoring sites on Bear Creek beginning in 1985. ESD staff collected sediment and/or floodplain soil samples in Bear Creek in 1982 (Van Winkle et al. 1984) and 1985 as part of the preliminary evaluation of the nature of contaminants in Bear Creek and East Fork Poplar Creek. Subsequently, ESD staff provided field oversight to the sampling of Bear Creek in 1985 and 1986 by Roy F. Weston, Inc. This included submission of aliquots of samples collected by Weston to be analyzed for PCBs, metals, and uranium to the ORNL Analytical Chemistry Division. ESD staff have also conducted the Bear Creek Ecological Characterization (Southworth et al. 1992).

3.5.1.3 USGS monitoring

USGS has conducted hydrologic monitoring of Bear Creek for several years. McMaster (1967) summarized some of the earliest data for monitoring sites in Bear Creek. Beginning in 1984 the USGS conducted several comprehensive surveys of stream discharge, specific-conductance, and selected water quality parameters in Bear Creek watershed. Results of these surveys have been published as Open File Reports of the USGS (Evaldi 1984; Pulliam 1985; Evaldi 1986) and in the Water Resources Data for Tennessee series of annual reports (1984-1987). Appendix E in Turner et al. (1991) tabulates the water quality data for Bear Creek. In addition to surface water investigations, the USGS has also installed a series of groundwater monitoring wells in Bear Creek watershed as part of a regional investigation of groundwater. Bailey and Withington (1988) recently described the USGS drilling effort. Limited chemical analyses for wells in BCV have been published in Water Resources Data for Tennessee (Lowery et al. 1987). Bailey and Lee (1991) have published the results of a groundwater flow model for BCV that incorporates shallow groundwater and surface water interaction along Bear Creek.

3.5.1.4 TVA monitoring

TVA conducted limited environmental sampling and analysis in Bear Creek in 1984 as part of the Oak Ridge Interagency Task Force evaluation of off-site contamination associated with the DOE facilities near Oak Ridge. The majority of the TVA analyses were related to mercury in East Fork Poplar Creek. However, 56 water samples, 15 sediment samples, and 26 aquatic biota samples were collected in Bear Creek. The TVA results are summarized in TVA (1986) and in Appendix E of Turner et al. (1991).

3.5.1.5 Contractor monitoring

Two large consulting companies (Bechtel National, Inc. and Roy F. Weston, Inc.) have undertaken extensive sampling and chemical analyses in BCV to characterize the nature and extent of contamination from waste disposal activities in the watershed. One additional contractor (Geraghty & Miller) has performed extensive evaluation of all extant data for Bear Creek watershed.

Bechtel National, Inc. installed numerous groundwater monitoring wells and conducted chemical monitoring of groundwater, surface water, soil, and sediment during the period

1983-84. Investigative and analytical methods employed by Bechtel are given in McCauley (1985d). Complete analytical results of the chemical monitoring are tabulated in McCauley (1985c), with analytical/QC data given in McCauley (1985b).

Roy F. Weston, Inc. conducted extensive monitoring of surface water, groundwater, and sediment in BCV in the period 1985-87. Sampling and analytical methods employed by Weston are described in Kimbrough (1987) and have conformed closely with EPA-approved methods. The complete results of the Weston monitoring have not been published in a comprehensive volume but are available in summary form in Turner et al. (1991). Limited results are published in topical reports (e.g., Southworth et al. 1992; Geraghty & Miller, Inc. 1987).

Geraghty & Miller, Inc. have prepared numerous reports characterizing groundwater, surface water, soil, and sediment in Bear Creek watershed. Geraghty & Miller, Inc. have also specified the locations and construction details for a number of monitoring wells in Bear Creek watershed and conducted special groundwater investigations.

3.5.1.6 Quality evaluation of extant monitoring data

Sampling and analytical methods for many environmental contaminants have been evolving rapidly over the past decade. Application of more rigorous sampling and analytical QA/QC protocols has also increased during this period. Both Bechtel National Inc. and Roy F. Weston Inc. generated extensive QA/QC data that accompany the environmental data in the large H&R Technical Associates computer data base. These data include results for trip blanks, field blanks, equipment rinsate blanks, process blanks, field duplicates, blind splits, matrix spikes, and standard reference materials. All analytical QA/QC data for the Bechtel National Inc. sampling campaigns have been tabulated in a report (McCauley 1985b). The analytical QA/QC data for the Roy F. Weston Inc. sampling campaigns have not been published.

Monitoring data generated by the Y-12 Plant, ORNL, and K-25 have also been collected under rigorous QA/QC protocols since about 1983. Field sampling and laboratory analytical procedures have been documented and controlled by written methods such as contained in the Energy Systems Environmental and Effluent Analysis Manual and in Methods and Procedures Utilized in Environmental Management Activities at ORNL as well as the methods given in *Test Methods for Evaluating Solid Waste* (EPA 1986) and *Methods for Chemical Analysis of Water and Wastes* (EPA 1979b). Each analytical laboratory and field sampling group has also been subjected to both internal and external audits. Annual environmental surveillance reports (e.g., ORNL 1986, Energy Systems 1987) have included summaries of QA/QC activities, including results of audits, interlaboratory comparisons, analyses of standard reference materials, and other performance checks. The summaries reflect a high quality effort and success in maintaining analytical performance at state-of-the-art levels.

As discussed subsequently, an important conclusion from the evaluation of the quality of environmental monitoring data for Bear Creek is the concordance of results among the various sampling and analytical groups who have performed monitoring in Bear Creek. Both the nature and concentrations of contaminants of concern have been similar regardless of which group performed the sampling and analyses. For example, uranium concentrations in Bear Creek surface water are reported consistently by Bechtel National Inc., Roy F. Weston

Inc., the USGS, the Y-12 Plant, and ORNL to occur at levels up to about 1.0 mg/L in the headwaters and to decrease to about 0.05 mg/L downstream.

The discussion above should not be taken to imply that no sampling or analytical problems have occurred during the extensive previous monitoring of Bear Creek and its floodplain. The formal and informal QA/QC protocols used by each investigative group have detected problems that were either corrected or the data flagged as suspicious.

3.5.1.7 Low-level waste disposal development and demonstration program

Environmental characterization of a site located in the western portion of BCV is being conducted as part of the Low-Level Waste Disposal Development and Demonstration (LLWDDD) Program. The site is located where Bear Creek turns north and flows through Pine Ridge. It is bounded by Bear Creek on the south and west, by Gum Hollow Road to the east, and by Pine Ridge to the north. The site is under consideration as the location of a future low-level waste disposal facility that would serve the three DOE plants on the ORR. The new facility will use advanced technology for the isolation of radioactive wastes. These technologies are being developed, with some being demonstrated at field scale.

The data collected under this initiative are presented and summarized in a data package (LLWDDD 1988) that will be used to generate the environmental impact statement for the future low-level waste disposal facilities.

Characterization is being coordinated by staff in the Energy Division, ORNL. As part of this activity, the USGS has collected stream flow discharge at five sites on Bear Creek and its tributaries starting from October 1, 1986 through October 1, 1990. Until recently (1991) measurements continued at three locations (two on Bear Creek and one on a tributary). In addition, the USGS has been collecting data at the monitoring site located at BCK-4.55 since March 1, 1985. Staff from the Environmental Monitoring and Compliance Division have conducted quarterly sampling of surface water at these six sites starting in December 1987.

Golder Associates, under subcontract to Energy Division, conducted geohydrologic characterization activities at the site. In Appendix G, Part 1, of LLWDDD (1988), drilling and well construction logs of 45 piezometers are presented. Four shallow (<100 ft) and nine bedrock (>100 ft) wells have been constructed on the Bear Creek floodplain. Three of these wells (GW443, GW467, GW468) were sampled for water quality starting December 1987. Sampling in these wells has been discontinued.

3.5.2 Surface Water Data

3.5.2.1 Introduction

Surface water in the Bear Creek watershed is affected by surface and subsurface drainage from waste burial grounds, the Oil Landfarm, the S-3 Ponds, construction-related land disturbances, and several large springs. These sources have contributed organic and inorganic chemical contaminants to Bear Creek. In recent years, actions have been taken to reduce the input of contaminants to Bear Creek from several of these sources, and several of these sources have been closed and capped. Intensive monitoring of stream chemistry was initiated at about the same time many of these actions were being taken (see Fig. 3.4).

3.5.2.2 Organic contaminants

Surface waters from Bear Creek and tributaries were analyzed for a broad spectrum of organic priority pollutants in 1983-1984 (McCauley 1985c). Further sampling conducted in 1985-1986 was restricted to mainstream Bear Creek. Only the VOCs were detected in the aqueous phase in the mainstream of Bear Creek. These compounds consist primarily of halogenated aliphatics and low molecular weight aromatics. Trace levels of PCE, toluene, and TCE were detected (about 10 $\mu\text{g/L}$ each) in the uppermost reaches of Bear Creek (BCK-12.36), while much higher levels of organics were detected farther downstream in the vicinity of the Burial Grounds. Trans-1,2-dichloroethene (trans-1,2-DCE), PCE, TCE, and vinyl chloride predominated, with traces of other halogenated aliphatics. Table 3.4 illustrates the summed concentrations (micrograms per liter) of VOCs in Bear Creek surface water at various sites. The results show the highest concentration of VOCs were detected at BCK-9.91. VOC concentrations decreased rapidly downstream from this site, undoubtedly caused by volatilization (Callahan et al. 1979). Concentrations generally dropped to about 5% of the level at BCK-9.91 within 0.5 km, and were always less than 10 $\mu\text{g/L}$ at BCK-7.87. Sources of the VOCs in this area are the Burial Grounds A-D, which are underlain by groundwater that is highly contaminated by VOCs and drained by tributaries (NT-7, NT-8) that are contaminated with VOCs to levels 10-20 times those observed in Bear Creek.

Table 3.4. Summed concentrations ($\mu\text{g/L}$) of volatile organic compounds in Bear Creek surface water at various sites

Site	Date						
	Sep 1983	Mar 1984	Aug 1984	Aug 1985	Jan 1986	May 1986	Sep 1986
BCK-12.39			<10	<10	<10	<10	<10
BCK-11.83			<10	<10	10	<10	<10
BCK-11.49	ND ^a	<10	ND	<10	<10	<10	
BCK-11.09	ND	ND			10		<10
BCK-10.32		ND		<10	<10		<10
BCK-9.91	1291	201	225	147	874	210	210
BCK-9.43	52	97	11	46	225	11	23
BCK-9.40				24	34	<10	12
BCK-7.87			<10	<10	<10	<10	<10
BCK-5.15				<10	<10	<10	<10
BCK-3.25				65 ^b	<10	<10	<10

^aNot detected.

^bCaused by methylene chloride, a likely laboratory contaminant.

Source: Turner et al. 1991.

The toxicities of VOCs to aquatic life are not extremely high. Listed toxicities in EPA water quality criteria indicate that acute toxicity has been observed at levels of 5-118 mg/L for these compounds. Acute toxicity was observed at 11.6 mg/L and 5.3 mg/L for DCE and PCE, respectively. Chronic effects were observed at 0.84 mg/L for PCE. Maximum concentrations of these compounds (which account for about 90% of total VOCs) in Bear Creek are thus about a factor of 4 below levels known to exhibit chronic toxicity. Levels of summed VOCs in sections of tributaries NT-7 and NT-8 exceeded 2-3 mg/L in March and August 1984. The high levels of VOCs observed at BCK-9.91 in September 1983 and January 1986, when tributaries were not sampled, suggest that levels of VOCs in NT-7 and/or NT-8 may have at times exceeded the observed levels by several fold. Recent measurements (Bogle and Turner 1991) of VOCs in the headwater seeps of NT-8 exceeded 3.5 mg/L (summed concentrations). The observed levels approach those known to produce acute toxicity in sensitive species, and could be chronically toxic to stream biota. Reduced survival and growth were observed in the toxicity tests conducted on water from NT-7 in October 1984 (Southworth 1992), but it is unlikely that VOCs were the cause of the toxicity, because they would be rapidly lost from the test solutions via volatilization.

3.5.2.3 Inorganic contaminants

Before the discontinuation of use and neutralization of the S-3 Ponds at the headwaters of Bear Creek, the upper reaches of the stream were acidic and highly enriched with many inorganic constituents (ERDA 1975; Turner and Kamp 1984; Y-12 HSEAD 1984). In 1974-75, upper Bear Creek (BCK-11.1, 11.9) exhibited pH values ranging from 3.5 to 6.8 over a 5-month period (ERDA 1975), while in 1981-83 a pH range of 3.9 to 7.5 was observed in reaches closer to the S-3 Ponds (BCK-12.1, 12.5) (Table 3.5). Before neutralization of the S-3 Ponds in summer 1983, upper Bear Creek (BCK-12.55) pH ranged from 4.0 to 4.5 during July-September (Y-12 HSEAD 1984). High levels of aluminum (more than 100 ppm) were noted in the acidified waters. The levels of acidity and aluminum observed before September 1983 are toxic to fish and sensitive aquatic invertebrates (Altshuler and Linthurst 1983), and would adversely affect the biotic community of Bear Creek. The acidity in the upper reaches of Bear Creek was neutralized as it was carried farther downstream. The limited historical data show nearly neutral pH below BCK-6.3 in the 1981-82 samples, and below BCK-4.3 in 1974-75 (Table 3.5). Neutral conditions probably existed much further upstream in 1974 (ERDA 1975). It is safe to assume that toxic conditions existed in upper Bear Creek before neutralization of the S-3 Ponds, and that this toxicity may have diminished within several kilometers downstream.

Profound changes in the chemistry of upper Bear Creek occurred following neutralization of the S-3 Ponds in 1983. Within several months, pH rose to more than 7.0, aluminum dropped from 97 mg/L to 4 mg/L, nitrate decreased from 1900 to 300 mg/L, uranium decreased from 21 to 1 mg/L, and other metals also declined significantly (Y-12 HSEAD 1984a,b). Intensive chemical and biological monitoring of the Bear Creek watershed was initiated after these changes took place.

Chemical analyses of Bear Creek surface waters since the S-3 Ponds were neutralized in 1983 have been conducted by Bechtel Inc. (McCauley 1985c), Roy F. Weston, Inc., [Appendix C, Turner et al. (1991) and summarized in Southworth et al. 1992], TVA (TVA 1986), USGS (Pulliam 1985), and ORNL (Southworth et al. 1992). These analyses show high concentrations of dissolved inorganic salts in the upper reaches of Bear Creek, typified by

Table 3.5. Mean pH (range in parentheses) of Bear Creek in three surveys conducted over a 10-year period

(Hydrogen ion concentrations were used in the calculation of mean pH)

Samples sites (BCK)	Sampling period/number of measurements	
	October–March 1974–75 ^a / 5 measurements	July–January 1983–84 ^b / 24 measurements
BCK-12.55	NS ^c	4.4 (4.0–4.6) ^d 6.7 (6.1–7.3) ^e
BCK-12.5	NS	NS
BCK-12.0	NS	NS
BCK-11.9	4.68 (3.50–5.09)	NS
BCK-11.1	6.32 (3.90–6.80)	NS
BCK-6.3	NS	NS
BCK-4.3	7.21 (6.95–7.58)	NS
BCK-1.8	7.12 (6.88–7.30)	NS

^aERDA 1975.

^bHSEAD 1984a,b.

^cNS = not sampled.

^dBefore September 29, 1983.

^eAfter September 29, 1983.

electrical conductivities of 2000–4000 $\mu\text{mho/cm}$ and total dissolved solids concentrations of 2000–5000 mg/L. Both of these concentrations are roughly 10- to 20-fold greater than values typical of reference sites. The contribution of solutes from the S-3 Ponds groundwater plume dominates the major ion inorganic chemistry of Bear Creek. The total salt content, as indexed by conductivity, closely follows the pattern expected if Bear Creek water was diluted only with uncontaminated groundwater downstream from BCK-12.4 (Table 3.6). Solute inputs and dilution vary as a result of variations in precipitation runoff and infiltration, with the highest solute concentrations generally occurring during periods of low flow.

Bear Creek surface water is highly enriched (relative to Grassy Creek reference sites) in many inorganic ions. The downstream variation in major ion chemistry is depicted in Table 3.7. Aluminum, barium, calcium, chloride, magnesium, manganese, nitrate, potassium, sodium, sulfate, strontium, and uranium are conspicuously high in the headwaters of Bear Creek, and decline gradually in concentration downstream. Table 3.7 indicates that nitrate concentrations are elevated between BCK-7.87 and BCK-9.91, which implies a hydrologic connection between nitrate sources at the S-3 ponds and this part of Bear Creek. The S-5 spring located at BCK-9.46 also shows the presence of S-3 Pond-associated contaminants. Analysis of historical data between BCK-7.87 and 9.91 to check the interconnections of Bear

Table 3.6. Dilution of upper Bear Creek solutes in Bear Creek
 (Data are mean $\pm$ s.d., n = 4 unless noted)

Site	Flow dilution ^a	Conductivity dilution ^b
BCK-12.36	1.0	1.0
BCK-11.83	0.58 $\pm$ 0.28	0.61 $\pm$ 0.27
BCK-11.49	0.21 $\pm$ 0.01 (n=2)	0.32 $\pm$ 0.08 (n=2)
BCK-11.09	0.43 $\pm$ 0.33 (n=2)	0.45 $\pm$ 0.44 (n=2)
BCK-10.32	0.35 $\pm$ 0.27 (n=3)	0.28 $\pm$ 0.28 (n=3)
BCK-9.91	0.15 $\pm$ 0.09	0.16 $\pm$ 0.04
BCK-9.43	0.15 $\pm$ 0.09	0.13 $\pm$ 0.05
BCK-9.40	0.12 $\pm$ 0.10	0.11 $\pm$ 0.06
BCK-7.87	0.09 $\pm$ 0.06	0.09 $\pm$ 0.05

^aDilution factor calculated from ratio of flow at BCK-12.36 to flow at other sites. Flow data from D. D. Huff, ORNL/ESD, for measurements made during 1985/1986.

^bDilution factor calculated from ratio of conductivity at Bear Creek sites minus 250 to conductivity at BCK-12.36 minus 250. Units are $\mu\text{mho/cm}$, 250 is the estimated conductivity of uncontaminated groundwater infiltrating Bear Creek. Conductivity measurements are from samples collected by Roy F. Weston, Inc, for chemical analysis, 1985-1986 (Turner et al. 1991).

Creek surface water with secondary nitrate sources is planned as part of this study. Lithium and boron are slightly elevated in the headwaters, but the highest levels occur below the burial grounds. Ammonia, beryllium, cadmium, cobalt, copper, lead, nickel, silver, and zinc are elevated in the uppermost reaches of Bear Creek, but decline to approximately control levels or below detection limits within a short distance downstream. A comparison of maximum concentrations in Bear and Grassy Creeks, reported toxicity values, and EPA water quality criteria for the protection of freshwater biota are presented in Table 3.8.

Table 3.7. Concentrations (mg/L) of major ions in unfiltered Bear Creek water
at various sites downstream from the S-3 Ponds

	Site									
	BCK-12-36	BCK-11-81	BCK-11-09	BCK-9-91	BCK-9-40	BCK-7-87	BCK-3-25	GCK-14-24		
Calcium	510 ± 68 (440 - 600)	305 ± 105 (200 - 440)	2701 (190 - 350)	18 ± 24 (83 - 130)	96 ± 24 (68 - 110)	95 ± 22 (66 - 120)	64 ± 20 (49 - 93)	33 ± 7 (26 - 42)		
Magnesium	69 ± 9 (61 - 82)	39 ± 17 (25 - 60)	39 (27 - 51)	22 ± 2.6 (19 - 25)	19 ± 2.6 (16 - 21)	18 ± 2.2 (16 - 21)	17 ± 2.6 (14 - 20)	14 ± 3 (9 - 17)		
Sodium	59 ± 10 (45 - 67)	37 ± 24 (19 - 72)	30 (18 - 43)	17 ± 1 (16 - 18)	12 ± 4.6 (8 - 17)	12 ± 4.1 (9.3 - 18)	7.8 ± 6.8 (4 - 18)	1.1 ± 0.8 ($<0.5-2.2$)		
Potassium	11.5 ± 2.2 (9.6 - 14)	7.3 ± 1.7 (6 - 9.2)	6.2 (4.3 - 8)	4.4 ± 0.2 (4.2 - 4.6)	3.1 ± 0.3 (2.8 - 3.4)	5.3 ± 2.5 (3 - 8)	2.3 ± 0.6 (1.8 - 3)	1.0 ± 0.3 (0.73 - 1.4)		
Manganese	4.4 ± 3.1 (1.4 - 8.8)	1.5 ± 1.4 ($<0.5-2.3$)	4.1 (1.5 - 6.6)	0.82 ± 0.29 ($<0.5-1.2$)	<0.5 <0.5	0.008 ($<0.5-0.008$)	0.023 ($<0.5-0.023$)	0.087 ($<0.5-0.087$)		
Aluminum	3.4 ± 2.5 ($<0.5-5.8$)	1.4 ± 0.79 ($<0.5-2.3$)	0.83 ($<0.5-0.83$)	0.90 ± 0.55 ($<0.5-1.7$)	0.53 ($<0.5-0.53$)	0.68 ± 0.29 ($<0.5-1.1$)	0.57 ± 0.08 ($<0.5-0.66$)	0.6 ($<0.5-0.6$)		
Strontium	1.3 ± 0.24 (0.97 - 1.5)	0.86 ± 0.40 (0.52 - 1.4)	0.81 (0.51 - 1.1)	0.31 ($<0.5-0.31$)	<0.5 <0.5	0.23 ($<0.5-0.23$)	0.18 (0.5 - 0.18)	0.059 ($<0.5-0.069$)		
Barium	0.83 ± 0.27 (0.57 - 1.2)	0.58 ± 0.26 (0.32 - 0.93)	0.58 (0.57 - 0.59)	0.25 ± 0.07 (0.19 - 0.34)	0.12 ± 0.09 (0.15 - 0.21)	0.17 ± 0.03 (0.15 - 0.20)	0.10 ± 0.05 (0.06 - 0.17)	0.06 ± 0.03 (0.03-0.11)		
Uranium ^b	0.51	0.58	0.48	0.16	0.15	0.14	0.10	---		
Nitrate	279 ± 121	161	72	4234 ±	1221 ±	1729 ±	128.0 ± 4.8	0.14 ± 0.14		
(NO ³ -N)	150 - 440	(82 - 240)	(38 - 46)	(23 - 50)	(5.8 - 40)	(14 - 43)	(2.4 - 14)	(0.04-0.39)		
Sulfate	65 ± 31 (21 - 86)	68 ± 15 (52 - 85)	64 (48 - 80)	37 ± 8 (25 - 44)	25 ± 5 (21 - 31)	36 ± 19 (21 - 64)	32 ± 5 (27 - 37)	<5 ($<5-6.4$)		

Table 3.7 (continued)

	Site							
	BCK-12.36	BCK-11.81	BCK-11.09	BCK-9.91	BCK-9.40	BCK-7.87	BCK-3.25	GCK-1.4,2,4
Chloride	123 ± 93 (69 - 230)	62 ± 19 (42 - 80)	41 (24 - 58)	82 ± 23 (56 - 100)	36 ± 22 (21 - 62)	32 ± 16 (22 - 51)	19 ± 15 (10 - 36)	<5 (<5 - 7.7)
Alkalinity (as CaCO ₃)	149 ± 86 (42 - 230)	156 ± 38 (120 - 210)	135 (120 - 190)	173 ± 21 (150 - 190)	260 ± 120 (140 - 380)	161 ± 21 (140 - 182)	145 ± 23 (120 - 165)	133 ± 23 (110 - 166)

^aValues are mean ± standard deviation, range in parentheses.

^bLow U results from January 1986 and May 1986 were excluded due to presumed inadequate digestion.

Source: McCauley 1985e, Y-12 HSEAD (Roy F. Weston, Inc.) data for August 1985, January 1986, May 1986, and September 1986 (ESD 1991).

Table 3.8. Maximum concentrations (mg/L), acute toxicity ranges, and water quality criteria for inorganic ions found at elevated levels in Bear Creek

Ion	Grassy Creek	Bear Creek	Acute toxicity (LC ₅₀)	Water quality criterion	Chronic screening criteria ^a
Aluminum	0.6	5.8	0.2-38.0	0.75	0.087
Ammonia	0.04	0.39		3.5 ^b	
Barium	0.044	1.2	13.5-105.0		
Boron	0.01	1.1	900.0		0.75
Cadmium	0.004	0.16	0.09-7.2	0.0011 ^c	
Calcium	42.0	600.0			
Chloride	7.4	230.0		860	230
Copper	0.02	0.04	0.014-1.0	0.012 ^c	
Fluoride	0.3	2.0			
Lead	0.1	0.4	1-482	0.0032 ^c	
Lithium	0.1	0.8			
Magnesium	17.0	82.0			
Manganese	0.087	8.8	1.5-1000.0		
Nickel	0.01	0.08	1.8-188.0	0.160 ^c	
Nitrate	0.6	440.0			
Potassium	0.9	14.0			
Silver	0.03	0.12	0.02-1.0	0.120 ^c	
Sodium	8.2	67.0			
Strontium	<0.5	1.5	86-10,000		
Sulfate	2.0	109.0			
Uranium	2.0	2.0	2.8-5.0		
Zinc	0.014	0.022	0.78-14.3	0.110 ^c	

^aEPA Region IV, to-be-considered guidelines.

^bpH 7, 25°C.

^cHardness dependent, to be calculated from site-specific data. (See Table 3.9.)

Sources: Southworth et al. 1992, EPA 1976, EPA Region IV 1992.

Hardness-dependent screening criteria for surface water will be calculated by using site-specific data for contaminant concentrations and hardness. The 5% lower-bound concentration of each contaminant will be used as a conservative screen. The equation to be used to calculate the screening criteria is presented in U.S. EPA Region IV guidance (1992):

$$\text{Screening Value} = \exp\{[a \times \ln(\text{Hardness})] + b\} ,$$

where hardness is expressed as mg CaCO₃/L. In the absence of hardness data, hardness will be estimated as

$$(\text{mg Ca/L}) \times 2.497 + (\text{mg Mg/L}) \times 4.116$$

(Standard Methods for the Examination of Water and Wastewater, Method 309A). The parameters *a* and *b* are specific for each element and are different for acute and chronic exposures. They are listed in Table 3.9.

Table 3.9 Parameters for hardness-dependent aquatic screening criteria

	Acute screening value		Chronic screening value	
	<i>a</i>	<i>b</i>	<i>a</i>	<i>b</i>
Cadmium	1.128	-3.826	0.7852	-3.49
Chromium III	0.019	3.698	0.819	1.561
Copper	0.9422	-1.464	0.8545	-1.463
Lead	1.273	-1.48	1.273	-4.703
Nickel	0.846	3.3612	0.746	1.1645
Silver	1.72	-6.52	<i>b</i>	<i>b</i>
Zinc	0.8473	0.9604	0.8473	0.7614

^aCalculated by the following equation:

Screening Value = $\exp\{[a \times \ln(\text{Hardness})] + b\}$, where hardness is expressed as mg CaCO₃/L.

^bNo criterion set.

Most of these inorganics are relatively nontoxic; many, such as calcium, magnesium, sodium, and sulfate are typical dissolved constituents of fresh waters. The pH of Bear Creek was generally between six and seven from late 1983-present. The high acidity noted before 1983 was not observed.

Toxicity tests were conducted in March 1988 on ambient Bear Creek water using both fathead minnows and *Ceriodaphnia dubia/affinis*. Water from the S-3 Ponds plume (from well GW-101, a highly contaminated well west of the S-3 ponds) was tested at the same time.

Concentrations of metals were determined in unfiltered water samples in order to include particle-reactive metals in the toxicity evaluation. Table 3.10 presents a summary of metals concentrations in water samples used in the test. The apparent toxicity of each water type was measured by the mortality rate of biota relative to controls. The concentrations of only a few metals (Cd, Co, Mn, and Ni) were found at higher concentrations in water causing *Ceriodaphnia* mortality than that found in nontoxic water. The levels of these were nevertheless low, and none could be considered to be present at known toxic concentrations (Table 3.10). Only cadmium was present in excess of its water quality criterion; however, it also exceeded the criterion in nontoxic water samples. The diluted (5%) GW-101 sample did not contain any of these metals at levels exceeding those in nontoxic Bear Creek water, but Ba, Ca, Mg, and Sr were higher in it than in nontoxic water from Bear Creek. Thus, while the toxicity of Bear Creek and S-3 plume water was clear, it was not possible to associate toxicity with any specific substance.

Aluminum concentrations in uppermost Bear Creek exceeded 4 ppm on numerous occasions in 1983 and 1984 following neutralization of the S-3 Ponds (Y-12 HSEAD 1984). These levels exceed the solubility of aluminum at pH 6-7. Precipitates rich in $\text{Al}(\text{OH})_3$ coat the stream bottom in the upper reaches of Bear Creek. Aluminum concentrations in natural waters at pH 7 commonly exceed the levels predicted by mineral equilibria, because of the formation of micro-colloids (Altshuller and Linthurst 1983). Groundwater in the vicinity of upper Bear Creek contains more than 10 ppm "dissolved" aluminum (Y-12 HSEAD 1984). Thus, it appears as though groundwater containing high levels of aluminum is migrating into the upper reaches of Bear Creek, where the pH rises and aluminum hydroxide polymerizes and precipitates. The toxicity of aluminum in uppermost Bear Creek is difficult to evaluate. Most studies have focused on the toxicity of aluminum in acidic waters, where it is highly toxic. At pH 6-7, while measured concentrations of aluminum may be high, much of it may be present as relatively inert particles. However, a study in which rainbow trout were exposed for 45 days to aluminum at 5.2 mg/L at pH 7 (conditions under which most of the aluminum was present as suspended particulates) resulted in high mortality and reduced growth. Exposure conditions in that study approximate conditions in the uppermost reaches of Bear Creek, suggesting that aluminum may be having a toxic effect on the stream biota. The relatively high levels of aluminum measured in Grassy Creek (~0.5 mg/L) suggest that suspended clay minerals may also be contributing to the observed aluminum concentrations in Bear Creek and Grassy Creek. Daily aluminum measurements of Bear Creek water for 1 week following a storm in March 1988 suggested a positive correlation between high suspended solids and measured aluminum concentrations. In August 1984, the maximum aluminum levels observed after neutralization of the S-3 Ponds occurred in Bear Creek. Concentrations decreased from 5.8 mg/L at BCK-12.36 to 1.2 mg/L at BCK-11.59. Concentrations remained about 1 mg/L downstream to BCK-5.15. While not a precipitous drop in concentration, the combination of dilution and conversion of aluminum to less toxic aluminum hydroxide polymers and aggregates would have reduced the toxicity, if any, present in the uppermost reaches.

Little pertinent toxicity data were found for manganese. Cited values in Table 3.10 refer to permanganate, a form not likely to be found in natural waters. Manganese is generally viewed as having low toxicity in aquatic systems (Altshuller and Linthurst 1983).

Table 3.10. Concentrations of metals (mg/L) in water from Bear Creek and the S-3 plume associated with toxicity to *Ceriodaphnia*^a

Metal	Max. toxic ^b	Min. toxic ^c	Max. nontoxic ^d	GW-101 ^e	Control ^f
Ag	0.008	0.003	0.009	<0.006	<0.006
Al ^{g,h}	1.1	0.09	0.14	0.02	<0.06
As	<0.06	<0.06	<0.06	<0.06	<0.06
B	<0.08	<0.08	<0.08	<0.08	<0.08
Ba	0.76	0.28	0.20	1.0	<0.002
Be	0.00077	0.00031	0.00036	0.00039	<0.0003
Ca	260.0	138.0	100.0	300.0	15.0
Cd ^h	0.014	0.0035	0.0021	0.0003	<0.0001
Co	0.0062	0.0024	<0.003	<0.003	<0.003
Cr	<0.006	<0.006	<0.006	<0.006	<0.006
Cu	<0.01	<0.01	<0.01	<0.01	<0.01
Fe	0.090	0.036	0.13	0.048	<0.02
Ga	<0.03	<0.03	<0.03	<0.03	<0.03
K	5.0	2.1	3.0	1.0	<0.1
Li	<0.2	<0.2	<0.2	<0.2	<0.2
Mg	32.0	16.0	16.0	29.0	0.4
Mn	3.4	0.8	0.45	0.20	0.006
Mo	<0.04	<0.04	<0.04	<0.04	<0.04
Na	13.0	5.2	15.0	14.0	1.4
Ni	0.074	0.018	<0.006	<0.006	<0.006
Pb	<0.05	<0.05	<0.05	<0.05	<0.05
Sb	<0.05	<0.05	<0.05	<0.05	<0.05
Se	<0.06	<0.06	<0.06	<0.06	<0.06
Sn	<0.05	<0.05	<0.05	<0.05	<0.05
Sr	0.67	0.27	0.30	1.3	0.05
Ti	<0.02	<0.02	<0.02	<0.02	<0.02
U ^h	0.21	0.08	0.32	0.0034	0.0006

Table 3.10 (continued)

Metal	Max. toxic ^b	Min. toxic ^c	Max. nontoxic ^d	GW-101 ^e	Control ^f
V	<0.02	<0.02	<0.02	<0.02	<0.02
Zn	0.020	<0.003	0.015	<0.003	<0.003

^aData are from March 16, 1988, when dissolved metal concentrations in creek were highest. Analyses by inductively coupled plasma (ICP) except where noted.

^bHighest concentration in a water sample in which *Ceriodaphnia* mortality was significantly higher than controls.

^cLowest concentration in a water sample in which *Ceriodaphnia* mortality was significantly higher than controls. Minimum toxic concentrations were estimated by multiplying the greatest dilution associated with toxicity by the metal concentration in the undiluted water sample.

^dHighest concentration in a water sample in which *Ceriodaphnia* mortality was not significantly different from controls.

^eS-3 plume water from well GW-101, diluted to 5%. No *Ceriodaphnia* mortality was associated with these concentrations; however, reduced fecundity was observed at 1/10 these concentrations.

^fControl water was a synthetic mixture used for toxicity tests, not uncontaminated stream or groundwater.

^gHigher levels of Al were observed on previous dates in association with turbid samples.

^hAl and Cd were analyzed by graphite furnace atomic absorption spectrophotometry; U by chemical separation and alpha spectrometry.

Source: Southworth et al. (1992).

Potentially, the most highly toxic constituents of Bear Creek surface waters are cadmium, copper, lead, nickel, silver, and zinc. These substances are elevated in upper Bear Creek sediments, and are found at levels close to detection limits in surface water. They presumably enter the stream in contaminated groundwater, and are sequestered by sediments and flocculated aluminum hydroxide upon dilution with stream water. As shown in Table 3.10, cadmium, copper, lead, and silver were found in upper Bear Creek at levels in excess of the EPA water quality criteria for the protection of aquatic life. The toxicity of these metals varies widely with species and water chemistry, and it is likely that the observed levels in Bear Creek are nontoxic to the biota inhabiting it. On the other hand, concentrations of cadmium, copper, lead, and silver are close enough to levels that produce toxicity to be possible causes of the toxicity seen in Bear Creek bioassays. The rapid downstream decrease in aqueous concentrations of these metals coincides with the decreased toxicity seen in bioassays. Arguing against this explanation, however, is the possible presence of suspended aluminum hydroxide, which is a highly effective sorbent for cations such as cadmium and copper. If the elevated levels of toxic cations are sequestered by colloids, they would be far less toxic.

Uranium concentration is elevated in Bear Creek, but is less than 2 mg/L at all sites. Uranium exhibits acute toxicity at approximately 3 ppm in very soft water, but is far less toxic (LC50 ca. 140 mg/L) in hard water such as is typical of Bear Creek.

The large spring (SS-5) at BCK-9.41 is contaminated with the same inorganics as Bear Creek, and this spring appears from dye tracer studies to be fed by water from a losing reach of Bear Creek above BCK-10.41. Levels of elevated metals and anions are about 17% to 33% of the levels seen in uppermost Bear Creek, except the sediment-accumulating metals such as cadmium, copper, nickel, lead, silver, and zinc. These metals are all below detection limits in the spring water. Spring SS-5 water was nontoxic in bioassays. The reduction in toxicity in comparison with upper Bear Creek water could be from removal of toxic metal ions during subsurface transport, or simply dilution with additional groundwater. Recent dye tracer studies have shown that springs SS-4 and SS-5 contain water originating from upper Bear Creek (Geraghty & Miller 1989).

Chemical analyses again prove inadequate to assess the toxicity of Bear Creek water. Depending on the toxicity criteria used, Bear Creek surface water can be estimated to be safe or toxic for aquatic life. The bioassays and instream faunal surveys provide a much better indication of the toxicity of Bear Creek water and can be a gauge for measuring improvement. Initial investigative studies, using bioassays, were not able to determine specific toxicants responsible for the observed bioassay toxicity.

3.5.2.4 Conclusions

Surface water in Bear Creek and those tributaries located in the Y-12 Plant waste disposal areas have been sampled extensively, and in some cases, intensively, since 1983. Virtually all sampling has been conducted under nonstorm flow conditions. The analyses performed have included both inorganic and organic contaminants and have typically been comprehensive, including in one case EPA Appendix IX contaminants. Results of these analyses suggest that nitrate, uranium, aluminum, and cadmium are the chief contaminants warranting human health and ecological concern. The concentrations of all these contaminants decrease downstream from the headwaters near the S-3 Ponds suggesting that the primary release to surface water is related to this source.

Given the extensive previous characterization of Bear Creek surface water by several agencies (Y-12 Plant, USGS, Roy F. Weston, Inc., Bechtel National, Inc., and TVA) and the general concordance of results, it seems likely that all contaminants of concern have been identified. However, previous work has not addressed either the locations of high contaminant input to surface waters (e.g., active spring) or storm flow transport of contaminants, either from the source areas or from historic deposits in the Bear Creek floodplain. Thus, the RI should include characterization of contaminant fluxes at active springs and storm flow contaminant transport.

3.5.3 Groundwater Data

One hundred ninety-five groundwater wells have been examined (out of more than 400 currently installed) in Bear Creek watershed. Most of these have been installed since 1983. As shown in Fig. 3.5, most of these wells have been installed in upper Bear Creek in the vicinity of the waste disposal facilities.

As discussed in Sect. 1.5, the scope of this phase of the BCV groundwater RI is limited to addressing data gaps that preclude evaluation of the primary remedial alternative. The issues of recharge of groundwater by Bear Creek along the losing reaches and groundwater migration of contaminants from the individual source areas is being addressed by the postclosure monitoring plans for these facilities, by the assessment and exit pathway monitoring for the BCHR under the Comprehensive Groundwater Monitoring Plan (Geraghty & Miller 1990) and this work plan.

For the purpose of developing the RI plan, only monitoring data from the 195 wells were reviewed. The available water level and water quality data for this subset of wells in the Bear Creek watershed are summarized and evaluated in this section.

3.5.3.1 Existing well information and descriptions

Information on location and construction details for the wells discussed in this document is available in *Updated Subsurface Data Base for Bear Creek Valley, Chestnut Ridge, and Parts of Bethel Valley on the U.S. Department of Energy Oak Ridge Reservation* (Jones et al. 1992).

3.5.3.2 Water level monitoring

Water level data are collected, at a minimum, each time monitoring wells are sampled as part of the Y-12 Plant compliance program. The results of water level measurements throughout BCV are summarized in the annual Groundwater Quality Assessment Report (GWQAR) (e.g., HSW Environmental Consultants 1992). Recent results reveal a groundwater piezometric surface (Fig. 3.6) sloping in from recharge areas on ridges to discharge along Bear Creek. The piezometric surface suggests a groundwater divide just east of the S-3 Ponds area as the eastern boundary of the BCHR.

In BCV several lines of evidence, including hydraulic and geochemical, support the contention that the void system within the Maynardville acts as a hydraulic drain (Fig. 3.7). Flow within the Maynardville appears to be along strike and down valley with significant interaction with Bear Creek surface water.

Fig. 3.5. Location of

- BEDROCK WELLS < 200'
- ABANDONED BEDROCK WELLS < 200'
- UNCONSOLIDATED WELLS
- ABANDONED UNCONSOLIDATED WELLS
- ▲ BEDROCK WELLS > 200'

TRIBUTARIES

Martin Marietta Energy Systems, Inc.
Environmental Management Department

FIGURE 3.5
LOCATION OF BEAR CREEK WELLS

Fig. 3.6. Groundwater elevations in the uncon-
Grounds to the Bear Creek S.3 site. (April 29 to

Fig. 3.7 Generalized cross-section of BCV showing inferred groundwater flow paths.

The majority of monitoring wells within BCV are screened either in unconsolidated material or weathered bedrock. Consequently, water level and hydrochemical data for these wells constitute the most appropriate information from which conclusions about the interaction between Bear Creek and the shallow groundwater flow system can be evaluated. Appendix A summarizes location and completion information for the wells used in preparation of this work plan.

Comparison of water levels within these monitoring wells with the elevation of the stream bed in the adjacent creek provides insight into the dynamics of the stream-groundwater system interaction. For many streams, water levels in nearby shallow monitoring wells lie above that of the stream, indicating that the stream is a site of discharge for the shallow groundwater system (i.e., a gaining stream). If the monitoring well water levels are less than that of the stream, the stream is a source of recharge to the groundwater system (i.e., a losing stream). For some streams, certain reaches may be gaining while others are losing. Furthermore, seasonal fluctuations in the water table can lead to periodic changes in the nature of stream-groundwater interaction such that a specific reach can be gaining during wet seasons and losing during dry periods.

Figure 3.8 shows a map of Bear Creek and its tributaries with the location of shallow floodplain monitoring wells. The signs in parentheses next to each well number indicate whether water level data from that well are suggestive of Bear Creek being locally gaining (+) or losing (-). The water level data used in this analysis consist nominally of weekly measurements collected over 6 months to several years. Except where noted, there is no indication of significant seasonal changes in the gaining or losing hydrologic properties of the stream.

Analysis of these water level data suggests that for a distance of approximately 1 mile downstream from its headwaters, Bear Creek is a site of groundwater discharge. From the vicinity of the Oil Landfarm westward to the Burial Grounds, Bear Creek appears to be a losing stream. Monitoring wells in the floodplain of Bear Creek near the western end of BCV where the stream turns northward to cross Pine Ridge appear to yield equivocal results. There is no clear tendency for the stream to be consistently gaining or losing along this reach. Further downstream, at the site of monitoring well GW-209 near Pine Ridge, evidence suggests a gaining reach for Bear Creek. The results of a dye tracer test (Geraghty & Miller 1989) suggest that most of the water discharging from spring SS-5 originates as water lost from Bear Creek channel between BCK-11.64 and BCK-9.41. Although a definitive conclusion could not be made for the origin of water discharging from spring SS-4, it appears likely that this water also is largely stream loss. In summary, most monitoring well water level data suggest gaining reaches near the headwaters and western sections of Bear Creek, with the remainder of stream probably constituting a losing reach.

3.5.3.3 Groundwater geochemistry

A calcium-magnesium-bicarbonate groundwater usually occurs in the unconsolidated zone and at shallow depths in the Conasauga Group shales and limestones. The calcium to magnesium molar ratio varies from approximately 5:1 to 1:1. Groundwater with low calcium to magnesium molar ratios generally occurs only in the Maynardville Limestone.

Fig. 3.8 Map showing location of shallow monitoring wells along Bear Creek with information on water levels.

Because a nearly equal molar ratio of calcium to magnesium is diagnostic of groundwater in contact with dolomite, the chemistry of the groundwater in the Maynardville may reflect the influence of the dolostone strata in the formation, a direct hydraulic connection with groundwater in the Copper Ridge Dolomite of the overlying Knox Group, or a combination of both.

The geochemistry of the groundwater in the shale formations of the Conasauga Group changes with depth. The calcium-magnesium-bicarbonate groundwater in the shallow bedrock abruptly changes to a sodium-bicarbonate type at depths of 85 to 100 ft below the ground surface. Deeper in the aquifer, typically more than 400 ft below ground surface, the sodium-bicarbonate groundwater grades to a sodium-chloride groundwater. These geochemical trends are accompanied by an increase in total dissolved solids (TDS) with depth. Similar changes in groundwater geochemistry in the Conasauga Group also are observed in Melton Valley.

The distinct changes in groundwater geochemistry that occur with depth in the shale formations of the Conasauga Group are generally not observed in the limestone formations. Virtually every well screened in the Conasauga Group limestones monitors calcium-magnesium-bicarbonate groundwater.

3.5.3.4 Extent of groundwater contamination

The principal constituents of concern in groundwater in the BCHR are trace metals, VOCs, nitrate, and radionuclides. Tables A.2 and A.3 in Appendix A give a summary of groundwater contamination data for wells in Bear Creek Valley from 1986 to 1992. The primary sources of VOCs in the BCHR are the S-3 Site, the Rust Spoil Area, the Oil Landfarm, and the Bear Creek Burial Grounds. The S-3 Site is the primary source of nitrates, metals, and radionuclides.

Trace Metals. As required by TDEC, the evaluation of groundwater and surface-water quality with respect to trace metals was based on total concentrations in unfiltered water samples. A different interpretation of water quality with respect to trace metals would result if the evaluation was based on dissolved metal concentrations in filtered water samples. Dissolved metal concentrations in groundwater exceed MCLs or screening levels far less frequently than total concentrations and generally occur only in groundwater samples from wells located within 500 ft of the S-3 Site. High concentrations of many metals, such as aluminum and iron, are probably the result of leaching of these metals from subsurface materials by acidic seepage from the S-3 site.

In 1991 total concentrations of barium, cadmium, chromium, lead, and mercury exceeded their respective MCLs in groundwater samples from one or more wells in the BCHR (see Table A.4 in Appendix A) (HSW 1992). Because the pH of the groundwater near the S-3 Site is acidic (usually less than 5.0), this is probably the only area in the BCHR where an actual "plume" of metal ions is present. Except for one well (GW-042) at the Burial Grounds, dissolved concentrations of barium, cadmium, chromium, and mercury exceeded MCLs only in groundwater samples collected from monitoring wells located near the S-3 Site. Few wells located elsewhere in the BCHR, where more neutral pH values prevail, consistently yield groundwater samples with total metal concentrations that exceed drinking-water standards.

A review of the 1991 data indicates that the elevated concentrations of uranium and strontium reported in 1991 may be indicative of groundwater contamination at sites in BCV (Table A.4). Elevated trace metal concentrations in samples from wells at other source sites in the BCHR probably do not reflect anthropogenic effects on groundwater quality. Typically only one of four samples taken in 1991 from many of the wells contained trace metal concentrations that were above the calculated screening levels. Results for some metals only slightly exceed their calculated screening levels. Many of the results for aluminum and iron that exceeded screening levels were probably artifacts of sampling (i.e., acidifying turbid samples), and results for other trace metals may be erroneous because of ICP analytical interferences caused by these unusually high aluminum and/or iron concentrations (HSW 1992).

Nitrate. Nitrate is a pervasive groundwater contaminant in the BCHR. Concentrations were highest in wells located near the S-3 Site: nitrate concentrations in the 1991 samples from well GW-243 averaged 7322 mg/L (Table A.5 in Appendix A). Downgradient of the S-3 Site, nitrate concentrations exceeding 10 mg/L occur only in groundwater in the Maynardville Limestone with the following two exceptions: in the Nolichucky Shale near the east side of the Oil Landfarm and in the unconsolidated zone by Bear Creek south of the Bear Creek Burial Grounds (HSW 1992).

The extent of the nitrate plume in groundwater in the unconsolidated zone is essentially defined by the existing monitoring well network. The plume extends from the S-3 Site to the west for about 1800 ft and then parallels Bear Creek for about 6000 ft downstream (Figs. 3.9 through 3.12).

About 3000 ft east of the S-3 Site, a lobe of the plume extending to the north of Bear Creek suggests that a second nitrate source area is located in the eastern section of the Oil Landfarm near unconsolidated zone well GW-537. Nitrate concentrations in samples collected from this well during 1991 averaged 1321 mg/L (Table A.5), 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 groundwater in the unconsolidated zone south of the Bear Creek Burial Grounds. The first quarter 1991 sample from well GW-052, which is located south of the site and about 100 ft north of Bear Creek, contained a nitrate concentration of 12 mg/L. Although the well was sampled only once during 1991 (it was dry during three sampling events), this result is consistent with historical data. Elevated nitrate concentrations in the well may indicate the presence of a local nitrate source area or may reflect hydraulic communication between the unconsolidated zone and Bear Creek.

Nitrate concentrations averaged 16 mg/L in the 1991 samples from Spring SS-4, which discharges groundwater to Bear Creek about 700 ft upstream of GW-052. Because Bear Creek loses flow to the groundwater system along the reach between the spring and the well (Geraghty & Miller 1989), it is possible that infiltration of surface water from Bear Creek locally affects groundwater quality in the unconsolidated zone. A hydraulic connection with Bear Creek also would be indicated if the occurrence of groundwater in GW-052 is related to flow conditions in the creek.

Fig. 3.9. Loc

<p>● BEDROCK MONITORING WELLS</p> <p>■ UNCONSOLIDATED MONITORING WELLS</p> <p>— CROSS-SECTION</p>	<p>Martin Marietta Energy Systems, Inc. Environmental Management Department</p> <p>FIGURE 3.9 LOCATION OF EXIT-PATHWAY CROSS-SECTIONS</p>
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Location of exit-pathway cross-sections.

Fig. 3.10 Nitrate in groundwater in the Maynardville Limestone.

Fig. 3.11 Cross-sections of nitrate plume in Maynardville/Knox groundwater.

Fig. 3.12 Nitrate in groundwater in the Bear Creek hydrogeologic regime.

Nitrate concentrations exceeded 10 mg/L in groundwater at shallow depths in the Nolichucky Shale for about 1600 ft along strike to the west of the S-3 Site. South of the S-3 Site, groundwater containing nitrate enters the Maynardville Limestone laterally along the contact with the Nolichucky Shale and vertically infiltrates from the unconsolidated zone. The nitrate plume at shallow depths in the Maynardville Limestone extends about 5000 ft west of the S-3 Site. Based on the data for well GW-085, a lobe of the nitrate plume extends northward across Bear Creek near the east-central section of the Oil Landfarm.

Nitrate concentrations in samples from well GW-085 averaged about 140 mg/L and were higher than the concentrations in samples from any other shallow bedrock well within 1000 ft. The data for well GW-085 may reflect transport of nitrate along strike from the source area near unconsolidated zone well GW-537.

In 1991 nitrate concentrations exceeded 10 mg/L in samples from shallow bedrock well GW-061 located south of the Bear Creek Burial Grounds (Table A.5). In this year nitrate concentrations did not exceed the MCL in samples from any other shallow bedrock well within several thousand feet of GW-061. Elevated nitrate concentrations in the well may indicate a local source area, infiltration of nitrate-contaminated groundwater in the unconsolidated zone near the well, or hydraulic communication with Bear Creek.

The nitrate plume in the deeper bedrock zones (>100 ft deep) extends much further to the west of the S-3 Site than in the shallow bedrock, particularly in the Maynardville Limestone, but concentrations in the deeper bedrock zones are generally less than that in the shallow bedrock. Monitoring well GW-615 is a notable exception. This is a 245-ft well completed in a stratigraphic interval in the Nolichucky Shale directly down-dip of the S-3 Site. Nitrate concentrations in 1991 groundwater samples from the well averaged 6758 mg/L and were considerably higher than the concentrations in samples from wells monitoring shallower intervals down-dip of the S-3 Site.

Nitrate concentrations exceeded the 10 mg/L MCL in groundwater samples from only one well greater than 300 ft deep: 66 mg/L in samples from well GW-601 located south of the Oil Landfarm. This monitoring well is completed in the Maynardville Limestone at a depth of 302 ft. Elevated nitrate concentrations in the samples from GW-601 suggest either substantial down-dip migration in the Maynardville Limestone south of the Oil Landfarm, along-strike migration at depth in the Maynardville from south (down-dip) of the S-3 Site, or a combination of both migration pathways.

Volatile Organic Compounds. Previous monitoring results have shown that VOCs are pervasive in groundwater in the BCHR and that each source site in the regime is a possible source area (Fig. 3.13).

The primary components of the VOC plumes in the BCHR are PCE, TCE, 1,2-DCE, 1,1,1-trichloroethane (1,1,1-TCA), and 1,1-dichloroethane (1,1-DCA). Acetone and chloroform are also present but generally only in groundwater near the S-3 Site. The types of VOCs detected in groundwater at varying depths are similar at each site, but some vertical segregation of VOCs is evident at the Oil Landfarm. The VOC plume in the unconsolidated zone at this site typically contains higher proportions of 1,2-DCE, PCE, and 1,1-DCA than

Fig. 3.13 Distribution of VOCs in groundwater associated with S-3 Ponds, Oil Landfarm, and Burial Ground source areas.
(HSW Environmental Consultants, 1992)

the plume in the bedrock. TCE makes up between 30% and 50% of summed VOC concentrations in samples from bedrock wells at the site, but rarely more than 10% of summed VOC concentrations in samples from the unconsolidated zone wells.

Summed VOC concentrations were highest in groundwater near the Bear Creek Burial Grounds, exceeding 10,000 $\mu\text{g/L}$ in samples collected from unconsolidated zone wells next to waste trenches and in bedrock wells located along the southern boundary of the site where DNAPLs were discovered in 1989. The DNAPLs were encountered about 270 ft below the site and were found to consist primarily of PCE, TCE, and 1,1,1-TCA, with high concentrations (19,000 $\mu\text{g/L}$) of PCBs (Haase and King 1990). Elsewhere in the BCHR, summed VOC concentrations are typically less than 1000 $\mu\text{g/L}$ (see Table A.6 in Appendix A). Summed VOC concentrations in groundwater at the primary source areas have remained relatively constant since 1990 (HSW 1991, 1992).

Groundwater in the unconsolidated zone underlying each source site in the BCHR contains VOCs, but the plume boundaries generally occur within 1000 ft of the site. Data obtained during 1991 confirm the lateral plume migration at the Burial Grounds indicated by 1990 data for wells GW-053 and GW-089. No VOCs were detected in samples collected from either well before 1990, but the samples collected that year contained summed average VOC concentrations of 72 $\mu\text{g/L}$ and 40 $\mu\text{g/L}$, respectively.

Two separate dissolved VOC plumes are evident in groundwater in the shallow bedrock (<100 ft deep); one in the Nolichucky Shale underlying the Bear Creek Burial Grounds and one extending from the S-3 Site south into the Maynardville Limestone and west along strike to just past the Oil Landfarm. Dissolved VOCs in groundwater at depths below 200 ft occur primarily near the southern portion of the Burial Grounds. Several monitoring wells (GW-623, GW-625, and GW-628) were installed at depths of 200 to 300 ft during the DNAPL investigation at the site, and samples from these wells contain VOC concentrations in excess of 10,000 $\mu\text{g/L}$ (Table A.6). These wells and several others generally define a VOC plume that appears to be confined to the Nolichucky Shale down-dip of the site.

Data for several monitoring wells suggest that the dissolved VOC plumes in the BCHR extend more than 300 ft below the ground surface. Movement of VOCs into the deep bedrock underlying the S-3 Site is illustrated by VOC concentrations in samples from monitoring wells GW-243, GW-615, and GW-125 (Fig. 3.14). Acetone is the primary compound in the samples from the wells, and the acetone concentrations steadily decrease with depth from 950 $\mu\text{g/L}$ in shallow bedrock well GW-243 to about 120 $\mu\text{g/L}$ in intermediate depth bedrock well GW-615 to 11.5 $\mu\text{g/L}$ in deep bedrock well GW-125.

Down-dip migration of VOCs near the Oil Landfarm is suggested by data reported for monitoring well GW-601. The groundwater samples collected from this well in 1991 contained an average TCE concentration of about 162 $\mu\text{g/L}$ (Table A.6). This is a 356-ft-deep well completed in the Maynardville Limestone, and the presence of TCE in the well suggests down-dip migration of a predominately TCE plume that is present in groundwater at shallower depths in the Maynardville.

Fig. 3.14 Vertical extent of VOCs in groundwater near the S-3 site and spoil area 1.

Data obtained from wells GW-117 and GW-119 show that low concentrations (less than 20 µg/L) of PCE and 1,1-DCE are present below 500 ft in the Nolichucky Shale down-dip of the disposal areas at the Bear Creek Burial Grounds.

Radioactivity. Radioactivity is a groundwater contaminant in shallow groundwater in the BCHR. Contamination is highest in wells located near the S-3 Site; 1991 samples from well GW-243 averaged 10,115 pCi/L and 45,068 pCi/L for gross alpha and gross beta activity, respectively (see Tables A.7 and A.8 in Appendix A) (Figs. 3.15 and 3.16). The primary alpha emitting radionuclides in the groundwater in the BCHR are most likely isotopes of uranium (^{234}U , ^{235}U , and ^{238}U); total uranium concentrations exceeded the 0.01 mg/L screening level in every well with elevated gross alpha activity except exit-pathway wells GW-710 and GW-711 (see Tables A.4 and A.7 in Appendix A). Data obtained during 1989 showed that isotopes of radium (^{223}Ra , ^{224}Ra , ^{226}Ra), neptunium (^{237}Np), and americium (^{241}Am) also may contribute to the gross alpha activity in groundwater near the S-3 Site (Geraghty & Miller 1990). Technetium (^{99}Tc) has been identified as the primary beta emitting radionuclide present in the groundwater in the BCHR, although strontium (^{90}Sr) and tritium (^3H) also may contribute to gross beta activity in groundwater at the S-3 Site (Geraghty & Miller 1990) (Table A.8).

3.5.3.5 Historical data analysis

Recently, Moore and Toran (1992) have investigated the possibility that, following the closure of the S-3 Ponds, the shallow groundwater and surface water system near the Bear Creek headwaters would be naturally flushed of contaminants and show a temporal decrease in contaminant concentrations. They used the groundwater monitoring data from two water table wells near the S-3 Ponds to illustrate an exponential decrease in nitrate concentrations beginning in mid-1987 (Fig. 3.17). Data from other monitoring wells do not support the natural flushing hypothesis. However, Moore and Toran suggest that purging associated with the sampling process in Nolichucky wells, where samples represent a mixture of waters from fractures that are more or less influenced by contaminant diffusion from intervening matrix, may obscure any trends in the data.

The natural flushing hypothesis is supported by historical data from a headwater stream location (BCK-11.97) when samples were screened to select those that were most representative of undiluted groundwater discharge. Moore and Toran found decreasing concentrations (Fig. 3.18) of major elements (e.g., Ca, Mg, Al) associated with acid leaching of the rocks as well as decreasing concentrations of constituents associated with the waste disposal (nitrate, U).

Additional support for the hypothesis is found in the historical resurgence of fish populations within Bear Creek (Southworth et al. 1992). Their analysis of data from 1984 through 1988 showed that fish populations were returning to the headwaters of Bear Creek after a long absence. Their data for macroinvertebrate populations in the stream bed did not show a similar trend through 1988.

Fig. 3.15 Gross alpha activity in groundwater in the Bear Creek hydrogeologic regime.

Fig. 3.16 Gross beta activity in groundwater in the Bear Creek hydrogeologic regime.

Fig. 3.17 Average normalized concentrations of nitrate as nitrogen in GW-106 and GW-276.

Fig. 3.18 Graph of average normalized concentrations for major constituents in Bear Creek.

3.5.3.6 Conclusions

Extensive groundwater sampling throughout BCV has revealed contaminant plumes emanating from the headwater source areas. The primary contaminant source appears to be the S-3 Ponds with a groundwater plume characterized by nitrate, VOCs, metals, and uranium. Detectable concentrations (and thus suggestive of contamination) of nitrate, a relatively mobile anion, are found down valley and generally define the horizontal extent of the plume. Secondary plumes of contaminants (primarily VOCs) are associated with the Oil Landfarm and the Burial Grounds.

With the possible exceptions of contaminants associated with the S-3 Ponds and DNAPLs associated with the Burial Grounds, the bulk of groundwater contamination is confined to the relatively shallow water table and bedrock groundwater system. Most contaminant source areas overlie Nolichucky soils and bedrock. Migration of some contaminants (e.g., metals) within the Nolichucky appears to be retarded. Downvalley transport of contaminant plumes is apparently controlled by more active conduit flow within the Maynardville and interactions between Maynardville groundwater and Bear Creek surface water.

Preliminary analyses of historical groundwater and surface water quality data suggest that source area controls (e.g., RCRA caps) are producing measurable decreases in contaminant concentrations. Verification of these results will require additional analysis of groundwater and surface water quality data from monitoring points that are demonstrably connected to the actively flowing portion of the groundwater system.

3.6 ECOLOGY

Ecological studies of the Bear Creek watershed were initiated in May 1984 and are continuing at the present time. A summary of the results of the sampling conducted from May 1984 through early 1990 are presented in Southworth et al. (1992). These studies consisted of an initial detailed characterization of the benthic invertebrate and fish communities in Bear Creek, followed by an ongoing monitoring phase (Fig. 3.19) with reduced sampling intensities. The characterization phase used two approaches: (1) instream sampling of benthic invertebrate and fish communities in Bear Creek to identify spatial and temporal patterns in distribution and abundance, and (2) laboratory bioassays of water samples from Bear Creek and selected tributaries to identify potential sources of toxicity to biota. The monitoring phase of the ecological program relates to the long-term goal of identifying and prioritizing contaminant sources and assessing the effectiveness of remedial actions. It continues activities of the characterization phase at less frequent intervals.

3.6.1 Flora

Vegetation in the Bear Creek watershed is predominantly oak, oak-hickory associations on the upper slopes and ridgetops, and planted pine along the creek and floodplain area. Pine Ridge is generally an oak, oak-hickory association with chestnut oak, red oak, tulip poplar, white oak, and hickory as the dominant species. The lower areas along Bear Creek and Bear Creek Road are mainly planted loblolly pine with some scattered areas of planted shortleaf,

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Fig. 3.19 Locations of existing biological monitoring sites.

natural pine, and oak-hickory communities. Also of interest is a large area of big bluestem grass that grows along Bear Creek Road. Large stands of this species are uncommon in east Tennessee. Plant communities in Bear Creek are depicted in Fig. 3.20 as components of the general plant communities found on the ORR (Welch 1989). This site is being considered as a National Environmental Research Park (NERP) Reference Area. More detailed information is available for portions of the Bear Creek watershed area in forest compartment maps and various documents (Bradburn and Rosenbalm 1984; Parr and Pounds 1987). Table 3.11 contains a listing of flora and fauna found within the ORR.

3.6.1.1 Rare plant species

Two areas contain rare plant populations, and these have been designated NERP Natural Areas. The Canada lily, *Lilium canadense*, occurs in NERP Natural Area 13 at the base of Pine Ridge. It grows along the forested edges of the powerline right-of-way in the drainage area. This plant species is state-listed as threatened. The other site, NERP Natural Area 4, contains the southern rein orchid, *Platanthera flava*. This is forested area with numerous wetlands around seeps and contains old stream or flood channels. An uncommon aquatic plant, *Orontium aquaticum*, occurs here also. The southern rein orchid is state-listed as a species of special concern. The site has also been registered as a State Natural Area in an agreement between DOE and the TDEC (Howell 1986).

3.6.2 Terrestrial Fauna

BCV OU 4 contains elements of the majority of wildlife habitat types found on the ORR (Fig. 3.21 and Table 3.11), and, therefore, the expected terrestrial fauna is that described for the entire reservation (Welch 1989).

Hardwood and mixed hardwood/conifer habitats compose the most abundant habitat types in Bear Creek watershed, followed by pine plantation and grassland habitats, with considerable riparian habitat along the length of Bear Creek. Species commonly found in these habitats are listed below.

Old-field and grassland habitat. In the grassland/forb stage of vegetation, the principal species of small mammals are the southeastern shrew, least shrew, short-tailed shrew, eastern harvest mouse, hispid cotton rat, pine mouse, and the eastern cottontail rabbit. The eastern mole occurs in areas of loose soil. Closely mowed or grazed areas and dense kudzu growth is good habitat for the groundhog. Also found there are the striped skunk, coyote, red fox, and white-tailed deer. In more brushy vegetation, the white-footed mouse, golden mouse, and opossum may be found. Bird species found in this habitat include bobwhite, red-tailed hawk, field sparrow, towhee, blue grosbeak, meadowlark, and red-winged blackbird. The eastern bluebird population has increased with the establishment of bluebird nesting boxes. The yellow-breasted chat is found in old fields. Numerous frog, toad, lizard, and snake species are found in the old-field areas.

Hardwood and mixed hardwood/conifer habitats. In wooded areas the eastern gray and southern flying squirrels, southeastern shrew, eastern mole, short-tailed shrew, white-footed mouse, white-tailed deer, and eastern chipmunk may be found. Predators such as the bobcat

General Vegetative Cover

LEGEND

	PINE-PINE-HARDWOOD FORESTS		BOTTOMLAND HARDWOOD FOREST
	CEDAR, CEDAR-PINE, AND CEDAR-HARDWOOD FOREST		NORTHERN HARDWOOD FOREST
	OAK-HICKORY FOREST		GRASSLAND, DEVEGETATED AREAS, AND CULTURAL FEATURES

2-040982-099

Fig. 3.20 General vegetation cover types on the ORR (from DOE-ORO 1980).

Table 3.11. Flora and fauna found within the ORR

Common Name	Scientific Name
<i>Flora</i>	
American chestnut	<i>Castanea dentata</i>
Northern red oak	<i>Quercus borealis</i>
Chestnut oak	<i>Q. prinus</i>
Yellow Poplar	<i>Liriodendron tulipifera</i>
Shortleaf pine	<i>Pinus echinata</i>
Virginia pine	<i>P. virginiana</i>
Beech	<i>Fagus grandifolia</i>
Sugar maple	<i>Acer saccharum</i>
Magnolia	<i>Magnolia acuminata and M. tripetala</i>
Buckeye	<i>Aesculus glabra</i>
Willow	<i>Salix sp.</i>
Willow	<i>Salix sp.</i>
Sycamore	<i>Platanus occidentalis</i>
Boxelder	<i>Acer negundo</i>
Loblolly pine	<i>Pinus taeda</i>
Hickory	<i>Carya sp.</i>
Hemlock	<i>Tsuga canadensis</i>
White pine	<i>Pinus strobus</i>
Eastern red cedar	<i>Juniperus virginianus</i>
Redbud	<i>Cercis canadensis</i>
Sassafras	<i>Sassafras albidum</i>
Cottonwood	<i>Populus deltoides</i>
Elm	<i>Ulmus sp.</i>
Ash	<i>Fraxinus sp.</i>
Silver maple	<i>Acer saccharinum</i>
River birch	<i>Betula nigra</i>
White oak	<i>Quercus alba</i>
Black oak	<i>Q. velutina</i>
Scarlet oak	<i>Q. coccinea</i>
Post oak	<i>Q. stellata</i>
Black gum	<i>Nussa sylvatica</i>

Table 3.11 (continued)

Common Name	Scientific Name
Dogwood	<i>Cornus florida</i>
Basswood	<i>Tilia americana</i>
Bluestem	<i>Andropogon sp.</i>
Bluegrass	<i>Poa sp.</i>
Orchard grass	<i>Dactylis glomerata</i>
Ragweed	<i>Ambrosia artemisifolia</i>
Crabgrass	<i>Digitaria sp.</i>
Horse weed	<i>Conyza canadensis</i>
Primrose	<i>Oenothera sp.</i>
Honeysuckle	<i>Lonicera japonica</i>
Broomsedge	<i>Andropogon virginicus</i>
Trumpet creeper	<i>Campsis radicans</i>
Sumac	<i>Rhus typhina</i> and <i>R. copallina</i>
Persimmon	<i>Diospyros virginiana</i>
White poplar	<i>Populus alba</i>
Watercress	<i>Nasturtium sp.</i>
Cattail	<i>Typha sp.</i>
Mammals	
Little Brown Bat	<i>Myotis lucifungus</i>
Keen's bat	<i>Myotis keenii</i>
Silver-haired bat	<i>Lasionycteris noctivagans</i>
Eastern pipistrelle	<i>Pipistrellus subflavus</i>
Big brown bat	<i>Eptesicus fuscus</i>
Red bat	<i>Lasiurus borealis</i>
Hoary bat	<i>Lasiurus cinereus</i>
Virginia opossum	<i>Didelphis virginiana</i>
Least shrew	<i>Cryptotis parva</i>
Southeastern shrew	<i>Sorex longirostis</i>
Short-tailed shrew	<i>Blarina brevicauda</i>
Southern short-tailed shrew	<i>B. carolinensis</i>
Gray bat	<i>Myotis grisescens</i>
Indiana bat	<i>M. sodalis</i>

Table 3.11 (continued)

Common Name	Scientific Name
Eastern cottontail	<i>Sylvilagus floridanus</i>
Eastern chipmunk	<i>Tamias striatus</i>
Gray squirrel	<i>Sciurus carolinensis</i>
Fox squirrel	<i>S. niger</i>
Southern flying squirrel	<i>Glaucomys Volans</i>
Marsh rice rat	<i>Oryzomys palustris</i>
Cotton rat	<i>Sigmodon hispidus</i>
Norway rat	<i>Rattus norvegicos</i>
White-footed mouse	<i>Peromyscus leucopus</i>
House mouse	<i>Mus musculus</i>
Cotton mouse	<i>P. gossypinus</i>
Golden mouse	<i>Ochrotomys nuttali</i>
Eastern harvest mouse	<i>Reithrodontomy shumulis</i>
Woodland (Pine) vole	<i>Microtus opimetrosum</i>
Eastern mole	<i>Scalopus aquaticus</i>
Muskrat	<i>Ondatra zibethica</i>
Red fox	<i>Vulpes vulpes</i>
Gray fox	<i>Urocyon cinereoargenteus</i>
Coyote	<i>Canis latrans</i>
Black bear	<i>Ursus americanus</i>
Ground hog	<i>Marmota monax</i>
Raccoon	<i>Procyon lotor</i>
Striped skunk	<i>Mephitis mephitis</i>
Eastern spotted skunk	<i>Spilogale putorius</i>
Long-tailed weasel	<i>Mustela frenata</i>
Mink	<i>Mustela vison</i>
Beaver	<i>Castor canadensis</i>
Mountain lion (eastern cougar)	<i>Felis concolor</i>
Bobcat	<i>Lynx rufus</i>
White-tailed deer	<i>Odocoileus virginianus</i>
Birds	
Sharp-shinned hawk	<i>Accipiter striatus</i>

Table 3.11 (continued)

Common Name	Scientific Name
Cooper's hawk	<i>A. cooperii</i>
Red-shouldered hawk	<i>Buteo lineatus</i>
Broad-winged hawk	<i>B. platypterus</i>
Southern bald eagle	<i>Haliaeetus l. leucocephalus</i>
Marsh hawk	<i>Circus cyaneus</i>
Osprey	<i>Pandion haliaetus</i>
Peregrine falcon	<i>Falco peregrinus</i>
Ruffed grouse	<i>Bonasa umbellus</i>
Bobwhite	<i>Colinus virginianus</i>
Turkey	<i>Meleagris gallopavo</i>
Mourning dove	<i>Zenaida macroura</i>
Common (yellow-shafted) flicker	<i>Colaptes auratus</i>
Red-bellied woodpecker	<i>Melanerpes carolinus</i>
Hairy woodpecker	<i>Picoides villosus</i>
Downy woodpecker	<i>P. pubescens</i>
Red-cockaded woodpecker	<i>P. borealis</i>
Blue jay	<i>Cyanocitta cristata</i>
Common crow	<i>Corvus brachyrhynchos</i>
Carolina chickadee	<i>Parus carolinensis</i>
Tufted titmouse	<i>P. bicolor</i>
Bewick's wren	<i>Thryomanes bewickii</i>
Wood thrush	<i>Hylocichla mustelina</i>
Red-eyed vireo	<i>Vireo olivaceus</i>
Pine warbler	<i>Dendrocia pinus</i>
Ovenbird	<i>Seiurus aurocapillus</i>
Kentucky warbler	<i>Oporornis formosus</i>
Yellow-breasted chat	<i>Icteria virens</i>
Scarlet tanager	<i>Piranga olivacea</i>
Summer tanager	<i>P. rubra</i>
Cardinal	<i>Cardinalis cardinalis</i>
Rufous-sided towhee	<i>Pipilo erythrophthalmus</i>
Grasshopper sparrow	<i>Ammodramus savannarum</i>

Table 3.11 (continued)

Common Name	Scientific Name
Bachman's sparrow	<i>Aimophila aestivalis</i>
White-throated sparrow	<i>Zonotrichia albicollis</i>
Reptiles and amphibians	
Eastern narrowmouth toad	<i>Gastrophryne carolinensis</i>
Northern cricket frog	<i>Acris crepitans</i>
Spring peeper	<i>Hyla crucifer</i>
Gray treefrog	<i>Hyla versicolor</i>
Upland chorus frog	<i>Pseudacris triseriata</i>
Bullfrog	<i>Rana catesbeiana</i>
Green frog	<i>Rana clamitans</i>
Pickerel frog	<i>Rana palustris</i>
Southern leopard frog	<i>Rana sphenoccephala</i>
American toad	<i>bufo americanus</i>
Fowler's toad	<i>B. woodhousei</i>
Hellbender	<i>Cryptobranchus alleganensis</i>
Northern dusky salamander	<i>Desmognathus fuscus</i>
Red-spotted newt	<i>Notophthalmus viridescens</i>
Tennessee cave salamander	<i>Gyrinophilus pallescens</i>
Mudpuppy	<i>Necturus maculosus</i>
Red-backed salamander	<i>Plethodon cinereus</i>
Slimy salamander	<i>P. glutinosus</i>
Northern red salamander	<i>Pseudotriton r. tuber</i>
Spotted salamander	<i>Ambystoma maculatum</i>
Marbled salamander	<i>Ambystoma opacum</i>
Two-lined salamander	<i>Eurycea bislineata</i>
Spring salamander	<i>Gyrinophilus porphyriticus</i>
Mud salamander	<i>Pseudotriton montanus</i>
Snapping turtle	<i>Chelydra serpentina</i>
Map turtle	<i>Graptemys geographica</i>
Eastern musk turtle	<i>Sternotherus odoratus</i>
Stripe-necked musk turtle	<i>Sternotherus minor</i>
Spiny softshell turtle	<i>Apalone spinifera</i>

Table 3.11 (continued)

Common Name	Scientific Name
Yellow-bellied turtle	<i>Chrysemys scripta</i>
Eastern box turtle	<i>Terrapene carolina</i>
Northern copperhead	<i>Agkistrodon contortrix mokasen</i>
Six-lined racerunner	<i>Cnemidophorus sexlineatus</i>
Northern black racer	<i>Coluber constrictor</i>
Timber rattlesnake	<i>Crotalus horridus</i>
Black rat snake	<i>Elaphe obsoleta</i>
Ground skink	<i>Scincella lateralis</i>
Five-lined skink	<i>Eumeces fasciatus</i>
Broodhead skink	<i>Eumeces laticeps</i>
Eastern hognose snake	<i>Heterodon platyrhinos</i>
Northern water snake	<i>Natrix s. sipedon</i>
Fence lizard	<i>Sceloporus undulatus</i>
Northern brown snake	<i>Storeria d. dekayi</i>
Eastern garter snake	<i>Thamnophis s. sirtalis</i>
Worm snake	<i>Carphophis amoenus</i>
Scarlet snake	<i>Cemophera coccinea</i>
Ringneck snake	<i>Diadophis punctatus</i>
Corn snake	<i>Elaphe guttata</i>
Mole snake	<i>Lampropeltis calligaster</i>
Milk snake	<i>Lampropeltis tringulum</i>
Common king snake	<i>Lampropeltis getula</i>
Pine snake	<i>Pituophis melanoleucus</i>
Common water snake	<i>Nerodia sipedon</i>
Rough green snake	<i>Ophedodrys aestivus</i>
Queen snake	<i>Regina septemvittata</i>
Brown snake	<i>Storeria dekayi</i>
Redbelly snake	<i>Storeria occipitomaculata</i>
Smooth earth snake	<i>Virginia valeriae</i>
Fish	
Rock bass	<i>Ambloplites rupestris</i>
Common shiner	<i>Notropis cornutus</i>

Table 3.11 (continued)

Common Name	Scientific Name
White sucker	<i>Catostomus commersoni</i>
Blacknose dace	<i>Rhinichthys atratolos</i>
Tennessee dace	<i>Phoxinos Tennesseensis</i>
Stoneroller	<i>Campostoma anomalum</i>
Creek chob	<i>Semotilus atromaculatus</i>
Northern Hogsucker	<i>Hypentelium nigricans</i>

General Wildlife Habitats

LEGEND

HARDWOOD/MIXED HARDWOOD HABITAT		AQUATIC HABITAT
PINE PLANTATION HABITAT		CAVE HABITAT
OLD FIELD AND GRASSLAND HABITAT		BUILDING HABITAT

Fig. 3.21 General wildlife habitats on the ORR.

and weasel occur here. Birds commonly found in forest areas (Kroodsmas 1991) include the yellow-shafted flicker, red-bellied woodpecker, hairy woodpecker, downy woodpecker, blue jay, Kentucky warbler, pine warbler, ovenbird, Carolina chickadee, tufted titmouse, and scarlet tanager. Hawks (red-shouldered, red-tailed, and broad-winged) are commonly found on the ORR, as are wild turkeys, which have been reintroduced to the area in recent years. Amphibians and reptiles found in the forest habitat include the dusky salamander, American toad, eastern box turtle, ground skink, worm snake, black racer, rat snake, black king snake, milk snake, and copperhead.

Pine plantation habitat. Very early stages of planted pine areas contain species similar to those in old-field habitats, and the small mammals present are much the same as in the late stages of old fields. The populations tend to be smaller, though, because of less tree diversity. Pine plantations with a dense canopy and no understory are essentially barren of both small and large mammals except around the edges. As plantations are thinned and canopies opened, undergrowth develops and provides habitat for species similar to those found in early- to mid-stage hardwood-mixed hardwood/conifer forests. Avian species have a low preference for the pure pine areas bordering the transmission line corridors. Pine warblers and white-throated sparrows are common, but few other species are evident. These habitats are little used by reptiles or amphibians (Johnson 1964).

Aquatic and riparian habitats. Many reptiles and amphibians occur in the various aquatic and wetland areas, including turtles, queen snake, water snake, salamanders, and frogs. The muskrat and beaver are bound closely to aquatic habitats. Rice rats, mink, and raccoons are also found in these areas. Many large mammals come frequently to this habitat to drink, and various small species are present at the water's edge. The American bald eagle occurs occasionally as a transient. The Canada goose, great blue herons, and green-backed herons nest on the ORR.

Rare and endangered species. Three mammal species on the federal list as endangered may occur on the ORR but have not been verified. These are the gray bat (*Myotis grisescens*), Indiana bat (*Myotis sodalis*) and eastern cougar (*Felis concolor*). Only one mammal species listed by the Tennessee Wildlife Resources Agency (TWRA) as in need of management, the southeastern shrew (*Sorex longirostris*), is known to occur on the reservation (Kroodsmas 1987). The pine snake, *Pituophis melanoleucas*, is listed as threatened by the TWRA, and its presence in the Bear Creek watershed has been verified. The Cooper's hawk (*Accipiter striatus*) occurs in forests throughout the ORR and is listed by the state as threatened (Kroodsmas 1987).

3.6.3 Aquatic Fauna

Nineteen species of fish have been found in Bear Creek in recent quantitative monitoring efforts conducted at seven sites along virtually the entire length of Bear Creek. Minnows (blacknose dace, *Rhinichthys atratulus*; Tennessee dace, *Phoxinos Tennesseeensis*; stoneroller, *Camptostoma anomalum*; and creek chub, *Semotilus atromaculatus*) were the predominant constituents of the fish fauna upstream from the weir at BCK-4.55. Below the weir, larger species (northern hogsucker, *Hypentelium nigricans*; white sucker, *Catostomus commersoni*; and rockbass, *Ambloplites rupestris*) were more common, the diversity of minnow species increased, and darters were found. Conclusions of the recent fish-monitoring studies were that

much of Bear Creek had a limited fish fauna (low species richness) characterized by robust population parameters (high densities and biomass). The uppermost site (BCK-12.36) did not have a stable, resident fish population. Water from this site was commonly toxic to fathead minnow larvae in toxicity testing and contained high levels of dissolved salts as a result of input of contaminated groundwater from the S-3 Pond site. The next two monitoring sites downstream, BCK-11.83 and BCK-11.09, had low fish density and biomass in 1984-85 but showed recovery in later sampling. No impacts on the fish fauna of Bear Creek were evident in the vicinity of inputs from the burial grounds (BCK-9.91 and BCK-9.40) despite the fact that qualitative surveys found no fish in the tributaries (NT-6-8) draining that site.

No endangered or threatened fish species have been found in Bear Creek. However, the Tennessee dace, a major constituent of the fish population above the weir at BCK-4.55, is listed as a species in need of management. Its habitat is protected by the state of Tennessee (Starnes and Etnier 1980). In Bear Creek, it occurs at every site above the weir and in at least four tributaries (NT-13, NT-14, NT-18, and ST-7).

Quantitative sampling of benthic invertebrates was conducted monthly at nine sites from BCK-12.36 to BCK-3.25 from June 1984 through May 1985 as part of Phase I of the ecological monitoring program for Bear Creek and at quarterly intervals thereafter. A total of 126 distinguishable taxa was collected in Bear Creek, including crustaceans (*Isopoda*, *Amphipoda*, and *Decapoda*), aquatic worms (*Oligochaeta*), snails (*Gastropoda*), mussels (*Pelecypoda*) and insects (*Insecta*). Eleven orders of insects were collected in Bear Creek, including springtails (*Collembola*), mayflies (*Ephemeroptera*), dragonflies and damselflies (*Odonata*), crickets and grasshoppers (*Orthoptera*), stoneflies (*Plecoptera*), true bugs (*Hemiptera*), alderflies and fishflies (*Megaloptera*), caddisflies (*Tricotera*), butterflies and moths (*Lepidoptera*), beetles (*Coleoptera*), and true flies (*Diptera*).

The invertebrate fauna of Bear Creek showed a pattern of increasing density, biomass, and taxonomic diversity and richness with increasing distance downstream from the uppermost sampling site (BCK-12.36). The paucity of benthic invertebrates found in the upper reaches of Bear Creek contrasted sharply with reference sites (unimpacted streams of similar size), which had relatively diverse and abundant assemblages of macroinvertebrates. Water from BCK-12.36 and BCK-11.83 was toxic to *Ceriodaphnia*, an invertebrate test species, but not to fathead minnow larvae, in toxicity tests run in March 1988. At the time of these tests, streamflow in Bear Creek was higher than normal, and contaminants from the S-3 Ponds groundwater plume were diluted more than would be the case under baseflow conditions. Under low-flow conditions, it is likely that Bear Creek water would be toxic to *Ceriodaphnia* as far downstream as BCK-9.4. While evidence of adverse effects on the fish communities of Bear Creek was not noted at sites downstream from BCK-11.83, the benthic fauna appeared to be more sensitive, with clear differences in faunal composition from unimpacted reference sites at all sites except BCK-3.25, where complete recovery appears to have occurred. Species intolerant of pollution (mayflies, stoneflies, and caddisflies) were absent in the upper reaches and became more common downstream. Mayflies, which are particularly sensitive to toxic metals, were virtually absent at all sites except BCK-3.25. Unlike the fish data, which provide evidence of ecological recovery in Bear Creek since 1984, the benthic macroinvertebrate fauna do not appear to have changed in a manner indicative of either improving or degrading water quality since 1984.

No threatened or endangered species of aquatic macroinvertebrates have been collected in Bear Creek.

A limited amount of data have been collected on the bioaccumulation of contaminants by aquatic biota in Bear Creek. Fish collected from lower Bear Creek contained elevated levels of mercury (0.2–0.5 µg/g, wet weight) in 1982 (Van Winkle et al. 1984), and 1984 (TVA 1986). While well below the FDA action level, these data do indicate the presence of biologically available mercury in the Bear Creek system. Fish from lower Bear Creek were also analyzed for cadmium, chromium, silver, arsenic, and nickel in 1984 (TVA 1986), and levels were found to be typical of fish from uncontaminated environments.

PCB contamination in fish from Bear Creek was evident in 1982, when rockbass collected from the lower reaches of the creek were found to contain 0.65 ± 0.29 ppm (wet weight) PCBs (McElhaney 1982). TVA analyzed fish from lower Bear Creek for organic priority pollutants, including PCBs in 1984; levels of all substances were below detection limits. Fish were collected from lower Bear Creek in 1987 as part of an effort to evaluate the importance (relative to other sources) of the UEFPC discharge at New Hope Pond as a source of PCB contamination to lower Poplar Creek and the Clinch River. In this collection, PCBs in rockbass averaged 0.28 ± 0.12 ppm ($n = 8$), a value comparable to the level of contamination found in sunfish in the lower third of EFPC and well above the level typical of fish from uncontaminated sites (0.02 ± 0.01 ppm). Clams held in Bear Creek (BCK-4.55) for 1 month as part of the same study accumulated 1.01 ppm PCBs (vs 0.05 ppm in controls), indicating that Bear Creek now contains a source of biologically available PCBs.

PCB contamination has been observed in fish in EFPC, Poplar Creek, and the Clinch River/Watts Bar Reservoir downstream from Bear Creek (TVA 1986). It is unlikely that a substantial fraction of this contamination is attributable to Bear Creek because sources of PCBs and similar levels of contamination are found in fish from these systems far upstream from the mouth of Bear Creek (TVA 1986). A similar situation exists for mercury (TVA 1986).

3.7 RADIOLOGICAL SURVEY

An aerial radiological survey was conducted in 1989 encompassing 440 km² that included the entire ORR and adjacent areas. Typical background exposure rates were found to vary from 7 to 11 microroentgens per hour. Preliminary data collected in a 1992 aerial radiological survey corroborate the 1989 data.

Although the survey results for BCV were found to be within background range, the data are not directly applicable to BCV OU 4 since the purpose of the aerial radiological survey was to identify areas of radiologically contaminated soil. BCV OU 4 is concerned with groundwater and surface water, and the resolution of this survey is such that it cannot be used to detect radiological contamination of these media. Radiological contamination of groundwater in BCV is limited to two areas (S-3 Ponds and Boneyard/Burnyard). Groundwater quality is monitored at both of these sites.

3.8 CONCEPTUAL SITE MODEL

A conceptual model for groundwater flow that is applicable throughout the ORR has been developed and summarized by Solomon et al. (1992). The components of that conceptual model are summarized here in general and applied to the specific needs of the shallow groundwater/surface water system within BCV.

In addition, the conceptual site models to be used in the evaluation of risk posed to human health and the environment by contaminants in BCV (including BCV OU 4) are illustrated and summarized in the following sections.

3.8.1 General Model Components

Two broad categories of hydrologic units exist within the ORR. The Knox aquifer, including rocks of the Knox Group and the Maynardville Limestone of the Conasauga Group, wherein groundwater flow is dominated by solution conduits, and the remaining rock units which comprise the ORR aquitards, wherein flow is dominated by fractures. For the purposes of this plan, conduit flow is defined as that occurring in solutionally enlarged openings related to fractures or bedding planes.

Each of the major hydrologic units can be subdivided into the following subsurface zones: stormflow, vadose, and groundwater. The groundwater zone can be further subdivided into the water table, intermediate, and deep intervals. Flow within and between any of these zones is influenced by topography, surface cover, geologic structure and lithology. Analyses by Moore (1988) suggest that a combination of topographic relief and a marked decrease, with depth, in permeability restrict the majority of flow to the shallow portions of the system.

3.8.1.1 Stormflow zone

The stormflow zone approximately corresponds to the root zone in naturally vegetated portions of the ORR. Moore (1988) suggests that approximately 90% of active subsurface flow occurs through a 1- to 2-m-deep stormflow zone in those areas. During storm events the stormflow zone transmits water laterally toward surface water discharge points. Surface runoff occurs when the stormflow zone becomes completely saturated.

Water flow within the stormflow zone occurs primarily through root channels, worm holes, and fractures. While these large pores transmit most of the water, the majority of water mass (and contaminant storage) within the zone resides within the less transmissive surrounding soil matrix wherein hygroscopic forces immobilize the water. Diffusion of contaminants between the matrix and large pores, during times of active stormflow, effectively reduces the rates of contaminant flushing relative to fluid flow through the large pores.

3.8.1.2 Vadose zone

The vadose zone underlies the stormflow zone and varies in thickness from a maximum near ridge tops to a minimum where the water table approaches the ground surface (e.g., near perennial streams). The vadose zone is composed of a regolith of clays and silts derived from the weathering of underlying bedrock and, in some cases, extends into the underlying bedrock.

The regolith often retains relict structures (e.g., fractures) from the parent bedrock. These structures appear to serve as discrete, oriented, permeable flow paths. Between recharge events, flow within the vadose zone decreases with water moving toward the water table.

3.8.1.3 Groundwater zone

The groundwater zone is divided into the water table, intermediate, and deep intervals. Evidence suggests that the bulk of water flow within the groundwater zone occurs through closely spaced, connected fractures within the water table interval. Within the water table interval in clastic rocks the bulk of water mass is held within the porous matrix between fractures. Contaminant migration within the zone is modified by diffusive exchange between the matrix and actively flowing water within fractures. The base of the water table interval tends to correspond to the top of unweathered bedrock.

Below the water table interval, fracture flow predominates but the fractures become less interconnected. Flow appears to become more sluggish with depth. Within the Maynardville Limestone portion of the Knox aquifer there are solution enlarged cavities at depth that appear to be well connected and comprise the strike-parallel conduit flow system.

3.8.2 BCV Shallow Groundwater

The major contaminant source areas in BCV tend to be located in the Nolichucky strike belt. During the operational history of the source areas the contaminants were either shallowly buried within the vadose zone or were spread on the ground surface. As a result, most of the contaminants that are migrating within BCV were mobilized by water moving through the stormflow zone and, perhaps, the water table interval of the groundwater zone.

Contaminants have migrated into deeper Nolichucky bedrock in two special case areas. Contaminants associated with the S-3 Ponds (e.g., nitrate) may have been driven to greater depths as a result of the combined effects of a groundwater recharge mound associated with the operation of the ponds and the relatively high total dissolved solids content of the waste stream. In the second special case, DNAPLs followed fractures and bedding plane partings into deeper sections of the Nolichucky near the Oil Landfarm and the Burial Grounds.

Regardless of whether the contaminants are migrating within the stormflow/water table zones or have penetrated into deeper bedrock, the conceptual model for BCV shallow groundwater indicates that flow from the Nolichucky toward the Maynardville is dominated by large pores (stormflow zone) and fractures with the bulk of water and contaminant storage in the intervening matrix. Diffusional exchange between water in the fractures and contaminants in the matrix will retard the transport of contaminants.

The major source areas are no longer receiving wastes and are in varying stages of closure. With the source removed the mass of contaminants in the soils and bedrock of the Nolichucky are being slowly flushed from the system at a rate determined by contaminant diffusion from the matrix into the active (fractures and large pores) flow system. The contaminant concentration in the actively flowing fractures and pores of the Nolichucky should be decreasing as the mass of contaminants in the matrix is depleted. Likewise, the flux of contaminants from the Nolichucky to the Maynardville conduit system should be

decreasing. Furthermore, contaminants entering the Maynardville from the Nolichucky will be diluted by relatively clean water entering from the stormflow zone and water table interval of Chestnut Ridge (Knox).

The conceptual model has implications for the sampling methods required to test the hypothesis that contaminants are being flushed from the system and contaminant concentrations are decreasing. As Moore and Toran (1992) noted, most of the data they analyzed from groundwater wells did not support the contaminant flushing hypothesis. Solomon et al. (1992) noted that contaminant monitoring in the groundwater zone is dependent upon placement of well screens with respect to fractures or conduits that are part of the active flow system. Furthermore, virtually all groundwater follows short flowpaths within the water table before discharging to a surface stream. Solomon et al. (1992) conclude that surface water monitoring may be a more valid method for acquiring contaminant flux information than continuing to monitor extensive systems of groundwater wells.

3.8.3 Potential Pathways

A site conceptual model has been developed (Fig. 3.22) that illustrates the major pathways for contaminant migration from a source area located in the Nolichucky (e.g., S-3 Ponds). Transport within the water table and shallow bedrock of the Nolichucky is toward the Maynardville conduit system wherein flow is predominantly along strike down the length of BCV. The depth of contamination within Nolichucky bedrock represents the effects of possible density driven or stratabound flow from the active operation period of S-3 Ponds. The maximum depth of contamination in the Nolichucky is ~500 ft. The contaminants are in the dissolved state at that depth. The deepest identified free-phase DNAPL in BCV is ~275 ft in the Nolichucky Shale (HSW 1992). Groundwater and surface water impacted by groundwater discharge are the media of concern in BCV OU 4. Atmospheric transport of contaminants is considered to be inconsequential and will not be addressed in this document.

3.8.3.1 Surface water

Surface water transport of contaminants within BCV OU 4 is possible. The flow of surface water over and through areas of contaminated soil provides a potential for transportation and redeposition of contamination. Furthermore, interactions between surface water and shallow groundwater, via gaining and losing stream reaches and springs, serve to blur the ultimate source of contaminants in either media. Surface water transport of contaminants from several of the source areas in the Bear Creek watershed is strongly suspected or documented. Sediment samples from tributaries to Bear Creek also indicate surface water transport of contaminants. The flow of surface water over and through areas of contaminated floodplain soils and sediments provides a potential for further transportation and redeposition of material within Bear Creek, as well as direct solubilization of contaminants retained in soils and sediments from historical releases. Chapter 6 of this Plan addresses strategies for delineating the contribution of the surface water system to the contamination of Bear Creek.

3.8.3.2 Groundwater

Groundwater is a media of concern when addressing subsurface transport of contaminants in BCV. Results of previous investigations (see Sect. 3.5) indicate that the

Fig. 3.22 BCV OU 4 conceptual model.

primary contaminants, PCBs, uranium, metals, and VOCs are associated either with the floodplain soils and sediments in the streambed or the fine-grained matrix of the Nolichucky and, as such, represent a potential source of continuing release to both groundwater and surface water systems associated with Bear Creek. As discussed in Sect. 3.5.3, the potential for groundwater recharge along losing reaches of Bear Creek, and the re-emergence of the creek further downstream, enhance the potential for leaching of contaminants such as uranium and PCBs from floodplain soils and sediments. The process of matrix diffusion and the possibility of density driven contaminant distribution within the Nolichucky suggest the potential for long-term leaching of contaminants.

Groundwater transport of contaminants in BCV OU 4 is highly dependent upon contaminants reaching the conduit flow system. Once contaminants reach the conduits, transport down valley may be rapid in either the subsurface or surface flow systems.

3.8.3.3 Air

Airborne contamination from Bear Creek and its floodplain is believed to be minimal. Disturbance of contaminated sections of the floodplain without application of effective dust suppression measures could lead to airborne contamination.

3.8.3.4 Biological

Uptake and transport of contaminants by aquatic biota is being addressed as part of the Biological Monitoring and Abatement Program (BMAP), a requirement of the Y-12 Plant NPDES permit. The concerns are that consumption of contaminated fish by humans or piscivorous wildlife may provide a significant contaminant pathway. Results to date indicate elevated tissue concentrations of mercury and PCBs in Bear Creek biota.

3.8.4 Potential Receptors and Exposure Conditions

3.8.4.1 Human receptors

Conceptual site model flow diagrams for human receptors for the entire BCV and for BCV OU 4 (the integrator OU only) are illustrated in Figs. 3.23 and 3.24, respectively. The BCV conceptual site model is shown in order to illustrate the relationship between the various source OUs and the integrator OU.

For Bear Creek Valley (Fig. 3.23), seven potentially contaminated media are considered: soil and sediment, surface water, shallow groundwater (active flow), groundwater (deep), air, and the food chain. The primary sources of the contaminants are the S-3 Ponds, Oil Landfarm, Burial Grounds, Boneyard/Burnyard, Sanitary Landfill 1, Rust Spoil Area, Spoil Area 1, and SY 200. The primary and secondary release mechanisms are chemical releases (including leaks and spills), runoff, infiltration/percolation, groundwater discharge, soil resuspension, plant and animal uptake, and volatilization.

Bear Creek Valley Conceptual Site Model for Risk Assessment

Fig. 3.23 Bear Creek Valley conceptual site model for human receptors.

BCV OU-4 - Conceptual Site Model for Risk Assessment

Fig. 3.24 Bear Creek Valley Integrator OU conceptual site model for human receptors.

The soil is a potential pathway of migration via runoff to surface water, percolation/infiltration into groundwater, resuspension of particles (wind generated dust) into the air pathway, uptake into plants and animals, and volatilization of contaminants into the air. The soil exposure medium is divided into soil (associated with each source OU) and soil/sediment (the BCV OU 3 flood plain soil). Both soil types will be evaluated in terms of human health risk, using the current on-source-OU industrial scenario (i.e., the MLE assessment, discussed in detail in Sect. 6.4) and the hypothetical future on-source-OU scenario (residential or industrial, depending on land use considerations). In addition, the soil/sediment (BCV OU 3 flood plain soils) will be evaluated in a future integrator OU RME assessment (refer to Sect. 6.4 for details); this scenario will include exposure to floodplain soils or soils that have been irrigated (for agricultural purposes) with contaminated surface water. Exposure pathways/routes which would be evaluated include ingestion of soil; inhalation of resuspended soil (dust); dermal contact with soil; inhalation of volatiles from the soil; ingestion of biota (meat, milk, and vegetables); and external exposure to radionuclides in the soil.

The exposure medium of contaminant releases into the air may occur as a result of resuspension of dust (from soil) and volatilization of contaminants from soil, surface water, and groundwater; residential uses of surface water and groundwater (e.g., showering) can result in volatilization of contaminants. Inhalation is the primary exposure route for contaminants in air, and this media will be evaluated in the current and future on-source-OU, off-source-OU, and integrator-OU risk evaluations.

The surface water exposure medium is believed to have the greatest potential for off-source-OU exposure (refer to Figs. 6.23 and 6.24). The potential for contaminant movement into groundwater is increased due to surface water infiltration to groundwater; in addition, groundwater can discharge to surface water (in Fig. 3.23, this secondary release mechanism is shown only as a dotted line). Surface water associated with a source OU will be evaluated in the hypothetical future on-source-OU RME assessment (Fig. 3.23). Exposure pathways that will be evaluated for the on-source-OU surface water are inhalation (of volatiles), dermal contact, and ingestion of the water.

The surface water exposure medium will be evaluated in this BCV OU 4 IP assessment (refer to Fig. 3.24) using residential exposure parameters for a current off-source-OU receptor [i.e., an IP receptor (see Sect. 6.4)]. The exposure pathways that will be evaluated are inhalation (of volatiles), dermal contact, and ingestion of the surface water. The hypothetical future integrator-OU RME assessment will also be evaluated for the ingestion, dermal contact, and inhalation pathways.

Deep groundwater and active flow groundwater are other potential exposure media and mechanisms for off-source-OU transport of contaminants (refer to Figs. 3.23 and 3.24). Again, groundwater associated with a source OU will be evaluated in a hypothetical future on-source-OU RME risk assessment (Fig. 3.23) and, if applicable, in the future integrator-OU RME assessment (Fig. 3.24) (refer to Sect. 6.4). The exposure pathways which will be evaluated include ingestion, inhalation of volatiles, and dermal contact with the groundwater.

Biota (i.e., plants, animals and fish) may accumulate contaminants that are present in the soil and irrigation water. This exposure medium (i.e., the food chain) will be evaluated using

the hypothetical future residential/agricultural on-source-OU scenario (RME assessment) and using the future integrator-OU RME risk assessment (for the flood plain soils and for surface water), that is, the BCV BRA. A quantitative risk assessment for exposure to these media (meat, milk, and vegetables) via ingestion will not be evaluated for this RI work plan phase of BCV OU 4 but will be considered in the future source-OU and integrator-OU RME assessments.

In summary, the conceptual site model for the entire BCV (Fig. 3.23) is shown to illustrate the relationships between the source OUs and the integrator OU. In addition, the different types of risk assessments which will be performed in the short term (titled "Current") and the long term (titled "Future") are summarized. In the short term, for this BCV OU 4 (integrator OU) RI work plan (Fig. 3.24), the surface water integrator will be evaluated in an IP risk assessment, and the on-source-OU soil will be evaluated in an MLE risk assessment. In the future (Figs. 3.23 and 3.24), all media from source OUs and the integrator OU will be evaluated and integrated into a BCV BRA/RME risk assessment.

3.8.4.2 Ecological receptors

The BCV ecological conceptual model is shown in Fig. 3.25. The ecological conceptual model is based on the generalized food web for BCV. For ecological risk assessment, source OU RIs will address the potential for lower members of the food chain (vegetation, earth worms, tadpoles, shrews) to take up contaminants and will model the potential effects on the ecosystem. Phase 1 of the integrator OU RI addresses the active flow system in BCV, and the ecological risk assessment will evaluate risks to aquatic biota (fish) in Bear Creek. Phase 2 of the integrator OU RI will address aquatic and terrestrial fauna in a BCV BRA. At this time all ecological data for BCV that have been collected by the source OU RIs, the integrator OU RI, and BMAP will be evaluated for completeness. Data gaps will be filled, and a BCV BRA will be completed. In addition, the ongoing ORR site-wide baseline ecological risk assessment will be addressing biota with ranges that are reservation-wide, such as deer, wild turkey, and bobcats.

3.8.5 Data Adequacy Summary

The main two objectives for site characterization in the RI are the nature and extent of contamination and contaminant fate and transport. The current knowledge of the nature and extent of contaminants in groundwater and surface water in BCV leaves almost no data gaps. Current data concerning surface water quality in Bear Creek Valley (BCV) are discussed in Section 3.5.2 of this report. Quality data for groundwater is detailed in Section 3.5.3 and current ecological data is presented in Section 3.6. For evaluation of fate and transport of contaminants in BCV there remain a number of data gaps. The current data gaps in BCV center around the hydrology of BCV and in particular the influence of fracture and conduit flow systems on hydrology such that the main data gaps in BCV are as follows:

- The probable orientation of fractures and groundwater conduits in BCV and their relationship to groundwater flow;
- The locations and dynamics of connections between the groundwater flow system and the surface water system in BCV;

Fig. 3.25 The Bear Creek Valley ecological conceptual model.

- The conceptual model for hydrology outlined in this report is based in part on research carried out at ORNL (Moore 1989; Moore 1992; Moore and Toran 1992) and the applicability of this conceptual model to BCV needs confirmation.

This work plan outlines an approach and sampling strategy that will address these data gaps by carrying out aquifer tests and sampling designed to evaluate groundwater flow dynamics.

In addition to the sample plan in this document, a number of research project are being carried out in BCV to better define the flow system. Although these studies are not included in the CERCLA process, data from these studies will be available to this RI and will increase understanding of the groundwater flow system in BCV. Because these projects have not been completed, publication of results at this time is not possible. The following section provides brief descriptions of current research projects in BCV.

3.8.6 Exit Pathway Program

3.8.6.1 Cross-borehole testing

Two cross borehole tests were conducted at exit pathway monitoring Transect A located at BCK 2.40 between July and August. The tests involved addition of ~2500 gal of deionized water to a well located in the center of the transect (GW-684) screened in a large cavity. Remote real-time monitoring of 10 wells surrounding the source well was conducted to detect changes in water level using pressure transducers and dataloggers. Five of the surrounding wells were monitored for pH, conductance, and temperature using Hydrolabs™. In addition, the SS-5 spring was instrumented with an ISCO water level measuring device to record continuous spring outflow levels.

During the first of the two tests, the addition of water was done under ambient conditions with the water introduction rate limited by natural hydraulic conductivity of the cavity and the hydraulic head generated by the height of the water tank above the water table. A stable specular hematite tracer was added to the well prior to the first test to examine transport of colloidal particles. Surrounding wells were sampled using low-flow purging for the presence of the hematite tracer. The second test was identical to the first test with the following two exceptions: Water was injected under ~ 40 psi and at a rate of ~ 190 gpm; and no hematite tracer was used. Also, pressure monitoring of the source well could not be done during the second test due to pumping equipment.

Analysis of data to date includes plots of water levels vs time in the surrounding monitor wells and in the SS-5 spring outflow. Results of the first test were ambiguous with no discernable spikes in water levels noted. Results of the second test showed a definite short-duration increase in water level related to the injection test in Well GW-683, upslope of the source well, and in the SS-5 spring. Other data is still being reduced and evaluated. Hematite analyses have not been completed. Tests will be conducted in Picket W in late August 1993.

3.8.6.2 Stratigraphic study

Work continues on a study of Maynardville Limestone diagenetic characteristics and detailed stratigraphic characteristics. The relationships of these items to development of flow pathways will be examined. Core and cuttings obtained over several years throughout Bear Creek Valley are being used for the study.

3.8.6.3 Statistical study of cavities/fractures

Multivariate statistics are being used to attempt to define statistical significance for a number of variables that potentially control development of contaminant exit pathways in the Maynardville Limestone. Variables such as elevation, base level, position of stratigraphic contacts, areal location, etc. are being modeled in relation to occurrence of cavities to define controlling factors for cavity development.

3.8.6.4 Geophysical studies

An expanded and refined gravity survey grid has been placed in the proximity of well GW-734 as part of continued geophysical investigations along exit pathway transect J. Future work will consist of additional gravity work and electrical logs in the vicinity of the well.

3.8.7 Colloid/Low-Flow Purge Study

A study of colloid movement related to purge rates has been initiated by the Y-12 Plant GWPP. A cross section of wells located in the Knox Group, Maynardville Limestone, and lower Conasauga Group will be sampled using low purge rates to determine the effects of purging on colloid transport to a well and water quality data. The study also involves sampling of several points within the screened or open portion of each monitoring well to examine optimum points of sampling using low-flow purging techniques. Ultimately the data will be used to petition state and federal regulators to reduce standard 3-bore volume purge requirements, which may detrimentally affect water quality data and result in excess sampling and waste disposal costs.

3.8.8 Helium Sampling

Sampling and analysis of selected wells in the Maynardville Limestone and Nolichucky Shale are being used to examine concentration differences of helium in groundwater on either side of the contact between the two formations. The study will allow relative age dating of groundwaters in both formations and provide insight regarding the rates of groundwater flux from the Nolichucky into the Maynardville. Preliminary data to date show that helium concentrations in the Nolichucky Shale are significantly greater than those in the Maynardville Limestone. This indicates that flow across the contact is not as rapid as previously thought, which has implications regarding rates of contaminant transport to the Maynardville Limestone and future risk assessment scenarios at integration points.

3.8.9 Noble Gas Tracer Study

A tracer study is under way in west Bear Creek Valley utilizing argon tracers to examine diffusion rates in the unconsolidated/weathered bedrock intervals of the lower Conasauga Group formations.

3.8.10 Borehole Dilution Tests

In an attempt to identify flowing zones in wells, research is under way to test wells for the rate at which groundwater chemistry recovers to ambient levels after controlled introduction of distilled water. This involves isolating a section of a well using packers and introducing distilled water to that zone while maintaining constant pressure head by removing well water at the same rate. After the conductivity of water in that section of the well reaches a minimum, then the distilled water supply is shut off and the conductivity of the water between the packers is monitored during recovery of well chemistry. It is assumed that the rate of chemical recovery is a function of the rate of groundwater flow through that section of the well. Preliminary results suggest that there are significant differences in recovery rate within individual wells suggestive of changes in hydraulic conductivity. This method will be evaluated further and may be used to identify groundwater conduits in BCV.

4. POTENTIAL RECEPTORS AND EXPOSURE PATHWAYS

Radionuclides and chemical pollutants that are introduced into the biosphere are subject to the same biogeochemical processes that normally cycle elements within and among ecosystems. Contaminants in the soil, groundwater, and surface water, for example, can be incorporated into plants by uptake through the root system. Pollutants released into the atmosphere can be incorporated into plant systems by foliar deposition and absorption. When this occurs, the pollutant may then pass directly to humans or to grazing animals as superficial or metabolically absorbed contamination. In addition, pollutants in surface water can be absorbed to or incorporated into periphyton or other materials that compose the base level of the food chain. These contaminants can then pass rather quickly through higher levels of the food chain, often accumulating in tissues of organisms occupying these levels. Direct exposure to human, animal, and fish (etc.) populations through primary pathways such as ingestion, inhalation, dermal contact, and external exposure are also possible.

An exposure pathway is the course that a chemical agent takes as it moves from source to receptor. An exposure pathway may include:

- a source of potential contamination;
- a mechanism for release from the source [e.g., chemical partitioning from solid to liquid (waste to rainwater) that infiltrates into and through the unit] and a route of migration from the source to a receiving environmental media (e.g., vertical transport through the unsaturated zone to the groundwater);
- a point of exposure (e.g., a groundwater well);
- a route of exposure (e.g., ingestion); and
- a receptor.

The integration of these factors results in a complete exposure pathway. Complete exposure pathways for BCV OU 4 are presented in Chap. 3 as part of the conceptual site model.

For BCV OU 4, the sources of potential contamination are buried waste in BCV, soils that have become contaminated via leaching from waste, and contaminated groundwater. Some exposures may occur through direct contact with the waste, and these pathways are addressed by the source OU RIs. Other exposures may occur through indirect contact after the waste has migrated away from the source. The primary release and transport mechanisms away from the source to the point of exposure in surrounding media include the following:

- vertical leaching to the groundwater;
- vertical/horizontal leaching through the storm flow system to surface water;
- runoff to surface water and sediments;
- volatilization into the air;
- particulate emissions into the air; and

- penetrating radiation.

Once the exposure point has been identified for each medium, an exposure route must be identified. Exposure routes are the mechanisms by which receptors contact the chemicals. The potential routes of direct exposure associated with the BCV OU 4 receptors include:

- soil, groundwater, and surface water ingestion;
- dermal contact with soil, groundwater, and surface water;
- inhalation of volatilized contaminants or dust; and
- external exposure to radionuclides.

Indirect exposure to the waste may occur through the following pathways:

- groundwater pathways
 - ingestion of groundwater
 - inhalation while showering
 - ingestion of vegetables, beef, and milk via use of groundwater for irrigating
- surface water pathways
 - ingestion of surface water
 - dermal contact with surface water
 - inhalation of volatiles from surface water
- air pathways
 - inhalation of volatiles in soil
 - inhalation of fugitive dusts
 - ingestion of vegetables, beef, and milk via deposition of fugitive dust

Additional secondary pathways may be identified through the course of the RI.

In this chapter, characterization of the human and ecological populations on or near the BCV OU 4 integrator OU site is considered. The receptor assessment aims to identify those individuals or populations with a current or future potential for exposure to site contaminants. The exposure pathway assessment identifies the routes by which a receptor might be exposed.

4.1 HUMAN POPULATIONS AND EXPOSURE PATHWAYS

The BCV OU 4 is within the Bear Creek Valley, which is between Pine Ridge and Chestnut Ridge, and is located within the Y-12 site (which is ~800 acres). The Y-12 Plant is part of the DOE ORR, which covers ~35,000 acres; this facility is located along the northeastern boundary of the ORR (which includes ORNL, the Y-12 Plant, and the K-25 Site), southwest of the city of Oak Ridge. Security precautions currently limit the presence

of unauthorized persons in this controlled area; consequently, the potential for human exposure to contaminants is limited at the present time.

Conceptual site models for Bear Creek Valley and for BCV OU 4 (for human receptors) are discussed in Sec. 3.8.4 and are illustrated in flow diagrams in Figs. 3.23 and 3.24, respectively. Inhalation, ingestion, dermal contact, and external exposure pathways (for both water and soil) were selected as potential pathways of concern at Bear Creek Valley. For BCV OU 4 (the integrator OU), surface water and groundwater exposure media are addressed because they have the highest potential for transport of contamination off the source OU and, therefore, potential for human exposure.

An exposure pathway is the means by which contamination from any contaminated medium is transported from a source to a receptor. The components necessary to complete the pathway are (1) a contaminated source and a mechanism for release, (2) a transport medium, (3) an exposure point, (4) potential receptors, and (5) an exposure route. Exposure can occur if contaminants migrate via BCV OU 4 to a receptor or if a receptor comes into direct contact with this integrator OU. Identification of exposure pathways for this OU includes descriptions of both primary and secondary sources (see Fig. 3.24).

For this integrator OU (BCV OU 4), the secondary sources of contamination are surface water and groundwater, which were contaminated from source OUs in BCV OU 1 and BCV OU 2; other sources which have not been identified at the present time may also contribute to contamination of BCV OU 4. The primary and secondary mechanisms for release include (1) chemical releases (from source OUs in BCV OU 1 and BCV OU 2), (2) surface water infiltration to groundwater, (3) groundwater discharge to surface water, (4) volatilization of VOCs in groundwater and surface water, and (5) plant and animal uptake. The exposure media identified for BCV OU 4 are soil/sediment (from BCV OU 3 flood plains), surface water, groundwater, air and biota. For the surface water exposure medium, a potential exists for ingestion, dermal contact, and inhalation of contaminants in the surface water.

4.1.1 On-Site Potential Human Receptors and Exposure Pathways

Employment at the Y-12 Plant (as of April 1993) consisted of ~6200 full-time on-site personnel, the majority of whom work in the main Y-12 Plant complex on the northeast part of the ORR. The on-site workers have the greatest risk of exposure to contaminants from BCV OU 4; however, BCV OU 4 is west of the main Y-12 Plant complex in an area where the majority of employees do not frequent. Because the majority of the source OU areas have been closed and intrusive activities are limited at this OU, exposure to the on-site worker is limited to a small group of maintenance workers and future sampling and remediation workers. Exposure to a trespasser (hiker or fisherman) must also be considered here.

Under the current land use conditions (i.e., industrial worker, remediation worker, and trespasser), the exposure pathways that will be considered are from exposure to (1) the surface water medium (which includes ingestion, inhalation, and dermal absorption of contaminants in the water exposure routes) and (2) the soil medium (which includes ingestion, inhalation, dermal contact, and external exposure to radionuclides exposure routes). The surface water exposure pathways will be evaluated using the IP assessment (residential

parameters), and the soil exposure pathways will be evaluated using the MLE assessment (industrial parameters). The IP and MLE assessments will be discussed in detail in Sect. 6.4.

For future land use, a RME risk assessment (BRA) will be performed; details for this type of risk assessment will also be discussed in Sect. 6.4. In the future integrator OU risk assessment, exposure to soil/sediment, surface water, groundwater, air, and biota will be assessed for all of Bear Creek Valley (Figs. 3.23 and 3.24). These media include the following exposure pathways: (1) ingestion of soil and water, (2) inhalation of wind-generated dust, (3) inhalation of volatiles in water, (4) dermal contact with soil and water, (5) external exposure to radionuclides in soil, and (6) ingestion of plants and animals (meat, milk, fish, and vegetables). Ingestion of biota will not be evaluated in this initial phase of the RI work plan for BCV OU 4.

4.1.2 Off-Site Potential Human Receptors and Exposure Pathways

The greatest potential for off-site human exposure is believed to be from possible surface water runoff and shallow groundwater discharge into Bear Creek. The contaminants found in the BCV OU 4 integrator may affect downstream surface water bodies, including the Lower East Fork Poplar Creek, Poplar Creek, Clinch River, and Watts Bar Lake. These water bodies may be used for domestic and industrial water supply, fishing and recreation, and irrigation. Regional demography is discussed in Sec. 3.3. Off-site receptors of contaminants in surface water from the entire ORR are currently being evaluated in the Clinch River ER Program RI.

Under the current land use conditions (Fig. 3.24), an IP assessment will be used to evaluate potential exposure to off-site and/or off-source-OU receptors. The details of this type of assessment will be discussed in Sect. 6.4. In brief, the IP assessment is designed to evaluate both on-site and off-site human health risk from exposure to contaminants in this integrator OU (i.e., BCV OU 4). This type of assessment will be used to support Records of Decision (RODs) for interim actions. Conservative (residential) exposure parameters will be used to evaluate risk from ingestion and dermal contact with surface water and from inhalation of volatile organic compounds in the water.

One identified sensitive subpopulation of potential off-site exposure is children. Children from ages 0 to 6 years will be evaluated separately to ensure protection of this subpopulation.

For future off-site land use, modeled results could be used to evaluate risk to off-site receptors. Exposure pathways to be evaluated include (1) ingestion of soil and water, (2) inhalation of wind-generated dust, (3) inhalation of volatiles in water, (4) dermal contact with soil and water, (5) external exposure to radionuclides in soil, and (6) ingestion of plants and animals (meat, milk, fish, and vegetables).

4.2 ECOLOGICAL POPULATIONS

Because Phase 1 of this RI is exclusively concerned with the groundwater in a portion of the Bear Creek watershed, the ecological assessment for Phase 1 is exclusively concerned with the biota that inhabit the surface waters which are partially fed by groundwater. The

Bear Creek Valley ecological conceptual model is shown in Fig. 3.25. The ecological conceptual model is based on the generalized food web for BCV. For ecological risk assessment, source OU RIs will address the potential for lower members of the food chain (vegetation, earthworms, tadpoles, shrews) to uptake contaminants and will model the potential effects on the ecosystem. Phase 1 of the integrator OU RI addresses the active flow system in BCV, and the ecological risk assessment will evaluate risks to aquatic biota in Bear Creek. Phase 2 of the integrator OU RI will address aquatic and terrestrial fauna in a BCV BRA. At this time all ecological data for BCV that have been collected by the source OU RIs, by the integrator OU RI, and BMAP will be evaluated for completeness. Data gaps will be filled and the integral effects of the various sources on BCV on terrestrial and aquatic biota will be evaluated in a BCV watershed BRA. In addition, the ongoing ORR site-wide ecological BRA will be addressing biota with reservation-wide ranges such as deer, wild turkey, and bobcats. The sources for the following description of the Bear Creek aquatic community are the monitoring performed since 1984 by the BMAP (Southworth et al. 1992), and the review of existing data in the RI Work Plan for the entire watershed (Turner et al. 1991).

4.2.1 Aquatic Biota

The abundance and productivity of fish populations are the primary assessment endpoint for aquatic ecological risk assessments on the ORR (Suter et al. 1992). Sixteen species of fish are found in Bear Creek (Table 4.1). Species richness in individual sampling reaches ranges from 14 species near the confluence with EFPC (BCK-3.25) to three in the headwaters (BCK-12.36). The species composition and density of this fish community compared to two reference streams suggests that some disturbance has resulted in losses of species.

Benthic invertebrates are not endpoint species, but they provide food to fish and analysis of their community characteristics can aid in interpretation of the cause of effects on fish populations. Like the fish community, the species richness of the benthic invertebrate community increases with distance downstream. The quality of the benthic invertebrate community, as reflected in the relative abundance of taxa characteristic of good and poor water quality, is low relative to reference sites until the last point downstream, BCK-3.25.

Because the S-3 Ponds, the major contaminant source in the watershed, are at the head of Bear Creek, changes in the stream biota down the stream gradient appear to be due to toxic effects. However, the species richness of stream communities tends to increase down the gradient of all streams of less than fifth order. In addition, the substrate becomes coarser and less embedded down the gradient of Bear Creek and the riparian vegetation provides a better canopy. Other factors influencing the biota include the weir at BCK-4.55, which blocks movement of fish into the upper reaches, and natural periods of low flow. One purpose of the ecological risk assessment will be to distinguish effects of these other factors from effects of the various contaminant sources, particularly the contaminated groundwater.

4.2.2 Threatened and Endangered Species

No federally listed threatened or endangered species occur in Bear Creek (Turner et al. 1991, Southworth et al. 1992). The Tennessee dace (*Phoxinus tennesseensis*), which occurs in

Bear Creek, is listed as a species in need of management in the state of Tennessee (Starnes and Etnier 1980). As a result, Bear Creek has special protection as habitat for this species.

Table 4.1. Fish species currently occurring in Bear Creek

Common name	Scientific name
<i>Cyprinidae</i>	
Blacknose dace	<i>Rhinichthys atratulus</i>
Creek chub	<i>Semotilus atromaculatus</i>
Emerald shiner	<i>Notropis atherinoides</i>
Rosefin shiner	<i>Notropis ardens</i>
Spotfin shiner	<i>Notropis spilopterus</i>
Striped shiner	<i>Notropis chrysocephalus</i>
Stoneroller	<i>Campostoma anomalum</i>
Tennessee dace	<i>Phoxinus tennesseensis</i>
<i>Catostomidae</i>	
Northern hogsucker	<i>Hypentelium nigricans</i>
White sucker	<i>Catostomus commersoni</i>
<i>Cottidae</i>	
Banded sculpin	<i>Cottus carolinae</i>
<i>Centrarchidae</i>	
Bluegill sunfish	<i>Lepomis macrochirus</i>
Warmouth sunfish	<i>Lepomis gulosus</i>
Rock Bass	<i>Ambloplites rupestris</i>
<i>Percidae</i>	
Stripetail darter	<i>Etheostoma kennicotti</i>
Tennessee snubnose darter	<i>Etheostoma simoterum</i>

Source: Southworth et al. 1992.

5. SCOPING

5.1 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)

5.1.1 Introduction

CERCLA was passed by Congress and signed into law on December 11, 1980 (Public Law 96-510). This act was intended to provide for "liability, compensation, cleanup, and emergency response for hazardous substances released into the environment and the cleanup of inactive waste disposal sites." SARA, adopted on October 17, 1986 (Public Law 99-499), did not substantially alter the original structure of CERCLA but provided extensive amendments to it.

In particular, Sect. 121 of CERCLA specifies that remedial actions for cleanup of hazardous substances must comply with requirements or standards under federal or more stringent state environmental laws that are applicable or relevant and appropriate to the hazardous substances or particular circumstances at a site. Inherent in the interpretation of ARARs is the assumption that protection of human health and the environment is ensured.

The purpose of this section is to supply a preliminary list of available federal and state chemical- and location-specific ARARs that might be considered for cleanup of BCV OU 4 which includes shallow groundwater flow in the Maynardville Limestone and Nolichucky Shale in BCV between Pine Ridge and Chestnut Ridge. The depth of the shallow flow system is not yet defined. This section also includes ARARs for surface water for that portion of Bear Creek into which the shallow groundwater flows. Sediments in Bear Creek will not be addressed here. Chemicals of potential concern identified for BCV OU 4, listed in Table 5.1, include VOCs, inorganics (nitrate, sulfate), metals, and gross alpha and beta emitters.

The process of ARAR identification is an iterative one that is continually changing as the RI/FS progresses. Therefore, this list of ARARs represents a compilation of potential ARARs, of which subsets will be used or additional ARARs added as further site characterization is done.

It is understood that DOE will comply with the requirements of NEPA as specified in DOE Order 5440.1D, "National Environmental Policy Act Compliance Program." Further, DOE Order 5400.4, "Comprehensive Environmental Response, Compensation, and Liability Act Requirements," calls for integration of NEPA and CERCLA requirements for DOE remedial actions at CERCLA sites. This issue has been reaffirmed in the FFA for ORR Sect. I(A)(3) and Sect. III(A)(2) and Secretary of Energy Notice (SEN) of February 5, 1990 (SEN-15-90), which was issued to ensure that DOE's NEPA activities are carried out in a centralized and uniform manner. Therefore, the regulations found in NEPA will not be addressed in this report as ARARs.

Similarly, DOE addresses occupational safety in DOE Orders 5480.11 ("Radiation Protection for Occupational Workers"), 5480.4 ("Environmental Protection, Safety, and Health Protection Standards"), 5483.1A ("Occupational Safety and Health Program for

Table 5.1. Chemicals of potential concern at BCV OU 4

Organics	Metals
Acetone	Aluminum
2-Butanone	Barium
Carbon tetrachloride	Cadmium
Chloroform	Chromium
1,1-Dichloroethane	Iron
1,1-Dichloroethylene	Lead
1,2-Dichloroethylene	Manganese
Methylene chloride (dichloromethane)	Mercury
Polychlorinated biphenyls	
Tetrachloroethylene	Uranium
1,1,1-Trichloroethane	
Trichloroethylene	
Vinyl chloride	
Inorganics	Miscellaneous
Nitrate	Gross alpha ^a
Sulfate	Gross beta ^a

^aU-238, Np-237, Tc-99, Sr-89, Sr-90, Am-241, tritium, and radium are the most probable emitters of gross alpha and beta.

Source: HSW Environmental Consultants, Inc. 1991.

Contractors at GOCO Facilities”), 5480.9 (“Construction Safety and Health Program”), and 5480.10 (“Contractor Industrial Hygiene Program”). However, ARARs apply to those federal and state regulations that are designed to protect the environment, and do not generally apply to occupational safety regulations. Therefore, the DOE orders related to occupational safety, as well as the regulations promulgated by the Occupational Safety and Health Administration (OSHA), are not addressed as ARARs unless they specifically apply to remedial action goals. The OSHA regulations will be addressed in the Health and Safety Plan for this OU.

5.1.1.1 Definitions

Applicable requirements are “those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site” (40 *CFR* 300.5).

Relevant and appropriate requirements are “those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site” (40 *CFR* 300.5).

Requirements under federal or state law may be *either* applicable *or* relevant and appropriate to CERCLA cleanup actions, but not both. However, requirements must be *both* relevant *and* appropriate for compliance to be necessary. In the case where a federal and a state ARAR are available, or where there are two potential ARARs addressing the same issue, the more stringent regulation must be selected. However, CERCLA Sect. 121(d)(4) provides several ARAR waiver options that may be invoked, providing that the basic premise of protection of human health and the environment is not ignored. A waiver is available for state standards that have not been applied uniformly in similar circumstances across the state. In addition, CERCLA Sect. 121(d)(2)(C) forbids state standards that effectively prohibit land disposal of hazardous substances.

CERCLA on-site remedial response actions must only comply with the substantive requirements of a regulation and not the administrative requirements to obtain federal, state, or local permits [CERCLA Sect. 121(e) and FFA Sect. XXII]. To ensure that CERCLA response actions proceed as rapidly as possible, EPA has reaffirmed this position in the final NCP (55 *FR* 8756, March 8, 1990). **Substantive requirements** pertain directly to the actions or conditions at a site, while **administrative requirements** facilitate their implementation. EPA recognizes that certain of the administrative requirements, such as consultation with state agencies and reporting, are accomplished through the state involvement and public participation requirements of the NCP. These administrative requirements should be observed if they are useful in determining cleanup standards at the site (55 *FR* 8757).

In the absence of federal- or state-promulgated regulations, there are many criteria, advisories, guidance values, and proposed standards that are not legally binding but may serve as useful guidance for setting protective cleanup levels. These are not potential ARARs but are “to-be-considered” (TBC) guidance.

5.1.2 Chemical-Specific ARARS

“Chemical-specific requirements set health- or risk-based concentration limits or discharge limitations in various environmental media for specific hazardous substances, pollutants, or contaminants” (53 *FR* 51437). These requirements generally set protective cleanup levels for the chemicals of concern in the designated media or else indicate a safe

level of discharge that may be incorporated when considering a specific remedial activity. Although limited in number, chemical-specific standards have been established under several statutes, including RCRA, the SDWA, the Clean Water Act (CWA), and the Clean Air Act (CAA).

5.1.2.1 Groundwater

As stated in the NCP (55 *FR* 8666, March 8, 1990), the goal of EPA's approach to cleanup of contaminated groundwater is to return usable groundwater to its beneficial use within a given time frame that is reasonable for the particular circumstances at a CERCLA site. Groundwater at the ORR has not been given an EPA classification. Although not an ARAR unless promulgated, the EPA guidance on groundwater classification should be used to determine whether groundwater at the ORR falls within Class I, II, or III. Classes I and IIA represent current sources of drinking water of varying value, Class IIB represents potential sources of drinking water, and Class III groundwater is not considered to be a potential source of drinking water and is of limited beneficial use.

The Ground Water Management Section of the Tennessee Division of Water Supply is in the process of developing a groundwater classification system for Tennessee groundwaters. The draft classification has been revised several times and will be resubmitted for public comment soon; a final version is expected by early 1993. At that time, the document should be consulted to determine which groundwater classification will be legally applicable to BCV OU 4 groundwater. Final determination of ARARs will depend on the chosen groundwater classification.

In the NCP, EPA states the preference for SDWA MCLs and nonzero maximum contaminant level goals (MCLGs) or other health-based standards, criteria, or guidance for cleanup of Class I and Class II groundwater at CERCLA sites (55 *FR* 8732). Alternate concentration limits (ACLs) may also be used when active restoration of the groundwater to MCLs or nonzero MCLGs is not practicable (55 *FR* 8754). For Class III groundwaters, EPA establishes remediation levels based on specific site conditions, the beneficial use of the groundwater, and environmental receptors (55 *FR* 8732). Federal MCLs/MCLGs and action levels for contaminants of concern at BCV OU 4 are listed in Table 5.2 (with corresponding required detection limits for analyses requested in Chap. 6).

MCLs are enforceable standards that take into consideration human health effects, available treatment technologies, and costs of treatment. MCLGs are strictly health-based standards that disregard cost or treatment feasibility and are not legally enforceable. MCLs are legally applicable to water "at the tap" but are not usually legally applicable to cleanup of groundwater or surface water. However, they may be considered as relevant and appropriate in situations where groundwater or surface water may be used for drinking water. CERCLA Sect. 121(d)(2)(A) specifically mentions that remedial actions must require a level or standard of control that at least attains MCLGs and federal ambient water quality criteria (WQC) where such goals or criteria are relevant and appropriate under the circumstances of the release. Although MCLGs and WQC are nonenforceable guidelines, Congress elevated them to a higher status by specifically mentioning them in CERCLA. Therefore, promulgated MCLGs are also listed in Table 5.2. At present, EPA is planning to use the SDWA MCLs

Table 5.2. Chemical-specific federal SDWA regulations for chemicals of potential concern at BCV OU 4^a

Chemical	SDWA MCLs (µg/L)	SDWA MCLGs (µg/L)	Analytical detection limits (µg/L)
Barium ^b	2,000	2,000	5
Cadmium ^c	5	5	2
Carbon tetrachloride ^d	5	0	5
Chromium (total) ^c	100	100	8
1,1-Dichloroethylene ^d	7	7	5
<i>cis</i> -1,2-Dichloroethylene ^e	70	70	5
<i>trans</i> -1,2-Dichloroethylene ^e	100	100	5
Dichloromethane (methylene chloride) ^f	5	0	5
Lead	15 ^g	0	2
Mercury ^c	2	2	0.1
Nitrate (as N) ^c	10,000	10,000	
Nitrate + Nitrite (as N) ^c	10,000	10,000	
Polychlorinated biphenyls	0.5 ppb	0	
Sulfate ^h	400,000/500,000	400,000/500,000	
Tetrachloroethylene ^e	5	0	5
1,1,1-Trichloroethane ^d	200	200	5
Trichloroethylene ^d	5	0	5
Trihalomethanes (total) ^{i,j}	100		
Vinyl chloride ^d	2	0	1

^aTennessee state MCLs/MCLGs are identical to the federal.

^b56 FR 30266 (July 1, 1991). Effective January 1, 1993.

^cThe final MCL/MCLG was set for this chemical (56 FR 3526, January 30, 1991) and supersedes the original interim SDWA MCL. Effective July 30, 1992.

^d52 FR 25690 (July 8, 1987).

^e56 FR 3526 (January 30, 1991). Effective July 30, 1992.

^f57 FR 31776 (July 17, 1992). Effective January 17, 1994.

^g56 FR 26460 (June 7, 1991). This "action level," when measured in the 90th percentile at the consumer's tap, triggers initiation of corrosion control studies and treatment requirements. Effective Dec. 7, 1992; interim MCL of 50 µg/L for lead remains in effect until that time.

^hThis is a **proposed** MCL/MCLG only (55 FR 30370, July 25, 1990). EPA has deferred setting a final MCL/MCLG for sulfate pending further study (57 FR 31776, July 17, 1992).

ⁱ40 FR 59570 (December 24, 1975).

^jTotal trihalomethanes refers to the sum of the concentration of chloroform, bromodichloromethane, dibromochloromethane, and bromoform.

for remedial action compliance for carcinogens that have an MCLG of zero and any nonzero MCLG for systemic toxicants (55 *FR* 8752).

EPA has revised its drinking water standards for lead, eliminating the MCL and replacing it with an "action level" of 15 $\mu\text{g/L}$ (56 *FR* 26460, June 7, 1991), applicable to community and nontransient, noncommunity water systems. Included in the national primary drinking water regulation is a treatment technique requirement. If the action level for lead is exceeded at the tap, a state is required to analyze source water samples and to decide what treatment levels are necessary to minimize lead levels delivered to users from the affected distribution system. In the instance of contaminated groundwater at BCV OU 4, the action level for lead is neither legally applicable nor relevant and appropriate at this time, although the Tennessee proposed draft rule, "Hazardous Substance Site Remedial Action" (Chapter 1200-1-13, August 4, 1992), cites federal MCLs and action levels as cleanup levels for remedial action sites. The EPA Office of Solid Waste and Emergency Response (OSWER) has recommended that a final cleanup level of 15 $\mu\text{g/L}$ for lead in groundwater usable for drinking water is protective of sensitive populations (OSWER memorandum dated June 21, 1990). This might be considered TBC guidance for remediation of lead-contaminated groundwater.

Chapter 1200-5-1 of the Rules of TDEC, as amended effective January 10, 1991, lists MCLs for public water systems which are identical to the federal MCLs in effect at that time. These regulations will be revised to incorporate the recent revisions in federal MCLs, with promulgation expected by June 1993; therefore they are not repeated here.

National Secondary Drinking Water Standards (NSDWS) regulate contaminants that affect the aesthetic qualities related to public acceptance of drinking water and are implemented in 40 *CFR* 143.3 as secondary maximum contaminant levels (SMCLs). These regulations are not federally enforceable but rather are intended to serve as guidelines for use by states in regulating water supplies. Tennessee has promulgated SMCLs in TDEC Rule 1200-5-1.12 (see Table 5.3). These regulations are designed to provide water to the consumer which is aesthetically pleasing. They apply to all community water systems and to those noncommunity water systems "as may be deemed necessary" by TDEC. In that context, they would not be legally applicable to cleanup of groundwater or surface water but may be considered as relevant and appropriate in instances where these media may provide private drinking water sources. Since the federal NSDWS will be incorporated into the TDEC secondary drinking water regulations (Foster 1990), they are included in Table 5.3 for completeness.

The TDEC Division of Superfund has issued a draft rule, "Hazardous Substance Site Remedial Action" (Chap. 1200-1-13, issued August 4, 1992), governing cleanup of remedial action Superfund sites in the state of Tennessee. Chapter 1200-1-13-.08 of the proposed rule lists cleanup levels for hazardous substance remediation and states that the objectives of this section are to ". . . (a) establish clear, objective cleanup levels by identifying and/or developing chemical-specific ARARs, and (b) insure consistent procedures for the development and usage of cleanup levels." The proposed rule states that where groundwater is classified for drinking water, cleanup levels shall either meet federal SDWA MCLs and action levels (see Table 5.2), SMCLs if MCLs are not available (see Table 5.3), or naturally occurring background levels. Chapter 1200-1-13-.08(5)(a) states that "Where numerical standards are not available, a groundwater cleanup level should be developed based on

Table 5.3. Federal and Tennessee secondary drinking water regulations for chemicals of potential concern at BCV OU 4

Chemical	Federal SMCL ^a (mg/L)	Tennessee SMCL ^b (mg/L)
Aluminum	0.05-0.02 ^{c,d}	
Iron	0.3	0.3
Manganese	0.05	0.05
Sulfate	250	250

^aFinal rule [44 FR 42198 (July 19, 1979)]. NSDWS are included in this table for completeness because they will be incorporated into the TDEC secondary drinking water regulations when they are revised.

^bChapter 1200-5-1.12 of the Rules of the TDEC.

^cNSDWS final rule [56 FR 3526 (January 30, 1991)]. Effective date July 30, 1992.

^dLevel recommended to prevent posttreatment precipitation in the distribution system.

(a) ingestion and inhalation effects by utilizing the *Human Health Evaluation Manual, Part B*, December 1991, or (b) a risk assessment shall be developed utilizing site-specific justifications, or (c) guidance levels established under the RCRA Hazardous Waste Regulations shall be utilized. Where groundwater is not classified for drinking water, cleanup levels shall be established in accordance with Chapter 1200-4-3.07(3)(d)(2). Chapter 1200-4-3.07(3)(d)(2) is not yet promulgated; it is part of the TDEC groundwater classification rule which is under development and due to be issued in early 1993. When the draft *Hazardous Substance Site Remedial Action* rule is promulgated, it will be legally applicable to cleanup of groundwater at BCV OU 4; until that time it can be considered TBC guidance.

5.1.2.2 Surface water

CERCLA Sect. 121(d)(2)(A) specifically states that remedial actions shall at least attain federal ambient WQC established under the CWA if they are relevant and appropriate. In determining whether any WQC are relevant and appropriate, one must consider the "designated or potential use of the surface or groundwater, the environmental media affected, the purposes for which the criteria were developed, and the latest information available" [CERCLA Sect. 121(d)(2)(B)]. Federal WQC are derived for the protection of freshwater aquatic organisms and for the protection of human health from the consumption of contaminated drinking water and/or aquatic organisms. Federal WQC are not promulgated standards. They are intended to serve as guidelines for individual states to use in promulgating state water quality standards. When a state adopts federal WQC and promulgates them in their state regulations, they then become legally enforceable under that state's law.

TDEC Rules Chapter 1200-4-3 lists seven use designation categories for Tennessee's surface waters. Specific water quality standards are promulgated for each use category. Under

the Tennessee Water Quality Control Act, the Tennessee Water Quality Control Board has classified Bear Creek from mile 0.0 to its origin for fish and aquatic life, recreation, irrigation, and livestock watering and wildlife uses (TDEC Rules Chapter 1200-4-4).

As part of the federal requirement for a triennial review of state water quality standards, the TDEC Division of Water Pollution Control has promulgated amendments to TDEC Rules Chapters 1200-4-3 and 1200-4-4. TDEC has revised its water quality standards (effective date August 30, 1991) to include criteria for protection of recreational uses. These criteria are human health criteria derived to protect the consumer from consumption of contaminated fish; these criteria are similar to the federal WQC for the protection of human health from consumption of fish alone. However, they are based on a risk factor of 10^{-5} rather than the 10^{-6} risk factor on which the federal WQC are based. Table 5.4 lists the revised Tennessee WQC for recreation and fish and aquatic life which would be ARAR for any portion of Bear Creek that would be cleaned up under the remedial actions for this OU.

Federal WQC would be ARAR in the absence of a state WQC for a particular chemical or if the federal WQC is more stringent than the state WQC. EPA Region IV has revised the federal WQC for the protection of freshwater aquatic life based on current toxicity and bioaccumulation data for aquatic organisms. Included in Table 5.4 are EPA Region IV WQC for aluminum, iron and trivalent chromium (EPA 1991a) because the state of Tennessee does not have promulgated WQC for the protection of freshwater organisms in surface waters for these chemicals. When the designated use classification requires protection of aquatic life or when environmental factors are being considered at a remedial action site, a WQC for the protection of aquatic life that is more stringent than the SDWA MCL may be relevant and appropriate (55 FR 8754) for CERCLA cleanup.

5.1.2.3 TBC guidance

In the absence of federally or state-promulgated ARARs, or in the case where ARARs are not adequately protective, EPA states a preference for reference doses (RfDs) or reference concentrations (RfCs) for systemic toxicants, and carcinogenic slope factors (CSFs) for carcinogens or Office of Drinking Water (ODW) Health Advisories (HAs) (EPA 1989b) for drinking water contaminants. The RfDs, RfCs, and CSFs are available through *IRIS* (EPA 1991b) and the *EPA Health Effects Assessment Summary Tables* (EPA 1992). Region IV surface water screening values may be used as to-be-considered values for parameters lacking water quality criteria values.

The EPA ODW has developed nonregulatory HAs for concentrations of noncarcinogenic contaminants in drinking water at which no adverse health effects would be expected to occur. A lifetime HA of 200 $\mu\text{g/L}$ is listed for 2-butanone. This is the only contaminant of concern at BCV OU 4 which does not have a promulgated MCL/SMCL but does have an HA available.

Table 5.4. Available Tennessee water quality criteria for designated water uses for chemicals of potential concern at BCV OU 4 ($\mu\text{g/L}$)^a

Chemical	Domestic water supply	Recreation ^b	Fish and aquatic life	
			CMC ^c	CCC ^d
Aluminum	NA	NA	750 ^e	87 ^f
Cadmium	10	NA	4 ^g	1 ^g
Carbon tetrachloride	5	44	NA	NA
Chloroform (trichloromethane)	NA	4700	NA	NA
Chromium (III)	NA	670,000	1,700 ^{e,g}	210 ^{f,g}
Chromium (hexavalent)	NA	NA	16	11
Chromium (total)	50	NA	NA	100
1,1-Dichloroethylene	7	32	NA	NA
Iron	0.0003 ^h	NA	NA	1,000 ^f
Lead	50	NA	82 ^g	3 ^g
Manganese	50 ^h	NA	NA	NA
Mercury	2	0.15	2.4	0.012
Methylene chloride (dichloromethane)	NA	16,000	NA	NA
Polychlorinated biphenyls	NA	0.001	NA	0.001
Tetrachloroethylene	NA	88	NA	NA
1,1,1-Trichloroethane	200	170,000	NA	NA
Trichloroethylene	5	807	NA	NA
Vinyl chloride	2	5250	NA	NA

^aRules of the TDEC, Chapter 1200-4-3.

^bBased on a 10^{-5} risk level.

^cCMC = criterion maximum concentration.

^dCCC = criterion continuous concentration.

^eOne-hour average concentration not to be exceeded more than once every 3 years. This is a federal water quality criteria; Tennessee does not have a water quality standard for surface waters for the protection of freshwater organisms for this chemical.

^fFour-day average concentration not to be exceeded more than once every 3 years. This is a federal water quality criteria; Tennessee does not have a water quality standard for surface waters for the protection of freshwater organisms for this chemical.

^gCalculated for a water hardness of 100 mg/L, the approximate average hardness of Bear Creek.

^hSecondary MCL; Rules of the TDEC, Chapter 1200-5-1.12.

5.1.3 Radiation Protection Standards

Very few applicable standards are available for the cleanup of radioactively contaminated CERCLA sites. The Atomic Energy Act (AEA) of 1954 and its amendments delegated authority for control of nuclear energy to DOE, the NRC, and EPA. In addition, certain states have regulatory authority and programs for radioactive waste. EPA's regulations are derived from several statutes and cover many types of activities and all types of radioactive materials. The NRC licenses the possession and use of various types of radioactive materials at certain types of facilities. Tennessee is an NRC-Agreement state and, as such, has its own authority and licensing regulations.

DOE is authorized to control all types of nuclear materials at sites under its jurisdiction and is exempt from the NRC licensing and regulatory requirements. Therefore, NRC regulations are not considered legally applicable to CERCLA cleanup activities at DOE facilities. However, all or parts of individual NRC regulations may be considered relevant and appropriate depending on the particular conditions at each OU. DOE regulations for handling and cleanup of radioactive materials are outlined in a series of internal DOE orders that are binding to DOE contractors but are not considered by EPA to be ARARs. Therefore, for the purposes of development of ARARs, DOE orders will be treated as TBC guidance.

5.1.3.1 EPA regulations

EPA has promulgated MCLs for radionuclides in community water systems (see Table 5.5). These MCLs appear in two forms—concentration limits for certain alpha-emitting radionuclides (40 *CFR* 141.15) and an annual dose limit for the ingestion of certain beta- and gamma-emitting radionuclides (40 *CFR* 141.16). MCLs and MCLGs were proposed for uranium and repropoed for ²²⁶Ra and ²²⁸Ra, beta emitters, and photon emitters on July 18, 1991, and are included in Table 5.5. Final promulgation of the concentration limits is not expected until April 1993. These concentration limits may be relevant and appropriate for cleanup of contaminated groundwater at BCV OU 4 and would become legally applicable when the Tennessee *Hazardous Substance Site Remedial Action* rule is promulgated.

Table 5.6 lists EPA, NRC, and DOE radiation protection standards that are described below. Subpart H of 40 *CFR* 61 addresses atmospheric radionuclide emissions from DOE facilities and may be applicable to airborne emissions during cleanup of BCV OU 4. EPA has issued a final National Emissions Standards for Hazardous Air Pollutants (NESHAPs) rule (54 *FR* 51654, December 15, 1989) that limits emissions of radionuclides to the ambient air from all sources at DOE facilities to amounts that would not cause any member of the public to receive an effective dose equivalent of 10 mrem/year (40 *CFR* 61.92).

5.1.3.2 NRC regulations

As mentioned previously, DOE is not regulated by the NRC; however, NRC regulations may be relevant and appropriate or provide some TBC guidance for cleanup of radioactive components of the groundwater at BCV OU 4. The standards for protection against radiation (10 *CFR* 20) were revised recently (56 *FR* 23360, May 21, 1991). They are designed to limit

Table 5.5. Radionuclide-specific standards under the SDWA for chemicals of potential concern in groundwater and surface water at BCV OU 4

Radionuclide	Current SDWA MCL	Proposed SDWA MCLs ^a
Radium ^b	5 pCi/L	20 pCi/L
Gross alpha ^c	15 pCi/L	15 pCi/L
Gross beta	4 mrem/year	4 mrem/year
Natural uranium		20 µg/L ^d
Strontium-90	8 pCi/L	42 pCi/L
Tritium	20,000 pCi/L	60,900 pCi/L
All other manmade radionuclides	4 mrem/year ^e	4 mrem/year ^e

^aProposed rule, July 18, 1991 (56 *FR* 33050); final rule expected December 1993.

^bThe present MCL applies to combined ²²⁶Ra and ²²⁸Ra; the proposed MCL applies to each separately.

^cThe present MCL excludes radon and uranium but includes ²²⁶Ra; the proposed MCL excludes all three radionuclides.

^dApproximately equal to 30 pCi/L.

^eIf two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any organ shall not exceed 4 mrem/year.

radiation exposures from NRC-licensed activities. They provide permissible worker exposure limits for restricted areas of 5 rem/year (10 *CFR* 20.1201) and lowered radiation exposure limits to the general public in unrestricted areas from 500 mrem/year to 100 mrem/year (10 *CFR* 20.1301).

Appendix B of 10 *CFR* 20.1001–20.2401 sets annual average concentration limits for radionuclides in airborne and liquid effluents. These represent the radionuclide concentrations which, if inhaled or ingested, would produce a total annual effective dose equivalent of 50 mrem.

The NRC has promulgated licensing requirements for land disposal of radioactive waste (10 *CFR* 61). Part 61 contains procedural requirements and performance standards applicable to any method of land disposal, with specific technical requirements for near-surface disposal of radioactive waste. Although not legally applicable, the substantive requirements found in this regulation may be relevant and appropriate or provide TBC guidance for remedial options selected at BCV OU 4 and will be addressed when remedial alternatives are selected. 10 *CFR* 61.41 states that concentrations of radioactive materials released to the environment in all media must not result in an annual dose exceeding 75 mrem to the thyroid and 25 mrem to total body or all other organs of any member of the public. In addition, reasonable effort must be made to maintain releases of radioactive materials to “as low as reasonably achievable” (ALARA).

5.1.3.3 DOE orders

DOE orders are not promulgated regulations and thus are not considered to be ARARs by EPA. They are, however, binding between DOE and Energy Systems because of contractual agreements. In particular, the derived maximum radionuclide concentration guidelines for

Table 5.6. Radiation protection standards that may be ARAR or TBC for BCV OU 4

Regulation	Applicability	Exposure conditions	Standard
40 <i>CFR</i> 61	NESHAPs for DOE facilities	Public exposure, airborne emissions	10 mrem/year
40 <i>CFR</i> 141	Drinking water MCLs	Community water systems, gross beta	4 mrem/year
10 <i>CFR</i> 20	Radiation from NRC-licensed facilities	Worker exposure limits in unrestricted areas	5 rem/year ^a
		Public exposure, unrestricted areas	100 mrem/year ^a
10 <i>CFR</i> 61	Licensing requirements for land disposal of radioactive waste	Public exposure, all sources	25 mrem/year (total body) 75 mrem/year (thyroid)
DOE Order 5400.5 ^b	Radiation protection of the public and the environment	Public exposure, all sources	100 mrem/year
		Temporary exemption, maximum limit	500 mrem/year
		Aquatic organism exposure, absorbed dose	1 rad/d
DOE Order 5820.2A	Radioactive waste management	Public exposure, all sources, excluding air	25 mrem/year
		Public exposure, atmospheric releases	10 mrem/year
DOE Order 5480.11 ^c	Radiation protection for occupational workers	Worker exposure limits, continuous exposure	5 rem/year, cancer effects 50 rem/year, noncancer effects, any organ or tissue
		Public exposures, controlled areas, effective dose equivalent	100 mrem/year

^aFinal rule of May 22, 1991 (56 *FR* 23360), effective June 21, 1991. Implementation of this regulation by NRC licensees may be deferred until January 1, 1994 (57 *FR* 38588, August 26, 1992). This rule deleted the quarterly limits for occupational exposures and lowered the limit for public exposure from 500 to 100 mrem/year.

^bDOE plans to propose this order as 10 *CFR* 834 in November 1992.

^cProposed as 10 *CFR* 835 (56 *FR* 64334, December 9, 1991). Final rule expected December 1992.

discharges of radioactively contaminated liquids to surface waters, aquifers, and soil that appear in the final DOE Order 5400.5 ("Radiation Protection of the Public and the Environment") may be useful as TBC guidance. A basic dose limit of 100 mrem/year is given for routine DOE activities, including remedial action monitoring, cleanup, and control of residual radioactive material. The over-riding principle of the order is that all exposures of the public shall be ALARA. DOE plans to propose this order for codification under 10 *CFR* 834 in November 1992. When promulgated, these standards will then become legally applicable to cleanup at BCV OU 4.

DOE Order 5820.2A ("Radioactive Waste Management," September 9, 1988) states that the management of low-level radioactive waste must ensure that external exposure to the waste and concentrations of radioactive material that may be released into surface water and soil do not exceed 25 mrem/year to any member of the public. Releases to the atmosphere shall not exceed 10 mrem/year. Reasonable effort should be made to maintain releases to the environment to ALARA levels.

DOE Order 5480.11 ("Radiation Protection for Occupational Workers") contains guidelines for worker protection which are similar to those of 10 *CFR* 20, i.e., 5 rem/year and 50 rem/year annual effective dose equivalent for stochastic (cancer) and nonstochastic (systemic) effects, respectively, from both internal and external sources for continuous exposures. Also included in the order are standards for the general public when entering a controlled area. Exposures to the public are limited to an effective dose equivalent of 100 mrem/year. As with other DOE orders, the ALARA principle prevails. DOE has proposed for codification in 10 *CFR* 835 the primary standards for radiation protection of occupational workers from normal operation of DOE facilities (56 *FR* 64334, December 9, 1991). A final rule is expected in December 1992. When promulgated, these standards will then be legally applicable to cleanup activities at BCV OU 4.

In the event that DOE orders are more stringent or cover remedial action activities not addressed by existing ARARs, they should be used as TBC guidance for developing protective remedies at BCV OU 4. The DOE orders will be addressed in detail following selection of remedial alternatives for BCV OU 4.

5.1.3.4 TBC guidance for radiological risk assessment

The EPA Office of Radiation Programs has derived slope and unit risk factors for radionuclides of concern at remedial sites for each of three major exposure pathways (inhalation, ingestion, and external exposure to contaminated soil). These are available in the EPA *Health Effects Assessment Summary Tables* (EPA 1992), and will be considered as TBC when the radionuclide contamination at BCV OU 4 is more clearly defined.

5.1.4 Location-Specific ARARS

Location-specific requirements "set restrictions upon the concentration of hazardous substances or the conduct of activities solely because they are in special locations" (53 *FR* 51437). Table 5.7 lists the major federal and state location-specific ARARs that might be pertinent to remedial actions at BCV OU 4.

Table 5.7. Location-specific ARARs for BCV OU 4

Location characteristic(s)	Operating condition(s)	Requirement(s)	Citation(s)
Wetlands			
Presence of wetlands as defined in Executive Order 11990 Sect. 7(c) and 40 CFR 6, Appendix A Sect. 4(j)	Agency action which involves: - acquiring, managing, and disposing of lands and facilities - providing federally undertaken, financed, or assisted construction and improvements - conducting federal activities and programs affecting land use	Whenever possible, actions must avoid or minimize adverse impacts on wetlands and act to preserve and enhance their natural and beneficial values. New construction in wetlands areas should be particularly avoided unless there are no practicable alternatives Wetlands protection considerations shall be incorporated into planning, regulating, and decision-making processes	Executive Order 11990 40 CFR 6.302(a) 40 CFR 6, Appendix A 10 CFR 1022
Presence of wetlands as defined in 40 CFR 230.3(t) and 33 CFR 328.3(b)	Action involving discharge of dredge or fill material into wetlands	Action to avoid degradation or destruction of wetlands must be taken to the extent possible. Discharges for which there is a practicable alternative with less adverse impacts or those which would cause or contribute to significant degradation are prohibited If adverse impacts are unavoidable, action must be taken to enhance, restore, or create alternative wetlands	CWA Sect. 404 40 CFR 230 33 CFR 320-330
Floodplains			
Within 100-year floodplain	Treatment, storage, or disposal facility RCRA-defined listed or characteristic hazardous waste (40 CFR 261) -or- RCRA- permitted facility	Facility must be designed, constructed, operated, and maintained to prevent washout of any hazardous waste by 100-year flood	40 CFR 264.18(b)

Table 5.7 (continued)

Location characteristic(s)	Operating condition(s)	Requirement(s)	Citation(s)
Within "lowland and relatively flat areas adjoining in-land and coastal waters and other floodprone areas such as offshore islands, including at a minimum, that area subject to a one percent or greater chance of flooding in any given year." [Executive Order 11988 Sect. 6(c) and 40 CFR 6, Appendix A Sect. 4(d)]	Action which involves: - acquiring, managing, and disposing of lands and facilities - providing federally undertaken, financed, or assisted construction and improvements - conducting federal activities and programs affecting land use	Action shall be taken to reduce the risk of flood loss, minimize the impact of floods on human safety, health and welfare, and restore and preserve the natural and beneficial values of floodplains The potential effects of actions in floodplains shall be evaluated and consideration of flood hazards and floodplain management ensured If action is taken in floodplains, alternatives that avoid adverse effects and incompatible development and minimize potential harms shall be considered	Executive Order 11988 40 CFR 6.302(b) 40 CFR 6 (Appendix A) 10 CFR 1022
Wilderness areas, Wildlife resources, Wildlife refuges, Scenic rivers			
Within area encompassing or affecting waters of the state of Tennessee as defined in TCA 69-3-103(32) and the presence of wildlife or aquatic life	Action involving the discharge of any pollutants into the waters of the state [see TCA 69-3-103(18) and (21) for noninclusive list]	Discharge of "substances" which "will result or will likely result in harm, potential harm or detriment to the health of animals, birds, fish, or aquatic life" is prohibited	Tennessee Water Quality Control Act of 1977 (TCA 69-3-101 <i>et seq.</i>) Stream Use Classifications (TDEC Rules - Chap. 1200-4-4)
Within area affecting stream or river - and- presence of fish or wildlife resources	Action which results in the control or structural modification of a natural stream or body of water	The effects of water-related projects on fish and wildlife resources must be considered Action must be taken to prevent, mitigate, or compensate for project-related damages or losses to fish and wildlife resources Off-site actions that alter a resource require consultation with the FWS ^c , NMFS ^d , and/or appropriate state agency Consultation is also strongly recommended for on-site actions	Fish and Wildlife Coordination Act (16 USC ^b 661 <i>et seq.</i>) 40 CFR 6.302(g)

Table 5.7 (continued)

Location characteristic(s)	Operating condition(s)	Requirement(s)	Citation(s)
Location encompassing aquatic ecosystem with dependent fish, wildlife, other aquatic life, or habitat	Action involving the discharge of dredge or fill material into aquatic ecosystem	Degradation or destruction of aquatic ecosystems must be avoided to the extent possible. Discharges which cause or contribute to significant degradation of the water of such ecosystem are prohibited	CWA Sect. 404 40 CFR 230 33 CFR 320-330
Location encompassing a state-designated natural area		The scientific, scenic, recreational, and educational values of these areas must be preserved and steps taken to prevent impairment thereof	TCA 11-14-101 <i>et seq</i>
Endangered, Threatened, or Rare Species			
Presence of endangered or threatened species -or- critical habitat of such species as designated in 50 CFR 17, 50 CFR 226, or 50 CFR 227	Action which is likely to jeopardize species or destroy or adversely modify critical habitat	Actions that jeopardize species/habitat must be avoided or appropriate mitigation measures taken Off-site actions that affect species/habitat require consultation with DOI, FWS, NMFS, and/or state agencies, as appropriate, to ensure that proposed actions do not jeopardize the continued existence of the species or adversely modify or destroy critical habitat Consultation is also strongly recommended for on-site actions	Endangered Species Act of 1973 (16 USC 1531 <i>et seq.</i>) 50 CFR 402 40 CFR 6.302(h) Fish and Wildlife Coordination Act (16 USC 661 <i>et seq.</i>)
Presence of endangered or threatened species or critical habitat (see above citation) of same within an aquatic ecosystem as defined in 40 CFR 230.3(c)	Action involving discharge of dredge or fill material into aquatic ecosystem	Dredge or fill material shall not be discharged into an aquatic ecosystem if it would jeopardize such species or would likely result in the destruction or adverse modification of a critical habitat of the species	CWA Sect. 404 40 CFR 230.10(b)

Table 5.7 (continued)

Location characteristic(s)	Operating condition(s)	Requirement(s)	Citation(s)
Presence of Tennessee state-listed endangered or threatened animal species as created and amended pursuant to TCA 70-8-105		Protected species may not be taken, possessed, transported, exported, processed, sold, offered for sale, or shipped. Certain exceptions may be allowed such as for educational, scientific, etc., reasons or where necessary to alleviate property damage or protect human health or safety. These exceptions require a permit if the remedial action or its attendant effects are off site	Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act of 1974 (TCA 70-8-101 <i>et seq.</i>)
Archaeologic and Historic Resources			
Presence of archaeological resources on public land	Action which would impact resource	Steps must be taken to protect archaeological resources and sites	Archaeological Resources Recovery Act of 1979 (16 USC 470aa-II) 43 CFR 7
Presence of archaeological or historic resources	Action involving dam construction or other alteration of terrain which might cause irreparable loss or destruction of significant scientific, prehistoric, historic, or archaeological data	The Secretary of Interior must be advised of the presence of the data A survey of affected areas for resources and data must be conducted and steps taken to recover, protect, and preserve data therefrom or request that DOI do so	Archaeological and Historic Preservation Act (16 USC 469a-c) 40 CFR 6.301

Table 5.7 (continued)

Location characteristic(s)	Operating condition(s)	Requirement(s)	Citation(s)
Presence of federally owned, administered, or controlled prehistoric or historic resources -or- the likelihood of undiscovered resources		<p>Cultural resources included on or eligible for inclusion on the National Register of Historic Places (36 CFR 60) or National Historic Landmark Program (36 CFR 65) must be identified</p> <p>Action(s) that will affect such resources must be identified and alternatives to the action(s) examined and considered</p> <p>When alteration or destruction of the resource is unavoidable, steps must be taken to minimize or mitigate the impacts and to preserve records and data of the resource</p> <p>When all or part of a remedial action is off site, the consultation requirements of 16 USC 470f must be completed</p> <p>Consultation is also strongly recommended for on-site actions</p>	<p>National Historic Preservation Act (16 USC 470a-w)</p> <p>Executive Order 11593</p> <p>40 CFR 6.301</p> <p>36 CFR 800</p>
Cemetery located on property within Tennessee		Destruction or degradation of property in a graveyard or cemetery is prohibited	Tennessee General Cemetery Act of 1968 (TCA 46-1-101 <i>et seq.</i>)

^aTCA = Tennessee Code Annotated.^bUSC = United States Code^cFWS = Fish and Wildlife Service.^dNMFS = National Marine Fisheries Service.^eDOI = U.S. Department of the Interior.

5.1.4.1 Wetlands and floodplains

The majority of Bear Creek is located in the BCV which is bounded on the north by Pine Ridge and on the south by Chestnut Ridge. Bear Creek flows south westward from its headwaters at the S-3 Ponds for ~4.5 miles, where it then turns northward to flow into EFPC. Altitudes of the land surface in the entire Bear Creek watershed range from 755 ft mean sea level (msl) to about 1200 ft msl on Pine Ridge and Chestnut Ridge. The total area of the Bear Creek watershed above the point where it crosses the Anderson/Roane county line is 1.57 miles². The area of the watershed at the NPDES station at BCK-4.55 is about 4.2 square miles. The area of the flood-of-record floodplain is 164 acres, with an average width of 169 ft (Turner et al. 1991).

As might be expected, there are a number of wetlands located around Bear Creek. A draft report of a recent wetlands survey was released in March 1991 (Cunningham and Pounds 1991). While the survey of the reservation was not exhaustive, several of the sites investigated near Bear Creek met the criteria for an area to be considered a wetland (Cunningham and Pounds 1991). Before any remedial action is taken, this report should be consulted and a survey conducted of the particular site that will be impacted.

If any remedial alternatives are selected which would impact the Bear Creek floodplain, the requirements found in Executive Order 11988, 40 *CFR* 264.18(b), 40 *CFR* 6.302(b), 40 *CFR* 6 (Appendix A), and 10 *CFR* 1022 would provide ARARs for BCV OU 4. If wetlands are affected, consideration should be given to Executive Order 11990, 40 *CFR* 6.302(a), 40 *CFR* 6 (Appendix A), and 10 *CFR* 1022. If any action involves the discharge of dredge or fill material into Bear Creek, the CWA Sect. 404, 40 *CFR* 230, and 33 *CFR* 320-330 may also be implicated. In addition, EPA intends to propose additional floodplain restrictions for location of TSD facilities Notice of Proposed Rulemaking [(NPRM), January 1993; Final Rule expected March 1994], and these restrictions will be incorporated into the TDEC Hazardous Waste Management regulations (Hinch 1989). At that time, the TDEC floodplain regulations may be ARARs for remedial actions at BCV OU 4.

5.1.4.2 Wilderness areas, wildlife resources, wildlife refuges, and scenic rivers

There are no known designated wilderness areas or wildlife refuges in the Bear Creek watershed, nor is Bear Creek listed as a state scenic river (Allen 1991). However, a variety of wooded and open areas along Bear Creek, as well as extensive edge communities, create favorable habitat for a wide variety of species of mammals, fish, and birds (DOE 1980, Kitchings and Story 1984). Therefore, if any remedial actions result in the control or structural modification of Bear Creek or otherwise impact aquatic resources, the provisions found in the Fish and Wildlife Coordination Act [16 USC 661 *et seq.*], 40 *CFR* 6.302(g), and the TDEC Water Quality Control Act may be applicable.

Slightly over 5000 acres of the ORR have been designated as a DOE NERP, which also includes Research Areas (RSAs) located both within and without the NERP itself (Parr and Pounds 1987). RSAs are designated when a specific area is being used to collect monitoring, baseline, or effects data and therefore requires protection from disturbance (Parr and Pounds 1987). RSA No. 27, Bear Creek characterization and monitoring, and RSA No. 28, EFPC may be impacted by remedial actions at BCV OU 4.

In addition to the NERP and its associated RSAs, DOE has also designated areas along certain portions of BCV as DOE-NERP Reference Areas (RAs) and DOE-NERP Natural Areas (NAs). RAs are those areas that are "representative of the vegetational communities of the southern Appalachian region or that possess unique biotic features" and are used exclusively for nonmanipulative research (Parr and Pounds 1987).

There is a large area of big bluestem, *Andropogon gerardii*, a species uncommon in East Tennessee, growing along Bear Creek and Bear Creek Road. This site is currently being considered for designation as a NERP RA (Parr and Pounds 1987). There are two other designated NERP NAs which must also be considered. NERP NA 13 is at the base of Pine Ridge, and NERP NA 4 is a forested area with wetlands and containing old stream or flood channels located on the north side of Pine Ridge. The NERP NA 4 site (covering areas on both the left and right sides of Highway 95) has also been registered as a State Natural Area (SNA) by agreement between DOE and TDEC (Howell 1986).

Because of the unique purposes and goals in establishing the NERP, the uses and restrictions that apply to these resources should be considered TBC guidance if remedial actions appear likely to impact the designated areas. Guidance regarding the permitted uses and restrictions of the various locations can be obtained from the NERP Project Manager at ORNL. In addition, should areas which are also designated SNAs (see above) by the state of Tennessee be affected, the provisions of the Tennessee Natural Areas Preservation Act of 1971 (TCA 11-14-101 *et seq.*) may be applicable.

5.1.4.3 Historic sites and archaeological findings

Several cemeteries appear to be located in the Bear Creek watershed. If any remedial alternatives will impact these cemeteries, the Tennessee General Cemetery Act of 1968 might be ARAR (see Table 5.7).

A number of archaeological and historic surveys of the reservation have been conducted over the years, and are summarized in Volume 3 of the *Resource Management Plan for the U.S. Department of Energy Oak Ridge Reservation* (Sanders 1984). A site north of Bear Creek Road and west of State Route 95 was examined in 1975 when Exxon Nuclear Company was considering a plant in that area. As a result of that survey, 20 historic structures were recorded (Fielder 1975). If any remedial alternatives are taken which would cause irreparable harm, loss, or destruction of any of these identified sites, the regulations found in the Archaeological and Historic Preservation Act might be applicable (see Table 5.7).

Also, a 1977 historic site reconnaissance survey located one standing structure, an essentially intact log house designated 853A, along a tributary of Bear Creek (Fielder 1977). It is identified as a Category 4 structure which can be preserved in its existing condition (stabilized), restored, or relocated. The 1977 survey team recommended that log house 853A be relocated.

Under the National Historic Preservation Act of 1966, as amended, a federal agency such as DOE is required to establish a program to "locate, inventory, and nominate" those properties under its control or ownership which "appear to qualify" for inclusion on the National Register of Historic Places. The agency must also "exercise caution to assure" that any of those properties which might qualify for inclusion are not inadvertently "demolished, substantially altered, or

allowed to deteriorate significantly" (16 USC 470h-2). Therefore, if a credible authority has not yet determined whether or not log house 853A appears to be qualified for inclusion on the National Register, such a determination must first be made. And if log house 853A does in fact appear qualified, the National Historic Preservation Act may be applicable for any remedial activities which would impact on log house 853A during the cleanup at BCV OU 4.

Moreover, there may be implications under the Archaeological Resources Protection Act of 1979 (ARPA) for log house 853A. ARPA was enacted for the purpose of protecting archaeological resources and sites on public lands, Sect. 2(b), and the definition of public lands includes those to which the United States holds free title Sect. 3(3)(B), and would include ORR. Under the implementing regulations for ARPA, found in 43 CFR 7, log house 853A appears to fall into a class of material remains which are considered "archaeological resources" [the survey team estimated its building date in the early to mid-nineteenth century (Sanders 1984)] and thus is protected under the Act [40 CFR 7, Sect. 7.3(3) and 7.3(3)(i)]. Although a permit would normally be required before interfering with an archaeological resource, CERCLA cleanup activities need only comply with the substantive requirements behind the permitting process pertaining to any sites (55 FR 8756, March 8, 1990). If any remedial alternatives are proposed which require the relocation, alteration, or defacement of log house 853A, the requirements set forth in 40 CFR 7, Sect. 7.8(a) may be applicable.

5.1.4.4 Rare, threatened, or endangered species

Presently, NERP NA 13 is home to the Canada lily, *Lilium canadense*, which is state-listed as threatened. NERP NA 4 contains both an uncommon aquatic plant, *Orontium aquaticum*, and the southern rein orchid, *Platanthera flava*. The southern rein orchid is state-listed as a species of special concern. During the wetlands survey, a twayblade orchid tentatively identified as *Liparis loeselii* (confirmation of identification to be made when it flowers) was found in the forested part of the wetland of an unnamed tributary of Bear Creek, and it is a state-listed endangered species. Finally *Platanthera peramoena*, the purple fringeless orchid, which is state-listed as threatened, has been identified where a tributary of Bear Creek crosses a powerline right-of-way near Pine Ridge (Cunningham and Pounds 1991).

No endangered or threatened fish species have been found in Bear Creek. However, the Tennessee dace, *Phoxinus tennesseensis*, has been found at every sampling site along Bear Creek above the weir and in at least four of the Bear Creek tributaries (Ryon 1990, Ryon and Loar 1988). This fish is listed as a species in need of management, and its habitat is state-protected (Starnes and Etnier 1980).

No threatened or endangered species of aquatic macroinvertebrates have been collected in Bear Creek. Only one species of reptile, the pine snake, *Pituophis melanoleucas*, has been verified in the Bear Creek watershed. It is listed by the Tennessee Wildlife Resources Agency as threatened (Kroodsma 1987).

Should any remedial actions at BCV OU 4 impact any federally listed endangered or threatened species, the provisions found in the Endangered Species Act of 1973 (16 USC 1531 *et seq.*), 50 CFR 492, 40 CFR 6.302(h), and the Fish and Wildlife Coordination Act (16 USC 661 *et seq.*) may be implicated as ARARs. If any proposed actions impact state-listed endangered or threatened animal species, the Tennessee Non-Game and Endangered or Threatened Wildlife

Species Conservation Act of 1974 (TCA 70-8-101 *et seq.*) may provide ARARs. The prohibitions of the Tennessee Rare Plant Protection and Conservation Act of 1985 (TCA 11-26-201 *et seq.*) do not apply to a landowner, lessee, or other person entitled to possession of the land on which the species is located (TCA 11-26-209). This also includes managers, in the case of publicly-owned land, as well as those with written permission of the landowner or manager (TCA 11-26-209). These exclusions would apparently apply to the ORR. However, the purpose of the statute to protect and preserve rare plants should be considered TBC guidance for any remedial actions on the reservation.

5.1.5 Action-Specific ARARS

Performance, design, or other action-specific requirements set controls or restrictions on particular kinds of activities related to the management of hazardous waste (52 FR 32496). Selection of a particular remedial action at a site will invoke the appropriate action-specific ARARs that may specify particular performance standards or technologies, as well as specific environmental levels for discharged or residual chemicals. Action-specific ARARs will be developed when remedial alternatives have been selected for BCV OU 4.

5.2 IDENTIFICATION OF PRELIMINARY REMEDIAL ACTION GOALS

The goal of the BC OU 4 RI and subsequent interim remedial action is to protect human health and the environment from contaminated groundwater and surface water within the OU. For each contaminant of concern and for each medium of concern, the preliminary remedial action goals will be set at whichever of the following values is lowest and technically feasible: (1) health-based criteria for carcinogenic effects or for systemic toxic effects, (2) the lowest chemical-specific ARARs, (3) ecologically based criteria, or (4) background concentrations.

The surface water in BCV (Bear Creek, springs, tributaries) and shallow groundwater within the Bear Creek Hydrogeologic Regime are the media of concern for this FS. Characterizing the shallow groundwater regime and the interaction between the surface water and groundwater systems is critical in understanding the migration pathways of contaminants. Specific remedial action objectives include the following:

- **Groundwater**—To protect public health and the environment by mitigating the effects of the migration of contaminants, minimizing further contaminant migration.
- **Surface water**—To protect human health and the environment by restoring Bear Creek to drinking water quality standards or a risk-based standard if technically feasible and by preventing further contaminant migration from BCV Waste Management Areas.

COPC listed on Table 2.2 for BC OU 4 are trace metals (As, Ba, Be, Cd, Cr, Pb, Hg, and Se); VOCs (PCE, TCE, 1,2-DCE, 1,1,1-TCA, and 1,1-DCA); nitrate; radionuclides (U, Pu, ⁹⁹Tc, Th, and possibly others); pesticides; and PCBs. The primary source of contamination is the S-3 Ponds; the Burial Grounds, Oil Landfarm, and Rust Spoil Area are also possible sources of contamination.

5.3 IDENTIFICATION OF POTENTIAL CLASSES OF REMEDIAL TECHNOLOGIES

5.3.1 Removal Actions

Two types of response actions are allowed by CERCLA regulations: removal actions and remedial actions. A removal action is an action to clean up or remove released hazardous substances from the environment where DOE has determined that such removal is necessary due to the threat to human health and the environment from the release. DOE may take any appropriate action to abate, prevent, minimize, stabilize, mitigate, or eliminate the release or threat of release. A remedial action reduces risk and must be preceded by the RI/FS process. Examples of removal actions that may be appropriate at BCV OU 4 are:

- removal of highly contaminated soil that is close to or near the surface and that may migrate into the surface water;
- capture and treatment of isolated areas of highly contaminated shallow groundwater;
- capture and treatment of highly contaminated surface water at seeps and springs;
- capture and treatment of any light nonaqueous phase liquids detected on the shallow groundwater system;
- fences, warning signs, or other security measures; and/or
- extension of the existing seepage collection systems located at the Burial Grounds.

5.3.2 Remedial Actions

EPA-established expectations pertaining to the remediation of CERCLA sites are listed in Sect. 300.430(a)(1)(iii) of the NCP. These expectations have been considered in developing the remediation goals and technologies for the BC OU 4 interim action and are summarized below.

- Engineering controls such as containment will be used for the groundwater and surface water associated with the waste areas that pose a relatively low long-term threat and for sites where treatment is impractical.
- Principal threats, such as highly mobile or highly toxic waste, will be treated, if practical.
- A combination of engineering controls and treatment will be used as appropriate to achieve protection of human health and the environment.
- Institutional controls, such as access and deed restrictions, will be used to supplement engineering controls, as appropriate, to prevent exposure to hazardous wastes.
- Innovative technologies will be considered when such technologies offer the potential for superior treatment performance or lower costs for performance similar to that of demonstrated technologies.
- Usable groundwater will be returned to beneficial uses whenever practical. When restoration of groundwater to beneficial uses is not practical, further migration of contamination and exposure to contaminated groundwater will be prevented, and further risk reduction will be evaluated.

Table 5.8 identifies a preliminary range of remedial action alternatives and associated technologies for both shallow groundwater and surface water. This table is not meant to present a detailed investigation of alternatives. Rather, it is intended to be a more general classification of potential remedial actions based on the initially identified routes of exposure and associated receptors. The identification of potential technologies at this stage will help ensure that data needed to evaluate them can be collected as early as possible. In addition, early identification of technologies allows a determination as to the need for treatability studies.

The general response actions for groundwater are (1) no action, (2) institutional controls, (3) monitoring, (4) containment, and (5) extraction and treatment. The "no action" response is included as a requirement of CERCLA and serves as a baseline comparison against which the other actions can be measured. Institutional controls include access and legal restrictions. Groundwater monitoring includes that from the existing monitoring well network. Containment actions include interception of groundwater, horizontal and vertical barriers, and containment by pumping. Treatment actions include physicochemical treatment, biological treatment, thermal treatment, electrical treatment, and in situ treatment.

The general response actions for surface water are (1) no action, (2) institutional controls, (3) monitoring, (4) containment, and (5) collection/treatment. The no action and institutional control response actions for surface water are the same as the general responses to groundwater. Surface water monitoring includes that from existing monitoring stations. Containment technologies include stream channelization, stream diversion, and horizontal and vertical barriers. Treatment technologies include physicochemical, biological, thermal, and electrical treatment technologies, including in situ technologies.

Table 5.8. Identification of preliminary remedial action goals, preliminary general response actions, and preliminary remedial technology types in specified media

Media	Remedial action goals	General response actions	Remedial technology type
Groundwater	For protection of human health:	No action and Monitoring 1. No action and ongoing monitoring	Monitoring programs 1. Sampling and analysis
	Prevent ingestion and/or inhalation of and/or direct contact with vapor from contaminated groundwater	Institutional actions: 1. Access restrictions 2. Legal restrictions	Institutional options: 1. Fence/access barriers 2. Deed restrictions
	For protection of environment:	Containment actions: 1. Containment	Containment technologies: 1. Vertical barriers 2. Horizontal barriers
	Isolate the contaminated groundwater and prevent further contamination of groundwater and other media	Collection/treatment actions: 1. Collection/treatment/discharge or re-injection 2. In situ groundwater treatment	3. Subsurface collection drains 4. Groundwater containment by pumping
			Interception technologies: 1. Groundwater extraction by pumping 2. Groundwater interception by drains
			Treatment technologies: 1. Physicochemical treatment 2. Biological treatment 3. Thermal treatment 4. Electrical treatment 5. In situ treatment

Table 5.8 (continued)

Media	Remedial action goals	General response actions	Remedial technology type
Surface Water	For protection of human health:	No action and Monitoring:	Monitoring programs:
	Prevent ingestion and/or inhalation of and/or direct contact with vapor from contaminated surface water	1. No action and ongoing monitoring	1. Sampling and analysis
	For protection of environment:	Institutional control:	Institutional control options:
		1. Access restrictions	1. Fence/access barriers
		2. Legal restrictions	2. Deed restrictions
	Isolate the contaminated surface water and prevent further contamination of surface water and other media	Containment actions:	Containment technologies:
		1. Containment	1. Channelization
			2. Diversion
		Collection/treatment actions:	3. Horizontal barriers
		1. Collection/treatment/discharge	4. Vertical barriers
		2. In situ surface water treatment	Collection technologies:
			1. Collection
			Treatment technologies:
			1. Physicochemical treatment
			2. Biological treatment
			3. Thermal treatment
			4. Electrical treatment
			5. In situ treatment

6. SITE DATA NEEDS

Each of the likely remedial alternatives requires data to support its selection. The data requirements for each alternative are discussed briefly in this section, followed by more detailed discussions of the data needs and planned actions to fill those needs for the three most likely alternatives. The data needs for the human health and ecological risk assessments are similar to those for the alternative selection. Groundwater and surface water quality data will support both the human health and ecological risk assessments. Additional data requirements for the ecological risk assessment (e.g., toxicity testing, whole fish tissue analyses) are addressed in Sect. 7.4.5.3.

Data from continued monitoring of surface water and groundwater will be used to test the hypothesis that, following closure and capping of the source areas, the main reservoir of contaminants is held within the Nolichucky soil and rock matrix. As described in the discussion of the conceptual site model (Sect. 3.8), this reservoir of contaminants is slowly being flushed from the matrix at rates determined by the diffusional flux from the matrix to the fracture flow system. Documenting decreasing concentrations of contaminants within the actively flowing groundwater will require selection of appropriate sampling points within that system. Groundwater wells that may be appropriate for data analysis and further sampling may be selected from those wells showing hydraulic connections to known source areas in tracer tests. Recognizing that monitoring wells may not be the best way to monitor a fracture-flow-dominated system (Solomon et al. 1992), surface-water-monitoring points downstream of the major source areas may provide the best data to support the alternative.

If contaminant concentrations are not demonstrably decreasing within the groundwater or if concentrations at the selected stream monitoring points represent a health concern, then interception of subsurface contaminants within the source (Nolichucky) is the preferred alternative. The conceptual model suggests that the majority of groundwater flow and contaminant transport occurs within the relatively shallow stormflow and water table zone. Based on the conceptual model, the use of collection trenches closer to the actual source areas or capture wells screened across the Nolichucky regolith/bedrock interface may be implemented. Either method will require knowledge of the flow paths from sources to the Maynardville. Data from the proposed tracer tests will support this alternative, as will the results of pumping tests conducted in the area of the S-3 Ponds (e.g., Geraghty & Miller 1986).

If contaminant capture within the Nolichucky is not practical, then contaminant capture at surface water discharge points (e.g., springs, stream segments) is the preferred alternative. Data required to support this alternative include the results of proposed tracer tests as well as more complete flow and contaminant discharge data at specific springs and stream monitoring locations. The results of detailed flow data will be used to support a water balance calculation within the upper reaches of BCV. Water balance calculations combined with data on the relative amounts of contaminants being discharged at specific points will support the selection and design of surface water interception points. The results of geophysical surveys will supplement the tracer test results and will be used to identify and map subsurface features associated with the Maynardville conduit system between the source areas and some likely surface water interception points.

If water balance and contaminant discharge calculations indicate that contaminants reaching the Maynardville are bypassing the surface water system near the source areas, then Maynardville groundwater interception is the preferred alternative. This alternative will require the installation of groundwater capture wells within the Maynardville conduit flow system to capture contaminants. Tracer tests will be expanded to encompass the length of BCV. Prior to initiating extensive tracer testing and to support subsequent water balance calculations, all major (and minor) springs and seeps throughout BCV must be identified. Continuous flow monitoring at major springs and along selected stream segments would provide the minimum data required for valley-wide water balance calculations. Installation of Maynardville capture wells will require knowledge of the conduit extent and interconnections throughout BCV but, in particular, downstream and downgradient of the major source areas. Geophysical survey results performed in support of the previous alternative will be used and refined to help locate subsurface targets for monitoring well installation. In addition, tracer tests will be conducted further down BCV to establish hydraulic connections between the Maynardville conduit system and surface discharge points.

The last alternative, encompassing in situ treatments in near-source areas, will require much of the data previously described for characterization of flow paths within the source areas (i.e., tracer tests) as well as the concentrations of contaminants that the treatment system will encounter.

The following sections present detailed discussions of the data needs and the activities planned to address those needs for the first three remedial alternatives (monitoring, source area groundwater capture, and contaminant capture in Bear Creek and at springs). The greatest level of detail is provided for the monitoring alternative, and decreasing levels of detail are provided for the two contingency alternatives. However, as Table 6.1 summarizes the range of data sources and proposed RI activities to support the first three alternatives, the overlap in uses of both historical data and proposed RI activities is apparent. The discussion is organized by remedial alternative. Within each remedial alternative the discussion is divided into those activities that involve analysis of historical data, the results from ongoing or planned activities that support the regulatory compliance program in BCV, and proposed RI activities. Within each discussion the proposed activity is identified and discussed in terms of the specific data requirement filled for that alternative.

6.1 PHYSICAL CHARACTERIZATION ACTIVITIES

6.1.1 Continued Monitoring of Surface Water and Groundwater

6.1.1.1 Existing data

Moore and Toran (1992) have analyzed historical groundwater and surface water monitoring data associated with the headwaters of Bear Creek and the S-3 Ponds. The same analysis should be performed using the historical data from groundwater monitoring wells adjacent to the other major source areas (Oil Landfarm and Burial Grounds).

The results of recent infrared aerial photography in BCV will be used to aid in identifying any groundwater discharge points to Bear Creek that have not already been

Table 6.1. Summary of data sources and proposed activities to support primary alternatives

Alternative	Existing data/source	Proposed RI activity
Monitoring surface water/groundwater	<ul style="list-style-type: none"> Groundwater quality/compliance monitoring and exit pathway wells Surface water quality BCK-11.97 BCK-12.4 	<ul style="list-style-type: none"> Groundwater quality data Pulse train analysis Chemical tracer tests Point dilution analysis Stormflow tube installation and monitoring Continuous flow monitoring—BCK-9.40 Weekly surface water quality sampling—BCK-9.40 Ecological—toxicity tests, whole fish analyses
Subsurface contaminant interception in Nolichucky	<ul style="list-style-type: none"> Groundwater quality/compliance monitoring and exit pathway wells Aquifer test data/Geraghty & Miller (1986)^a 	<ul style="list-style-type: none"> Pulse train analysis Chemical tracer tests Ecological
Surface water interception in Bear Creek, springs, and seeps	<ul style="list-style-type: none"> Surface water quality/compliance monitoring program SS-1 SS-4 SS-5 SS-6 SS-8 Surface water flow/NPDES^b BCK-4.55 (continuous) Various (instantaneous) 	<ul style="list-style-type: none"> Continuous flow monitoring at active spring Weekly surface water quality sampling at springs Pulse train analysis Chemical tracer tests Geophysical survey analysis Ecological

^aGeraghty & Miller 1986.^bNational Pollutant Discharge Elimination System.

identified. The results of this analysis will be used in planning the proposed tracer tests. This analysis is particularly important in selecting the monitoring points for those tests.

6.1.1.2 Ongoing/planned activities

The groundwater compliance monitoring program will continue to collect data from selected wells and surface monitoring points to define the bounds of contaminant plumes within BCV. The data from these monitoring efforts in addition to results from recently installed Maynardville exit pathway wells will supplement the historical data being reviewed to support this alternative and the proposed screening risk assessment.

Surface water flow data from the continuous flow monitoring site at BCK-4.55 and from various instantaneous monitoring points throughout Bear Creek and its tributaries are being analyzed by the Surface Water Hydrology Group of the ESD at ORNL. The results of these analyses will be used to calculate a preliminary water balance for BCV. The results of these analyses will be available in early 1993 and will be used to guide the installation of surface water monitoring points proposed in Sect. 7.4.3.

6.1.1.3 Proposed RI activities

Proposed RI activities focus on identifying appropriate groundwater and surface water monitoring locations to support the monitoring alternative. Appropriate groundwater and surface water monitoring locations are those locations that are demonstrably part of the flow path between source areas in the Nolichucky and the Maynardville conduit flow system. The results of the existing data analysis (Sect. 6.1.1.1) may indicate that appropriate groundwater monitoring locations already exist. However, a series of tracer tests (pulse train and chemical tracers) are proposed to confirm or identify hydraulic connections between source areas, monitoring wells, and surface water discharge points.

Groundwater/Surface Water Connections. Pulse train analysis—measurement of an induced pressure pulse between an injection well and suspected connected wells or springs—will be used first to identify hydraulic connections. The tests are proposed to address the three major source areas within BCV. The results of the test will be used to identify or confirm hydraulic connections between the source area and groundwater- and surface-water-monitoring points. After hydraulic connections have been demonstrated, the connections will be confirmed with a chemical tracer test.

The combined results of the pulse train analysis and the chemical tracer test will be used to identify any groundwater monitoring points hydraulically connected to the source areas that are not being monitored by the Compliance Program. These wells will be monitored as part of the RI and the data analyzed for evidence of temporal decreases in contaminant concentrations. In addition, the results of the hydraulic connection tests will identify Maynardville wells that can be monitored to evaluate the concentrations of contaminants reaching the Maynardville conduit system. Finally, the pulse train and chemical tracer analyses will serve to identify any surface-water-discharge points that should be added to the historical-trend-monitoring program.

Surface Water Monitoring. Solomon et al. (1992) have suggested that, given the complexities of groundwater flow in a fracture-dominated area such as the Nolichucky, monitoring wells that tap an active portion of the flow system may be rare. They suggest that groundwater monitoring may be best accomplished in stream segments that represent the discharge from the active flow system. Moore (1992) has proposed a hydrograph analysis technique that separates the stormflow zone component of flow from the total surface water flow such that the baseflow groundwater discharge to the stream can be identified. Combined stormflow zone hydrograph analysis with continuous flow measurement and weekly water quality sampling at a Bear Creek station downstream of the major sources in BCV will be used to identify those data that best represent groundwater discharge. Those data will be analyzed to identify a temporal decrease in contaminant concentrations similar to those observed by Moore and Toran (1992) in the headwaters of Bear Creek.

Stormflow Tube Installation and Monitoring. Stormflow tubes will be installed in upper BCV on both the Chestnut Ridge side and the Nolichucky side of the valley. The Chestnut Ridge side of the valley was chosen because it is steeper and has undergone less disturbance of the natural vegetation—criteria for development of a stormflow zone (see Sect. 3.8). Data from the Nolichucky stormflow tubes will be used to verify the hypothesis that the stormflow zone is insignificant in an area of relatively disturbed soil/regolith.

Stormflow tube construction and installation will follow Moore (1992). Each stormflow tube will be equipped for continuous water level monitoring and will provide sufficient data to calculate an average for using storm hydrograph analysis (Moore 1992). Data collected from the stormflow tubes will be used to analyze the continuous flow data from the Bear Creek Station as described by Moore (1992). The analysis primarily will identify periods of baseflow in the creek for analysis of temporal changes in direct groundwater-discharge concentrations.

Flow Monitoring Installations. As Solomon et al. (1992) have suggested, surface water monitoring locations may be the best groundwater monitoring points in fracture-dominated flow systems. Surface water flow and water quality monitoring are required to complement, or perhaps replace, groundwater data for temporal trend analyses (Moore and Toran 1992). A permanent streamflow monitoring station will be installed and equipped to collect flow measurements and water quality samples. Flow data will be analyzed to identify water quality samples that are most representative of groundwater discharge. The water quality data will be analyzed to identify any temporal decreases in contaminant concentrations.

6.1.2 Subsurface Contaminant Interception in Nolichucky Source Areas

If temporal decreases in contaminant concentrations cannot be demonstrated or if the concentration of contaminants is reaching the Maynardville conduit system, the next most likely alternative will be to prevent contaminants from reaching the Maynardville by implementing either downgradient collection trenches or a plume capture system employing extraction wells.

6.1.2.1 Existing data

Geraghty & Miller (1986) conducted an aquifer test and prepared preliminary designs for a groundwater recovery system near the S-3 Ponds. The results of these analyses will be combined with the results of pulse train analysis and chemical tracer tests to identify the possible extraction wells and the zones of influence of capture wells in the areas of S-3 Ponds, the Oil Landfarm, and the Burial Grounds.

Groundwater flow models developed for the S-3 Ponds area (Geraghty & Miller 1989) may be used to model the steady-state response of water table elevation to proposed remedial installations (e.g., collection trenches). The models have been calibrated to steady-state conditions near the S-3 Ponds and would not be useful in predicting the response of the aquifer to groundwater extraction wells.

6.1.2.2 Proposed RI activities

The results of the pulse train analyses associated with individual source areas will be used to identify hydraulic connections within the shallow groundwater zone. These tests will identify active flow paths between points within the regolith and shallow bedrock. The depths of these pathways will be used to differentiate between flow paths that may be intercepted by collection trenches and those requiring extraction wells.

6.1.3 Surface Water Interception in Bear Creek and at Springs and Seeps

If groundwater contaminants cannot be captured within the source area, the next most likely remedial alternative will seek to capture contaminants within Bear Creek and at springs and seeps. The data required to support this alternative encompass all of the data collected for the preceding alternatives. In particular, water balance data collected through the use of surface water flow monitoring combined with frequent water quality monitoring will be used to identify active springs that are contributing to contaminant flux. These results will be used to locate points for efficient contaminant capture.

6.1.3.1 Existing data

Surface water flow data from the continuous flow monitoring site at BCK-4.55 and from various instantaneous monitoring points throughout Bear Creek and its tributaries are being analyzed by the Surface Water Hydrology Group of the ESD at ORNL. The results of these analyses will clearly identify gaining and losing stream reaches within Bear Creek as well as form the basis for water budget calculations for BCV OU 4. The results of these analyses will be available in early 1993 and will be used to guide the installation of surface water monitoring points proposed in Sect. 7.4.3.

6.1.3.2 Ongoing/planned activities

The Geophysics Group of the ESD at ORNL has conducted a series of geophysical surveys in the area of the Burial Grounds. Data from these surveys are being processed with data analysis and interpretation to follow. The results of these analyses will be combined with data from recent well installations in the area to provide an interpretation of subsurface

structures (e.g., depth, lateral continuity) identified by the various techniques. Data analysis and interpretation should be complete by early 1993. The results of these analyses will be used to suggest a combination of geophysical survey techniques that will reliably identify subsurface conduits. If a reliable combination of techniques can be developed, it will be used to identify conduit pathways and to guide the selection of surface water monitoring points proposed in Sect. 7.4.3.

6.1.3.3 Proposed RI activities

Data collected to support the preceding alternatives (e.g., pulse train analysis, tracer tests) which will identify hydraulic connections and be used to calculate flow velocities between source areas and monitoring points will also be used to support this alternative. Major data requirements unique to this alternative include more detailed flow and contaminant monitoring at selected springs and identification of possible contaminant capture points further downstream.

Flow and Contaminant Monitoring at Active Springs and Tributaries. Implementation of this alternative is based on the observation that active springs are significant contributors to flow in Bear Creek. In addition, several springs and tributaries may be the primary conduits for contaminant discharge into Bear Creek. Installation of continuous-flow-monitoring stations is proposed. The data from these stations will be used to identify those springs and tributaries that are the best candidates for contaminant capture. In addition, data will be used to aid in design of the capture and treatment system. Identification of likely contaminant capture points will be based on the calculated mass of contaminants contributed to Bear Creek at each spring. Data useful in the design of the capture and treatment system include the seasonal range of flow and contaminant concentrations at each spring.

Geophysics Surveys. Implementation of this alternative will require additional definition of the conduit flow system and its relationship to proposed surface water collection/treatment points. If a reliable combination of geophysical techniques can be developed (Sect. 6.1.3.2), they will be used to identify potential conduit pathways from source areas to proposed surface water collection/treatment points.

6.2 SAMPLING AND ANALYTICAL REQUIREMENTS

Sampling and analytical requirements are discussed in detail in Sect. 7.4.5.

6.3 DATA EVALUATION AND INTERPRETATION

6.3.1 Water Quality Data

Groundwater and surface water quality data, both historical and that collected as part of ongoing compliance monitoring of the proposed RI activities, will be analyzed for temporal trends using the methods described by Moore and Toran (1992). In that analysis, annual average contaminant concentrations (C) at a monitoring point were divided by the earliest available (typically 1984–1985) concentration (C_0) data at that point. Plots of $\ln(C/C_0)$ versus

time were used to demonstrate exponential decreases in contaminant concentrations over the monitoring time interval. Moore and Toran (1992) used the plots to calculate the contaminant decrease half-life and to predict the time when contaminant concentrations would decrease below current regulatory limits.

Surface water quality data collected at active springs using flow-paced sampling techniques will be combined with corresponding continuous flow data to calculate the flux of contaminants, and variability of the flux, at each monitoring point.

6.3.2 Pulse Train and Tracer Test Data

Hydraulic connections will be identified and mapped between injection points and sampling points for both the pulse train and the chemical tracer tests. In addition, continuous measurement of temperature and specific conductance at monitoring points during the pulse train tests may identify the time of arrival of the distilled water slug. Arrival times will be used to calculate an estimate of the flow velocity between the injection point and the monitoring point.

Flow velocities will be confirmed by use of point dilution analysis (e.g., Davis et al. 1985) during the chemical tracer test. Sampling in the injection well after addition of the tracer will be used to calculate the rate of dilution of the tracer slug and, thereby, the groundwater flow velocity at that point.

6.3.3 Stormflow and Streamflow Hydrographs

Stormflow tube stage will be combined with data from continuous flow measurement stations on Bear Creek (e.g., proposed BCK-9.40, BCK-12.36, and NT2 to NT8) to identify the contribution of the stormflow zone during hydrograph recession (Moore 1992). The results will be used to clearly identify periods of baseflow in the stream for use in identifying those water quality data that represent groundwater discharge.

Continuous flow measurements in Bear Creek will be used to supplement the existing flow data in water balance calculations.

6.3.4 Risk Assessment Data

Data evaluation and interpretation for the human health and ecological risk assessment are discussed in Sect. 6.4.

6.4 RISK ASSESSMENT METHODOLOGY

6.4.1 Human Health Risk Assessment Methodology

The regulatory agencies involved in ER activities on the ORR have partitioned the sites (in this particular case, the Oak Ridge Y-12 Plant BCV) into two categories of OUs which include source control OUs and integrator OUs. Source OUs are defined as on-site waste areas (property owned/managed by DOE-ORO) which are currently releasing or have the

potential to release contaminants into the environment. Integrator OUs can receive the contaminants released from source OUs and transport them to an off-site receptor. Because of the complexity of the hydrogeologic regime and because many different sources could contribute to groundwater and surface water contamination, this classification was necessary. As a result, immediate attention can be given to source OUs while continued monitoring, characterization, and investigations of integrator OUs are conducted.

A new human health risk assessment approach, described below, was developed to further expedite remedial actions for the source OUs and, therefore, accelerate the RI/FS process, with the end result of protecting human health and the environment. The BCV OU-4 human health risk assessment will be divided into two land use scenarios (current and future) for on-source exposure and exposure at an integration point. To support RODs for interim actions (risk-based removal actions) for source OUs, the current land use scenario will be used in an MLE risk assessment and in an IP risk assessment. For final action RODs, a future land use scenario will be used (this land use will be agreed on by the regulators) in a baseline risk assessment (an RME risk assessment) for each BCV source OU and the BCV OU 4 integrator OU.

For this initial phase of the BCV OU 4 RI work plan, an MLE assessment, instead of a baseline risk assessment, will be performed for the source OUs. The exposure pathways evaluated in the MLE assessment include ingestion of and dermal contact with soil (and/or sediment), inhalation of wind generated dust and volatiles from the soil, and external exposure to radionuclide contaminants in the soil. Surface water and groundwater exposure media are not evaluated as part of the MLE assessment. The MLE assessment uses a modified industrial exposure scenario; the exposure time is reduced to 10% (48 min/day) of the 8-h work day. This reduction is considered to be representative of actual exposures at most source OUs. The MLE assessments will be used to identify and prioritize the source OUs in support of expedited interim action remediation. The MLE assessments will be used in conjunction with the IP assessment to support interim action RODs or removal actions.

The IP assessment is designed to use monitoring, surveillance, compliance, and RI data to evaluate off-site and/or off-source OU risk from exposure to contaminants in the surface water integrator OU (BCV OU 4). The IP assessment is a flux-based risk assessment which is calculated at a specific point in the surface water body. Because of the numerous potential sources of contaminants in BCV, the variability in flow rates (flux) for different surface water components, and therefore transport of the contaminants to the integrator OU, is important. The risk from the various source OUs is apportioned based on the contaminant flux into the integration point. The IP assessment uses residential exposure parameters for exposure routes which include ingestion and dermal contact with and inhalation of volatile organic compounds in the surface water. Source control actions, taken at areas of a high flux of integrator chemicals of potential concern, are quick means to reduce off-site and/or off-source OU exposure. The effects of source control actions on the integrator OU can also be evaluated using an IP assessment. In summary, an IP assessment can be used to establish a reference point (or many reference points) for evaluating risk within the integrator, to identify and prioritize contaminant sources, and to monitor and document the degree of risk reduction achieved by a source control action.

These two approaches (MLE and IP assessments) will provide an understanding of the risk posed to on-source OU receptors (MLE assessment) as well as giving an indication of the relative contribution of risk from each source OU to off-site and/or off-source OU receptors (IP assessment). The result is more immediate attention to the interim action remediation of source OUs, with continuing investigation for long-term remediation (RODs) of both source and integrator OUs. On completion of all source OU interim actions, continued monitoring data from the integrator OUs will be used to determine if the interim actions have been effective; depending on these monitoring results, further remediation may be necessary in the integrator OU ROD.

The surface water and shallow groundwater in BCV OU 4 are interconnected (Fig. 3.20), and RME assessments will be used to evaluate risk posed by contaminants in the shallow groundwater. Pathways to be included in the assessment are ingestion, inhalation, and dermal contact with the shallow groundwater. Risk characterization will be conducted using data from three exit pathway pickets. Each picket will have specific chemicals of potential concern and associated risks. Groundwater wells beneath source OUs will also be evaluated (on source OU RME assessments) and used to determine which source OUs are contributing to contaminants found in the pickets. This information will also be used in conjunction with the IP and MLE assessments to prioritize the source OUs for interim actions. Risk characterization of the deep groundwater system and the biota exposure medium will be evaluated in the future using the future on-source-OU scenario (RME assessment/baseline risk assessment).

The methodology employed to conduct the RME risk assessment will follow guidelines established in the *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A)* (EPA 1989b). In addition, recommendations from the ER Risk Assessment Council and other supporting documentation will be followed for the MLE and IP risk assessments. The results of the Phase I and Phase II Background Soil Characterization Project for the ORR will also be available for use in the RI.

6.4.2 Ecological Risk Assessment Methodology

Ecological risk assessment for waste sites differs from human health risk assessment in that the consequences of the risks can be measured. Biological surveys provide a direct measure of the state of the biotic communities that constitute the ecological assessment endpoints. Hence, ecological epidemiology will be employed (Suter 1990, Suter 1992; Suter and Loar 1992). In ecological epidemiology, the primary data are the field survey data that indicate the actual state of the system relative to the expected uncontaminated state. Other data are used to support inferences concerning the causes of any deviations from the expected state. This approach is consistent with *Risk Assessment Guidance for Superfund, Vol. II* (EPA 1989a).

The ecological risk assessment for this RI will be a screening assessment. That is, it will not attempt to quantify the actual level of injury under current conditions or project future injury levels in the absence of remediation. That level of assessment is more properly included in the baseline ecological risk assessment for the watershed, which will include all sources and contaminated media, not just the contribution of groundwater to surface water contamination. Screening assessments indicate whether existing contaminant levels constitute a sufficient risk to justify further analysis or interim remedial actions.

The standard paradigm for ecological risk assessment will be followed in the assessment (Suter 1992; Risk Assessment Forum 1992). It begins with a scoping phase termed hazard definition or problem definition which defines the sources of concern (contaminated ground water), the media of concern (surface water), the spatial extent (all of Bear Creek), and the assessment endpoints (20% or greater reductions in the abundance or production of any fish population or any population of piscivorous wildlife). No new data are needed for this phase.

After the problem is defined, exposure and effects are assessed. The primary exposure data are analyses of contaminants in the waters of Bear Creek, its tributaries, and associated springs and seeps. These data are summarized in Sect. 3.5. The primary data needed for aquatic exposure assessment are dissolved concentrations of chemicals. Most data are for total recoverable concentrations, which are appropriate for human health assessments but not for ecological assessments (Health and Ecological Criteria Division 1992). A second source of exposure data is the analyses of contaminant concentrations in fish flesh. Concentrations in fish indicate the internal exposure levels of the fish and the dietary exposure levels of piscivorous wildlife. The existing data are concentrations in fillets which are appropriate for human health assessments, but not for ecological assessments. Some analyses of whole fish concentrations are needed. The analyses of dissolved water concentrations and whole fish need not be as extensive as those for total recoverable water concentrations and fish fillets. Rather, it is sufficient to perform enough analyses to determine the mean and variance of the ratios of the ecological exposure measures to the human health exposure measures. These can be used to correct the human health exposure measures.

Three types of effects data will be used. As stated earlier, the primary effects data are the biological survey data obtained by the BMP (Southworth et al. 1992). Effects data are also supplied by the ambient toxicity testing that has been performed by the BMP (Southworth et al. 1992). Finally, regulatory criteria and literature toxicity values will be used to characterize effects of individual aqueous contaminants found in Bear Creek water in terms of standard toxicological benchmarks (Suter et al. 1992). All three of these types of effects data are available for aquatic biota. However, effects assessment of piscivorous wildlife will rely on toxicological benchmarks for individual chemicals because wildlife survey data or toxicity testing are not available or feasible for this assessment.

The primary data need for effects assessment is additional toxicity testing of ambient water. The BMP has tested water from nine sites in Bear Creek, sites on four tributaries, and sites on two reference streams at different times beginning in 1984. Currently, only six sites in Bear Creek are tested. The tests used are EPA's 7-d fathead minnow larval test and *Ceriodaphnia dubia* test. To the extent possible, the toxicity of all tributaries and contaminated springs and seeps should be tested. In addition, those tributaries, springs, and seeps that are contributing to toxicity in Bear Creek should be sampled under a range of hydrological conditions to characterize the influence of source variability. Water for toxicity testing should be collected in conjunction with collection of samples for chemical analyses.

The risk characterization phase combines the data from the exposure assessment and effects assessment to characterize the risks to the assessment endpoints, and summarizes and explains the results and associated uncertainties. The aquatic biological survey data will be compared site by site to the information on the location of the samples relative to tributaries, springs, and seeps to determine what contaminant sources may be responsible for observed

effects. Alternative causal factors such as habitat quality will also be considered. The ambient water toxicity data will be used to determine whether apparent ambient toxic effects of particular sources are credible given the toxicity of the source water and diluted source water in Bear Creek. Comparisons of the aquatic toxicological benchmarks to water concentrations will be used to determine which particular contaminants are responsible for the toxicity. A weight of evidence approach will be used to integrate these three lines of evidence and present a characterization of ecological risks to fish populations due to groundwater in Bear Creek. Risk characterization for piscivorous wildlife will consist simply of comparisons of contaminant concentrations in fish to toxicological benchmarks for wildlife.

6.5 FEASIBILITY STUDY

This section presents the efforts necessary to perform the FS process for the BC OU 4 interim action. The FS process will integrate NRDA and NEPA requirements. Pursuant to CERCLA, the process will also require preparation of a Proposed Plan and a ROD for interim action.

6.5.1 Scope and Assumptions

The purposes of the CERCLA activities for BC OU 4 at this time are to identify, organize, and examine remedial alternatives; mitigate the risks identified in the Phase I and Phase II RI reports; justify selection of a preferred remedial alternative or a set of alternatives; and prepare the decision documents required by the regulators to summarize the FS process, outline the selected remediation methods, and establish the remediation schedule.

The FS contractor will be responsible for completing the BC OU 4 FS/Proposed Plan/ROD process. This process will require the preparation of the following milestone documents: (1) the FS report, which documents the process used to examine the remedial technologies; (2) the Proposed Plan, which provides a brief summary of all the alternatives studied in the detailed analysis phase of the FS, highlights the key factors that led to the identification of the preferred alternative, and is presented to the public; and (3) the ROD for interim action, which is the legal document that confirms that selected remediation methods meet statutory and regulatory requirements. The FS/Proposed Plan/ROD process will be accomplished by the following principal Work Breakdown Structure elements:

- technology screening activities;
- alternatives development and analysis;
- treatability study;
- FS development;
- NEPA activities;
- NRDA activities;
- FS OU coordination/oversight;

- Proposed Plan development; and
- ROD development.

Detailed descriptions of the scope of each activity follow.

6.5.2 FS Report

The following sections describe the tasks necessary to conduct and produce the FS report. This report will follow the format outlined in EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988d) and the annotated outline developed by the DOE-ORO Document Content and Review Committee.

6.5.2.1 Technology screening activities

In general, remedial alternatives address surface water and/or groundwater capture and treatment. These alternatives will be screened to eliminate those judged too difficult to implement based on unproven technologies, those judged not sufficient to remediate the site within a reasonable time period, or those judged to have limited application for the specific contaminant or site conditions. Those technologies judged to have a reasonable chance of success for remediation will be carried forward for more detailed development and analysis. A technical memorandum summarizing the findings of this task will be issued to DOE.

Before these technologies can be screened, the following data gaps need to be addressed:

- evaluate and augment existing surface water flow data and contaminant data to perform contaminant mass balance calculations;
- complete QA validation of existing groundwater and surface water data of Bear Creek as required for the screening level/baseline RA;
- quantify gaining and losing reaches of Bear Creek (including seasonal variations);
- evaluate any potential influence of the dissolved phase DNAPLs on the shallow groundwater system;
- identify hydraulic boundaries;
- identify hydraulic flow system (conduit flow);
- monitor the effects of a pump test on the surface water system (if pumping alternative is chosen); and
- evaluate effectiveness of existing collection system in the Burial Grounds.

6.5.2.2 FS development

The FS contractor will use the format presented in the CERCLA FS guidance document and the DOE-ORO Document Content and Review Committee FS annotated outline to develop the FS. As required, exceptions and modifications to the format will be made for site-specific conditions in BC OU 4. Based on the information obtained during the RI, the FS will be developed in sufficient detail to allow for the selection of preferred alternatives in the

Proposed Plan. Criteria will be developed to assess the ability of the alternatives to meet the cleanup goals and to comply with administrative and regulatory requirements. The draft FS report will be issued to EPA and TDEC for review. Submittal of the FS report to EPA and TDEC is a milestone required by the FFA.

6.5.2.3 FS OU coordination/oversight

The FS contractor will provide technical support and oversight to ensure that the FS report is prepared within project quality, cost, and scheduling goals. The FS contractor will provide engineering and technical resources to support QC efforts, provide project management, and coordinate project activities to ensure that established goals are achieved. Monthly progress reports on the FS process will be issued to DOE and FS oversight participants.

The objective of FS oversight activities is to provide technical input and oversight during the FS to ensure that the data and information obtained during the Phase I and Phase II RIs are incorporated properly into the FS report and that they are adequate to prepare a Proposed Plan and support the development of a ROD for interim action. FS oversight activities will begin with scoping activities and be completed upon final approval of the FS report.

6.5.2.4 Treatability studies

Treatability studies will be conducted to provide data to allow treatment alternatives to be fully developed and evaluated during the detailed analysis and to support the remedial design of a selected alternative.

6.5.2.5 NEPA activities

To comply with the federal facility requirements under NEPA, the interim remedial alternatives will be evaluated for their impact on the environment. NEPA establishes public policies and goals for protecting environmental quality and mandates procedural requirements to be considered when implementing decisions that may impact the environment. DOE Order 5400.4 requires that NEPA and CERCLA be integrated to the maximum extent possible to avoid duplication of efforts that might slow the process. NEPA issues to be addressed include rare and endangered species, wetlands, and floodplains. The environmental impacts of the alternatives will be considered an integral component of the evaluation and selection process.

An EA is the appropriate level of NEPA documentation for initial remedial activities at BC OU 4 as described in C14 of DOE NEPA Implementing Procedures 10 CFR 1021 Subpart D, Appendix X. An EAD will be drafted at the beginning of the RI/FS process.

6.5.2.6 NRDA activities

To comply with NRDA, the Natural Resource Trustees may assess damages for injuries to natural resources resulting from the release of hazardous substances. DOE ER activities require NRDA and CERCLA to be integrated to avoid duplication of efforts. The first step

in the NRDA process is to perform a preassessment screen. If the screening indicates that NRDA is not appropriate, no further assessment actions will be taken. However, if the preassessment screen indicates that NRDA is appropriate, a Type B assessment will begin by requiring an injury determination phase, a quantification phase, and a damage determination.

6.5.3 Proposed Plan

The Proposed Plan to remediate BC OU 4 will be prepared using the preferred remediation alternative(s). The Proposed Plan documents the investigation process, administrative and regulatory actions, and the remedial alternatives. The Proposed Plan is a primary milestone document subject to public notice and review and to administrative and regulatory reviews.

6.5.4 ROD

The final step in the decision process to implement an interim action at BC OU 4 will be preparation of the ROD, the legal document that formally describes the preferred remediation alternative(s) and establishes the remediation schedule and monitoring plan for the site. The BC OU 4 ROD will be written in accordance with the statutory requirements of CERCLA and applicable federal and state requirements. The ROD will contain a decision summary outlining the nature and extent of the contamination and associated risks at BC OU 4, the evaluation and analysis of the RA alternatives considered, and an explanation of how the selected alternatives will meet statutory requirements. The ROD will also contain a responsiveness summary addressing the public comments obtained during public review and public examination of the administrative record. The FS contractor will issue the draft ROD to DOE and the regulatory agencies for review. The final ROD for the interim action is a primary milestone document required by the FFA.

6.6 RA PLAN AND REMEDIAL DESIGN

6.6.1 Remedial Action

This section presents the scope of the RA activities required to prepare an RA work plan and implement the remediation of BC OU 4. The risk and uncertainties and interface issues for the remedial activities are identified as well.

6.6.1.1 Scope and assumptions

The scope of the RA includes the RA work plan, construction management, Title III services, construction of one remediation design package, construction support, independent certification, and verification.

6.6.1.2 RA work plan

The CM will prepare the draft RA work plan, which (1) defines the scope and objectives of the RA based on the ROD and final RD; (2) documents the specific construction

components of the RA; and (3) presents the RA schedule, subcontracting strategy, QA Plan, Health and Safety Plan, and RA Monitoring Plan.

After comments from DOE, EPA, and TDEC are incorporated, the final RA work plan will be prepared for approval and implementation.

6.6.1.3 RA work plan oversight activities

The purpose of this activity is to provide technical input and oversight during the preparation of the RA work plan. During the preparation of the draft RA work plan, Energy Systems, FS contractor, and the CM contractor will provide necessary coordination and review the work plan to ensure that the proposed construction efforts will implement the ROD consistent with the final RD reports. The oversight activities will also ensure that the bid process and implementation plans comply with administrative and regulatory requirements.

6.6.1.4 RA integration

The objective of this element is to provide construction management, independent certification, Title III services, and construction support as required.

RA integration for BC OU 4 remedial activities includes the following tasks:

- ensure that subcontracted work is performed on schedule, in accordance with all technical requirements, and in compliance with the ES&H Program, the QA Program, the Waste Management Program, and the Security Program;
- perform field inspections, provide as-built drawings, approve Design Change Notices and Field Change Requests as applicable, and ensure that construction is accomplished according to final design requirements; and
- prepare detailed Quarterly Progress Reports that EPA will use to monitor the remedial construction activities.

6.6.2 Remedial Design

This section presents the scope of the RD effort required to prepare an RD work plan; perform any required engineering studies; prepare a Title I 30% design package; and prepare Title II 60%, 90%, and 100% Final Design reports for BC OU 4 remediation.

6.6.2.1 Scope and assumptions

The scope of the RD work for the remediation of BC OU 4 is to provide necessary supporting documents that implement all RA activities. These documents require approval from DOE-ORO, DOE-HQ, TDEC, and EPA. The following sections present details of the scope of work and assumptions associated with remediation of BC OU 4.

6.6.2.2 RD work plan

The RD work plan will provide the technical and management approach for the RD work. The RD contractor will prepare a draft RD work plan based on the scope and design criteria specified in the Proposed Plan and ROD. The RD work plan will include the detailed design process and schedule for the design effort and be prepared in accordance with CERCLA/EPA regulations. The RD contractor will incorporate comments from Energy Systems, DOE, EPA, and TDEC and submit the final work plan for approval.

6.6.2.3 RD work plan oversight activities

During the preparation of the RD work plan, the FS contractor, CM, and Energy Systems will provide review and technical input to ensure that the scope of work is adequately defined in accordance with the criteria specified in the ROD. Review of the draft RD work plan will also ensure that the selected technologies do not violate the intent of the ROD and that the overall work plan meets all regulatory and administrative requirements.

6.6.2.4 RD report Title I design

Based on the engineering studies and other information available from the RI/FS, the RD contractor will prepare preliminary (30%) design/construction drawings for remedial activities showing the extent of remedial activities, site plan, details, and outline of specifications for the work involved.

6.6.2.5 RD report Title II design

Upon approval of the Title I design document, the RD contractor will prepare engineering designs, analysis, and calculations required for all civil, structural, mechanical, and electrical construction, construction drawings, technical specifications, and cost estimates.

All documents will be submitted to Energy Systems for comment at 60% completion. Upon resolution of comments, the 90% design package will be submitted to Energy Systems and DOE for review and comments. Upon resolution of comments, the final Design Report (100%) for remedial activities will be submitted to EPA and TDEC for review and approval. Agency comments will then be incorporated to prepare design documents certified for construction.

6.6.2.6 RD oversight activities

During the review of the design documents at 30%, 60%, and 90%, all participants will provide their oversight and technical input to help submit the final design document to DOE and EPA in the given time frame.

7. FIELD SAMPLING PLAN

7.1 INTRODUCTION AND PURPOSE

BCV OU 4 is the groundwater/surface water integrator unit in the valley (see Fig. 1.1). The accompanying work plan represents the first phase of investigation of the integrator unit and specifically addresses the shallow groundwater and surface water component of BCV OU 4. The scope of this work plan is further limited to addressing the shallow groundwater and surface water in a narrow belt of the Bear Creek watershed underlain by the Nolichucky Shale (which underlies the major sources) and the Maynardville/Knox carbonate aquifer.

Valley-wide groundwater and surface water monitoring programs provide a significant source of data which can now be used to begin assessing the impacts of source control measures on the concentrations of contaminants in the shallow groundwater and Bear Creek surface water. Preliminary results of these analyses suggest that contaminant concentrations in groundwater and surface water near one major source area (S-3 Ponds) are decreasing.

Application of the observational approach to the development of the RI work plan entailed development of a site conceptual model and development of a focused list of likely remedial alternatives that include

1. no action,
2. monitoring the effects of ongoing source control measures in surface water and groundwater,
3. prevention of Maynardville contamination by instituting appropriate controls within the Nolichucky shale (soil and/or bedrock),
4. surface water interception of contaminants downstream of all sources at springs and/or within Bear Creek,
5. Maynardville groundwater interception with wells within the conduit flow system, and
6. in situ treatment in source areas.

With the exception of no action, the alternatives are ranked in order of preference. The observational approach entails design of data collection activities to support the primary alternative with contingencies for the data requirements of the remaining alternatives. Based on the conceptual model and the preliminary results of historical data analyses, data collection and analysis activities described in the work plan are designed to support alternative 2, with additional activities designed to gather data for alternatives 3 and 4.

7.2 PROJECT ORGANIZATION AND RESPONSIBILITIES

The BCV OU 4 project organization is illustrated in Fig. 7.1.

Fig. 7.1 BCV OU 4 RI functional organization chart.

7.3 PROJECT DESCRIPTION

The project description has been discussed in detail in Chaps. 1 through 6 of this work plan. The history and current conditions of OU 4 are described in Chap. 2. The OU 4 shallow groundwater conceptual site model is described in Sect. 3.8. Investigation requirements, including summaries of ARARs, remedial action goals, and feasible treatment technologies, are identified in Chap. 5. The site data needs are described in Chap. 6.

7.4 SITE ACTION PLAN

The site action plan describes the site characterization activities required for the alternatives discussed in Chap. 6. The alternatives for which characterization activities are described here include continued monitoring of surface water and groundwater, subsurface contaminant interception in Nolichucky source areas, and surface water interception in Bear Creek and at springs and seeps. The activities focus on

- identifying flow paths within the shallow groundwater of BCV OU 4 between major Nolichucky source areas and surface water, and
- sampling and analysis of shallow groundwater and surface water within identified flow paths.

The methods proposed to accomplish the site characterization include the use of historical data, data collected from current ongoing and planned future activities, and data collected from new activities specifically proposed for this RI. Sections 6.1 and 6.2 detail the rationale for the characterization activities and explain how historical data and data collected from ongoing or planned activities will be used in the BCV OU 4 RI. This chapter details specific sampling locations and provides sample apportionment and analysis for data to be acquired by the RI field activities. Sample analysis methods are summarized in Sect. 7.4.5. References to standard sampling methods are presented in Chap. 9.

7.4.1 Continued Monitoring of Surface Water and Groundwater

The monitoring of surface water and groundwater will require the analysis of historical data, data collected from ongoing and planned projects, and data collected from activities specifically designed for this RI.

The analysis of historical data collected from 25 groundwater-monitoring wells (Fig. 7.2 and Table 7.1) located adjacent to the Oil Landfarm and Burial Grounds is proposed. The groundwater monitoring wells were selected based on their association with the respective source areas and their relatively long monitoring history (i.e., 10 to 20 monitoring events). The historical data from the monitoring wells will be analyzed in the manner of Moore and Toran (1992). In addition to data collected from these monitoring wells, the data collected by the groundwater compliance monitoring program from selected wells and surface monitoring points will be used as well as the data collected from the recently installed Maynardville exit-pathway wells (Figs 7.3, 7.4, and 7.5). Data from the continuous-flow-monitoring site at BCK-4.55 and from various instantaneous monitoring points throughout Bear Creek and its tributaries, collected by the Surface Water Hydrology Group of ESD at

BURIAL GROUNDS

All location information presented in this figure is based upon MMES engineering drawings, results of previous MMES investigations, and/or field determinations of feature and sampling locations. No representation or warranty, expressed or implied, is made as to the accuracy of the information or statements presented in this figure.

SCALE
1"=1000'

Legend

Fig. 7.2. Groundwater wells proposed for contin'

← CREEK AND TRIBUTARIES == ROADS	● BEDROCK WELLS < 200' ■ UNCONSOLIDATED WELLS ▲ BEDROCK WELLS > 200'

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Groundwater Wells Proposed for
Continued RI Monitoring

Table 7.1. Characteristics of wells selected for continued monitoring

Well	Number of sampling events	Open/ screened	Interval (ft BLS ^a)	Aquifer ^b	Formation ^c	Notes
<i>Oil Landfarm Area</i>						
GW-073	13	S	69.8-79.8	WB/B	N	
GW-097	13	S	11.8-16.8	WB	N	
GW-098	13	S	82.4-103.4	B	N	
GW-120	13	O	130.0-180.0	B	N	
GW-227	26	O	30.0-40.0	WB	Mn	Cavity @ 34.5-35.0, 37.0-37.5, water (2-5 gpm) @ 30-40
GW-228	17	O	80.0-100.0	B	Mn	Cavity @ 90-100, water (30-40 gpm) @ 35-100
GW-229	17	O	40.0-55.0	WB	Mn	Cavity @ 43-55, water (8 gpm) @ 30-55
<i>S-3 Ponds</i>						
GW-108	15	S	46.7-55.7	WB	N	
GW-109	15	S	102.9-121.9	B	N	
GW-122	19	O	92.0-142.0	B	Mn	Water (25-35 gpm) @ 45-100
GW-123	20	O	522.0-572.0	B	Mn/N	
GW-124	14	O	100.0-150.0	B	Mn	
GW-125	20	O	502.0-552.0	B	Mn/N	
GW-243	19	S	45.0-72.9	WB	N	
GW-244	13	S	47.3-75.4	WB	N	
GW-245	11	S	43.6-71.6	WB	N	
GW-246	11	S	46.5-74.6	WB	N	
GW-247	11	S	46.9-74.9	WB	N	

Table 7.1 (continued)

Well	Number of sampling events	Open/ screened	Interval (ft BLS) ^a	Aquifer ^b	Formation ^c	Notes
GW-094	13	S	93.8-114.8	B	Mn	
GW-095	20	S	134.8-155.8	B	Mn	
GW-117	20	O	480.0-530.0	B	Mn/N	
GW-118	20	O	525.0-575.0	B	Mn/N	
GW-126	13	O	105.0-155.0	B	N	
GW-290	10	S	25.1-35.1	B	Mry	
GW-291	10	S	11.5-16.5	WB	Mry	

^aBelow land surface.^bWB = weathered bedrock, B = bedrock.^cN = Nolichucky, Mn = Maynardville, Mry = Maryville.

Fig. 7.3. Proposed groundwater sampling locations at the

REEK AND TRIBUTARIES * 1993 COMPLIANCE SAMPLING LOCATIONS

ROADS

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PROPOSED GROUND WATER SAMPLING LOCATIONS
S-3 SITE AND OIL LANDFARM

S-3 Site and Oil Landfarm. (See Table A.1 for well construction details.)

Fig. 7.4. Proposed groundwater sampling locations at

AND TRIBUTARIES * 1993 COMPLIANCE SAMPLING LOCATIONS

Martin Marietta Energy Systems, Inc.
Environmental Management Department

PROPOSED GROUND WATER SAMPLING LOCATIONS
BURIAL GROUNDS

the Burial Grounds. (See Table A.1 for well construction details.)

Fig. 7.5. Proposed groundwater sampling locations

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Environmental Management Department

PROPOSED GROUND WATER SAMPLING LOCATIONS
BEAR CREEK VALLEY

* 1993 COMPLIANCE SAMPLING LOCATIONS

BEAR CREEK AND TRIBUTARIES
WELL SPRING
== ROADS

ORNL, will also be used. Existing data from the results of recent infrared aerial photography and aerial electromagnetic surveys will be used to aid in identifying any groundwater discharge points to Bear Creek; these data will be essential to the planning and selection of monitoring points for the proposed tracer tests.

Surface water and groundwater data collected specifically for this RI will be that derived from pulse train analysis, chemical tracer tests, installation and monitoring of stormflow tubes, installation of permanent stream-flow-monitoring stations, and installation of temporary continuous monitoring stations.

7.4.1.1 Pulse train analysis and tracer test

Pulse train analysis will be used to identify hydraulic connections. Three tests are proposed to address the three major source areas within BCV. Figure 7.6 illustrates the areas for the proposed pulse train tests (S-3, Oil Landfarm, Burial Grounds). Each test will consist of the following steps:

- selection of an injection well within the Nolichucky (preliminary selections are identified in Fig. 7.6 and Table 7.2);
- selection of monitoring points (preliminary points identified in Fig. 7.6 and Table 7.3, and springs identified in Fig. 7.7);
- instrumentation of monitoring points with continuous recording pressure transducers, conductivity, and temperature probes;
- measurement of pretest conditions for 1 month to establish short-term natural variability; and
- distilled water injection with continuous monitoring.

The results of the test will be used to confirm or identify hydraulic connections between the source area and groundwater and surface water monitoring points. The initial tests will be confined to identifying proximal connections. The initial tests will also test the possible short-range attenuation of the induced pulse train within the Nolichucky and thereby the viability of the technique to larger scale tests.

After hydraulic connections have been demonstrated, the hydraulic connections will be confirmed with a chemical tracer test. The test will consist of the following steps:

- selection of a chemical tracer (an inorganic bromide salt is preferred over an organic dye to avoid sorption loss of tracer within the Nolichucky);
- selection of an injection well based on the results of the pulse train analysis;
- selection of monitoring points based on the results of the pulse train analysis (preliminary points in Fig. 7.6);
- background monitoring of the sampling points for 1 month to establish variability;
- tracer injection with sample extraction from the injection well for point dilution analysis; and

Fig. 7.6. Proposed areas for pulse train analysis

	CREEK AND TRIBUTARIES		MONITORED WELLS
	ROADS		INJECTION WELLS

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Proposed Areas for Pulse Train
Analysis

sis. (See Table A.1 for well construction details.)

Table 7.2. Characteristics of wells for proposed pulse train analysis

Well	Aquifer*	Formation*	Top of fresh bedrock (ft BLS)	Open/ screened	Interval (ft BLS)	Notes
<i>Oil Landfarm</i>						
GW-073	WB/B	N	36.0	S	69.8-79.8	
GW-097	WB	N		S	11.8-16.8	
GW-098	B	N	7.5	S	82.4-103.4	
GW-120	B	N	17.0	O	130.0-180.0	
GW-225	B	Mn	30.0	O	150.8-200.0	
GW-226	WB	Mn	28.0	O	45.0-55.0	Water: 1-2 gpm @ 30-55
GW-229	WB	Mn		O	40.0-55.0	Cavity 43-55, water: 1 gpm @ 30-40, 8 gpm @ 30-55
GW-368	B	K/Mn	32.0	O	225.0-245.0	Water: 25-35 gpm @ 45-100
GW-369	B	K/Mn	68.0	O	115.8-150.2	
GW-601	B	K/Mn		O	318.5-356.0	
<i>S-3 Ponds</i>						
GW-101	U/WB		17.5		10.1-17.5	
GW-122	B	Mn	37.0	O	92.0-142.0	Water: 25-35 gpm @ 45-100
GW-123	B	Mn/N	38.0	O	522.0-572.0	
GW-124	B	Mn	30.0	O	100.0-150.0	
GW-125	B	Mn/N	25.0	O	502.0-552.0	
GW-127	U/WB	Mn/N		S	18.8-22.8	
GW-243	WB	N		S	45.0-72.9	
GW-244	WB	N		S	47.3-75.4	
GW-245	WB	N		S	43.6-71.6	
GW-246	WB	N		S	46.5-74.6	

Table 7.2 (continued)

Well	Aquifer ^c	Formation ^b	Top of fresh bedrock (ft BLS)	Open/ screened	Interval (ft BLS)	Notes
GW-247	WB	N		S	46.9-74.9	
GW-315		Mn		S	93.3-103.3	
<i>Burial Grounds</i>						
GW-045	U/WB			S	3.0-13.0	
GW-094	B	Mn	17.0	S	93.8-114.8	
GW-095	B	Mn	24.0	S	134.8-155.8	
GW-117	B	Mn/N	18.0	O	480.0-530.0	
GW-118	B	Mn/N	15.0	O	525.0-575.0	
GW-126	B	N	27.0	O	105.0-155.0	
GW-626	B	N	64.0	S	67.7-77.7	Fracture with water @ 73
GW-627	B	N	43.0	O	254.0-270.0	Fracture with water @ 74, 256
GW-053	U/WB	Mn		S	26.6-31.6	
GW-624	WB	N		S	16.9-27.2	Water @ 22

^aU = unconsolidated, WB = weathered bedrock, B = bedrock.^bK = Knox, Mn = Maynardville, N = Nolichucky.^cBelow land surface.

**Table 7.3. Proposed analytical parameters for surface water
and groundwater samples during RI at BCV OU 4**

Parameter	Method
CLP metals	ILM02.0 ^a
Total	
Dissolved	
AAS metals (total and dissolved)	ILM02.0 ^a
Chromium	
Cadmium	
Lead	
Mercury	
CLP volatile organics	OLM01.8 ^b
Anions	
Chloride	325.2 ^c
Cyanide	9010 ^d
Nitrate	9200 ^d
Sulfate	9035 ^d
Fluoride	340.2 ^c
Bromide	320.1 ^c
Radiologicals (total and dissolved)	
Gross alpha	9310
Gross beta	9310
Isotopic uranium	EC-1920
Miscellaneous	
pH	9040
Specific conductance	9050
Total suspended solids (TSS)	160.2 ^c
Total dissolved solids (TDS)	160.1 ^c
Alkalinity	310.1 ^c
Turbidity	180.1 ^c

^aEPA 1991c.

^bEPA 1991d.

^cEPA 1979b.

^dEPA 1986.

Fig. 7.7. Location of active springs and proposed permanent flow-monitoring site, BCK-9.40.

- sample collection at monitoring points—hourly samples for the first 8 h followed by daily samples for 2 weeks, weekly samples for 3 months, and biweekly samples for the next 3 months.

The results of the chemical tracer/point dilution test will

- confirm the pulse train analysis results,
- identify longer-range connections between source areas and discharge points that could not be addressed because of pressure pulse attenuation, and
- be used to calculate the flow velocity in the active flow portion of the Nolichucky.

The combined results of the pulse train analysis and the chemical tracer test will be used to identify any groundwater monitoring points that are hydraulically connected to the source areas that are not being monitored by the compliance program. These wells will be monitored as part of the RI with the data analyzed for evidence of temporal decreases in contaminant concentrations. In addition, the results of the hydraulic connection tests will identify Maynardville wells that can be monitored to evaluate the concentrations of contaminants reaching the Maynardville conduit system. Finally, the pulse train and chemical tracer analyses will serve to identify any surface water discharge points that should be added to the historical trend monitoring program.

All groundwater and surface water samples collected as part of RI activities will be analyzed using Contract Laboratory Program (CLP) Level III quality criteria. Level III data will be used to verify the existing monitoring data and support its use in defining temporal trends. Furthermore, Level III data collected in this initial phase of the BCV OU 4 investigation will be used in preparation of the baseline risk assessment at the end of all characterization studies. Finally, 10% of the water samples will be submitted to the laboratory for CLP Level IV analysis. This level of laboratory QC is requested as a check on the laboratory and as an indicator of the quality of the Level III data.

7.4.1.2 Stormflow and stream-flow monitoring

Given the complexities of groundwater flow in a fracture-dominated area such as the Nolichucky, Solomon et al. (1992) suggest that groundwater monitoring may be best accomplished in stream segments that represent the discharge from the active flow system. Moore (1992) has proposed a hydrograph analysis technique that separated the stormflow zone component of flow from the total surface-water flow such that the baseflow groundwater discharge to the stream can be identified. Combining stormflow-zone-hydrograph analysis with continuous flow measurement and weekly water quality sampling at a Bear Creek station downstream from the major sources in BCV will be used to identify those data that best represent groundwater discharge. Those data will be analyzed to identify a temporal decrease in contaminant concentrations similar to those observed by Moore and Toran (1992) in the headwaters of Bear Creek. Stormflow tubes will be installed at six locations (Fig. 7.8) in upper BCV.

Six locations will be equipped for continuous stormflow water monitoring (eliminating the need to arrange for stormflow monitoring by field personnel). Six locations will provide

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Proposed Locations for Stormflow
Tube Installations

ations for stormflow tube installations.

sufficient data to calculate an average for use in storm hydrograph analysis (Moore 1992). Stormflow tubes will be installed in time to monitor throughout the late fall and winter period when evapotranspiration is insignificant (Moore 1992). Stormflow tube construction and installation will follow that described in Moore (1992).

Surface water flow and water quality monitoring are required to complement, or perhaps replace, groundwater data for temporal trend analyses (Moore and Toran 1992). A permanent streamflow monitoring station will be installed at BCK-9.40 (Fig. 7.7). The location will be equipped for continuous flow measurements, and weekly water-quality samples will be collected for a period of 7 months that will include both high- and low-level flow seasons. The location for the stream monitoring station is downstream of the source areas in BCV, below a major spring (SS-5) that has shown some evidence for nitrate contamination (HSW Environmental Consultants 1992), and downstream of a gaining reach of Bear Creek (Bailey and Lee 1991).

In addition seven tributaries (NT2 to NT8) and one site on Bear Creek (BCK 12.36) will be installed with constant stream flow monitoring and paced water sampling devices (Fig. 7.9). Monitoring sites will be located on the Maynardville/Nolichucky contact to ensure that no groundwater flow in Bear Creek Valley from upgradient of the tributary is included in the sample.

All sites will be monitored for 7 months. The channel at each site will be flow rated. Surface water flow data will be recorded constantly using dataloggers, and composite flow paced water samples will be taken weekly. Surface water samples will be taken following procedures in ESP 301-3. In the case of high flow rates causing the sampling device to fill up before the weekly sample is taken, the date and time at which the sample device switches off will be recorded. Composite samples will be analyzed for metals and radiological contaminants. VOCs cannot be analyzed in composite samples and will be analyzed in grab samples taken at the time of composite sample collection.

Flow data will be analyzed in conjunction with stormflow data to identify water quality samples that are most representative of groundwater discharge. Water quality data from this monitoring station will be analyzed to identify any temporal decreases in contaminant concentrations.

7.4.2 Subsurface Contaminant Interception in Nolichucky Source Areas

If temporal decreases in contaminant concentrations cannot be demonstrated, or if the concentration of contaminants reaching the Maynardville conduit system constitutes an unacceptable risk, the next most likely alternative will be to prevent contaminants from reaching the Maynardville by implementing either downgradient collection trenches or a plume capture system employing extraction wells. Analysis of historical data and data collected from activities specifically designed for this RI will be used to support this activity.

Geraghty & Miller (1986) conducted an aquifer test and prepared preliminary designs for a groundwater recovery system near the S-3 Ponds. Tests conducted to construct these designs will be combined with the results of pulse train analysis and chemical tracer tests and will be used to identify hydraulic connections within the shallow groundwater zone. Using

Fig. 7.9. Proposed tributary s

Sampling locations in Bear Creek Valley.

these data, active flow paths between points within the regolith and shallow bedrock will be identified and the depths of these pathways will be used to differentiate between flow paths that may be intercepted by collection trenches and those requiring extraction wells. The location of possible collection trenches and extraction wells and the zones of influence of those trenches and capture wells in the S-3 Ponds area, the Oil Landfarm, and the Burial Grounds will then be determined.

7.4.3 Surface Water Interception in Bear Creek and at Springs and Seeps

If groundwater contaminants cannot be captured within the source area, the next most likely remedial alternative will seek to capture contaminants within Bear Creek and at springs and seeps. The data requirements to support this alternative encompass all of the data collected for the preceding alternatives. In particular, water balance data collected through the use of surface-water-flow monitoring combined with frequent water-quality monitoring will be used to identify active springs that are contributing to contaminant flux. These results will be used to locate points for efficient contaminant capture.

As discussed previously in Sect. 7.4.1, surface-water-flow data from the continuous-flow-monitoring site at BCK-4.55 and from various instantaneous monitoring points throughout Bear Creek and its tributaries are being analyzed by the Surface Water Hydrology Group of ESD at ORNL. The results of these analyses will clearly identify gaining and losing stream reaches within Bear Creek as well as form the basis of water budget calculations for BCV OU 4. The results of these ongoing analyses will be used to guide the installation of surface-water-monitoring points. In addition, the results of data analyses from recent geophysical surveys of the Burial Grounds and from data collected from recent well installations in the area will be combined to provide an interpretation of subsurface structures (e.g., depth, lateral continuity). Figure 7.10 illustrates the general area covered by seismic reflection, very low frequency, ground penetrating radar, and microgravity surveys. The results of these analyses will be used to suggest a combination of geophysical survey techniques that will reliably identify subsurface conduits. If a reliable combination of techniques can be developed, it will be used to identify conduit pathways and to guide the selection of surface water monitoring points as proposed.

Data collected to support the preceding alternatives (e.g., pulse train analysis, tracer tests) will also be used to support this alternative. However, major data requirements unique to this alternative include more detailed flow and contaminant monitoring at selected springs and identification of possible contaminant-capture points further downstream. Installation of continuous-flow-monitoring stations is proposed for the following springs: SS-1, SS-4, SS-5, SS-6, and SS-8, or others identified as part of a spring/seep inventory of BCV conducted as part of this RI (Fig 7.7). In addition, weekly flow-paced water-quality samples will be collected at these monitoring locations. Data will be collected from each station for 7 months. The data from these locations will be used to identify those springs that are the best candidates for contaminant capture. In addition, data will be used to aid in design of the capture and treatment system. Identification of likely contaminant-capture points will be based on the calculated mass of contaminants contributed to Bear Creek at each spring. Data useful in the design of the capture and treatment system include the seasonal range of flow and contaminant concentrations at each spring. Implementation of this alternative will require additional definition of the conduit flow system and its relationship to proposed surface water

Fig. 7.10. Sketch of approximate location of seismic reflection and VLF lines and microgravity survey.

collection/treatment points. If a reliable combination of techniques can be developed, it will be used to identify potential conduit pathways from source areas to proposed surface-water-collection/treatment points and to guide the selection of surface-water-monitoring points as proposed.

7.4.4 Schedule of Proposed Field Activities

Figure 7.11 presents a schedule of the primary field activities that have been discussed in the preceding sections. The schedule assumes a start date in the early summer of 1993 such that chemical tracer tests and stormflow tube monitoring will occur during the wet and nongrowing (minimal evapotranspiration) seasons. Scheduled field activities emphasize collection of data required by all of the three alternatives (e.g., pulse train analysis, tracer tests), the human health and ecological risk assessments, and those activities that require implementation during this phase of the BCV OU 4 characterization to support subsequent characterization studies (e.g., installation of continuous-flow-monitoring stations at springs).

7.4.5 Proposed Sampling Activities and Analytical Methods

The sampling and analytical requirements described in this section supplement the detailed descriptions of activities proposed for the RI and discussed in the previous section. The proposed sampling activities follow:

- four rounds of water quality sampling in 25 wells (Fig. 7.2) to support temporal trend analysis for the monitoring alternative;
- continuous hydraulic head, specific conductance, and temperature monitoring in pulse train analysis wells (Fig. 7.6);
- water sampling for chemical tracer in the source well (for point dilution analysis) and at monitoring locations (Fig. 7.6);
- continuous flow monitoring at BCK-9.40, BCK-12.36, NT2 0.11, NT3 0.06, NT4 0.06, NT5 0.04, NT6 0.11, NT7 0.11, and NT8 0.15;
- weekly flow-paced water-quality sampling at BCK-9.40, BCK-12.36, NT2 0.11, NT3 0.06, NT4 0.06, NT5 0.04, NT6 0.11, NT7 0.11, and NT8 0.15 (Fig. 7.9) for a minimum of 7 months;
- continuous stage monitoring at stormflow tubes (Fig. 7.7);
- continuous flow monitoring at springs SS-1, SS-4, SS-5, SS-6, and SS-8 for a minimum of 7 months (Fig. 7.7); and
- weekly flow-paced water-quality sampling at springs SS-1, SS-4, SS-5, SS-6, and SS-8.

7.4.5.1 Water quality data

Level III water quality data will be collected at the groundwater and surface water monitoring locations identified in Figs. 7.2 and 7.7. The samples will be analyzed for the constituents and parameters in Table 7.3. Gross alpha and beta will be used for screening, and isotopic analysis will be performed if the MCL for either of these values is exceeded. Isotopic analyses will be conducted for isotopic thorium, technetium-99, and strontium-90. The

RI ACTIVITY SCHEDULE

ACTIVITY	MONTH ¹											
	1	2	3	4	5	6	7	8	9	10	11	12
Groundwater quality monitoring												
Continuous water levels for background												
Pulse train tests												
Data analysis <i>Pulse train</i> <i>Infrared aerial photos</i> <i>Spring survey</i>												
Select tracer monitoring and injection pts.												
Conduct tracer tests												
Install storm flow tubes (Scout locations & Install)												
Continuous monitoring of storm flow tubes												
Install surface water flow monitors <i>BCK 9,40, SS-1,2,4,5 & 8</i>												
Calibrate flow monitors												
Continuous flow data												
Weekly water samples												
Geophysical data analysis												

¹ Schedule assumes field activities will commence one month after NTP.

Fig 7.11. Schedule of proposed field activities.

analyses will be conducted for isotopic thorium, technetium-99, and strontium-90. The numbers of samples and the distribution of QC samples are listed in Table 7.4. Level IV analyses will be requested on a randomly selected 10% of all batches submitted to each laboratory.

Discrete samples for the chemical tracer test (Sect. 7.4.1) will be analyzed for the proposed tracer (Table 7.3, bromide, Br⁻). The number of samples proposed for the test is summarized in Table 7.4 and is based on the assumption that 32 monitoring points will be sampled on the following schedule:

- hourly samples for the first 8 h (8 samples per location);
- daily samples for 2 weeks (14 samples per location);
- weekly samples for 3 months (12 samples per location); and
- biweekly samples for 3 months (6 samples per location).

The sampling frequency during the early stages of the test is crucial and may be modified, based on the results of the pulse train analysis, for monitoring points close to the injection well.

Water quality samples will be collected weekly following the installation of the continuous flow monitoring station at BCK-9.40 and at major springs in BCV (SS-1, SS-4, SS-5, SS-6, and SS-8). According to the proposed schedule (Fig. 7.10), there will be 28 water quality samples collected at each of the six surface water monitoring locations.

7.4.5.2 Hydraulic data

Hydraulic data collected during the proposed field activities will comprise continuous flow data at surface water monitoring locations (BCK-9.4 and major springs), continuous pressure transducer data from selected monitoring points during the pulse train tests, and continuous stage recording in the six stormflow tubes.

Collection of continuous surface water flow data will require six dedicated flow recording devices (BCK-9.40, SS-1, SS-4, SS-5, SS-6, and SS-8) for a minimum of 8 months. Continuous stage recording in stormflow tubes will require six dedicated continuous water level recorders for a minimum of 7 months (Fig. 7.11).

During the pulse train test, each monitoring point (Fig. 7.6) will be instrumented with a pressure transducer, conductivity probe, and temperature probe. Each monitoring point will require a dedicated data logger and set of probes for 1 month of baseline readings and 1 week of test data collection per test area (11 monitoring points at S-3 Ponds, 9 monitoring points at Oil Landfarm, and 9 monitoring points at Burial Grounds).

7.4.5.3 Ecological data

Two types of ecological data are required to support the risk assessment. Water samples will be collected specifically for toxicity testing from all of the tributaries receiving contaminated groundwater (NT-1 through NT-8) (Fig. 7.9) and from active springs (SS-1,

Table 7.4. Numbers of samples and quality control for water quality samples

Medium	Parameter	Number of sites	Number of sampling events	Number of samples	Duplicates ^a	Trip blanks ^b	Field blanks ^c	Equipment rinseate blanks ^d	Total samples
Surface water/ springs ^{e,f}	<u>Metals^g</u>	14	28	784	79		72	40	975
	<u>Radiologicals^g</u>								
	Gross alpha	14	28	784	79		72	40	975
	Gross beta								
	Isotopic uranium								
	<u>Volatiles</u>	14	28	392	40	112	36	20	600
	<u>Anions</u>	14	28	392	40		36	20	488
	Sulfate								
	Fluoride								
	Nitrate								
	Chloride								
	Cyanide								
	<u>Miscellaneous</u>	14	28	392	40		36	20	488
	Alkalinity								
	Total suspended solids								
	Total dissolved solids								
Groundwater ^f	Temperature ^h								
	Dissolved oxygen ^h								
	Redox ^h								
	pH ^h								
	Specific conductance								
	Turbidity								
	<u>Metals^g</u>	25	4	200	20		22	16	258
	<u>Radiologicals^g</u>								
	Gross alpha	25	4	200	20		22	16	258
	Gross beta								
	Isotopic uranium								
	<u>Volatiles</u>	25	4	100	10	28	11	8	157

Table 7.4 (continued)

Medium	Parameter	Number of sites	Number of sampling events	Number of samples	Duplicates ^c	Trip blanks ^d	Field blanks ^e	Equipment rinsate blanks ^f	Total samples
	Anions	25	4	100	10		11	8	129
	Sulfate								
	Fluoride								
	Nitrate								
	Chloride								
	Cyanide								
	Miscellaneous	25	4	100	10		11	8	129
	Alkalinity								
	Total suspended solids								
	Total dissolved solids								
	Temperature ^g								
	Dissolved oxygen ^h								
	Redox ⁱ								
	pH								
	Specific conductance ^h								
	Turbidity								
Groundwater tracer test	Bromide	32	44	1408	141		88	98	1735
Ecological	Toxicity	20	2	40	4		4	4	52
	Whole fish analyses (Table 6.6)	3	1	24					24

^aMinimum 10%.^bOne trip blank per cooler, one set of samples per cooler. Based on 3-d sampling per event.^cType A: one field blank per ASTM water lot #; Type B: decontamination source water every 2 weeks; Type C: 5% frequency.^dOne per group of equipment used per event per 20 samples. Based on 3-d sampling per event.^eSee Table 6.4 for analytical methods and reporting detection limit.^fWeekly surface water sampling in conjunction with continuous flow measurement.^gBoth filtered and unfiltered samples will be collected.^hField measurement.ⁱIf gross alpha or gross beta exceeds MCL, sample will be analyzed for Technetium 99, Strontium 90, and Thorium.

SS-4, SS-5, SS-6, and SS-8) (Fig. 7.7). The water samples will be collected in the summer, when the tributaries and springs will be near baseflow, and in the spring when flows may be considerably higher. Water samples for toxicity testing will also be taken at the biological monitoring stations on Bear Creek (see Fig. 3.15) at the same time.

Samples of fish in Bear Creek will be collected from three locations (Fig. 7.12) for whole body analyses. The locations have been selected to represent a headwater site (BCK-12.46), a site downstream of the major source areas (BCK-9.40), and one site that has experienced minimal impact (BCK-3.25). A minimum of eight individuals (Stonerollers, *Campostoma anomalum*) will be collected at each location and, if possible, individually analyzed for the following constituents.

- Metals/inorganics

Antimony	Copper	Lead	Selenium	Uranium
Arsenic	Chromium	Mercury	Silver	Zinc
Beryllium	Copper	Nickel	Thallium	

- Pesticides/PCBs

- Radionuclides

^{60}Co ^{137}Cs ^{90}Sr

Details of analytical methods and detection limits can be found in Appendix B.

These RI-specific data will be supplemented by ecological data collected at existing sampling locations (see Fig. 3.15). Data will include surveys of benthic macroinvertebrates and the results of analyzing fish filets for the analytes listed above.

7.4.5.4 Sample apportionment

Based on the proposed sampling activities described in Sect. 7.4, Table 7.5—an explicit sample apportionment and analysis table—has been generated to guide field sampling activities. Data presented in Table 7.5 are used to generate project-specific forms (e.g., sample labels, sample log sheets, groundwater purge worksheets). Examples of these forms are included in Appendix D.

7.5 SAMPLE TRACKING AND RECORDS MANAGEMENT

7.5.1 Sample Tracking

Samples and sample results will be tracked from the time they are identified in the work plan through preprinting of field log books, receipt of the analytical data packages, verification, and validation. All sample descriptive information (e.g., sample survey locations, sample identification numbers, media, depth of sample, type of analysis, field QC samples) detailed in the work plan will be entered into a sampling and analysis plan (SAP) data base.

Fig. 7.12. Locations of proposed RI biological monitoring sites.

Table 7.5. Sample apportionment and analysis summary for shallow groundwater/surface water and ecological activities, BCV OU 4

Location	Sample type	Station	Northing	Easting	No. events	Analysis category
Oil Landfarm	Grab	GW-073	29791	46986	4	Metals
	Grab	GW-097	29459	46959	4	Volatiles
	Grab	GW-098	29452	46959	4	Anions
	Grab	GW-120	29455	46942	4	Radiologicals
	Grab	GW-227	29172	47802	4	Alkalinity
	Grab	GW-228	29171	47791	4	Total suspended solids
	Grab	GW-229	29256	47017	4	Total dissolved solids
	Grab	GW-229	29256	47017	4	Specific conductance
S-3 Ponds	<i>Groundwater Monitoring</i>					
	Grab	GW-108	30069	53207	4	Turbidity
	Grab	GW-109	30055	53207	4	Field measurements
	Grab	GW-122	29741	51807	4	Metals
	Grab	GW-123	29742	51794	4	Volatiles
	Grab	GW-124	29656	52223	4	Anions
	Grab	GW-125	29646	52208	4	Radiologicals
	Grab	GW-243	30155	51990	4	Alkalinity
	Grab	GW-244	30060	51974	4	TSS*
	Grab	GW-245	29977	51992	4	TDS*
	Grab	GW-246	29992	52098	4	Specific conductance
	Grab	GW-247	30005	52181	4	Turbidity
	Grab	GW-094	29167	42911	4	Field measurements
	Grab	GW-095	29142	43363	4	Metals
	Grab	GW-117	29183	42918	4	Volatiles
	Grab	GW-118	29147	43404	4	Anions
Burial Grounds	Grab	GW-126	29361	42679	4	Radiologicals
	Grab	GW-290	30445	42580	4	Alkalinity
	Grab	GW-291	30449	42583	4	TSS
	Grab	GW-291	30449	42583	4	TDS

Table 7.5 (continued)

Location	Sample type	Station	Northing	Easting	No. Events	Analysis Category
<i>Groundwater monitoring—QC samples</i>						
To be determined	Duplicate	001			4	Metals Volatiles Anions Radiologicals Alkalinity TSS TDS
	Duplicate	002			4	Specific conductance Turbidity Field measurements
	Duplicate	003			4	Volatiles
To be determined	Trip Blank	001			4	Metals Volatiles Anions Radiologicals
	Trip Blank	002			4	
To be determined	Field Blank	001			4	
	Field Blank	002			4	
	Field Blank	003			4	
To be determined	Rinsate	001			4	Metals Volatiles Anions Radiologicals
	Rinsate	002			4	
	Rinsate	003			4	

Table 7.5 (continued)

Location	Sample type	Station	Northing	Easting	No. events	Analysis Category
Oil Landfarm	<i>Groundwater pulse train/tracer studies</i>					
	Grab	GW-073	29791	46986	40	Bromide
	Grab	GW-097	29459	46959	40	
	Grab	GW-098	29452	46959	40	
	Grab	GW-120	29455	46942	40	
	Grab	GW-225	29155	47461	40	
	Grab	GW-226	29156	47473	40	
	Grab	GW-229	29256	47017	40	
	Grab	GW-368	28913	47618	40	
	Grab	GW-369	28921	47628	40	
	Grab	GW-601	28903	47629	40	
	Grab	GW-101	30069	53207	40	Bromide
	Grab	GW-122	29741	51807	40	
	Grab	GW-123	29742	51794	40	
	Grab	GW-124	29656	52223	40	
	Grab	GW-125	29646	52208	40	
S-3 Ponds	Grab	GW-127	29850	51828	40	
	Grab	GW-243	30155	51990	40	
	Grab	GW-244	30060	51974	40	
	Grab	GW-245	29977	51992	40	
	Grab	GW-246	29992	52098	40	
	Grab	GW-247	30005	52181	40	
	Grab	GW-315	29455	52268	40	
	Grab	GW-045	29140	43357	40	Bromide
	Grab	GW-053	29061	43091	40	
	Grab	GW-094	29167	42911	40	
	Grab	GW-095	29142	43363	40	
	Grab	GW-117	29183	42918	40	
Burial Grounds						

Table 7.5 (continued)

Location	Sample type	Station	Northing	Easting	No. events	Analysis Category
	Grab	GW-118	29147	43404	40	
	Grab	GW-126	29361	42679	40	
	Grab	GW-624	29421	43007	40	
	Grab	GW-626	29535	42772	40	
	Grab	GW-627	29505	42774	40	
To be determined	Duplicate	001			40	Bromide
	Duplicate	002			40	
	Duplicate	003			40	
To be determined	Field Blank	001			40	Bromide
To be determined	Rinsate	001			4	Bromide

Table 7.5 (continued)

Location	Sample type	Station	Northing	Easting	No. events	Analysis Category
<i>Surface water—flow monitoring</i>						
Upper BCV		SS-1			Continuous	Flow Monitoring
		SS-4			Continuous	
		SS-5			Continuous	
		SS-6			Continuous	
		SS-8			Continuous	
NPDES Monitoring Point		BCK-9.40			Continuous	Flow Monitoring
		BCK 12.36			Continuous	Flow Monitoring
		NT2 0.11			Continuous	
		NT3 0.06			Continuous	
		NT4 0.06			Continuous	
		NT5 0.04			Continuous	
		NT6 0.11			Continuous	
		NT7 0.11			Continuous	
		NT8 0.15			Continuous	
<i>Surface water—storm flow</i>						
Upper Bear Creek		001			Continuous	Stage Monitoring
		002			Continuous	
		003			Continuous	
		004			Continuous	
		005			Continuous	
		006			Continuous	

Table 7.5 (continued)

Location	Sample type	Station	Northing	Easting	No. Events	Analysis Category
Upper BCV	<i>Surface water—water quality</i>					
	Flow Paced	SS-1			28	Metals Volatiles
	Flow Paced	SS-4			28	Anions Radiologicals
	Flow Paced	SS-5			28	Alkalinity TSS
	Flow Paced	SS-6			28	TDS Specific conductance
	Flow Paced	SS-8			28	Turbidity Field measurements
NPDES Monitoring Point	Flow Paced	BCK-9.40			28	Metals
	Flow Paced	BCK-12.36			28	Volatiles
	Flow Paced	NT2 0.11			28	Anions
	Flow Paced	NT3 0.06			28	Radiologicals
	Flow Paced	NT4 0.06			28	Alkalinity
	Flow Paced	NT5 0.04			28	TSS
	Flow Paced	NT6 0.11			28	TDS
	Flow Paced	NT7 0.11			28	Specific conductance
	Flow Paced	NT8 0.15			28	Turbidity
	Flow Paced				28	Field measurements

Table 7.5 (continued)

Location	Sample type	Station	Northing	Easting	No. events	Analysis Category
Surface water - QC samples						
To be determined	Duplicate	001			84	Metals Volatiles Anions Radiologicals Alkalinity Total suspended solids Total dissolved solids Specific conductance Turbidity Field measurements
To be determined	Trip Blank	001			84	Volatiles
To be determined	Field Blank	001			84	Metals Volatiles Anions Radiologicals
To be determined	Rinsate	001			84	Metals Volatiles Anions Radiologicals

Table 7.5 (continued)

Location	Sample type	Station	Northing	Easting	No. events	Analysis Category
To be determined	Grab	001	<i>Ecological</i>		2	Ecological toxicity
	Grab	002			2	
	Grab	003			2	
	Grab	004			2	
	Grab	005			2	
	Grab	006			2	
	Grab	007			2	
	Grab	008			2	
	Grab	009			2	
	Grab	010			2	
	Grab	011			2	
	Grab	012			2	
	Grab	013			2	
	Grab	014			2	
	Grab	015			2	
	Grab	016			2	
	Grab	017			2	
	Grab	018			2	
	Grab	019			2	
	Grab	020			2	

Table 7.5 (continued)

Location	Sample type	Station	Northing	Easting	No. Events	Analysis Category
<i>Ecological—QC Samples</i>						
To be determined	Duplicate	001			2	Ecological toxicity
	Duplicate	002			2	
To be determined	Field Blank	001			2	Ecological toxicity
	Field Blank	002			2	
To be determined	Rinsate	001			2	Ecological toxicity
	Rinsate	002			2	
<i>Ecological—Fish</i>						
To be determined	Composite of 8 Specimens	001			1	Whole body: Metals
	Composite of 8 Specimens	002			1	Gamma scan Radiologicals
	Composite of 8 Specimens	003			1	

^aTSS = total suspended solids.

^bTDS = total dissolved solids.

The information contained in the SAP data base is used to preprint field log books and sample container labels and tags. The logbooks contain a table of contents, task team activity sheets, preprinted log sheets, blank log sheets, calibration sheets, and a number of other forms dependent on the specific requirements of the sampling activity. (Appendix D contains copies of the field sampling forms.) Specific values for the log sheets are extracted from the data tables contained in the SAP data base and are printed in the appropriate fields on the field log sheets.

Entries to the field logbook are made daily by the Field Sampling Team. The Field Sampling Team, in addition to taking samples, labeling the sample containers, and placing them in a transportation case, also completes and includes in the shipment a chain-of-custody form. Chain-of-custody procedures create an accurate written record that can be used to track the handling and possession of a sample from collection through analysis. When transferring possession of samples, the transferee signs and records the date and time on the chain-of-custody record. Each sample is accounted for by a custody transfer, although samples may be transferred as a group. A sample chain-of-custody form is provided in Appendix D.

After the analytical laboratory receives the sample containers and logs them into their laboratory tracking system, they return a Letter of Receipt (LOR) indicating the sample identification number (ID), laboratory ID, and analyses scheduled for each sample, and a copy of the chain-of-custody form. The LOR is reviewed by the Data Manager and compared to the contents of the SAP data base to ensure that the proper chemical and radiological analyses are specified and understood by the analytical laboratory. The date of sample receipt is then entered into the SAP data base and a sample status report is generated and routed to the project manager to track sample status.

When the data packages are received from the analytical laboratory, sample tracking information (sample IDs, sample delivery groups, analysis types, dates, package completion status) are entered into the SAP data base and compared to the original plan. The date of data package delivery and status is then entered into the SAP data base, and a report is generated and routed to the project manager for review.

After the data packages have been reviewed using the verification and validation procedures described in Sect. 9.9, the SAP data base is updated with verification and validation data quality flags. A final sample tracking status report is created and submitted to the project manager detailing all samples that have completed the verification and validation process.

7.5.2 Records Management

The process of records management and data archival requires the transfer of data and documents (metadata) from the SAP data structures to structures compatible with the Oak Ridge Environmental Information System. Sufficient documentation, including the associated metadata, shall accompany the archived data to fully describe the source, contents, and structure of the data to ensure the future usability of the data. Computer programs used to manipulate or report the archived data should be included in the data archive information package to further enhance the data's future usability.

The purpose of the transfer is to provide long-term secure storage and to ensure maximum accessibility by the environmental community. After the data for a given sample or group of samples are complete and have been transferred, the Records Manager ensures that logbooks and other field records are complete and properly stored. This includes both the electronic form and all the associated data packages. Each piece of information is documented as to its sources, hard-copy information is appropriately indexed and filed, and metadata is added to the SAP and linked to the corresponding data.

Hard copies of all original field and analytical results, data reduction and summarization programs, data packages and associated QA/QC forms should be classified, indexed, and stored into appropriate file groups and record series within project files. The Records Manager will work in coordination with the ORR Administrative Record Coordinator to ensure that all required Administrative Record File documents are acquired and indexed.

7.6 DATA ASSESSMENT AND INTERPRETATION

The validated analytical data will be combined with the field data and analyzed, summarized, and mapped in the final RI and FS reports. Data base subsets for analysis, including combinations of site, location, station, sampling date, analysis type, analyte, data quality flag, and upper and lower data values, are extracted from the SAP data base with standardized and quality-controlled retrieval programs. These subsets are then passed to specific data-analysis and data-display applications programs. Analyses and summaries to be presented in the RI/FS reports include: (1) contaminants of concern; (2) statistical analyses that compare concentration values to background levels, regulatory limits, and ARARs; (3) risk assessments; (4) transport modeling; (5) estimating precision, accuracy, representativeness, completeness, and comparability parameters; and (6) various tabular listings of the data.

Coordinate and attribute data subsets of site characterization data contained in the SAP will be extracted and stored in a spatial data base using a Geographic Information System. The spatial data base will be used for spatial analysis, interpretation, and mapping.

APPROVALS

FIELD QUALITY ASSURANCE PROJECT PLAN FOR THE REMEDIAL INVESTIGATION OF THE BEAR CREEK OPERABLE UNIT 4 AT THE OAK RIDGE Y-12 PLANT

DOE/OR/01-1115&D3

September 1993

9/28/93

Technical Support Contractor Program Manager

Date

9/28/93

Technical Support Contractor QA/QC Officer

Date

10/8/93

DOE ER Site Program Manager

Date

9/28/93

DOE ER Division QA Program Manager

Date

9/29/93

Energy Systems ER Site Program Manager

Date

9/28/93

Energy Systems ER Site Project Manager

Date

9/29/93

Energy Systems ER Site QA Specialist

Date

8. FIELD QUALITY ASSURANCE PROJECT PLAN (QAPP)

8.1 INTRODUCTION

This QAPP has been developed for use in the site preparation and sample collection activities during the RI for BCV OU 4 to ensure that appropriate levels of QA and QC are achieved. This QAPP defines procedures that will be followed in the collection, custody, and handling of data used in the RI for BCV OU 4. These procedures are intended to define the methods applied to achieve the QA/QC goals established for the BCV OU 4 project.

This QAPP establishes QA requirements and responsibilities applicable to project participants and establishes methods through which project participants implement the requirements of the project. Where no appropriate procedure exists, this QAPP requires that one be developed by one or more cognizant individuals or organizations.

This QAPP is designed to comply with both the EPA Quality Assurance Management Staff (QAMS) *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans* (EPA 1980) and the American National Standards Institute/American Society of Mechanical Engineers (ANSI/ASME) NQA-1 guidelines and the *Environmental Restoration Quality Program Plan* (Energy Systems 1992a).

Table 8.1 provides a guide to the location of all relevant QA elements in this work plan.

8.2 DATA QUALITY OBJECTIVES

8.2.1 Project Objectives and Intended Data Usages

The objectives for BCV OU 4 are detailed in Sect. 1.8 of this Work Plan.

Water samples will be collected and analyzed for the constituents shown in Table 6.4 in Sect. 6.2. Data collected from the BCV OU 4 stations will be evaluated to determine the need for additional long-term monitoring and will be reviewed for concentrations of contaminants greater than health and environmental criteria given by regulatory agencies. Specific sampling locations, including maps, and sample collection methodology are discussed in more detail in the field sampling plan (Chap. 7).

The purpose of this section is to implement applicable regulatory requirements and to provide internal control and review so the data are scientifically sound and legally defensible.

QA objectives for data are as follows:

- scientific data generated will withstand scientific scrutiny;
- data will be gathered using appropriate procedures for field sampling, chain of custody, laboratory analyses, and data reporting; and
- data will be of known precision and accuracy.

Table 8.1. Cross reference of EPA QAMS 005/80 and ES/ER/TM-4R-1 elements with BCV OU 4 RI Work Plan sections

EPA QAMS 005/80	ES/ER/TM-4R-1 Element	Location in Remedial Investigation Workplan
1. Title Page	6. Document Control	Title Page, Sects. 8, 9
2. Table of Contents	6. Document Control	Table of Contents
3. Project Description	2. QA Program 6. Document Control	Executive Summary
4. Project Organization and Responsibility	1. Organization	Sect. 7.2
5. QA Objectives	3. Design Control	Sects. 8.2, 9.2
6. Sampling Procedures	3. Design Control 6. Document Control 9. Control of Processes	Sects. 8.3, 9.3, 8.7
7. Sample Custody	6. Document Control 13. Handling, Storage, and Shipping	Sects. 8.4, 9.4
8. Calibration Procedures and Frequency	8. Identification and Control of Items 12. Control of Measuring and Test Equipment	Sects. 8.5, 9.5
9. Analytical Procedures	9. Control of Processes	Sect. 9.3
10. Data Reduction, Validation, and Reporting	9. Control of Processes	Sects. 8.8, 9.7
11. Internal QC Checks	3. Design Control	Sects. 8.9, 9.8
12. Performance and System Audits	18. Audits and Surveillance	Sects. 8.11, 9.10
13. Preventive Maintenance	12. Control of Measuring and Test Equipment	Sects. 8.6, 9.6
14. Specific Routine Procedures Used to Assess Data Precision, Accuracy, Representativeness, Completeness, and Comparability	3. Design Control	Sects. 8.10, 9.7
15. Corrective Actions	15. Control of Nonconforming Items	Sects. 8.12, 9.11
16. QA Reports to Management	2. QA Program 16. Corrective Action	Sects. 8.13, 9.12

The procedures to be used for assessing the quality of field data are described in Sect. 8.8.

8.2.2 Level of Analysis

The specific QA objectives for all data are to obtain reproducible, precise, and accurate measurements consistent with the intended use of the data and the limitations of the sampling procedures used. These objectives are accomplished through the assignment of measurement tasks to the appropriate analytical level (I through IV) as defined in *Data Quality Objectives for Remedial Response Activities* (EPA 1987a). Field data, such as those collected during organic vapor and radiation monitoring, will meet the requirements for Level I data quality. Laboratory data will meet the requirements for Level III data quality.

8.2.3 Data Quality Parameters

Typical quantitative limits applicable to this project are presented in the EPA CLP statements of work (SOW) (EPA 1991c and d) as applicable, as are sample precision, accuracy, and completeness objectives. The QA objectives for QC data are designed to (1) screen out data of unacceptable precision or accuracy and (2) provide data that will meet the data quality goals for this project.

This project will follow the definitions for precision, accuracy, completeness, comparability, and sensitivity given in the *Handbook for Analytical Quality Control in Water and Wastewater Laboratories* (EPA 1979a).

8.2.4 Field Activities

Precision between monitoring instruments is determined by comparison of readings during calibration to a standard. Precision in sampling is measured through the use of field duplicates.

Accuracy is addressed by the use of standard criteria for container and equipment cleaning, sample collection, personnel training and performance criteria, uniform sample handling techniques, and blanks to detect contamination.

Representativeness of samples collected is controlled through adherence to the sampling plan and to detailed descriptions of sampling procedures, which will be included in the final BCV OU 4 Field SAP.

The QA completeness objective for this project is to obtain valid analytical results for at least 85% of the samples collected during the project. This means that completeness of sample collection (number planned vs number collected for which valid data can be obtained) must be essentially 100% to allow for some laboratory wastage. Accountability of samples collected, from field to final disposal, must be 100% complete.

Objectives for comparability between samples collected for this and other RIs are met by the following: (1) narrowly defined sampling methodologies; (2) site surveillance, use of standard sampling devices, and monitoring devices; (3) training of personnel;

- (4) documentation of sampling point; (5) stringent control limits for the daily QC checks; (6) reporting results in appropriate, comparable units; and (7) standard analytical methods.

Staff responsible for particular instruments will maintain a log of calibration procedures and results to remain with the instrument as a means of establishing a record of calibration. The Sampling Team Leaders will inspect such logs, which will become part of the project records. Each operator must be trained in the proper use of the instrument, be familiar with the instrument's use, be able to interpret data from the instrument, and be able to produce documentation certifying the skills.

8.2.5 Readiness Review

Before mobilizing for the field effort, a readiness review is led by the QA Officer and is attended, at a minimum, by the project manager, key field team members, Contracts Manager, Health and Safety Officer, and a DOE representative. The readiness review follows a checklist (Fig. 8.1) that ensures that all proper work plans and standard operating procedures are approved and controlled; all assigned personnel are trained; the drilling subcontractor is available to begin with qualified personnel, materials, and equipment; the site logistics have been handled; the laboratory is ready to accept samples; and the QA system is implemented on the field activity.

8.3 SAMPLE COLLECTION PROCEDURES

8.3.1 Field Procedures

The equipment and the techniques that will be employed to obtain representative samples will be in accordance with the approved EPA Region IV *Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual* (EPA 1991e).

8.3.2 Sampling Program

Groundwater and surface water samples will be collected at BCV OU 4 for the RI investigation. Table 6.5 shows the numbers of samples to be collected, the number of analyses estimated to be conducted, and the field quality control samples to be collected and sent to the analytical laboratory.

Groundwater samples will be collected using the following procedures from Kimbrough et al. (1990): ESP-302-1 (Water Level Measurements Using Water Level Indicator), ESP-302-2 (Guidelines for Well Pumping), ESP-302-3 (Using a Bailer), and ESP-302-4 (Using a Gas-Driven Piston Pump). Surface water samples will be collected with dippers (ES-301-1). Field measurements will be conducted in accordance with TP-307-8, Field Measurement Procedure: pH, Temperature, Conductivity (LWA 1990). Fish samples will be collected in accordance with TP-309-5, Fish Sampling in Streams (LWA 1990).

Project: _____

Site: _____

I. DOCUMENTATION

- A. Are all the appropriate documents for the Project in their final, approved form?
[(Work Plan, Field Sampling and Analysis Plan, QA Project Plan, Health and Safety Plan, Others (specify))]:
Yes_____ No_____ N/A_____ Comments:_____
- B. Are copies of the approved documents (above) in the hands of the Subcontractors Project Management, assigned field personnel, and Analytical Laboratory personnel?
Yes_____ No_____ N/A_____ Comments:_____
- C. Are applicable forms available and current with contract specifications? (Well Construction Log, Groundwater/Surface Water/Sediment Sampling Form, Field Change Request Form, etc.)
Yes_____ No_____ N/A_____ Comments:_____

II. STANDARD OPERATING PROCEDURES

- A. Have Standard Operating Procedures (SOPs) been prepared and approved for all field activities identified in the Field Sampling and Analysis Plan, QA Project Plan, and the Health and Safety Plan?
Yes_____ No_____ N/A_____ Comments:_____
- B. Do the Subcontractor's assigned field personnel and the selected analytical laboratory personnel have copies of, and have they been trained on, the SOPs that govern their work assignments? (Attach documentation of dates and subjects of training and names of personnel attending.)
Yes_____ No_____ N/A_____ Comments:_____
- C. Are the appropriate documents (See I.A) on-site and available to the field personnel?
Yes_____ No_____ N/A_____ Comments:_____
- D. Are required site and field logbooks and field personnel information available?
Yes_____ No_____ N/A_____ Comments:_____
- E. Are the site and field logbooks of the appropriate type and construction?
Yes_____ No_____ N/A_____ Comments:_____
- F. Are chain-of-custody forms required and have the field personnel been fully trained in the proper documentation for using and completing these forms?
Yes_____ No_____ N/A_____ Comments:_____

Fig. 8.1. Readiness review checklist.

III. PERSONNEL AND TRAINING

- A. Have an appropriate number of personnel with the appropriate speciality training been assigned to this project to ensure appropriate and consistent results? (Attach roster of personnel and brief description of qualifications.)
Yes_____ No_____ N/A_____ Comments:_____
- B. Is there documented evidence that the assigned field personnel have been adequately trained in the specifics of this project, such as field sampling methods, to accomplish their tasks?
Yes_____ No_____ N/A_____ Comments:_____
- C. Is there documented evidence and or training certificates that the field personnel have been adequately trained in the Health and Safety requirements? (OSHA 40-hour training, medical records, site-specific H&S training, CPR, and first aid)
Yes_____ No_____ N/A_____ Comments:_____
- D. Has chain of command from field operations to management been defined and communicated to all personnel?
Yes_____ No_____ N/A_____ Comments:_____
- E. Is there backup personnel properly trained and available?
Yes_____ No_____ N/A_____ Comments:_____
- F. Have personnel been trained in DOE Order 5000.3A?
Yes_____ No_____ N/A_____ Comments:_____

IV. MATERIALS AND EQUIPMENT

- A. Is the drilling company ready to begin work with the appropriate equipment and personnel for this project? Are there backup pieces of key equipment available? (Attach list of equipment and personnel assigned to this project.)
Yes_____ No_____ N/A_____ Comments:_____
- B. Have the qualifications of the drilling company personnel been verified? (Attach verification documentation.)
Yes_____ No_____ N/A_____ Comments:_____
- C. Have the materials for well construction been verified to meet the specifications of the Statement of Work (SOW) and the Field Sampling and Analysis Plan?
Yes_____ No_____ N/A_____ Comments:_____
- D. Have well materials (such as bentonite, gel and sand packs) been analyzed and certified analyte free? If not analyte free, has material background been analyzed and documented? (Attach certification or analysis documentation.)
Yes_____ No_____ N/A_____ Comments:_____
- E. Have the necessary instruments/measurement equipment and associated calibration devices been assembled on-site to conduct the specified tests and analyses for this job? Is all the equipment currently in calibration? Please attach list of all equipment used on the project with measurement and calibration documentation for each piece. Ensure initial calibration logs for each piece of equipment are in the appropriate log books.
Yes_____ No_____ N/A_____ Comments:_____

Fig. 8.1 (continued)

- F. Have all necessary materials and equipment been assembled to correctly collect, identify, preserve, and transport the types and number of samples to be taken for this job? (Attach a list of the type and quantity of materials/equipment available for this project.)
Yes_____ No_____ N/A_____ Comments:_____
- G. Have all the necessary types of personnel protection and decontamination equipment (clothing, breathing apparatus, respirators, face masks, gloves, plastic sheeting, plastic baggies, spare compressed air bottles, boots, decontamination gear, etc.) been assembled and made ready for this job? (Attach a list of the types and quantities of equipment available for this project.)
Yes_____ No_____ N/A_____ Comments:_____
- H. Has the Health and Safety Officer been identified? Have all site personnel received H&S training? Has H&S Officer verified that all health and safety precautions can be implemented? (Attach documentation of dates and subjects of training and names of personnel attending.)
Yes_____ No_____ N/A_____ Comments:_____
- I. Have all materials and pieces of equipment (communication devices, drinking water, first aid kits, etc.) been assembled to meet the requirements of the Health and Safety Plan?
Yes_____ No_____ N/A_____ Comments:_____
- J. Have all required interfacing arrangements (telephone numbers, site contacts, emergency signals, medical response team, etc.) been made and tested satisfactorily?
Yes_____ No_____ N/A_____ Comments:_____

V. SITE LOGISTICS

- A. Have clearances been obtained for all job-site personnel? Is the site security organization aware of the project, the scope of activities to be accomplished, and the estimated duration of the project?
Yes_____ No_____ N/A_____ Comments:_____
- B. Have all drilling permits/clearances been granted or a schedule established for obtaining them? Have permits/clearances been obtained for any radioactive materials to be taken on-site? (Attach permits or schedules as appropriate.)
Yes_____ No_____ N/A_____ Comments:_____
- C. Have the appropriate site commands/facilities/functions been informed of the activities and potential interfaces in their work areas?
Yes_____ No_____ N/A_____ Comments:_____
- D. Have arrangements been made for the disposal of drill cuttings, refuse, contaminated materials, rinsate, etc.?
Yes_____ No_____ N/A_____ Comments:_____
- E. Have arrangements been made for the location of field laboratories (phone, electricity, etc.) and storage facilities for bottles, samples, solvents, and sampling equipment?
Yes_____ No_____ N/A_____ Comments:_____

Fig. 8.1 (continued)

VI. LABORATORY LOGISTICS

- A. Has a contract-approved laboratory been selected and been made aware of the data quality objectives and the anticipated schedule of project activities? Have laboratory personnel been advised of any unusual requirements or circumstances? (Indicate name and address of primary laboratory.)
Yes_____ No_____ N/A_____ Comments:_____
- B. Has the selected laboratory been notified when sampling will begin, the projected volume of samples, the types of samples, and when samples should start arriving for analysis?
Yes_____ No_____ N/A_____ Comments:_____
- C. Has a secondary, backup laboratory been selected and approved in case of emergency situations? (Indicate name and address of backup laboratory.)
Yes_____ No_____ N/A_____ Comments:_____
- D. Has notification been made to the selected sample transportation company? Have arrangements been made to ensure that appropriate chain-of-custody and quality control requirements can be achieved? (Indicate name and address of transportation company.)
Yes_____ No_____ N/A_____ Comments:_____
- E. Are an appropriate number of the correct type(s) of sample containers available for the anticipated work? (Attach a list of the types and numbers of containers available for this project.)
Yes_____ No_____ N/A_____ Comments:_____

VII. QUALITY ASSURANCE

- A. Is a Quality Assurance Program being implemented?
Yes_____ No_____ N/A_____ Comments:_____
- B. Have arrangements been made to have QA audits and surveillances?
Yes_____ No_____ N/A_____ Comments:_____
- C. Do the various plans and manuals require a document control program? If yes, is this being implemented? (Supply the Document Control Coordinator name and address.)
Yes_____ No_____ N/A_____ Comments:_____
- D. Is there a system in place to identify, report, and evaluate any conditions adverse to quality?
Yes_____ No_____ N/A_____ Comments:_____

ATTESTATION

By my signature, I do hereby attest, to the best of my knowledge and professional ability, that this Readiness Review Checklist accurately reflects the status of our Company to complete the authorized task(s) at _____ (Base name or site)
per Task Order _____ (Contract Task Order Number)
scheduled to begin on _____ (Date).

Fig. 8.1 (continued)

8.3.3 Sample Containers, Preservation, Transport, and Storage

Sample preservation, holding times, storage conditions, container materials, and the procedures required to properly package containers of environmental samples for transportation shall be in accordance with EPA Region IV *Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual* (EPA 1991e).

8.3.4 Prevention of Cross Contamination

Sampling equipment will be decontaminated before use and between collection of each sample per ESP-900 (Kimbrough et al. 1990). Each decontamination activity will be recorded in the field logbook.

8.3.5 Decontamination of Equipment and Supplies

Decontamination of sample containers and sampling devices given in ESP-900 (Kimbrough et al. 1990) will be followed. Equipment used in field investigations—including well drilling equipment, soil sampling equipment, and field test equipment—will be decontaminated as described in ESP-901 (Kimbrough et al. 1990).

8.3.6 Field Documentation

An integral part of the sample tracking and QA/QC Plan for the field activities will be to maintain accurate and complete field records through the use of the pre-printed logbooks. Field logbooks shall be hardcover with stitched bindings and water-resistant pages. The data recorded in the field logbooks will include any modifications to the procedures outlined in the SAP with justifications for such modifications. Field measurements and observations are entered directly into the project logbooks. Any unusual occurrences or circumstances are documented in these logs and are used for reference in determining the possible causes for data anomalies discovered during data analysis. Data are recorded directly and legibly in field logbooks with entries signed and dated. Following data recording, an independent QA review is made by a different sampling team member. Changes made to original notes are made so as not to obliterate the original information and are dated and signed.

Entries in the field logbooks will be made in water-resistant ink and will include the information given in ESP-500 Sect. VII, Part D (Kimbrough et al. 1990).

8.3.7 Variance System

Procedures that properly anticipate all conditions encountered during a field sampling program cannot be prepared. Variances from approved operating procedures in the BCV OU 4 RI Plan, SAP, the QAPP, or the Health and Safety Plan will be documented in a field change request form (Fig. 8.2) and in the logbooks.

The Sampling Team Leader will initiate and chronologically maintain a variance or field change request log. A variance requires the approval of the BCV OU 4 project manager and the QA Specialist (QAS) before work proceeds. As appropriate, regulatory agencies will be notified of any variances that significantly affect project scope or objectives and approval will

FIELD CHANGE REQUEST FORM

Field Change No. _____
Page _____ of _____

Project _____

Project No. _____

Applicable Document: _____

Description:

Reason for change:

Recommended disposition:

Impact on present and completed work:

Final Disposition:

Requested by:

Field/Project Manager: _____

Approvals:

Project Manager: _____

Fig. 8.2. Field change request form.

be obtained if needed. Any variances from the Health and Safety Plan must be approved by the Health and Safety Coordinator. Approval by the BCV OU 4 project manager and QAS can be initiated verbally via the telephone or radio with follow-up sign-off. In no case will non-BCV OU 4 project personnel initiate a variance. Copies of the field change request form will be maintained by sampling teams until the fieldwork is complete and will then be forwarded to the BCV OU 4 project manager and sent to the Document Management Center.

8.3.8 Sample Identification

The identification of samples will be established and maintained as specified by the chain-of-custody procedures described in ESP-500 (Kimbrough et al. 1990).

8.3.9 Shipping and Handling

Handling, shipping, and storage of samples and data resulting from field activities will adhere to chain-of-custody protocol (Sect. 8.3) and will ensure that sample integrity for analytical purpose is maintained. Specific shipping and handling procedures are described in ESP-800 (Kimbrough et al. 1990).

8.3.10 Sample Turnaround Time

Sample analyses will be scheduled according to site investigation needs and consistent with the sample holding times. These requirements shall be included in any contractual agreement between the BCV OU 4 project and contract laboratories.

8.3.11 Field Data Management

Field records will be recorded legibly in permanent ink and will be sufficiently complete to permit reconstruction of data-gathering activities by a qualified individual (other than the originator) when data are reduced. Field notebook entries should be factual, detailed, and objective. The field records will be the basis for later written reports and all entries must be free of inappropriate terminology. The Sampling Team Leaders will collect and review field-generated data sheets daily for accuracy and completeness before being transferred to the Analytical Services Coordinator (ASC). Manual entry of field data will be coordinated by the ASC. Data entry clerks will enter field data into specified computer systems to facilitate retrieval by BCV OU 4 personnel. Quality will be checked by double entry and verification of entered data. The BCV OU 4 project manager will forward field notebooks to the Document Management Center at the conclusion of field activities.

8.4 SAMPLE CUSTODY PROCEDURES

Chain-of-custody procedures require documented sample possession from the time of collection to disposal. Chain of custody shall be maintained in accordance with ESP-500 (Kimbrough et al. 1990).

Sample custody will be initiated at the time of sample collection. Sample tags or other appropriate labels will be used to identify field samples with the following information: unique sample identification code, date and time of sampling, sampling location or station, preservation, analysis, and any additional comments that are applicable. Descriptions of sampling activities and sample identification data will also be recorded in a field notebook. Field chain-of-custody forms containing the same information will be completed for each set of samples. A line item on the sample chain-of-custody form will be completed for each sample, and the sampling technician will confirm (by signature) the completeness of the information on the form. Each individual who assumes responsibility for the samples will sign the chain-of-custody form.

Sample custody will be maintained by BCV OU 4 staff until custody is transferred to an overnight express company. The overnight express company delivers samples and transfers custody to particular analytical laboratories, where their intralaboratory chain-of-custody procedures will be in effect. On completion of analyses, sample custody will be returned to BCV OU 4 staff. Samples residues will be disposed of by contractor laboratories in accordance with ESP-1000 (Kimbrough et al. 1990) or other EPA-recommended procedures. The chain-of-custody form terminates upon final disposal of the sample. The BCV OU 4 project manager will be responsible for ensuring that the original chain-of-custody form is submitted to the Document Management Center.

8.4.1 Field Custody Procedures

Field custody procedures include the following steps:

- Before sampling begins, the QAS will instruct sampling personnel on the chain-of-custody and sample-labeling procedures, as necessary.
- A chain-of-custody record will be initiated in the field for each sample and will correspond to the sample identification label.
- Each time sample custody is transferred, the person relinquishing the sample and the new custodian will sign the record and note the date and time.
- The analyses to be performed for each sample will be recorded on a request-for-analysis form or on the chain-of-custody record.
- The Sampling Team Leader will confirm that proper custody procedures were used during the fieldwork and that results were documented in the field logbook.
- Samples transferred to analytical laboratories are recorded in the field logbook at the end of the collection period.

8.4.2 Sample Labeling

Sample labels or tags will contain sufficient information to identify the sample in the absence of other documentation. The label or tag will be directly affixed to the sample container, will be completed with black indelible ink, and will include the following as a minimum:

- project name,
- unique sample number,
- sample location,
- sampling date and time,
- signature of individual collecting the sample, and
- preservation method employed.

In the event that samples arrive damaged or with custody seals broken, a Nonconformance Report (NCR) (Sect. 8.11) will be initiated. The project manager will be advised and will make a decision as to the fate of the nonconforming sample. The BCV OU 4 project manager and the QAS will sign the NCR noting the reason for sample disposition and will initiate corrective actions if necessary.

Once samples are in the possession of the laboratory, their internal chain-of-custody and sample-handling procedures will be in effect (Sect. 8.4).

8.5 CALIBRATION PROCEDURES AND FREQUENCY

8.5.1 Instrument Calibration Procedures and Frequency

A list of all measuring and test equipment to be used, along with a schedule for calibration, will be prepared prior to initiating fieldwork. In general, field calibration methods will be those recommended by the manufacturer. Instrument logbooks will be established.

Calibrated equipment will be uniquely identified by using either the manufacturer's serial number or other means. All equipment shall be categorized as one of the following:

- **Category A**—Casual devices and systems (rulers, tape measures, graduated cylinders, pipettes, etc.) that are not to be calibrated in service (i.e., not calibrated other than by the manufacturer).
- **Category B**—Routine devices and systems (balances, spectrophotometers, etc.) that are to be included in a calibration recall program on a regular cycle.
- **Category C**—Field experiment devices and systems (pH meters, turbidimeters, etc.) that are to be calibrated before use.

The appropriate category decal with the identification number and the due date of the next calibration will be attached to the equipment. If this identification is not possible, records traceable to the equipment will be readily available for reference.

8.5.2 Calibration Failures

Scheduled periodic calibration of equipment will not relieve field personnel of the responsibility to employ properly functioning equipment. If an individual suspects an

equipment malfunction, he/she should remove the device from service, tag it so it is not inadvertently used, and notify project management. If equipment is found to be out of calibration, the Sampling Team Leader will evaluate and document (in the instrument logbook) the validity of previous inspection or test results and the acceptability of similar equipment previously inspected or tested. The responsible supervisor will ensure that the devices that are out of calibration are (1) tagged or segregated from other equipment and (2) disposed of or not used until they are calibrated. Any equipment that is consistently found to be out of calibration will be repaired or replaced. Any repair or replacement should be recorded in the instrument logbook.

All standards used for equipment calibration will be traceable to the EPA, the National Institute of Standards and Technology, or a commercially available certified standard. The source of the standard used must be documented in a calibration logbook.

8.5.3 Calibration Records

Calibration data will be recorded in the instrument logbook. The information will include the date, operator, signature, and standard that was used. Records will be prepared and maintained for each piece of calibrated equipment to indicate that established calibration procedures have been followed. The Sampling Team Leader will ensure that records of calibration data are kept current. Records for field equipment used will be maintained by the Sampling Team Leader and kept in the project files.

8.6 PREVENTIVE MAINTENANCE

Periodic preventive maintenance is required for all measuring and test equipment. Instrument manuals will be kept on file for reference purposes if equipment needs repair. Maintenance frequency will be based on manufacturer's recommendations, intended use, and experience. The troubleshooting section of factory manuals may be used to assist personnel in performing maintenance tasks. Routine maintenance will be performed on instruments to reduce the incidence of extensive repairs immediately prior to sampling and analysis.

8.6.1 Field Instruments

The frequency of preventive maintenance for field equipment is usually indicated in each operating instruction manual. Maintenance will be documented and maintained in permanent records by the individual responsible for each instrument. Critical spare parts will be identified and stocked to minimize equipment downtime and lost field sampling effort.

8.7 FIELD ANALYSES

All field measurements will follow the ESP-307 Series (Kimbrough et al. 1990) and will be recorded in the field logbooks or on specially designated data forms. All data will be directly entered in the field, signed, and dated. If entry changes are made, one line will be drawn through the error, and the change and explanation will be signed and dated in the notebook or on the data form. Changes made to original notes should not obliterate the

original information. All field data records will be organized into standard format when possible. Team leaders are responsible for review of daily entries in the field logbooks.

8.8 DATA REDUCTION AND REPORTING

Data validation is a systematic process for reviewing a body of data against a set of criteria to provide assurance that the data are adequate for their intended use. Data validation consists of data screening, checking, auditing, verifying, flagging, certifying, and reviewing.

All data for this project will be evaluated by QA/QC methods and internal peer review consistent with the guidelines for EPA Level III or IV validation of data. Data will be entered into common standardized formats. In addition to following field sampling documentation and QA/QC procedures, data are verified using a variety of computerized checks. These procedures will ensure that data are entered, encoded, and manipulated in a consistent way and are available to BCV OU 4 investigators in a usable format.

8.8.1 Field Data Reduction and Evaluation

Data collected during field activities will be evaluated by checking the procedures used and comparing the data with previous measurements. The QA/QC Coordinator and Sampling Team Leaders will be responsible for checking field QC sample results to ensure that field measurement and sampling protocols have been observed. These reviews will check the following:

- date and time sampled,
- preservation,
- standard operating procedures,
- calibration method and frequency, and
- chain-of-custody documentation.

Reviewers are responsible for ensuring that data reduction calculations are documented and checked by qualified personnel. Written reports that include reduced and summarized data will include the raw data in appendixes. Specific calculations used for data reduction will also be included.

8.9 FIELD QA/QC SAMPLES

QC samples will be collected as a check on the quality of different phases of sampling. Field QC samples include blanks, rinsates, and duplicates as follows:

Trip Blanks. A trip blank is a sample bottle filled at the laboratory with analyte-free reagent water, transported to the site, and returned to the laboratory unopened. They are used to detect contamination by VOCs at the time the samples are handled and shipped.

Field Blanks. Field blanks are samples of the source water, ASTM Type II, used in the decontamination and cleaning of equipment used in sample collection. A field blank is a sample container filled with distilled, deionized water that is exposed during sampling and then analyzed to detect accidental or incidental contamination.

Equipment Rinsates. An equipment rinsate is a blank of the last rinse using ASTM Type II water that has been pumped into or poured through the sampling equipment. The purpose is to check for residual contamination as a measure of the effectiveness of decontamination. If more than one type of equipment is used to obtain samples for a particular matrix, a rinsate blank must be collected from each piece of equipment. Equipment rinsates are analyzed for the same analytes as samples collected. One equipment rinsate blank will be taken from each type of equipment used per sampling event or one blank for every 20 field samples collected.

Field Duplicates. Additional samples may be taken near the field samples co-located to determine total measurement error variance. Field duplicates for water samples will be collected simultaneously. Samples submitted for VOC analyses will not be homogenized. Collection frequency of duplicates will be specified in the project-specific QAPP.

The quantities and collection procedures for each field QC sample type are specified in Chap. 6. Results of these samples will be included in the analytical data report. Results for QC samples will not be used to adjust the results obtained for original samples. If contaminants are found in blanks, attempts will be made to identify the source of contamination, and corrective action will be initiated in accordance with Sect. 8.11.

8.10 DATA VALIDATION AND ASSESSMENT PROCEDURES

A statistical evaluation of laboratory analytical results will be performed to apply precision and accuracy criteria for each parameter analyzed. When the analysis of a sample set is completed, the QC data generated will be reviewed and evaluated by an organization other than the analytical laboratory to validate the data set. All QC data will be reported to the BCV OU 4 project manager, along with the sample analysis results. The QC data will be reviewed for precision and accuracy.

8.10.1 Precision

Precision is defined as the reproducibility or degree of agreement among duplicate measurements under a given set of conditions. The closer the measurements approach each other, the more precise the measurement. The level of precision is determined by calculating the relative percent difference (RPD) between the two measurements; thus,

$$RPD = \frac{(D_1 - D_2) \times 100}{(D_1 + D_2) / 2} ,$$

where D_1 = value of first measurement,
 D_2 = value of second measurement.

8.10.2 Accuracy

Accuracy is achieved by the use of standard criteria for container and equipment cleaning, sample collection, personnel training and performance criteria, uniform sample handling techniques, and blanks to detect contamination.

8.11 FIELD AUDITS AND SURVEILLANCES

Audits are performed to review and evaluate the adequacy of field performance and to ascertain whether the QA/QC Plan is being completely and uniformly implemented. The following requirements are adapted from basic requirement 18, "Audits," of ANSI/ASME NQA-1 (ANSI/ASME 1986), and *Environmental Restoration Quality Program Plan* (Energy Systems 1992a). Planned and scheduled audits will be performed to verify compliance with all aspects of the QA program and to determine the program's effectiveness. These audits will be conducted in accordance with written procedures and checklists and will be performed by personnel who do not have direct responsibility for performing the activities being audited. Audit results will be documented and will be reported to and reviewed by responsible management. Follow-up action will be taken by the responsible line organization when necessary.

The objectives of performance and systems audits are to (1) ensure that the QA program developed for this project is being implemented according to the specified requirements, (2) assess the effectiveness of the QA program, (3) identify nonconformances, and (4) verify that identified deficiencies are corrected. Upon discovery of any significant deviation from the QA program, the project manager will be informed of the nature, extent, and corrective action taken to remedy the deviation.

An individual audit plan will be developed to provide a basis for each audit. This plan will identify the audit scope, the activities to be audited, the audit personnel, any applicable documents, and the schedule. Records of audits will be maintained in the project files. Audit files will include—as a minimum—the Surveillance Report, the reply to audit, and any supporting documents. The BCV OU 4 project manager is responsible for conforming to audit procedures, particularly as to timely replies to audit reports and implementation of such corrective action indicated.

8.11.1 Frequency of Audits

The QAS is responsible for internal audits and will perform them according to a schedule that coincides with appropriate activities on the project schedule and sampling plans. Such scheduled audits may be supplemented by additional audits for one or more of the following reasons:

- when significant changes are made in the QA/QC Plan,
- when it is necessary to verify that corrective action has been taken on a nonconformance reported in a previous audit, or
- when requested by the project manager.

In addition to these internal audits, surveillance of selected activities may be performed on a periodic basis.

8.11.2 Performance Audits

A performance audit can be defined as a review of the existing project and QC data to determine the accuracy of a total measurement system(s) or a component part of the system. The QAS or his designee will check the logging of samples, proper chain of custody, and related documentation. Any irregularities in QA procedures that are not immediately corrected will be brought to the attention of the BCV OU 4 project manager.

8.11.3 Systems Audits

A systems audit consists of an evaluation to determine if the components of a measurement system were properly selected and are being used correctly. A systems audit includes a careful evaluation of field QC procedures to ensure that the QA/QC procedures are being adhered to. Systems audits are conducted as deemed necessary by the QAS, normally either before or shortly after systems are operational. The systems audit is reported in formal audit reports.

8.11.4 Field Surveillance

An individual surveillance plan will be developed to provide a basis for each field surveillance. This plan will identify the scope, activities, and personnel to be involved, any applicable documents, and the schedule for each field surveillance. Checklists may be prepared and used to conduct all surveillances. These checklists will be developed to accomplish the review of necessary items and to document the results of the surveillance.

Field surveillance will involve an on-site visit by the QAS or appropriate surveillance personnel. Items to be examined may include, but are not limited to, the availability and implementation of approved work procedures; calibration and operation of equipment; packaging, storage, and shipping of samples; documentation procedures and instructions; and documentation of nonconformances.

The records of field operations will be reviewed to verify that field-related activities were performed in accordance with standard procedures. Items reviewed may include, but are not limited to, calibration records of field equipment, daily field activity logbooks, chain-of-custody records, and data resulting from field operations.

During a surveillance and upon its completion, the surveillance personnel and the individuals surveyed will discuss the observations of deviations and will agree on corrective actions to be initiated. A surveillance report will be completed for each surveillance activity.

Minor administrative findings that can be resolved to the satisfaction of the surveillance personnel during a surveillance are not required to be cited as items requiring corrective action. Findings that are not resolved during the course of the surveillance and findings affecting the overall quality of the project will be noted on the checklists and included in the surveillance report.

8.12 CORRECTIVE ACTIONS

This section identifies methods and policies for the documentation, evaluation, corrective action, and verification activities necessary when a deviation from established procedure occurs. Requirements for the documentation and implementation of corrective actions are also included.

Any deviation or nonconformance will be evaluated with respect to its possible impact on reportable data. All deviations from standard operating procedures, equipment calibrations, or any aspect of the QA plan will be evaluated and documented. Significant deviations identified using the statistical assessment of quality data will also be used in Nonconformance and Corrective Action Procedures.

8.12.1 Responsibilities of Project Participants

BCV OU 4 personnel will ensure the prompt identification, control, and disposition of nonconforming items. Each laboratory participant is responsible for submitting records of all nonconformance events to the appropriate Sampling Team Leader and/or the QAS within a reasonable period of time following the initial identification and documentation of the nonconformance. The nonconformance will then be evaluated by Team Leaders, QAS, project manager, and others as is deemed relevant. This evaluation will determine the disposition of the nonconformance.

8.12.2 Nonconformances and Corrective Action Procedures

Nonconforming equipment, items, activities, conditions, and unusual incidents that could affect compliance with project requirements will be identified, controlled, and reported in a timely manner. A nonconformance is defined as a malfunction, failure, deficiency, or deviation from specified requirements. The originator of an NCR will describe the finding on the form provided for this purpose and will notify the BCV OU 4 project management and the QAS. Each nonconformance will be reviewed and a disposition given for the item, activity, or condition. Evaluations also will determine if the event justifies the issuance of a Corrective Action Report (CAR). The CAR will document the event, the findings of the evaluation, and the required corrective actions. The disposition of a nonconformance will be documented and approved by the BCV OU 4 project manager. The QAS will concur with the disposition of the nonconformance.

The QA/QC Coordinator for a particular laboratory is responsible for the assessment of laboratory QC sample information. If data fall outside accepted limits, established laboratory procedures for identifying the problem and taking appropriate corrective actions will be employed. Completion of corrective action should be evident when deviations return to prescribed acceptable limits.

The modification, repair, rework, or replacement of nonconforming equipment, items, or activities will require the reverification of acceptability. In certain instances, as determined by project management, these activities may require that corrective action be completed and verified before site work continues.

If, in the opinion of project management and the QAS, the nonconformance does not significantly affect the technical quality or use of the work, then the work may continue, pending resolution of the nonconformance. The basis for such a decision will be documented on the NCR and submitted to the QAS for review and approval. The documentation will include the statement that the decision was made before continuing with the work. The records of nonconformance and their dispositions will be maintained by the BCV OU 4 project manager and forwarded to the Document Management Center.

8.13 QA REPORTS

The active participation of management in the BCV OU 4 Project is fundamental to the success of this QA/QC Plan. Management will be aware of project activities and will participate in development, review, and operation of the project. Management will be informed of QA status and activities through the receipt, review, and/or approval of the following:

- regular quality status reports,
- laboratory and project-specific QA/QC plans and procedures,
- postaudit reports and audit closures,
- surveillance reports,
- corrective action overdue notices, and
- NCRs.

Copies of these reports will be distributed to appropriate management and regulatory agencies. In addition, periodic assessment of QA/QC activities and data precision, accuracy, representativeness, completeness, and comparability will be conducted and reported by the analytical laboratories.

As appropriate, project management will inform the QAS of the QA status of the project, especially any significant quality accomplishments. BCV OU 4 personnel are required to inform the project manager or project support staff of all nonconformances or quality failures. The project manager will document and immediately report any nonconformance or quality failure to the QAS.

APPROVALS

LABORATORY QUALITY ASSURANCE PROJECT PLAN FOR THE REMEDIAL INVESTIGATION OF THE BEAR CREEK OPERABLE UNIT 4 AT THE OAK RIDGE Y-12 PLANT

DOE/OR/01-1115&D3

September 1993

9/28/93

Technical Support Contractor Program Manager

Date

9/28/93

Technical Support Contractor QA/QC Officer

Date

10/9/93

DOE ER Site Program Manager

Date

10/8/93

DOE ER Division QA Program Manager

Date

9/29/93

Energy Systems ER Site Program Manager

Date

9/28/93

Energy Systems ER Site Project Manager

Date

9/29/93

Energy Systems ER Site QA Specialist

Date

9. LABORATORY QAPP

9.1 INTRODUCTION

This QAPP has been developed for use in the sample analysis activities during the RI for OU 4 to ensure that appropriate levels of QA and QC are achieved. This QAPP defines procedures that will be followed in the custody, analysis, and handling of data used in the RI for OU 4. These procedures are intended to define the methods applied to achieve the QA/QC goals established for the OU 4 project.

This QAPP establishes QA requirements and responsibilities applicable to laboratory project participants and establishes methods through which project participants implement the requirements of the project. Where no appropriate procedure exists, this QAPP requires that one be developed by one or more cognizant individuals or organizations.

This QAPP is designed to comply with both the EPA QAMS *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans* (QAMS-005/80) (EPA 1980) and the ANSI/ASME NQA-1 guidelines (ANSI/ASME 1986).

9.2 DATA QUALITY OBJECTIVES

The purpose of this section is to implement applicable regulatory requirements and to provide internal control and review so that the data are scientifically sound and legally defensible. QA objectives for data are as follows:

- scientific data generated will withstand scientific scrutiny;
- data will be gathered using appropriate chain-of-custody procedures, laboratory analyses, and data reporting; and
- data will be of known precision and accuracy.

The QA requirements for the OU 4 RI are defined previously in this report. The procedures to be used for assessing the quality of analytical laboratory data are described in Sect. 9.9. Analytical laboratories selected for this project must meet criteria for laboratory certification and adherence to regulatory QA requirements.

9.2.1 Level of Analysis

The specific QA objectives for all data are to obtain reproducible, precise, and accurate measurements consistent with the intended use of the data and the limitations of the sampling and analytical procedures used. This is accomplished through the assignment of measurement tasks to the appropriate analytical level (I through IV) as defined in *Data Quality Objectives for Remedial Response Activities* (EPA 1987a). Analytical laboratory data generated from the analysis of surface water, groundwater, sediment, and soil samples will meet the requirements for Level III data quality.

9.2.2 Data Quality Parameters

Typical quantitation limits applicable to this project are presented in the EPA CLP SOW for inorganics and organics (EPA 1991c and d) as applicable, as are sample precision, accuracy, and completeness objectives. The QA objectives for QC data are designed to (1) screen out data of unacceptable precision or accuracy and (2) provide data that will meet the data quality goals for this project.

This project will follow the definitions for precision, accuracy, completeness, comparability, and sensitivity given in the *Handbook for Analytical Quality Control in Water and Wastewater Laboratories* (EPA 1979a).

9.2.3 Laboratory Activities

The QA objectives for precision and accuracy in the laboratory are defined by control limits established by the EPA CLP (EPA 1991c and d). The laboratory will be required to submit the results of all control sample analyses to ensure conformance with established control limits and other QA requirements.

The QA completeness objective for this project is to obtain valid analytical results for at least 85% of the samples collected. Laboratory completeness will be determined by the extent to which data are substantiated by hard-copy documentation, which includes chain-of-custody request for services and instrument calibration forms. Comparability and sensitivity criteria are established by either CLP (EPA 1991c and d) or standard operating procedures for particular analytical laboratories.

9.3 SAMPLE PREPARATION AND ANALYSIS PROCEDURES

9.3.1 Sample Preparation

The sampling program and sample preparation procedures are discussed in Sect. 8.2. Table 6.5 shows the numbers of samples to be collected, the number of analyses estimated to be conducted, and the field quality control samples to be collected and sent to the analytical laboratory.

Sample analyses will be scheduled according to site investigation needs and consistent with the sample holding times. These requirements will be included in any contractual agreement between the BCV OU 4 project and contract laboratories.

9.3.2 Laboratory Analyses

OU 4 samples will be analyzed for potential contaminants of concern using methods in EPA CLP SOW ILMO2.0 and OLMO1.1-8 (EPA 1991c and d) for organic and inorganic parameters specified by EPA CLP respectively. Non-CLP parameters may be analyzed by using *Test Methods for Evaluating Solid Waste* (EPA 1986), *Methods for Chemical Analysis of Waters and Wastes* (EPA 1979b), *Guidelines Establishing Test Procedures for the Analysis of Pollutants under the Clean Water Act* (40 CFR Part 136), and *Martin Marietta Energy Systems*

Environmental and Effluent Analysis Manual (Energy Systems 1986). A listing of the recommended methods and detection limits to be used for samples collected at OU 4 is provided in Table 6.4 of this plan.

9.3.3 Analytical Laboratories

Contracts will be established with analytical laboratories to analyze samples collected during the sampling phase of the OU 4 project.

Each contractor laboratory that analyzes samples will provide quantification limits for each constituent analyzed. The method detection limit (MDL) is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the value is >0 . The MDL actually achieved in a given analysis will vary depending on instrument sensitivity and interferences. The objectives for precision and accuracy for each chemical are based mainly on the capabilities of the recommended EPA analytical method with respect to laboratory QC.

In addition to evaluating each set of data for accuracy and precision, an assessment will also be made of the completeness of the data. This assessment will involve computing the fraction of the reported values that remain valid after the sampling procedures have been reviewed and the results have been assessed for precision and accuracy.

9.4 SAMPLE AND DOCUMENT CUSTODY PROCEDURES

Chain-of-custody procedures require documented sample possession from the time of collection to disposal. Sample custody will be maintained by OU 4 project staff until custody is transferred to an overnight express company. The overnight express company delivers samples and transfers custody to particular analytical laboratories, where their intralaboratory chain-of-custody procedures will be in effect. On completion of analyses, sample custody will be returned to OU 4 project staff. The chain-of-custody form terminates on final disposal of the sample. The OU 4 project manager will be responsible for ensuring that the original chain-of-custody form is submitted to the Document Management Center.

9.4.1 Laboratory Receipt and Handling of Samples

When each sample identification is received at the laboratory, it is compared to the information contained on the included chain-of-custody documents. If discrepancies exist, appropriate note (signed and dated) will be made on the chain-of-custody document, and the project manager or designated person will be notified.

After receipt and initial inspection of samples and accompanying forms, the following items are checked and recorded:

- seals and tapes on the transportation container are unbroken,
- sample containers in the transportation container are intact and at correct temperature,

- check is made with survey instruments to determine external activity and smear surfaces for removal of contamination,
- pH of preserved samples (except VOCs) is checked and documented, pH of preserved VOCs is checked upon analysis and documented,
- identification on the sample bottles corresponds to the entire description on the chain-of-custody record, and
- number of sample containers received is equal to the number of samples listed on the chain-of-custody records.

In the event that samples arrive damaged or with custody seals broken, an NCR (Sect. 9.11) will be initiated. The project manager will be advised and will make a decision as to the fate of the nonconforming sample. The OU 4 project manager and the QAS will sign the NCR noting the reason for sample disposition and will initiate corrective actions if necessary.

Once samples are in the possession of the laboratory, their internal chain-of-custody and sample-handling procedures will be in effect. If samples are to be shipped from one laboratory to another, proper chain-of-custody and packaging procedures will be maintained, as specified in ESP-800 (Kimbrough et al. 1990). Preanalysis sample storage procedures used are described in the CLP SOW (EPA 1991c and d). Anticipation of reanalysis requires proper environmental control of samples following analysis. Samples requiring refrigeration will remain refrigerated for 3 months unless prior arrangements have been made by the OU 4 project manager. Unused sample portions will be archived. If re-analysis is not anticipated, then environmental conditions will be observed, and the samples will be stored at room temperature. Sample residues will be disposed of by contractor laboratories in accordance with ESP-1000 (Kimbrough et al. 1990), or other EPA-recommended procedures.

9.5 CALIBRATION PROCEDURES AND FREQUENCY

9.5.1 Instrument Calibration Procedures and Frequency

A list of all measuring and test equipment to be used, along with a schedule for calibration, will be prepared prior to initiating field work. In general, calibration methods will be those recommended by the manufacturer. Instrument logbooks will be established and maintained.

Laboratory equipment will be calibrated in accordance with the CLP (EPA 1990) or other contractor laboratory QA manual when CLP protocol is not established. Calibration frequency will be based on the analytical methods employed, type of equipment, inherent stability, manufacturer's recommendations, values given in national standards, intended use, and experience.

Calibrated equipment will be uniquely identified by using either the manufacturer's serial number or other means. All equipment shall be categorized as one of the following:

- **Category A**—Casual devices and systems (rulers, tape measures, graduated cylinders, pipettes, etc.) that are not to be calibrated in service (i.e., not calibrated other than by the manufacturer).
- **Category B**—Routine devices and systems (balances, spectrophotometers, etc.) that are to be included in a calibration recall program on a regular cycle.
- **Category C**—Experimental devices and systems (pH meters, turbidimeters, etc.) that are to be calibrated before use.

The appropriate category decal with the identification number and the due date of the next calibration will be attached to the equipment. If this identification is not possible, records traceable to the equipment will be readily available for reference.

Volumetric glassware will be used to prepare calibration standards, bench standards, samples for analysis, etc.; thus the glassware used for these preparations must be of known accuracy. Glassware may be purchased with known accuracy per federal and American Society for Testing and Materials specifications.

9.5.2 Calibration Failures

Scheduled periodic calibration of equipment will not relieve laboratory personnel of the responsibility to employ properly functioning equipment. If an individual suspects an equipment malfunction, he/she should remove the device from service, tag it so it is not inadvertently used, and notify project management. If equipment is found to be out of calibration, the laboratory supervisor will evaluate and document (in the instrument logbook) the validity of previous inspection or test results and the acceptability of similar equipment previously inspected or tested. The responsible supervisor will ensure that the devices that are out of calibration are (1) tagged or segregated from other equipment and (2) disposed of or not used until they are recalibrated. Any equipment that is consistently found to be out of calibration will be repaired or replaced. Any repair or replacement should be recorded in the instrument logbook.

All standards used for equipment calibration will be traceable to the EPA, the National Institute of Standards and Technology, or a commercially available certified standard. The source of the standard used must be documented in a calibration logbook.

9.5.3 Calibration Records

Calibration data will be recorded in the instrument logbook. Records will be prepared and maintained for each piece of calibrated equipment to indicate that established calibration procedures have been followed. The laboratory supervisor will ensure that records of calibration data are kept current. Records for laboratory equipment used will be maintained by the laboratory supervisor and kept in the project files.

9.6 PREVENTIVE MAINTENANCE

Periodic preventive maintenance is required for all measuring and test equipment. Instrument manuals will be kept on file for reference purposes if equipment needs repair. Maintenance frequency will be based on manufacturer's recommendations, intended use, and experience. The troubleshooting section of factory manuals may be used to assist personnel in performing maintenance tasks. Routine maintenance will be performed on instruments to reduce the incidence of extensive repairs immediately prior to analysis.

9.6.1 Laboratory Instruments

Laboratory equipment requiring routine maintenance will have a control system indicating the date of required maintenance, person maintaining the equipment, and the next maintenance date. Information pertaining to life histories of equipment maintenance will be kept in an individual log for each instrument. Preventive maintenance for laboratory equipment will follow established procedures and will be documented.

9.7 DATA REDUCTION AND REPORTING

Data reduction and reporting will be in accordance with a Data Management Plan (in review) and Data Management Procedures (in preparation). These procedures will ensure that data are entered, encoded, and manipulated in a consistent way and are available to OU 4 investigators in a usable format.

Once the data for a given sample or group of samples have been validated and are complete, they will be entered into the SAP data base. Procedure-based routines for establishing data security, backup, archival, and maintaining proper data base change procedures are also used to assure the integrity of the data base. The data base, once loaded, will be secured from physical corruption (i.e., hardware or software failure) or from unauthorized access and illegal updating. Physical security requires recovery procedures, time-stamping, and other related standard operating processes and controls.

9.7.1 Analytical Laboratory Data Reduction and Evaluation

Analytical data generated during the OU 4 project will be evaluated for completeness, precision, and accuracy. The completeness evaluation will include, but not be limited to, review of completed custody logs, photocopied pages of laboratory notebooks, and data forms completed by the laboratory staff, including sample weights, dilutions, concentrations, data reduction, instrument logs, and all raw data. In the data review process, the data are compared with information such as the sample history, sample preparation, and QC sample data to evaluate the validity of the results. Analytical data validation, discussed in Sect. 9.9, includes:

- use of QC criteria to reject or accept specific data in accordance with EPA CLP laboratory data validation functional guidelines for evaluating organic and inorganic data (EPA 1988a, EPA 1988b);

- examination of all data for a sample and site by evaluating ion balance, checking for consistency among replicate samples, sending split samples to other laboratories for analysis, and using frequency distribution and range checks to evaluate outliers; and
- determination of compliance with holding time requirements.

The evaluation criteria of the QC sample data for the target compound list have been established for the EPA CLP (EPA 1991c and d). The control limits for other compounds are derived from laboratory control charts. These criteria provide a means of categorizing a data set as being quantitative, semiquantitative, or qualitative. Where applicable, contract laboratories will use data qualifiers to clearly identify results as qualitative and semiquantitative. Otherwise, reported data are to be considered quantitative. These results provide information on the relative quality of sampling and analytical procedures. Deviations suggested by these assessments will be utilized in nonconformance and corrective action procedures (Sect. 9.11).

A statistical evaluation of laboratory analytical results will be performed to apply precision and accuracy criteria for each parameter analyzed. When the analysis of a sample set is completed, the QC data generated will be reviewed and evaluated to validate the data set. All QC data will be reported to the OU 4 project manager, along with the sample analysis results. The QC data will be reviewed for precision and accuracy.

Precision is defined as the reproducibility or degree of agreement among duplicate measurements under a given set of conditions. The closer the measurements approach each other, the more precise the measurement. The level of precision is determined by calculating the RPD between the two measurements; thus,

$$RPD = \frac{(D_1 - D_2) \times 100}{(D_1 + D_2) / 2},$$

where D_1 = value of first measurement,
 D_2 = value of second measurement.

Accuracy will be assessed by splitting a sample into two portions, spiking (i.e., adding known quantity of the constituents of interest to one of the portions), and then analyzing both portions for these parameters. The difference in the concentration levels of the constituents of interest should be equal to the quantity of the spike added to one of the two portions. The percent recovery (%R) is calculated as follows:

$$\%R = \frac{O_i - O_s}{T_i} \times 100,$$

where O_i = observed spiked sample concentration,
 O_s = observed sample concentration,
 T_i = true or actual concentration of the spike.

Recovery of 100% is equivalent to 100% accuracy. Values <100% may indicate a sample matrix effect and a false reading. A periodic program of sample spiking is required, for example, one matrix spike and one matrix spike duplicate per 20 samples.

Blank spikes or laboratory control samples check the accuracy of the analyst, the sample preparation, and the analytical methodology free of sample matrix effects. Blank samples are spiked with known concentrations of the compounds of interest and then prepared and analyzed as samples. The level of accuracy is measured by calculating the %R as follows:

$$\%R = (O/T) \times 100,$$

where %R = percent recovery,

O = observed or measured concentration,

T = true or known concentration.

The coefficient of variation (C_v) of the percent recovery values is calculated as follows:

$$C_v = (SD/APR) \times 100,$$

where SD = standard deviation of the percent recoveries for the various spiked constituents,

APR = average or mean percent recovery.

9.7.2 Data Reporting of Analytical Results

The format and content of hard-copy and electronic-data reports will adhere to project needs. These needs include contract requirements of DOE and reporting formats of regulatory agencies. The laboratory supervisors are responsible for the preparation of each technical report including the process of data validation. The preferred hardcopy report format is the complete CLP data package, including case narrative.

Final data presentation will be checked in accordance with data validation requirements and approved by the appropriate laboratory manager. Each page of analytical data will be identified with the project number or project name, sample delivery group number, and date of issue. Electronic copies of the data must match the hardcopy reports. Electronic data contents in the report will include the following:

- sample identification number used by the laboratory and /or sample identification provided to the laboratory, if different from that used in the laboratory;
- sample delivery group number;
- chemical parameters analyzed, reported values, laboratory data qualifiers, and units of measure;
- quantification limit of the analytical procedure;
- results of QC sample analysis;
- achieved accuracy, precision, and completeness of data;

- references to specific data, if required, to explain reported values, and
- analytical methods used.

These methods will be specifically referenced on all laboratory reports. Any method modification will be included in the case narrative. Data for field and laboratory QC samples will be reported in the same format as actual samples.

9.8 INTERNAL QC

The basic elements of QC are listed below, proceeding from general to specific:

- technical competence of staff,
- appropriate equipment and instruments,
- good sampling practices,
- good measurement practices,
- project procedures,
- field implementation procedures,
- inspection,
- documentation, and
- training.

The staff must have the necessary competence (defined as education, skill, technical judgment, experience, and professional attitude) to reduce variability in executing procedures, taking measurements, and obtaining data in the field.

The QC procedures presented in this section are designed to accomplish the following:

- achieve the QA objectives for precision, accuracy, completeness, representativeness, comparability, and sensitivity;
- document data quality and provide accountability information about data received from each laboratory;
- provide criteria to ensure that analytical results are statistically valid; and
- provide sufficient documentation of analytical procedures to establish that the resulting parameter estimates are defensible and the comparability of estimates from each laboratory is quantifiable.

Internal QC procedures involve reviewing the documentation of maintenance and operational procedures and inspecting the instruments and equipment by personnel other than instrument users. Inspection entails the spot inspections conducted by the QAS in

combination with the continuous process of inspection conducted by the laboratory supervisors as part of normal procedures.

Achieving the highest level of documentation quality is imperative to QC. Bound notebooks with numbered pages will be used to record all events and activities. Data forms will be used to record selected laboratory measurements. All notebooks and data forms will be subject to custody requirements, including limited distribution, secure storage, and long-term retention.

9.8.1 Laboratory QC Procedures

A number of laboratory QC samples will be analyzed to check and monitor laboratory performance, precision, and accuracy. The control samples listed in this section are defined in general terms. Analysis-specific control samples may be required as indicated by EPA CLP procedures. QC samples will consist of blanks, duplicates, and spikes. Laboratory standards will also function as QC components. QA procedures for laboratory processing include laboratory duplicates of all field samples to determine the precision of laboratory results. Laboratory QC samples will include the following:

Method Blank. A method blank is a blank sample made up of a pure, noncontaminated substance of the matrix of interest (usually distilled/deionized water or silica sand) that is subjected to all of the sample preparation (e.g., digestion, distillation, extraction) and analytical methodology applied to the samples. The purpose of the method blank is to check for contamination from within the laboratory that might be introduced during sample analysis that would adversely affect analytical results.

Calibration/Continuing Calibration Blank. A calibration blank is the substance that is used to "zero" the instrument. The calibration blank is composed of the solvent used for the preparation of the calibration standards and samples. The calibration blank accounts for any interference from the solvent matrix.

Sample Container Cleaning Blanks. If sample containers are cleaned in the laboratory, "sample container cleaning blanks" are taken for each batch of containers that are cleaned. If contamination is detected, the containers associated with that cleaning batch will be re-cleaned and another blank taken and analyzed.

Laboratory Duplicates. Laboratory duplicates are aliquots of a single sample that are prepared at the laboratory. This duplicate sample should not be a method blank, trip blank, or field blank. The primary purpose of the laboratory duplicate is to check the precision of the laboratory analyst, the sample preparation methodology, and the analytical methodology. If there are significant differences between the duplicates, the affected analytical results will be qualified.

Matrix Spikes/Matrix Spike Duplicates. Matrix spikes (MS) are used to determine the effect of matrix interference on analytical results. A known concentration of the compounds as specified by the method are added to an aliquot of the sample. The percent recovery of the values of the spiked compounds is taken as a measure of the accuracy of the analytical method and an indication of the interferences present.

A matrix spike duplicate (MSD) is a second aliquot of the same sample as the MS with the same known quantities of compounds added. The purpose of the MSD, when compared to the MS, is to determine method precision.

Laboratory Control Sample (LCS). An LCS is a laboratory blank with a known amount of analytes added or a commercially available standard representative of the contaminants to be determined. The purpose of this program is to demonstrate that the laboratory process for sample preparation and analysis is in control. The LCS program is monitored through the use of control charts.

The Laboratory QA/QC Coordinator is responsible for having QC standards prepared and for sending QC samples to the laboratory for analysis. Statistical analyses will then be performed utilizing the results of QC sample analyses. Each laboratory will apply precision and accuracy criteria to each parameter that is analyzed. When analysis of a sample set is completed, the QC data are reviewed and evaluated using control charts to validate the data set. Laboratory QC standards will include the following:

Calibration Standards. Calibration standards are standards made up of the compounds of interest at known concentrations. Calibration standards are prepared from EPA reference material or from commercially available, certified reference materials traceable to the National Institute of Standards and Technology. Calibration standards for each analyte are prepared for at least three concentration levels throughout the calibration range required for the analysis. Calibration standards are not subjected to all of the preparation (e.g., extraction, distillation, digestion) that is applied to the sample. Calibration standards are used initially to calibrate the instrument by providing reference points throughout the calibration range and to establish linearity throughout the calibration range and working range of the instrument. The instrument is then checked throughout the analysis with the calibration standards to check for any instrument drift.

Performance Evaluation Samples. Performance evaluation samples consist of known concentrations of the analytes submitted to the laboratory being audited. These samples are obtained through various EPA-sponsored programs and private vendors to provide an objective evaluation of laboratory performance and comparison with other participating laboratories.

Control charts are statistical representations of the laboratory's performance and are used to monitor laboratory performance and to establish control limits or the acceptance criteria for all compounds of interest. For each analyte, a separate control chart is required for each type of control sample that measures precision or accuracy and for each matrix type and concentration level. A minimum of ten measurements of precision and accuracy is required before control limits can be established. Control limits of three standard deviations shall be utilized for all samples. Each control chart must consist of a centerline, two warning limits, and two control limits. Control charts must be updated daily.

Once established, control limits are updated as additional precision and accuracy data become available. Any control sample data point that falls beyond the control limits or any data trend will require an investigation and corrective action. For all identified contaminants of concern, control limits and corrective actions will be in accordance with EPA protocol.

Additional statistics for organics work will be done in accordance with SW-846 (EPA 1986) or the CLP SOW (EPA 1991c and d), as applicable.

9.9 DATA VALIDATION AND PROCEDURES

Data validation is a systematic process for reviewing a body of data against a set of criteria to provide assurance that the data are adequate for their intended use. Data validation consists of data screening, checking, auditing, verifying, flagging, certifying, and reviewing.

The data packages received from the analytical laboratories are reviewed and verified using verification procedures and checklists appropriate to the analytical method employed by the laboratory. For CLP data packages, automated data verification and preliminary validation (using the diskette deliverables) is performed using the EPA's Contract Compliance Screening (CCS) and SAIC's Computer Aided Validation and Evaluation Assessment Tool (CAVEAT) software tools. The output from both CCS and CAVEAT is summarized in a report and transmitted with the data packages to the data validators for evaluation. For non-CLP data packages, verification procedures and checklists appropriate to the analytical method are used to generate a summary report for submission to the data validators.

The data validators evaluate the data verification and validation summary reports and review the data packages. They also examine a 10% subset of the data packages and evaluate the data to ensure that all calculations and transcriptions from the instrumentation data to the data package forms were conducted correctly. The data validators use this information and their professional experience and judgment to assign data qualifiers and usability flags to each analytical result following EPA's or other's functional guidelines for data validation. The data qualifiers and usability flags are then entered into the SAP data base.

All discrepancies discovered during the verification and validation process are documented following applicable NCR procedures. The resolution of these NCRs are handled by the QA Supervisor and the analytical laboratory QA Manager.

9.10 LABORATORY AUDITS AND SURVEILLANCES

Audits are performed to review and evaluate the adequacy of laboratory performance and ascertain whether the QA/QC Plan is being completely and uniformly implemented. The following requirements are adapted from basic requirement 18, "Audits," of ANSI/ASME NQA-1 (ANSI/ASME 1986), and Environmental Restoration Quality Program Plan (Energy Systems 1992a). Planned and scheduled audits will be performed to verify compliance with all aspects of the QA program and to determine the program's effectiveness. These audits will be conducted in accordance with written procedures and checklists and will be performed by personnel who do not have direct responsibility for performing the activities being audited. Audit results will be documented, reported to, and reviewed by responsible management. When necessary, follow-up action will be taken by the responsible line organization.

The objectives of performance and systems audits are to (1) ensure that the QA program developed for this project is being implemented according to the specified requirements, (2) assess the effectiveness of the QA program, (3) identify nonconformances, and (4) verify that identified deficiencies are corrected. Upon discovery of any significant deviation from the QA program, the project manager will be informed of the nature and extent of any deviation and corrective action taken to remedy the deviation.

An individual audit plan will be developed to provide a basis for each audit. This plan will identify the audit scope, the activities to be audited, the audit personnel, any applicable documents, and the schedule. Records of audits will be maintained in the project files. Audit files will include, as a minimum, the audit report, the reply to audit, and the supporting documents. The OU 4 project manager is responsible for conforming to audit procedures, particularly as to timely replies to audit reports and implementation of such corrective action indicated.

9.10.1 Frequency of Audits

The QAS is responsible for internal audits and will perform them according to a schedule that coincides with appropriate activities on the project schedule and sampling plans. Such scheduled audits may be supplemented by additional audits for one or more of the following reasons:

- when significant changes are made in the QA/QC Plan,
- when it is necessary to verify that corrective action has been taken on a nonconformance reported in a previous audit, or
- when requested by the project manager.

In addition to these internal audits, surveillance of selected activities may be performed on a periodic basis.

9.10.2 Performance Audits

A performance audit can be defined as a review of the existing project and QC data to determine the accuracy of a total measurement system(s) or a component part of the system. The analysis of laboratory performance evaluation samples and the participation in scheduled interlaboratory studies may be included as part of the performance audit. Laboratory audits are further described in QA/QC procedures for particular analytical laboratories.

A surveillance of the laboratory activities will also be made during the first sampling phase. The QAS or his designee will check on the logging of the samples, proper chain of custody, and related documentation. Any irregularities in QA procedures that are not immediately corrected will be brought to the attention of the OU 4 project manager.

9.10.3 Systems Audits

A systems audit consists of an evaluation to determine if the components of a measurement system were properly selected and are being used correctly. A systems audit

includes a careful evaluation of laboratory QC procedures to ensure that the QA/QC procedures are being adhered to. Systems audits are conducted as deemed necessary by the QAS, normally either before or shortly after systems are operational. The systems audit is reported in formal audit reports.

9.11 CORRECTIVE ACTIONS

This section identifies methods and policies for the documentation, evaluation, corrective action, and verification activities necessary when a deviation from established procedure occurs. Requirements for the documentation and implementation of corrective actions are also included.

Any deviation or nonconformance will be evaluated with respect to its possible impact on reportable data. All deviations from standard operating procedures, equipment calibrations, or any aspect of the QA plan will be evaluated and documented. Significant deviations identified using the statistical assessment of quality data will also be used in Nonconformance and Corrective Action Procedures.

9.11.1 Responsibilities of Project Participants

OU 4 personnel will ensure the prompt identification, control, and disposition of nonconforming items. Each laboratory participant is responsible for submitting records of all nonconformance events to the QAS within a reasonable period of time following the initial identification and documentation of the nonconformance. The nonconformance will then be evaluated by Team Leaders, QAS, project manager, and others as is deemed relevant. This evaluation will determine the disposition of the nonconformance.

9.11.2 Nonconformances and Corrective Action Procedures

Nonconforming equipment, items, activities, conditions, and unusual incidents that could affect compliance with project requirements will be identified, controlled, and reported on an NCR in a timely manner. A nonconformance is defined as a malfunction, failure, deficiency, or deviation from specified requirements. The originator of an NCR will describe the finding on the form provided for this purpose and will notify the OU 4 project management and the QAS. Each nonconformance will be reviewed and a disposition given for the item, activity, or condition. Evaluations also will determine if the event justifies the issuance of a CAR. The CAR will document the event, the findings of the evaluation, and the required corrective actions. The disposition of a nonconformance will be documented and approved by the OU 4 project manager. The QAS will concur with the disposition of the nonconformance.

The QA/QC Coordinator for a particular laboratory is responsible for the assessment of laboratory quality control sample information. If data fall outside accepted limits, established laboratory procedures for identifying the problem and taking appropriate corrective actions will be employed. Completion of corrective action should be evident when deviations return to prescribed acceptable limits.

The modification, repair, rework, or replacement of nonconforming equipment, items, or activities will require the reverification of acceptability. In certain instances, as determined by project management, these activities may require that corrective action be completed and verified before site work continues.

If, in the opinion of project management and the QAS, the nonconformance does not significantly affect the technical quality or use of the work, then the work may continue, pending resolution of the nonconformance. The basis for such a decision will be documented on the NCR and submitted to the QAS for review and approval. The documentation will include the statement that the decision was made before continuing with the work. The records of nonconformance and their dispositions will be maintained by the OU 4 project manager and forwarded to the Document Management Center.

9.12 QA REPORTS

The active participation of management in the OU 4 Project is fundamental to the success of this QA/QC Plan. Management will be aware of project activities and will participate in development, review, and operation of the project. Management will be informed of QA status and activities through the receipt, review, and/or approval of the following:

- regular quality status reports,
- laboratory and project-specific QA/QC plans and procedures,
- postaudit reports and audit closures,
- surveillance reports,
- corrective action overdue notices, and
- NCRs.

Copies of these reports will be distributed to appropriate management. In addition, periodic assessment of QA/QC activities and data precision, accuracy, representativeness, completeness, and comparability will be conducted and reported by the analytical laboratories.

As appropriate, project management will inform the QAS of the QA status of the project, especially any significant quality accomplishments. OU 4 personnel are required to inform the project manager or project support staff of all nonconformances or quality failures. The project manager will document and immediately report any nonconformance or quality failure to the QAS.

APPROVALS

HEALTH AND SAFETY PLAN FOR THE REMEDIAL INVESTIGATION OF THE BEAR CREEK OPERABLE UNIT 4 AT THE OAK RIDGE Y-12 PLANT

DOE/OR/01-1115&D3

September 1993

9/28/93
Technical Support Contractor Program Manager	Date
9/28/93
Technical Support Contractor Field Team Leader	Date
9/28/93
Site Health and Safety Officer	Date
9/29/93
Energy Systems ER Program Manager	Date
9/28/93
Energy Systems ER Site Project Manager	Date

10. HEALTH AND SAFETY PLAN

10.1 SITE HEALTH AND SAFETY PERSONNEL

A site health and safety officer (SHSO) will be designated by the Energy Systems project manager or by the subcontractor to ensure that the site safety and health plan (Appendix C) remains in compliance with 29 *CFR* 1910 as amended by 29 *CFR* 1910.120. The SHSO will be designated no less than 2 weeks before starting field work and will be identified in the site Health and Safety Plan. The SHSO or an alternate will implement, monitor, and assist the site manager in enforcing the site Health and Safety Plan. The SHSO of the Health, Safety, and Environmental Affairs Division has the duty to coordinate the plan and ensure its implementation. The subcontractor SHSO may coordinate between the Y-12 Plant Industrial Hygiene and Health Physics Departments on matters of employee health and safety, such as personal monitoring, on-site monitoring, and incident reporting.

10.2 SAFETY RISK ANALYSIS

10.2.1 Sources of Contamination

For the purpose of this RI Plan, the Y-12 Plant waste disposal facilities located in the Bear Creek watershed are considered to be the primary contaminant sources. A Y-12 RFA listed nine source areas associated with the Y-12 Plant, including two construction spoil areas, liquid-waste percolation ponds, a sanitary landfill, an oil landfarm, a hazardous-chemical disposal/storage area, a solid-waste burial area and two ponds used to capture any oil that might seep from the Burial Grounds.

While the source areas may have been the original sources of contamination, secondary sources now exist in the sediments and floodplain deposits of Bear Creek. These secondary sources may continue to release contaminants into Bear Creek surface water and groundwater even after upstream releases from the source areas are eliminated.

An all inclusive list of contaminants of concern is not available; however, the following represents the primary contaminants of concern presently identified for the source areas.

Organics	Inorganics	Metals	Miscellaneous
tetrachloroethylene	nitrate	aluminum	gross alpha (U and Np-237)
trichloroethylene	sulfate	barium	gross beta (Tc-99, Sr-90 & H3)
1,2-dichloroethylene		cadmium	Americium-241
1,1,1-trichloroethane		chromium	radium
1,1-dichloroethane		iron	strontium-89
1,1,-dichloroethylene		mercury	
vinyl chloride		manganese	

Organics	Inorganics	Metals	Miscellaneous
acetone		lead	
chloroform		uranium	
2-butanone			
carbon tetrachloride			
methylene chloride			

10.2.2 On-Site Safety Hazards

The primary hazards associated with the sampling activities planned include the risks posed by organic vapors which may be encountered while sampling the permanent monitoring wells as well as possible splash hazards associated with potentially contaminated groundwater and surface water. The SHSO will implement and enforce all safety procedures associated with these sampling activities. These procedures will be followed strictly to avoid accidents. Groundwater sampling of permanent monitoring wells will be performed under the close supervision of the SHSO and project manager with all members of the sampling team observing all safety precautions specified in the plan while sampling. Potential organic vapor hazards in the monitoring wells shall be surveyed for VOCs through the use of all applicable monitoring instruments. Splash hazards from potentially contaminated groundwater and surface water should be minimized by following proper sampling techniques to limit the potential for splashes to occur. Adequate personal protective equipment (PPE) including safety glasses with sideshields, rubber boots, rubber gloves, and splash resistant tyveks should be worn to limit eye and skin contact to potentially contaminated media. Precautions for the use of a submersible pump should include inspecting the wiring for cut or frayed sections that may pose an electrical shock hazard. Personnel should also wear steel-toed boots while working with any submersible pump. Employees should also maintain an observant eye for snakes, ticks, and other environmental threats while in the field. Only authorized personnel will be allowed in the immediate vicinity of the sampling area.

10.3 TRAINING REQUIREMENTS

OSHA 40-h health and safety training, as specified in 29 *CFR* 1910.120, will be required for all employees engaged in hazardous waste operations in addition to a minimum of 3 days (24 hours) of actual field experience under an experienced and qualified individual. All personnel will also be required to have an 8-h refresher and training course. All personnel working on site must have attended the pre-entry health and safety briefing and be on a medical monitoring program for hazardous waste site work. These requirements must be fulfilled and documented in the field logbook before site access will be granted. All personnel will also be on the Energy Systems Health Physics Department radiological dosimetry program and dosimetry badges will be required for all field activities.

10.4 PERSONNEL PROTECTIVE EQUIPMENT

The level of personal protection required for RI sampling activities at BCV OU 4 will be dictated by the location and type of sampling to be conducted. The planned activities consist of surface water sampling of springs and streams, and the collection of groundwater samples from permanent monitoring wells. Sampling is not expected to occur within the source areas; however, contaminant plumes may be encountered. Although contaminants such as trichloroethylene vinyl chloride, mercury, and radionuclides could potentially be encountered at concentrations that constitute a health hazard, (based on the low-risk tasks being conducted) the initial personal protection level recommended during sampling at BCV OU 4 is Level D (see Table 10.1), which is defined in 29 *CFR* 1910.120 Appendix B.

During sampling activities, organic vapors, mercury vapor and radioactivity will be monitored continuously. If increased protection is needed, the protection level can be upgraded at the discretion of either the SHSO, the subcontracting project manager, or the Energy systems project manager.

The SHSO (or the health and safety officer provided by the subcontractor or project manager) will select the type of equipment needed and determine whether additional PPE is needed. All sampling activities will be performed under the close supervision of the site project manager, with all members of the field crew observing the PPE requirements specified in the plan while conducting sampling activities. Workers will be required to wear appropriate PPE, including rubber gloves, steel-toed boots for foot protection, splash-resistant tyveks, and approved safety glasses for eye protection. Hard hats will be required when workers are in the vicinity of any overhead hazards. Only authorized and properly protected personnel will be allowed in the immediate vicinity of the sampling areas.

Table 10.1. Level of protection

Level designation	Monitoring parameters	
A _____	Airborne pollutants ^a	X
B _____	Explosion potential ^b	X
C _____	Radiation	X
D X _____	Total particulates	_____

^a Organic vapors and mercury vapors.

^b For identification of a potentially explosive atmosphere.

10.5 MEDICAL SURVEILLANCE

As required by 29 *CFR* 1910.120, medical surveillance of all personnel involved in hazardous waste site operations shall be conducted. Baseline and annual physical examinations will be performed by the Y-12 Plant Medical Center or a qualified occupational physician. Subcontractors will be responsible for ensuring that their employees receive the required examinations. Persons who have not received the necessary physical examinations or who are

not medically approved to perform their duties at a hazardous waste site will be excluded from all areas of the site.

In the unlikely event of radioactive contamination, whole body counts of workers from the affected site will be performed by the Y-12 Plant medical staff. Work at BCV OU 4 will be suspended until the conditions abate or PPE is upgraded. When operations are continued, a personal dosimetry program will be instituted by the Y-12 Plant Health Physics Department.

10.6 MONITORING AND SAMPLING

During sampling activities, the work areas will be monitored for airborne pollutants (organics, mercury), and radiation. All monitoring will be conducted in accordance with procedures described in the *Environmental Surveillance Procedures, Quality Control Program* (Kimbrough, Long, and McMahon 1990).

If any of the following conditions occur, the SHSO will either remove all personnel from the affected area until the conditions abate or upgrade the protection level as described in the Y-12 RCRA Facility Investigation Plan—General Document as developed by Welch (1989):

- organic vapor levels in the breathing zone exceed background conditions for >1 min as determined by a photoionization detector (PID) or flame ionization detector (FID);
- mercury vapor levels in the breathing zone exceed 0.1 mg/m³ as measured by a Jerome Mercury Analyzer; and
- radiation levels in the work zone exceed background conditions for >1 min as determined by a beta/gamma detector.

The SHSO is responsible for ensuring that vapor and radiological monitoring are performed at the site. These parameters should be monitored continuously while sampling activities are in progress.

Unusual conditions at the site, such as the detection of peculiar odors, will be investigated by the SHSO. In cases of extremely high organic vapor readings (>50 ppm), the SHSO will stop work activities and contact the Y-12 Plant Industrial Hygiene Department to determine whether any other immediate actions may be needed to mitigate health and safety concerns.

Radiation monitoring will be performed for BCV OU 4. The SHSO will be responsible for performing radiation monitoring and for ensuring that this monitoring is scheduled through Health Physics Department and completed. The SHSO in conjunction with the Health Physics Department will perform all radiation surveys at the site and will observe all recommendations made by the Health Physics Department to protect personnel working in the area based on the interpretation of these surveys. The frequency of monitoring will be determined by the potential for exposure to radiation at the site and for all samples collected. Exposure will be maintained at a level that is ALARA.

10.7 SITE CONTROL MEASURES

Access to the site will be controlled to reduce the potential exposure of personnel to any contaminants that may be present and to prevent the dispersal of contaminants by personnel or equipment leaving the site. Site control efforts will be the responsibility of the SHSO in coordination with the Y-12 Plant Industrial Safety and Security departments. Measures such as signs, fencing, and ropes, if necessary, may be used as controls.

10.8 DECONTAMINATION PROCEDURES

Specific decontamination procedures are required for Level D protection. Decontamination procedures are thoroughly discussed in the *Environmental Surveillance Procedures, Quality Control Program* (Kimbrough, Long, and McMahon 1990). Workers will be required to follow the standard safety practice of washing hands and faces on leaving the work area and before eating, drinking, smoking, or engaging in any other activity that could cause the ingestion of unwanted materials.

10.9 SITE OPERATING PROCEDURES

A work area zone will be established around the sampling area to keep out unauthorized personnel. Because low risk of contamination is expected, Level D protection has been established. Based on a hazards evaluation and the tasks to be performed, there is little potential for exposure to airborne contaminants. Sufficient air monitoring for all potential airborne contaminants will be provided to monitor for contaminant exposure potential which is expected to be low. Provisions shall be made to immediately provide the proper level of respiratory protection from any contaminant exposure hazards that may be found during site air monitoring.

10.10 CONTINGENCY PLAN

A written contingency plan is required by 29 CFR 1910. Before operations begin on the site, requirements 120(e)(1) and (2) must be completed. In the event of an emergency at BCV OU 4, the SHSO or the site manager must immediately contact the Plant Shift Superintendent (PSS) and ensure that the plan is followed exactly. The PSS on duty is responsible for initiating and coordinating all emergency response operations at the Y-12 Plant. This plan will include a form providing all essential emergency information and contacts and will be made available to the field team. The SHSO will be responsible for maintaining current information on the form and for informing the field team of the form location and the means of contacting emergency aid. A map highlighting the most direct route to the nearest hospital must be included in the contingency and health and safety plans. Table 10.2 is the emergency reference form, and a map to the Oak Ridge hospital follows it (Fig. 10.1).

Table 10.2. Emergency reference form

SITE: Bear Creek Valley Operable Unit 4 Project No. _____	
Local Emergency information:	
Ambulance (name):	Y-12 ambulance service; from Y-12 extension, 911; from commercial extension, 576-1890
Hospital (name):	Methodist Medical Center of Oak Ridge, 990 Oak Ridge Turnpike, Oak Ridge, TN. Emergency Phone, 481-1190 or 911
Police (local or state):	Y-12 Safety and Security; from Y-12 extension, 911; from commercial extension, 574-7272
Fire Department (name)	Y-12 Fire Department; from Y-12 extension, 911; from commercial extension, 576-1890
Radio channel:	
Nearest telephone:	
Project manager:	
SHSO:	
Local emergency services:	Methodist Medical Center of Oak Ridge, 990 Oak Ridge Turnpike, Oak Ridge, TN 37831-2529; emergency phone 481-1190 or 911; Oak Ridge Fire Department, Police Department, and Methodist Medical Center may be reached at 911; ambulance phone, 457-2520
Emergency contact (medical and health):	
• Emergency (plant phones only)	911
• Y-12 Plant all Emergency Services PSS	4-7172*
• Y-12 Plant Guard Department	4-7272*
• Y-12 Plant Medical	4-1577*
• Y-12 Plant Industrial Hygiene Manager	6-7182*
• Y-12 Plant Health Physics Manager	4-3547*
• Y-12 Plant Safety Department Manager	4-1562*
• Methodist Medical Center of Oak Ridge	481-1190*
• Park West Hospital, Knoxville	696-5740 ^b
• University of Tennessee Hospital, Knoxville	544-9401 ^b
• Tennessee Emergency Management Agency (TEMA)	1-800-262-3300 ^b
• CHEMTREC	1-800-424-9300 ^b
• Toxicity Database	4-7587 ^b
• National Response Center	1-800-424-8802 ^b
• Poison Information Center:	544-9400 ^b
FOR ENVIRONMENTAL EMERGENCY ONLY:	1-800-424-3002
• Office	
Directions to hospital: (see attached map)	From BCV OU 4, turn left onto Bear Creek Road, travel approximately 2 1/4 + miles and turn left onto Lafayette Road, travel approximately 1 3/4 miles to the Oak Ridge turnpike, turn right and the Methodist Hospital is immediately to the left.

* Y-12 Plant telephones, interplant communications. If called from outside plant telephones, precede with 57.

^b If called from Y-12 Plant telephones, precede with 3.

Fig. 10.1. Map of the Oak Ridge area.

10.11 SPECIAL HAZARD PROCEDURES

No requirements exist to enter a confined space while conducting field activities at BCV OU 4. If confined work spaces are encountered and must be entered, an Occupational Safety Work Permit for confined space entry as required by Y-12 Plant procedure 70-750 will be issued and followed exactly.

APPROVALS

WASTE MANAGEMENT PLAN FOR THE REMEDIAL INVESTIGATION OF THE BEAR CREEK OPERABLE UNIT 4 AT THE OAK RIDGE Y-12 PLANT

DOE/OR/01-1115&D3

September 1993

9/28/93
Technical Support Contractor Program Manager	Date
9/28/93
Technical Support Contractor QA/QC Officer	Date
10/9/93
DOE ER Division Program Manager	Date
9/29/93
Energy Systems ER Site Program Manager	Date
9/28/93
Energy Systems ER Site Project Manager	Date
9/29/93
Plant ER Waste Management Coordinator	Date

11. WASTE MANAGEMENT PLAN

11.1 INTRODUCTION

BCV OU 4 contains several sources that contribute to the contamination of surface and subsurface water in BCV. Chapter 2 of this document provides a detailed discussion of the site history and expected contaminants. In performing the proposed activities for the BCV OU 4 RI (Chap. 6), the wastes that are expected to be generated must be managed in accordance with the Y-12 Plant guidelines as well as with applicable federal and state regulations.

11.2 WASTE MANAGEMENT PLANNING CHECKLIST

The Waste Management Planning Checklist follows. It defines the procedures for segregating, characterizing, and controlling all investigation-derived waste (IDW) from the point of generation through TSD.

**Environmental Restoration
Waste Management Planning Checklist**

- 1) Project Name: Remedial Investigation for Bear Creek Valley OU 4
Plant: Y-12 Date: 10/23/92
Organization: Environmental Restoration Division
- 2) Responsible Project Manager: Judy Hodgins (Energy Systems)
- 3) Expected Start/Completion Dates: TBD (Summer 1993)
- 4) Project Description (Brief): Project involves implementation of CERCLA RI Work Plan for Bear Creek Valley Operable Unit 4. Investigation to include water sampling, and routine equipment decontamination wastes.
- 5) Project Participants: (for waste management interface only)
Waste Generator:	SAIC
Waste Handler:	SAIC
Waste Transporter:	Energy Systems
Interim Waste Storage:	DARA Facility (solid wastes)
Permanent Waste Storage:	TBD
Waste Treatment:	West End Treatment Facility
Waste Disposal:	TBD
- 6) Waste Generation:

				Characterization Based on	
				Process Knowledge	Sampling and Analysis
Decon/purge water	Rad	TBD	Metals Rads Organics	X	
PPE/trash	Non-Hazardous	TBD	Metals Rads Organics	X	
Sanitary trash	Sanitary	Unknown	None	X	

**Environmental Restoration
Waste Management Planning Checklist**

Waste Generation (cont.)

7) Containerizing and Labeling Requirements

Waste type	Package/container	Labeling Requirements
Decon/purge water	DOT 6D, bung top drum, polylined. For quantities greater than 220 gal. Contact waste management for containers (See PP 70-903)	Form UCN-15C*
PPE/trash	Bags, boxes, fiber drums	None
Sanitary trash	Bags, boxes, fiber drums	None

*Oak Ridge Y-12 Plant Procedure (PP) 70-903, Transfer, storage, or disposal of waste, contains specific instructions for selecting the type of container for the waste type being containerized and appropriate labeling requirements.

8) Waste Analysis and Characterization: Decontamination and purge water will be drummed in same container. Waste disposition will await sample analyses described in RI Work Plan (Y/ER/Sub/91-99069/D1).

9) Waste Staging Area: Y/N
 Location: Within BCV OU 4
 Special requirements: Flagging around area to segregate drums

10) Transport Across Public Access Roads Required: Y/N
 Roads Involved: Hwy 58, Hwy 95, Bear Creek Road
 DOT Regulations to be applied : Y/N
 Reportable Quantities of Anticipated DOT Regulated Hazardous Materials (if required):

**Environmental Restoration
Waste Management Planning Checklist**

Waste Generation (cont.)

11) Waste Storage Requirements:

Field Staging Area: Y/N/NA CERCLA Staging Area

Location: Staging area in BCV OU 4

Responsible Organization: SAIC

90-Day Storage Area: Y/N/NA

Location:

Capacity:

Waste Acceptance Criteria Requirements:

Responsible Organization:

Permitted (or Interim Status) Storage: Y/N/NA

Location:

Capacity:

Waste Acceptance Criteria Requirements:

Responsible Organization:

12) Identification of Potential Treatment Options: Purge, and Decon Waters

Location: West End Treatment Plant

Responsible Organization: Energy Systems

Special Waste Acceptance Criteria Requirements:

13) Identification of Potential Disposal Options: Sanitary Waste

Location: Y-12 Sanitary Landfill

Responsible Organization: Energy Systems

Special Waste Acceptance Criteria Requirements:

Identification of Potential Disposal Options: N/A

Location:

Capacity:

Responsible Organization:

Special Waste Acceptance Criteria Requirements:

**Environmental Restoration
Waste Management Planning Checklist**

Waste Generation (cont.)

14) Waste Minimization and Reduction Techniques to be Implemented:

Segregation ☒	In-Field Pretreatment ☐
Decontamination ☐	Waste Handling (Spill Control): ☐
Compaction ☒	Material Recycle (Solvents, Containers) ☒ Aluminum Wraps
Solvent Substitution ☐	Material Reuse (Solvents, Wash Waters) ☐
Sludge Dewatering ☐	Cutting Fluids Recovery ☐
Selection of PPE ☒	Selection of Equipment ☐
Other ☒	

Description of Special Techniques and Expected Effectiveness:

Effort will be made to minimize all waste generation. There is no reason to assume a listed waste as a contaminant, therefore the clothing may be considered non-hazardous, and bagged for disposal at the Y-12 landfill.

Prepared by: _____ Date: _____

Review:

Plant Environmental Compliance Organization:

Central ER Waste Management:

ER Waste Reduction Manager:

Approvals:

Plant ER Waste Management Organization: _____ Date: _____

Plant Waste Management Organization: _____ Date: _____

Central Waste Management Division: _____ Date: _____

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APPENDIX A

BCV GROUNDWATER SUMMARY

Note: Tables A.2 through A.8 herein have been added since the publication of the D1 version of this document.

Table A.1 Bear Creek Valley groundwater summary
 Well depth, rock formations, and data availability
 (Source: Jones et al. 1992)

----- Site=Landfill I -----				
Well	First Year Data	Last Year Data	Well Depth (ft)	Rock Formation
GW-363	1988	1990	75.0	Nolichucky
GW-364	1988	1991	60.3	Maynardville
GW-365	1988	1991	150.0	Maynardville
GW-366	1988	1991	102.5	Maynardville
GW-367	1988	1991	151.4	Maynardville
GW-368	1988	1990		Maynardville
GW-369	1988	1991	150.2	Maynardville
GW-520	1988	1991	80.3	Knox/Maynardville
----- Site=Spoil Area I -----				
Well	First Year Data	Last Year Data	Well Depth (ft)	Rock Formation
GW-313	1988	1991	113.0	Maynardville
GW-314	1988	1991	115.0	Maynardville
GW-315	1988	1991	104.0	Maynardville
GW-316	1988	1991	80.0	Maynardville
GW-317	1988	1991	132.0	Maynardville
GW-323	1988	1991	108.0	Knox Group

Table A.1 (continued)

----- Site=Picket Wells -----

Well	First Year Data	Last Year Data	Well Depth (ft)	Rock Formation
GW-683	1991	1991	197.5	Knox Group
GW-684	1991	1991	129.6	Maynardville
GW-685	1991	1991	138.3	Maynardville
GW-694	1991	1991		Maynardville
GW-695	1991	1991	62.6	Maynardville
GW-703	1991	1991	182.0	Maynardville
GW-704	1991	1991		Maynardville
GW-705	1991	1991		Nolichucky
GW-706	1991	1991	182.5	Maynardville
GW-710	1991	1991		Maynardville
GW-711	1991	1991		Maynardville
GW-712	1991	1991		Maynardville
GW-713				Maynardville
GW-714				Maynardville
GW-715				Maynardville
GW-723				Maynardville
GW-724				Maynardville
GW-725				Maynardville
GW-736				Maynardville
GW-737				Maynardville
GW-738				Maynardville
GW-739				Maynardville
GW-740				Maynardville

----- Site=Lysimeter Demo -----

Well	First Year Data	Last Year Data	Well Depth (ft)	Rock Formation
GW-376	1988	1990		Maryville
GW-531	1988	1991	39.5	Maryville
GW-532	1989	1991	29.7	Maryville
GW-533	1990	1991	30.1	Conasauga
GW-534	1990	1991	47.0	Conasauga
GW-535	1989	1991	19.5	Nolichucky
GW-536	1989	1990	19.7	Nolichucky
GW-537	1989	1991	24.5	Nolichucky
GW-538	1990	1991	42.5	Conasauga
GW-630	1990	1991	28.6	Conasauga

Table A.1 (continued)

----- Site=Bear Creek-S3 Ponds -----				
Well	First Year Data	Last Year Data	Well Depth (ft)	Rock Formation
GW-100	1986	1990	20.7	Maynardville
GW-101	1986	1991	17.5	Nolichucky
GW-103	1986	1986	25.0	Nolichucky
GW-104	1986	1986	74.0	Nolichucky
GW-115	1987	1991	53.0	Maryville
GW-122	1986	1991	142.0	Maynardville
GW-123	1986	1991		Maynardville/Nolichucky
GW-124	1986	1990	150.0	Maynardville
GW-125	1986	1991		Maynardville/Nolichucky
GW-127	1986	1990	24.0	Maynardville/Nolichucky
GW-236	1988	1990	18.5	Maynardville
GW-243	1986	1991	77.0	Nolichucky
GW-244	1987	1990	77.0	Nolichucky
GW-245	1987	1990	76.0	Nolichucky
GW-246	1987	1990	76.0	Nolichucky
GW-247	1987	1990	78.0	Nolichucky
GW-276	1986	1990	18.5	Nolichucky
GW-277	1986	1990	77.4	Nolichucky
GW-324	1987	1991	80.0	Nolichucky
GW-325	1987	1991	17.9	Nolichucky
GW-345	1988	1991	26.3	Nolichucky
GW-346	1988	1990	65.3	Nolichucky
GW-347	1988	1991	27.8	Maynardville
GW-348	1988	1991	80.9	Maynardville
GW-526	1988	1991	123.0	Nolichucky
GW-613	1990	1991	42.0	Nolichucky
GW-614	1990	1991	90.2	Nolichucky
GW-615	1990	1991		Nolichucky
GW-616	1990	1991		Maynardville/Nolichucky

Table A.1 (continued)

----- Site=Y-12 Burial Grounds -----

Well	First Year Data	Last Year Data	Well Depth (ft)	Rock Formation
GW-374	1988	1990	150.1	Nolichucky
GW-375	1988	1990	161.5	Maynardville
GW-502	1988	1990		Maryville
GW-621	1990	1991	43.0	Maynardville
GW-622	1990	1991	20.5	Nolichucky
GW-623	1990	1991		Nolichucky
GW-624	1990	1991	27.2	Nolichucky
GW-626	1990	1991	78.0	Nolichucky
GW-627	1990	1991		Nolichucky
GW-629	1990	1991		Nolichucky
GW-639	1990	1991	125.5	Nolichucky
GW-640	1990	1991	47.4	Nolichucky
GW-641	1990	1991	24.3	Nolichucky
GW-642	1990	1991	36.9	Rogersville

----- Site=Y-12 Old Sanitary Landfill -----

Well	First Year Data	Last Year Data	Well Depth (ft)	Rock Formation
GW-225	1986	1991	200.0	Maynardville
GW-226	1986	1991	55.0	Maynardville
GW-227	1986	1991	40.0	Maynardville
GW-228	1986	1990	100.0	Maynardville
GW-229	1986	1990	55.0	Maynardville

Table A.1 (continued)

----- Site=Oil Landfarm -----

Well	First Year Data	Last Year Data	Well Depth (ft)	Rock Formation
GW-003	1988	1988	35.2	Nolichucky
GW-005	1990	1991	12.5	Nolichucky
GW-007	1987	1990	16.5	Nolichucky
GW-010	1987	1990	15.0	Nolichucky
GW-013	1990	1991	33.8	Nolichucky
GW-043	1987	1991	40.0	Maryville
GW-044	1990	1991	70.0	Maryville
GW-063	1987	1991	35.0	Maynardville
GW-064	1987	1991	57.0	Maynardville
GW-067	1987	1990	16.5	Maynardville
GW-073	1987	1990	81.0	Nolichucky
GW-074	1990	1991		Nolichucky
GW-075	1990	1991	200.0	Nolichucky
GW-076	1990	1991	81.0	Nolichucky
GW-084	1987	1991	34.0	Maryville
GW-085	1987	1991	62.0	Nolichucky
GW-086	1990	1991	33.5	Nolichucky
GW-087	1987	1990	19.0	Nolichucky
GW-097	1987	1990	19.2	Nolichucky
GW-098	1987	1990	104.0	Nolichucky
GW-120	1987	1990	180.0	Nolichucky
GW-601	1990	1991		Maynardville
GW-602	1990	1991		Maynardville

----- Site=Rust Spoil Area -----

Well	First Year Data	Last Year Data	Well Depth (ft)	Rock Formation
GW-306	1988	1991	58.5	Maynardville
GW-307	1988	1991	41.6	Maynardville
GW-308	1988	1991	37.7	Maynardville
GW-309	1988	1991	38.0	Maynardville
GW-310	1988	1991	27.1	Maynardville
GW-311	1988	1991	40.3	Maynardville
GW-312	1988	1991	41.0	Maynardville

----- Site=U.S. Geological Survey Sites -----

Well	First Year Data	Last Year Data	Well Depth (ft)	Rock Formation
GW-209	1990	1991	48.1	Rome
GW-210	1990	1991	124.0	Rome
GW-211	1990	1991		Rome

Table A.1 (continued)

----- Site=East Fork-S3 Ponds -----

Well	First Year Data	Last Year Data	Well Depth (ft)	Rock Formation
GW-105	1986	1990	17.0	Nolichucky
GW-106	1986	1990	75.0	Nolichucky
GW-107	1986	1990	14.2	Nolichucky
GW-108	1986	1990	58.6	Nolichucky
GW-109	1986	1990	147.6	Nolichucky
GW-617	1990	1991	18.0	Maynardville
GW-618	1990	1991	37.0	Maynardville
GW-619	1990	1991	40.8	Maynardville
GW-620	1990	1991	75.0	Maynardville

----- Site=Y-12 Burial Grounds -----

Well	First Year Data	Last Year Data	Well Depth (ft)	Rock Formation
GW-014	1987	1990	13.2	Nolichucky
GW-021	1987	1987	15.0	Nolichucky
GW-027	1987	1988	30.5	Maryville
GW-037	1990	1991	70.0	Maryville
GW-039	1987	1988	22.5	Maryville
GW-040	1987	1991	35.0	Pumpkin Valley
GW-042	1987	1991	30.0	Pumpkin Valley
GW-045	1987	1990	15.2	Maynardville
GW-046	1987	1990	20.5	Nolichucky
GW-047	1987	1990	25.5	Nolichucky
GW-052	1990	1991	19.5	Maynardville
GW-053	1990	1991	39.7	Maynardville
GW-054	1990	1991	40.0	Maynardville
GW-056	1990	1991	55.2	Maynardville
GW-057	1990	1991	25.0	Maynardville
GW-058	1987	1991	45.2	Maynardville
GW-061	1989	1991	25.0	Maynardville
GW-068	1987	1990	85.0	Nolichucky
GW-069	1990	1991	100.0	Nolichucky
GW-071	1987	1991		Nolichucky
GW-072	1987	1991	101.4	Nolichucky
GW-077	1990	1991	100.5	Nolichucky
GW-078	1990	1991	21.1	Nolichucky
GW-079	1990	1991	65.0	Rogersville
GW-080	1990	1991	30.0	Rogersville
GW-082	1987	1991	35.0	Maryville
GW-083	1990	1991	30.0	Nolichucky
GW-089	1990	1991	25.0	Rutledge
GW-094	1987	1990	131.0	Maynardville
GW-095	1987	1991	156.0	Maynardville
GW-117	1987	1991		Maynardville/Nolichucky
GW-118	1987	1991		Maynardville/Nolichucky
GW-119	1987	1991		Maynardville/Nolichucky

Table A.1 (continued)

----- Site=Y-12 Burial Grounds -----
 (continued)

Well	First Year Data	Last Year Data	Well Depth (ft)	Rock Formation
GW-126	1987	1990	155.0	Nolichucky
GW-162	1987	1991	125.0	Pumpkin Valley
GW-163	1987	1991		Pumpkin Valley
GW-164	1987	1991		Pumpkin Valley
GW-237	1988	1988	13.7	Maynardville
GW-242	1987	1990	17.0	Pumpkin Valley
GW-248	1988	1990	62.0	Maryville
GW-249	1989	1990	35.1	Maryville
GW-250	1987	1990	61.7	Maryville
GW-257	1988	1990	33.7	Maryville
GW-258	1988	1990	50.0	Nolichucky/Maryville
GW-259	1988	1990	33.5	Nolichucky/Maryville
GW-286	1987	1991	32.3	Nolichucky/Maryville
GW-287	1987	1991	12.5	Nolichucky/Maryville
GW-288	1988	1990	60.0	Nolichucky/Maryville
GW-289	1988	1990	40.8	Nolichucky/Maryville
GW-290	1988	1991	35.5	Maryville
GW-291	1988	1991	17.0	Maryville
GW-342	1990	1991	75.0	Pumpkin Valley
GW-343	1988	1991	185.0	Pumpkin Valley
GW-344	1990	1991		Pumpkin Valley
GW-370	1988	1991	33.1	Maryville
GW-371	1988	1991	125.0	Maryville
GW-372	1988	1991	51.6	Maryville
GW-373	1988	1991	158.0	Maryville

Table A.2 Summary of the frequency of analysis and results above detection limits for chemicals in groundwater in the Bear Creek Hydrologic Regime, 1986-1992

PARAMETER (UNITS)	YEAR						
	86 ^a	87	88	89	90	91	92
1,1,1-TRICHLOROETHANE, $\mu\text{g/L}$	6/17 ^b	32/59	41/85	27/100	29/155	37/135	5/51
1,1,2,2-TETRACHLOROETHANE, $\mu\text{g/L}$	0/17	5/59	0/85	1/100	0/155	2/135	1/51
1,1,2-TRICHLOROETHANE, $\mu\text{g/L}$	1/17	4/59	2/85	0/100	0/155	0/135	0/51
1,1-DICHLOROETHANE, $\mu\text{g/L}$	3/17	21/59	32/85	25/100	30/155	20/135	6/51
1,1-DICHLOROETHENE, $\mu\text{g/L}$	3/17	21/59	25/85	14/100	19/155	14/135	3/51
1,2,4-TRICHLOROBENZENE, $\mu\text{g/L}$ ^c	0/2	0/2	-	0/6	0/6	-	-
1,2-DICHLOROBENZENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
1,2-DICHLOROETHANE, $\mu\text{g/L}$	2/17	9/59	11/85	3/100	5/155	4/135	1/51
1,2-DICHLOROETHENE, $\mu\text{g/L}$	-	-	-	-	-	-	15/51
1,2-DICHLOROETHENE (Total), $\mu\text{g/L}$	-	-	15/62	30/100	41/155	27/135	-
1,2-DICHLOROPROPANE, $\mu\text{g/L}$	0/17	0/59	0/85	0/100	0/155	0/135	0/51
1,3-DICHLOROBENZENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
1,4-DICHLOROBENZENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
106-RUTHENIUM, pCi/L	-	-	0/21	0/23	-	-	-
125 + 129 - IODINE, pCi/L	-	-	-	24/25	23/23	8/8	-
125 + 129 IODINE, pCi/L	-	-	0/21	-	-	-	-
126-IODINE, pCi/L	-	-	0/21	-	-	-	-
131-IODINE, pCi/L	-	-	0/21	-	-	-	-
134-CESIUM, pCi/L	-	-	0/21	1/23	-	-	-
137-CESIUM, pCi/L	-	-	0/21	0/29	2/12	2/2	-
144-CESIUM, pCi/L	-	-	0/21	0/23	-	-	-
2,4,5-T, $\mu\text{g/L}$	-	0/2	0/25	-	-	-	-
2,4,5-TRICHLOROPHENOL, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
2,4,6-TRICHLOROPHENOL, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
2,4-DICHLOROPHENOL, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
2,4-DIMETHYLPHENOL, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-

Table A.2 (continued)

PARAMETER (UNITS)	YEAR						
	86	87	88	89	90	91	92
2,4-DINITRIPHENOL, $\mu\text{g/L}$	-	-	-	0/6	-	-	-
2,4-DINITROPHENOL, $\mu\text{g/L}$	1/2	1/2	-	-	-	-	-
2,4-DINITROTOLUENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
2,6-DINITROTOLUENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
2-BUTANONE, $\mu\text{g/L}$	6/17	53/59	12/85	38/100	3/155	0/135	6/51
2-CHLOROETHYL VINYL ETHER, $\mu\text{g/L}$	1/17	0/59	0/85	-	-	-	-
2-CHLORONAPHTHALENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
2-CHLOROPHENOL, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
2-HEXANONE, $\mu\text{g/L}$	0/17	33/59	2/85	2/100	1/155	1/135	4/51
2-METHYLNAPHTHALENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
2-METHYLPHENOL, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
2-NITROANILINE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
2-NITROPHENOL, $\mu\text{g/L}$	1/2	1/2	-	0/6	0/6	-	-
224+226-RADIUM, pCi/L	-	-	9/19	-	-	-	-
228-RADIUM, pCi/L	-	-	7/21	26/26	16/16	-	-
228-THORIUM, pCi/L	-	-	17/19	8/9	-	-	-
230-THORIUM, pCi/L	-	-	11/19	5/9	-	-	-
231+234 THORIUM, pCi/L	-	-	8/19	-	-	-	-
232-THORIUM, pCi/L	-	-	10/19	3/4	-	-	-
234-URANIUM, pCi/L	-	-	-	2/2	20/22	20/29	2/4
235-URANIUM, pCi/L	-	-	-	2/2	13/22	9/29	1/3
237-NEPTUNIUM, pCi/L	-	-	16/19	8/10	-	5/5	1/4
238-PLUTONIUM, pCi/L	-	-	-	-	-	0/1	-
238-URANIUM, pCi/L	-	-	-	2/2	18/22	19/29	3/4
239-PLUTONIUM, pCi/L	-	-	17/19	10/10	-	1/1	-
241-AMERICIUM, pCi/L	-	-	12/19	3/10	-	4/5	2/4
3,3-DICHLOROBENZIDINE, $\mu\text{g/L}$	0/2	-	-	-	-	-	-

Table A.2 (continued)

PARAMETER (UNITS)	YEAR						
	86	87	88	89	90	91	92
3,3-DICHLOROBENZIDINE, $\mu\text{g/L}$	-	0/2	-	0/6	0/6	-	-
3-NITROANILINE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
4,4-DDD, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-
4,4-DDE, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-
4,4-DDT, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-
4,6-DINITRO-2-METHYLPHENOL, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
4-BROMOPHENYL PHENYL ETHER, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
4-CHLORO-3-METHYLPHENOL, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
4-CHLOROANILINE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
4-CHLOROPHENYL PHENYL ETHER, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
4-METHYL-2-PENTANONE, $\mu\text{g/L}$	1/17	14/59	13/85	8/100	1/155	28/135	26/51
4-METHYLPHENOL, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
4-NITROANILINE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
4-NITROPHENOL, $\mu\text{g/L}$	1/2	1/2	-	0/6	0/6	-	-
95-NIOBIUM, pCi/L	-	-	2/21	-	-	-	-
95-ZIRCONIUM, pCi/L	-	-	0/21	0/23	-	-	-
99-TECHNETIUM, pCi/L	-	-	21/21	21/26	5/18	13/17	2/4
ACENAPHTHENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
ACENAPHTHYLENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
ACETONE, $\mu\text{g/L}$	11/17	53/59	23/85	65/100	71/155	21/135	23/51
ALDRIN, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-
ALPHA-BHC, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-
ALPHA-CHLORDANE, $\mu\text{g/L}$	-	-	0/16	0/6	0/6	-	-
ALPHA-ENDOSULFAN, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-
ALUMINUM, mg/L	16/16	55/56	27/28	18/18	113/113	128/135	50/52
DISSOLVED ALUMINUM, mg/L	14/16	37/56	23/27	18/18	102/113	119/135	47/52
AMMONIA NITROGEN, mg/L	7/15	1/2	-	-	-	-	-

Table A.2 (continued)

PARAMETER (UNITS)	YEAR						
	86	87	88	89	90	91	92
ANILINE, $\mu\text{g/L}$	0/2	-	-	-	-	-	-
ANTHRACENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
ANTIMONY, mg/L	0/16	5/56	5/28	0/18	0/113	1/135	0/52
DISSOLVED ANTIMONY, mg/L	0/16	5/56	3/28	0/18	1/113	2/135	1/51
ARSENIC, mg/L	5/17	12/60	0/28	6/18	35/113	13/135	0/52
DISSOLVED ARSENIC, mg/L	4/17	3/60	1/28	9/18	30/113	9/135	1/51
BARIUM, mg/L	17/17	58/60	98/105	83/89	123/123	135/135	52/52
DISSOLVED BARIUM, mg/L	17/17	58/60	93/104	79/89	123/123	135/135	51/51
BENZENE, $\mu\text{g/L}$	3/17	24/59	20/85	12/100	35/155	12/135	1/51
BENZIDINE, $\mu\text{g/L}$	0/2	-	-	-	-	-	-
BENZO(A)ANTHRACENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
BENZO(A)PYRENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
BENZO(B)FLUORANTHENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
BENZO(G,H,I)PERYLENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
BENZO(K)FLUORANTHENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
BENZOIC ACID, $\mu\text{g/L}$	0/2	2/2	-	0/6	0/6	-	-
BENZYL ALCOHOL, $\mu\text{g/L}$	1/2	1/2	-	0/6	0/6	-	-
BERYLLIUM, mg/L	5/16	18/56	17/85	9/66	29/113	27/135	14/52
DISSOLVED BERYLLIUM, mg/L	3/16	11/56	8/84	4/66	14/113	15/135	8/51
BETA-BHC, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-
BETA-ENDOSULFAN, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-
BIS(2-CHLOROETHOXY)METHANE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
BIS(2-CHLOROETHYL)ETHER, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
BIS(2-CHLOROISOPROPYL)ETHER, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
BIS(2-ETHYLHEXYL)PHTHALATE, $\mu\text{g/L}$	2/2	2/2	-	3/6	1/6	-	-
BORON, mg/L	16/16	47/56	28/28	16/18	112/113	134/135	52/52
DISSOLVED BORON, mg/L	16/16	49/56	25/27	18/18	112/113	135/135	51/51

Table A.2 (continued)

PARAMETER (UNITS)	YEAR						
	86	87	88	89	90	91	92
BROMODICHLOROMETHANE, $\mu\text{g/L}$	1/17	0/59	0/85	1/100	0/155	1/135	1/51
BROMOFORM, $\mu\text{g/L}$	2/17	3/59	3/85	3/100	1/155	2/135	0/51
BROMOMETHANE, $\mu\text{g/L}$	0/16	0/59	0/85	0/100	0/155	0/135	0/51
BUTYL BENZYL PHTHALATE, $\mu\text{g/L}$	2/2	0/2	-	0/6	0/6	-	-
CADMIUM, mg/L	8/17	35/60	45/105	42/97	67/142	38/135	15/52
DISSOLVED CADMIUM, mg/L	7/17	26/60	37/104	34/97	55/142	29/135	9/52
CALCIUM, mg/L	17/17	57/57	105/105	100/100	155/155	135/135	52/52
DISSOLVED CALCIUM, mg/L	17/17	57/57	104/104	100/100	155/155	135/135	51/51
CARBON DISULFIDE, $\mu\text{g/L}$	1/17	17/59	8/85	1/100	1/155	0/135	6/51
CARBON TETRACHLORIDE, $\mu\text{g/L}$	3/17	6/59	23/85	13/100	12/155	12/135	4/51
CHLORDANE, $\mu\text{g/L}$	-0	0/2	0/25	-	-	-	-
CHLORIDE, mg/L	17/17	54/57	103/105	100/100	149/155	119/135	45/52
CHLOROBENZENE, $\mu\text{g/L}$	2/17	2/59	12/85	3/100	1/155	2/135	0/51
CHLORODIBROMOMETHANE, $\mu\text{g/L}$	2/17	0/59	0/85	0/100	0/155	0/135	0/51
CHLOROETHANE, $\mu\text{g/L}$	1/17	13/59	8/85	5/100	4/155	5/135	3/51
CHLOROFORM, $\mu\text{g/L}$	12/17	54/59	51/85	28/100	29/155	31/135	7/51
CHLOROMETHANE, $\mu\text{g/L}$	2/17	3/59	1/85	2/100	0/155	0/135	0/51
CHROMIUM, mg/L	9/17	36/60	54/105	39/100	63/113	64/135	23/52
DISSOLVED CHROMIUM, mg/L	5/17	17/60	23/104	14/100	48/113	40/135	9/52
CHRYSENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
CIS-1,3-DICHLOROPROPENE, $\mu\text{g/L}$	0/17	3/59	0/85	0/100	0/155	0/135	0/51
COBALT, mg/L	9/16	17/56	4/28	5/18	19/113	15/135	8/52
DISSOLVED COBALT, mg/L	7/16	14/56	1/27	0/18	8/113	4/135	3/52
COLIFORM, COL/100M	0/2	11/57	5/27	6/18	3/23	-	-
COPPER, mg/L	10/16	24/56	24/28	12/18	102/113	113/135	41/52
DISSOLVED COPPER, mg/L	7/16	8/56	20/27	12/18	95/113	101/135	46/51
DELTA-BHC, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-

Table A.2 (continued)

PARAMETER (UNITS)	YEAR						
	86	87	88	89	90	91	92
DI-N-BUTYLPHTHALATE, $\mu\text{g/L}$	1/2	0/2	-	1/6	0/6	-	-
DI-N-OCTYLPHTHALATE, $\mu\text{g/L}$	2/2	0/2	-	0/6	0/6	-	-
DIBENZ(A,H)ANTHRACENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
DIBENZOFURAN, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
DIELDRIN, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-
DIETHYLPHTHALATE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
DIMETHYLPHTHALATE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
ENDOSULFAN SULFATE, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-
ENDRIN, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-
ENDRIN KETONE, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-
ETHYL BENZENE, $\mu\text{g/L}$	1/17	10/59	44/85	5/100	1/155	3/135	0/51
FLUORANTHENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
FLUORENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
FLUORIDE, mg/L	4/5	53/57	59/75	31/43	79/123	104/135	42/52
GAMMA-CHLORDANE, $\mu\text{g/L}$	-	-	0/16	0/6	-	-	-
GROSS ALPHA, pCi/L	17/17	46/60	102/105	99/100	156/156	134/135	38/51
GROSS BETA, pCi/L	17/17	56/60	105/105	99/100	155/156	134/135	43/51
HEPTACHLOR, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-
HEPTACHLOR EPOXIDE, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-
HEXACHLOROBENZENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
HEXACHLOROBUTADIENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
HEXACHLOROCYCLOPENTADIENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
HEXACHLOROETHANE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
INDENO(1,2,3-CD)PYRENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
IRON, mg/L	17/17	56/57	28/28	18/18	113/113	134/135	52/52
DISSOLVED IRON, mg/L	17/17	45/57	22/27	13/18	106/113	131/135	51/51
ISOPHORONE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-

Table A.2 (continued)

PARAMETER (UNITS)	YEAR						
	86	87	88	89	90	91	92
LEAD, mg/L	15/17	56/60	96/105	78/100	112/155	62/135	25/52
DISSOLVED LEAD, mg/L	12/17	44/60	74/105	50/100	63/155	14/135	4/52
LINDANE, µg/L	-	0/2	0/28	0/6	0/6	-	-
LITHIUM, mg/L	15/16	52/56	25/28	-	-	-	-
DISSOLVED LITHIUM, mg/L	14/16	52/56	19/27	-	-	-	-
MAGNESIUM, mg/L	16/16	56/56	105/105	100/100	155/155	135/135	52/52
DISSOLVED MAGNESIUM, mg/L	16/16	56/56	103/104	100/100	155/155	135/135	51/51
MANGANESE, mg/L	17/17	56/57	28/28	18/18	113/113	134/135	52/52
DISSOLVED MANGANESE, mg/L	17/17	53/57	25/27	17/18	108/113	130/135	49/51
MERCURY, mg/L	7/17	16/60	11/48	7/43	15/123	16/135	3/52
DISSOLVED MERCURY, mg/L	3/17	7/60	6/51	4/43	13/123	7/135	2/52
METHOXYCHLOR, µg/L	-	0/2	0/28	0/6	0/6	-	-
METHYLENE CHLORIDE, µg/L	8/17	57/59	66/85	27/100	51/155	66/135	30/51
MOLYBDENUM, mg/L	2/16	7/56	8/28	3/18	5/113	13/135	3/52
DISSOLVED MOLYBDENUM, mg/L	2/16	3/56	4/27	2/18	8/113	10/135	5/51
N-NITROSO-DI-N-PROPYLAMINE, µg/L	0/2	0/2	-	0/6	0/6	-	-
N-NITROSODIMETHYLAMINE, µg/L	0/2	-	-	-	-	-	-
N-NITROSODIPHENYLAMINE, µg/L	0/2	0/2	-	0/6	0/6	-	-
NAPHTHALENE, µg/L	1/2	1/2	-	0/6	0/6	-	-
NICKEL, mg/L	9/16	27/56	10/28	8/18	65/113	63/135	24/52
DISSOLVED NICKEL, mg/L	9/16	19/56	4/27	7/18	55/113	51/135	15/51
NIOBIUM, mg/L	8/16	16/56	14/28	-	-	-	-
DISSOLVED NIOBIUM, mg/L	8/16	19/56	9/27	-	-	-	-
NITRATE, mg/L	2/2	-	-	-	-	-	-
NITRATE NITROGEN, mg/L	16/17	30/57	58/75	55/100	63/155	54/135	22/52
NITRITE, mg/L	1/14	-	-	-	-	-	-
NITRITE NITROGEN, mg/L	-	1/2	-	-	-	-	-

Table A.2 (continued)

Parameter (Units)	Year						
	86	87	88	89	90	91	92
NITROBENZENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
PCB-(AROCOLOR)-1016, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-
PCB-(AROCOLOR)-1221, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-
PCB-(AROCOLOR)-1232, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-
PCB-(AROCOLOR)-1242, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-
PCB-(AROCOLOR)-1248, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-
PCB-(AROCOLOR)-1254, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-
PCB-(AROCOLOR)-1260, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-
PENTACHLOROPHENOL, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
PHENANTHRENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
PHENOL, $\mu\text{g/L}$	0/2	0/2	-	0/6	1/6	-	-
PHENOLS, mg/L	0/2	29/57	13/28	7/18	2/27	0/7	-
PHOSPHOROUS, mg/L	5/16	3/56	5/28	-	-	-	-
DISSOLVED PHOSPHOROUS, mg/L	2/16	0/56	1/27	-	-	-	-
POTASSIUM, mg/L	16/16	50/56	105/105	100/100	153/155	135/135	52/52
DISSOLVED POTASSIUM, mg/L	16/16	49/56	102/104	99/100	148/155	132/135	51/51
PROTACTINIUM, mg/L	-	-	0/20	1/29	0/12	-	-
PYRENE, $\mu\text{g/L}$	0/2	0/2	-	0/6	0/6	-	-
RADIUM, pCi/L	1/2	13/38	32/56	41/41	48/48	-	-
SELENIUM, mg/L	2/17	7/60	0/78	3/63	6/113	7/135	6/52
DISSOLVED SELENIUM, mg/L	3/17	5/60	0/78	0/63	8/113	5/135	7/51
SILICON, mg/L	16/16	56/56	28/28	18/18	113/113	129/129	-
DISSOLVED SILICON, mg/L	16/16	55/56	27/27	18/18	113/113	129/129	-
SILVER, mg/L	3/17	2/60	6/58	0/43	2/113	9/135	6/52
DISSOLVED SILVER, mg/L	1/17	1/60	4/57	0/43	4/113	7/135	6/51
SILVEX, $\mu\text{g/L}$	-	0/2	0/28	0/6	0/6	-	-
SODIUM, mg/L	17/17	57/57	105/105	100/100	155/155	135/135	52/52

Table A2. (Continued)

PARAMETER (UNITS)	YEAR						
	86	87	88	89	90	91	92
DISSOLVED SODIUM, mg/L	17/17	57/57	104/104	100/100	155/155	135/135	51/51
STRONTIUM, pCi/L	16/16	56/56	21/21	22/29	11/14	133/133	32/452
DISSOLVED STRONTIUM, mg/L	16/16	56/56	27/27	18/18	113/113	133/133	51/51
STYRENE, µg/L	0/17	1/59	11/85	0/100	0/155	0/135	0/51
SULFATE, mg/L	15/17	53/57	98/105	95/100	146/155	134/135	52/52
TETRACHLOROETHENE, µg/L	10/17	48/59	56/85	50/100	51/155	27/135	14/51
THALLIUM, mg/L	1/16	0/15	0/28	0/18	0/23	-	-
DISSOLVED THALLIUM, mg/L	0/16	0/15	0/28	0/18	0/23	-	-
THORIUM, mg/L	1/16	3/56	0/28	0/18	0/113	0/135	0/52
DISSOLVED THORIUM, mg/L	2/16	1/56	0/27	0/18	0/113	0/135	0/51
THORIUM-234, pCi/L	-	-	20/21	22/29	9/12	-	-
TIN, mg/L	-	-	4/14	-	-	-	-
DISSOLVED TIN, mg/L	-	-	2/14	-	-	-	-
TITANIUM, mg/L	10/16	36/56	25/28	-	-	-	-
DISSOLVED TITANIUM, mg/L	4/16	30/56	20/27	-	-	-	-
TOLUENE, µg/L	8/17	50/59	50/85	21/100	14/155	67/135	9/51
TOTAL KJELDAHL NITROGEN, mg/L	12/15	2/2	-	-	-	-	-
TOTAL XYLENES, µg/L	-	32/59	34/85	9/100	3/155	4/135	0/51
TOXAPHENE, µg/L	-	0/2	0/28	0/6	0/6	-	-
TRANS-1,2-DICHLOROETHENE, µg/L	7/17	32/59	29/85	-	-	-	-
TRANS-1,3-DICHLOROPROPENE, µg/L	0/17	0/59	1/85	0/100	0/155	0/135	0/51
TRICHLOROETHENE, µg/L	7/17	36/59	46/85	45/100	57/155	48/135	15/51
TRITIUM, pCi/L	-	-	16/21	15/29	23/23	11/12	2/4
URANIUM FLUOROMETRIC, mg/L	16/16	59/60	89/105	72/100	72/155	80/135	31/52
DISSOLVED URANIUM FLUOROMETRIC, mg/L	16/16	57/60	81/105	71/100	65/155	70/135	24/51
VANADIUM, mg/L	3/16	9/56	7/28	6/18	11/113	19/135	9/52
DISSOLVED VANADIUM, mg/L	1/16	1/56	0/27	0/18	3/113	6/135	0/51

Table A.2 (continued)

PARAMETER (UNITS)	YEAR						
	86	87	88	89	90	91	92
VINYL ACETATE, $\mu\text{g/L}$	1/17	3/59	3/85	0/100	13/155	1/135	1/51
VINYL CHLORIDE, $\mu\text{g/L}$	1/17	11/59	11/85	6/100	9/155	7/135	4/51
ZINC, mg/L	16/16	49/56	28/28	18/18	111/113	134/135	52/52
DISSOLVED ZINC, mg/L	14/16	42/56	25/27	18/18	111/113	134/135	51/51
ZIRCONIUM, mg/L	7/16	8/56	8/28	-	-	-	-
DISSOLVED ZIRCONIUM, mg/L	4/16	5/56	3/27				

^aData source: H&R Technical Associates

^bNumber of hits/Number of wells sampled

^cBlanks indicate chemical not analyzed for

Note: Produced by programs hits.sql and hits.sas on 24 June 93 using preliminary OREIS data files.

Table A.3 Summary of the maximum recorded concentrations of contaminants, 1986-1992, in Bear Creek Hydrologic Regime groundwater and the well(s) in which the maximum was recorded*

PARAMETER, UNITS	YEAR (MAX/WEELL)						
	1986	1987	1988	1989	1990	1991	1992
1,1,1-TRICHLOROETHANE, µg/L ^b	28.00/GW-103	13000.00/GW-039	4900.00/GW-039	540.00/GW-046	970.00/GW-046	610.00/GW-623	13.00/GW-365
1,1,2,2-TETRACHLOROETHANE, µg/L	-	41.00/GW-087	-	2.00/GW-042	-	2.00/GW-704	1.00/GW-080
1,1,2-TRICHLOROETHANE, µg/L	1.00/GW-276	300.00/GW-039	180.00/GW-039	-	-	-	-
1,1-DICHLOROETHANE, µg/L	20.00/GW-229	7800.00/GW-039	5500.00/GW-039	720.00/GW-068	550.00/GW-014	3200.00/GW-623	14.00/GW-053
1,1-DICHLOROETHENE, µg/L	9.00/GW-225	13000.00/GW-039	5600.00/GW-039	100.00/GW-046	140.00/GW-046	660.00/GW-623	36.00/GW-365
1,2-DICHLOROETHANE, µg/L	4.00/GW-276	102.00/GW-039	100.00/GW-039	11.00/GW-087	18.00/GW-046	8.00/GW-623	2.00/GW-053
1,2-DICHLOROETHENE, µg/L	-	-	-	-	-	-	100.00/GW-243
1,2-DICHLOROETHENE (TOTAL), µg/L	-	-	2900.00/GW-039	2000.00/GW-046	5400.00/GW-624	800.00/GW-624	-
125+129- IODINE, pCi/L ^c	-	-	-	351.00/GW-243	27.00/GW-306	2.70/GW-243	-
	-	-	-	-	27.00/ GW-307	2.70/ GW-306	-
134-CESIUM, pCi/L	-	-	-	14.00/GW-162	49.40/GW-306	17.10/GW-309	-
2,4-DINITROPHENOL, µg/L	11.00/GW-276	77.00/GW-276	-	-	-	-	-
2-BUTANONE, µg/L	96.00/GW-243	3600.00/GW-027	1500.00/GW-014	66.00/GW-243	32.00/GW-615	-	7.00/GW-117
	-	-	-	7.00/GW-317	-	-	-
2-CHLOROETHYL VINYL ETHER, µg/L	4.00/GW-127	-	-	-	-	-	-
2-HEXANONE, µg/L	-	220.00/GW-027	5.00/GW-119	5.00/GW-042	5.00/GW-210	5.00/GW-704	4.00/GW-064
2-NITROPHENOL, µg/L	18.00/GW-276	71.00/GW-276	-	-	-	-	-
224 + 226-RADIUM, pCi/L	-	-	75.60/GW-039	-	-	-	-
228-RADIUM, pCi/L	-	-	89.10/GW-244	99.90/GW-243	91.80/GW-244	-	-
	-	-	-	99.90/GW-244	-	-	-
228-THORIUM, pCi/L	-	-	9.00/GW-245	9.00/GW-244	-	-	-

Table A.3 (continued)

PARAMETER, UNITS	YEAR (MAX/WEILL)						
	1986	1987	1988	1989	1990	1991	1992
230-THORIUM, pCi/L	-	-	4.00/GW-247	3.00/GW-064 3.00/GW-115 3.00 GW-243	-	-	-
231 + 234 THORIUM, pCi/L	-	-	41400.00/GW-243	-	-	-	-
232-THORIUM, pCi/L	-	-	3.00/GW-243	2.00/GW-243 2.00 GW-244	-	-	-
234-URANIUM, pCi/L	-	-	-	0.004/GW-276	40.540/GW-373	4650.00/GW-243	1980.00/GW-243
235-URANIUM, pCi/L	-	-	-	0.340/GW-243 0.340/GW-276	16.220/GW-325	475.00/GW-245	547.00/GW-243
237-NEPTUNIUM, pCi/L	-	-	699.00/GW-243	530.00/GW-243	-	1090.00/GW-243	534.00/GW-243
238-URANIUM, pCi/L	-	-	-	99.660/GW-276	28.480/GW-061	13600.00/GW-243	4880.00/GW-243
239-PLUTONIUM, pCi/L	-	-	6.00/GW-117	5.00/GW-227	-	41.00/GW-243	-
241-AMERICIUM, pCi/L	-	-	30.440/GW-243	17.00/GW-243	-	27.780/GW-243	38.00/GW-243
4-METHYL-2-PENTANONE, µg/L	14.00/GW-243	320.00/GW-027	11.00/GW-243	22.00/GW-046	2.00/GW-210	8.00/GW-306	97.00/GW-243
4-NITROPHENOL, µg/L	41.00/GW-276	120.00/GW-276	-	-	-	-	-
95-NIOBIUM, pCi/L	-	-	234.90/GW-243	-	-	-	-
99-TECHNETIUM, pCi/L	-	-	72180.00/GW-243	63405.00/GW-243	60800.00/GW-243	80400.00/GW-243	74300.00/GW-243
ACETONE, µg/L	555.00/GW-243	850.00/GW-027	310.00/GW-243	390.00/GW-243	460.00/GW-243	1300.00/GW-243	6000.00/GW-243
ALUMINUM, mg/L	2000.00/GW-104	1900.00/GW-243	31.00/GW-531	76.00/GW-531	730.00/GW-243	790.00/GW-243	800.00/GW-243
DISSOLVED ALUMINUM, mg/L	1790.00/GW-104	2000.00/GW-243	4.40/GW-312 4.40/GW-531	6.80/GW-531	750.00/GW-243	760.00/GW-243	780.00/GW-243
AMMONIA NITROGEN, mg/L	4.10/GW-276	4.760/GW-276	-	-	-	-	-

Table A.3 (continued)

PARAMETER, UNITS	YEAR (MAX/WELL)						
	1986	1987	1988	1989	1990	1991	1992
ANTIMONY, mg/L	-	0.140/GW-115	0.20/GW-312	-	-	0.051/GW-083	-
DISSOLVED ANTIMONY, mg/L	-	0.170/GW-250	0.240/GW-290	-	0.50/GW-615	0.073/GW-163	0.070/GW-314
ARSENIC, mg/L	0.073/GW-103	0.050/GW-040	-	0.170/GW-257	0.840/GW-615	0.095/GW-122	-
DISSOLVED ARSENIC, mg/L	0.047/GW-103	0.018/GW-243	0.012/GW-259	0.140/GW-257 0.140/GW-537	1.10/GW-101	0.090/GW-071	0.079/GW-085
BARIUM, mg/L	59.00/GW-104	270.00/GW-244	168.00/GW-244	140.00/GW-244	350.00/GW-615	390.00/GW-615	9.30/GW-243
DISSOLVED BARIUM, mg/L	56.00/GW-104	290.00/GW-244	187.00/GW-244	150.00/GW-244	360.00/GW-615	390.00/GW-615	7.90/GW-243
BENZENE, µg/L	10.00/GW-229	180.00/GW-014	95.00/GW-027	69.00/GW-046	130.00/GW-071	420.00/GW-071	1.00/GW-118
BENZOIC ACID, µg/L	-	58.00/GW-276	-	-	-	-	-
BENZYL ALCOHOL, µg/L	2.00/GW-276	2.00/GW-276	-	-	-	-	-
BERYLLIUM, mg/L	0.310/GW-104	0.20/GW-243	0.007/GW-040 0.007/GW-364	0.007/GW-531	0.070/GW-243	0.080/GW-243	0.078/GW-243
DISSOLVED BERYLLIUM, mg/L	0.260/GW-104	0.230/GW-243	0.002/GW-248	-	0.070/GW-243	2.00/GW-243	0.082/GW-243
BIS(2-ETHYLHEXYL)- PHTHALATE, µg/L	32.00/GW-277	19.00/GW-276	-	12.00/GW-535	17.00/GW-536	-	-
BORON, mg/L	6.00/GW-229	31.00/GW-027	5.10/GW-291	0.270/GW-502	1.30/GW-243	4.40/GW-615	2.10/GW-243
DISSOLVED BORON, mg/L	6.20/GW-229	29.00/GW-027	4.90/GW-291	0.280/GW-502	1.40/GW-243	10.00/GW-615	2.00/GW-243
BROMODICHLOROMETHANE, µg/L	3.00/GW-276	-	-	0.70/GW-310	-	2.00/GW-626	4.00/GW-315
BROMOFORM, µg/L	4.00/GW-243	8.00/GW-046	4.00/GW-046 4.00/GW-243	11.00/GW-046	20.00/GW-046	1.00/GW-367 1.00/GW-704	- -
BUTYL BENZYL PHTHALATE, µg/L	1.00/GW-276	-	-	-	-	-	-
1.00/GW-277	1.00/GW-277	-	-	-	-	-	-

Table A.3 (continued)

PARAMETER, UNITS	YEAR (MAX/WELL)						
	1986	1987	1988	1989	1990	1991	1992
CADMIUM, mg/L	2.80/GW-104	2.80/GW-243	4.30/GW-257	1.70/GW-243	29.00/GW-042	4.00/GW-243	2.80/GW-243
DISSOLVED CADMIUM, mg/L	2.80/GW-104	2.90/GW-243	5.80/GW-122	1.60/GW-243	21.00/GW-042	4.70/GW-243	2.80/GW-243
CALCIUM, mg/L	4200.00/GW-243	14000.00/GW-244	11000.00/GW-346	8200.00/GW-244	9100.00/GW-615	10000.00/GW-615	7000.00/GW-243
DISSOLVED CALCIUM, mg/L	6000.00/GW-101	14000.00/GW-244	7600.00/GW-244	6500.00/GW-244	10000.00/GW-615	11000.00/GW-615	7100.00/GW-243
CARBON DISULFIDE, µg/L	1.00/GW-228	12.00/GW-027	36.00/GW-039	1.00/GW-042	2.00/GW-210	-	2.00/GW-061 2.00/GW-118 2.00/GW-342 2.00/GW-365
	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
CARBON TETRACHLORIDE, µg/L	26.00/GW-226	190.00/GW-027	76.00/GW-027	9.00/GW-225	13.00/GW-623	50.00/GW-626	8.00/GW-225
CHLORIDE, mg/L	430.00/GW-243	3250.00/GW-118	46200.00/GW-118	3270.00/GW-118	8010.00/GW-118	3520.00/GW-118	4842.00/GW-118
CHLOROBENZENE, µg/L	3.00/GW-229 3.00/GW-276	4.00/GW-229	5.00/GW-095	6.00/GW-229	5.00/GW-226	8.00/GW-226	-
	-	-	-	-	-	-	-
CHLORODIBROMOMETHANE, µg/L	1.00/GW-243 1.00/GW-276	-	-	-	-	-	-
	-	-	-	-	-	-	-
CHLOROETHANE, µg/L	5.00/GW-229	740.00/GW-021	180.00/GW-039	9.00/GW-046 9.00/GW-097	45.00/GW-089	33.00/GW-623	13.00/GW-089
CHLOROFORM, µg/L	68.00/GW-104	1700.00/GW-027	67.00/GW-087	54.00/GW-046	59.00/GW-046	38.00/GW-243 38.00/GW-623	69.00/GW-243
	-	-	-	-	-	-	-
CHLOROMETHANE, µg/L	14.00/GW-125	12.00/GW-063	7.00/GW-123	10.00/GW-277	-	-	-
CHROMIUM, mg/L	0.420/GW-243	0.730/GW-063	0.410/GW-243	0.510/GW-259	0.392/GW-044	0.710/GW-057	0.280/GW-243
DISSOLVED CHROMIUM, mg/L	0.420/GW-243	0.610/GW-243	0.40/GW-243	0.40/GW-243	1.30/GW-101	2.50/GW-243	0.30/GW-243
CIS-1,3-DICHLOROPROPENE, µg/L	-	4.00/GW-014	-	-	-	-	-
COBALT, mg/L	2.60/GW-104	2.80/GW-243	0.021/GW-257	0.040/GW-531	1.20/GW-243	1.80/GW-243	1.90/GW-243

Table A.3 (continued)

PARAMETER, UNITS	YEAR (MAX/WELL)						
	1986	1987	1988	1989	1990	1991	1992
DISSOLVED COBALT, mg/L	2.40/GW-104	2.80/GW-243	0.006/GW-248	-	1.20/GW-243	3.50/GW-243	1.80/GW-243
COLIFORM, COL/100M	-	100.00/GW-063	93.00/GW-311	40.00/GW-309	2.00/GW-502	-	-
COPPER, mg/L	3.10/GW-103	1.80/GW-243	6.60/GW-291	0.062/GW-531	1.40/GW-243	1.60/GW-615	1.40/GW-243
DISSOLVED COPPER, mg/L	2.90/GW-103	2.20/GW-243	0.310/GW-324	0.036/GW-310	1.40/GW-243	3.20/GW-243	1.30/GW-243
DI-N-BUTYLPHTHALATE, µg/L	2.00/GW-277	-	-	1.00/GW-537	-	-	-
DI-N-OCTYLPHTHALATE, µg/L	3.00/GW-277	-	-	-	-	-	-
ETHYL BENZENE, µg/L	1.00/GW-276	21.00/GW-027	9.00/GW-117	4.00/GW-246	1.00/GW-347	33.00/GW-623	-
FLUORIDE, mg/L	8.00/GW-125	10.00/GW-244	9.40/GW-244	36.00/GW-244	7.00/GW-245	110.00/GW-243	9.00/GW-123
GROSS ALPHA, pCi/L	33000.00/GW-243	35000.00/GW-243	15191.00/GW-243	13622.00/GW-243	8720.00/GW-243	15000.00/GW-243	24400.00/GW-243
GROSS BETA, pCi/L	1600000.00/GW-243	78500.00/GW-243	79226.00/GW-243	37922.00/GW-243	72400.00/GW-243	75000.00/GW-243	48100.00/GW-243
IRON, mg/L	56.00/GW-226	290.00/GW-242	33.00/GW-291	73.00/GW-531	82.00/GW-086	230.00/GW-705	49.00/GW-343
DISSOLVED IRON, mg/L	22.00/GW-277	17.00/GW-229	3.10/GW-531	5.30/GW-531	28.00/GW-615	40.00/GW-226	6.50/GW-118
LEAD, mg/L	0.280/GW-276	0.620/GW-125	0.70/GW-291	1.50/GW-117	0.660/GW-005	1.30/GW-615	0.078/GW-052
	-	-	-	-	0.660/GW-246	-	-
	-	-	-	-	0.660/GW-247	-	-
DISSOLVED LEAD, mg/L	0.150/GW-103	0.050/GW-125	0.096/GW-007	0.133/GW-502	0.710/GW-246	1.30/GW-615	0.010/GW-052
	0.150/GW-276	-	-	-	-	-	-
LITHIUM, mg/L	3.70/GW-104	7.90/GW-243	0.062/GW-502	-	-	-	-
DISSOLVED LITHIUM, mg/L	3.50/GW-103	8.50/GW-243	0.059/GW-502	-	-	-	-
MAGNESIUM, mg/L	610.00/GW-104	1900.00/GW-244	2280.00/GW-346	1100.00/GW-244	2200.00/GW-615	2500.00/GW-615	720.00/GW-243
DISSOLVED MAGNESIUM, mg/L	590.00/GW-104	1900.00/GW-244	960.00/GW-244	970.00/GW-244	2200.00/GW-615	2600.00/GW-615	730.00/GW-243

Table A.3 (continued)

PARAMETER, UNITS	YEAR (MAX/WELL)						
	1986	1987	1988	1989	1990	1991	1992
MANGANESE, mg/L	170.00/GW-104	360.00/GW-243	3.70/GW-257	6.70/GW-531	170.00/GW-243	210.00/GW-243	220.00/GW-243
DISSOLVED MANGANESE, mg/L	160.00/GW-104	350.00/GW-243	1.40/GW-309	3.00/GW-309	170.00/GW-243	210.00/GW-243	220.00/GW-243
MERCURY, mg/L	0.141/GW-104	0.046/GW-243	0.040/GW-243	0.043/GW-243	0.042/GW-243	0.110/GW-243	0.110/GW-243
DISSOLVED MERCURY, mg/L	0.113/GW-104	0.044/GW-243	0.036/GW-243	0.051/GW-243	0.040/GW-243	0.10/GW-243	0.10/GW-243
METHYLENE CHLORIDE, µg/L	73.00/GW-104	3400.00/GW-087	99.00/GW-039	87.00/GW-243	160.00/GW-243	310.00/GW-243	560.00/GW-243
MOLYBDENUM, mg/L	0.034/GW-228	0.026/GW-242	0.070/GW-323	0.027/GW-312	0.028/GW-117	0.092/GW-695	0.032/GW-117
DISSOLVED MOLYBDENUM, mg/L	0.028/GW-228	0.022/GW-250	0.056/GW-312	0.026/GW-312	0.130/GW-615	2.30/GW-243	0.033/GW-117
NAPHTHALENE, µg/L	1.00/GW-276	1.00/GW-276	-	-	-	-	-
NICKEL, mg/L	18.00/GW-103	40.00/GW-243	1.70/GW-257	0.50/GW-259	16.00/GW-243	20.00/GW-243	20.00/GW-243
DISSOLVED NICKEL, mg/L	19.00/GW-103 19.00/GW-104	42.00/GW-243 -	0.240/GW-257 -	0.040/GW-259 -	17.00/GW-243 -	22.00/GW-243 -	19.00/GW-243 -
NIObIUM, mg/L	0.033/GW-226	0.10/GW-246	0.087/GW-323	-	-	-	-
DISSOLVED NIObIUM, mg/L	0.031/GW-122	0.028/GW-071	0.026/GW-310	-	-	-	-
NITRATE, mg/L	34400.00/GW-104	-	-	-	-	-	-
NITRATE NITROGEN, mg/L	11063.00/GW-243	5712.00/GW-243	6700.00/GW-243	10800.00/GW-246	13400.00/GW-615	10900.00/GW-615	6656.00/GW-243
NITRITE, mg/L	10.00/GW-228	-	-	-	-	-	-
NITRITE NITROGEN, mg/L	-	6.70/GW-276	-	-	-	-	-
PHENOL, µg/L	-	-	-	-	2.00/GW-532	-	-
PHENOLS, mg/L	-	0.060/GW-071	0.033/GW-258	0.20/GW-259 0.20/GW-535 0.20/GW-537	0.094/GW-626 - -	- - -	- - -

Table A.3 (continued)

PARAMETER, UNITS	YEAR (MAX/WELL)						
	1986	1987	1988	1989	1990	1991	1992
PHOSPHOROUS, mg/L	2.40/GW-104	2.90/GW-242	1.10/GW-257	-	-	-	-
DISSOLVED PHOSPHOROUS, mg/L	2.50/GW-104	-	0.210/GW-324	-	-	-	-
POTASSIUM, mg/L	130.00/GW-104	480.00/GW-243	220.00/GW-243	210.00/GW-243	140.00/GW-243	200.00/GW-243	190.00/GW-243
DISSOLVED POTASSIUM, mg/L	130.00/GW-104	360.00/GW-243	220.00/GW-243	200.00/GW-243	140.00/GW-243	160.00/GW-615	160.00/GW-243
	-	-	220.00/GW-244	-	-	-	-
PROTACTINIUM, mg/L	-	-	-	764.00/GW-243	-	-	-
RADIUM, pCi/L	1.30/GW-276	35.10/GW-276	59.40/GW-244	81.00/GW-244	5.130/GW-531	-	-
SELENIUM, mg/L	0.008/GW-101	0.014/GW-243	-	0.066/GW-531	0.130/GW-118	0.670/GW-705	0.064/GW-227
	-	0.014/GW-246	-	-	-	-	-
DISSOLVED SELENIUM, mg/L	0.007/GW-101	0.018/GW-246	-	-	0.110/GW-537	0.110/GW-226	0.390/GW-013
SILICON, mg/L	100.00/GW-226	140.00/GW-242	44.00/GW-531	100.00/GW-531	87.00/GW-086	71.00/GW-623	-
DISSOLVED SILICON, mg/L	34.00/GW-103	14.00/GW-243	20.00/GW-531	24.00/GW-531	19.00/GW-531	18.00/GW-623	-
	34.00/GW-104	-	-	-	19.00/GW-642	-	-
SILVER, mg/L	0.037/GW-229	0.014/GW-276	0.20/GW-289	-	0.064/GW-243	0.130/GW-367	0.640/GW-243
DISSOLVED SILVER, mg/L	0.006/GW-276	0.010/GW-276	0.330/GW-310	-	0.075/GW-243	1.80/GW-243	0.630/GW-243
SODIUM, mg/L	880.00/GW-243	2300.00/GW-118	1900.00/GW-118	1900.00/GW-118	2800.00/GW-615	3600.00/GW-615	1800.00/GW-118
	-	1800.00/GW-243	-	-	-	-	-
DISSOLVED SODIUM, mg/L	890.00/GW-243	1800.00/GW-118	1800.00/GW-118	1800.00/GW-118	3200.00/GW-615	3700.00/GW-615	1800.00/GW-118
STRONTIUM, mg/L	20.00/GW-122	73.00/GW-244	3.10/GW-312	2.00/GW-537	310.00/GW-615	360.00/GW-615	254.00/GW-243
DISSOLVED STRONTIUM, mg/L	22.00/GW-101	70.00/GW-244	3.20/GW-312	1.90/GW-537	330.00/GW-615	330.00/GW-615	12.00/GW-243
STRONTIUM, pCi/L	-	-	378.00/GW-243	302.00/GW-243	250.00/GW-243	370.00/GW-615	254.00/GW-243

Table A.3 (continued)

PARAMETER, UNITS	YEAR (MAX/WEEL)						
	1986	1987	1988	1989	1990	1991	1992
STYRENE, µg/L	-	12.00/GW-027	0.90/GW-043 0.90/GW-067 0.90/GW-085	-	-	-	-
SULFATE, mg/L	830.00/GW-103	620.00/GW-243	848.00/GW-243	714.00/GW-243	1140.00/GW-211	2217.00/GW-711	1453.00/GW-243
TETRACHLOROETHENE, µg/L	970.00/GW-243	63000.00/GW-027	3300.00/GW-027	2300.00/GW-243	3700.00/GW-243	25000.00/GW-623	9000.00/GW-243
THALLIUM, mg/L	0.010/GW-277	-	-	-	-	-	-
THORIUM, mg/L	0.280/GW-103	0.310/GW-118	-	-	-	-	-
DISSOLVED THORIUM, mg/L	0.230/GW-103 0.230/GW-104	0.210/GW-118 -	- -	- -	- -	- -	- -
THORIUM-234, pCi/L	-	-	12849.00/GW-243	17154.00/GW-243	11100.00/GW-243	-	-
TIN, mg/L	-	-	0.018/GW-127	-	-	-	-
DISSOLVED TIN, mg/L	-	-	0.014 GW-246	-	-	-	-
TITANIUM, mg/L	1.70/GW-226	3.40/GW-242	0.130/GW-248	-	-	-	-
DISSOLVED TITANIUM, mg/L	0.043/GW-101	0.330/GW-244	0.070/GW-289	-	-	-	-
TOLUENE, µg/L	7.00/GW-243	190.00/GW-027	56.00/GW-027	14.00/GW-243	12.00/GW-243	670.00/GW-623	2.00/GW-118
TOTAL KJELDAHL NITROGEN, mg/L	9.130/GW-104	1.80/GW-276	-	-	-	-	-
TOTAL XYLENES, µg/L	-	120.00/GW-027	13.00/GW-117	20.00/GW-046	35.00/GW-046	130.00/GW-623	-
TRANS-1,2-DICHLOROETHENE, µg/L	37.00/GW-229	50000.00/GW-027	7800.00/GW-027	-	-	-	-
TRANS-1,3-DICHLOROPROPENE, µg/L	-	-	15.00/GW-039	-	-	-	-
TRICHLOROETHENE, µg/L	520.00/GW-225	17000.00/GW-027	3700.00/GW-027	660.00/GW-068	1800.00/GW-623	15000.00/GW-623	370.00/GW-225
TRITIUM, pCi/L	-	-	12000.00/GW-064	63838.00/GW-243	-	83700.00/GW-526	9180.00/GW-061

Table A.3 (continued)

PARAMETER, UNITS	YEAR (MAX/WEEL)						
	1986	1987	1988	1989	1990	1991	1992
TRITIUM AND RAD ERRORS, pCi/L	-	-	-	5130.00/GW-243	4590.00/GW-243	5400.00/GW-243	-
URANIUM FLUOROMETRIC, mg/L	158.00/GW-103	87.10/GW-243	60.50/GW-243	38.90/GW-243	34.90/GW-243	44.00/GW-243	36.00/GW-243
DISSOLVED URANIUM FLUOROMETRIC, mg/L	159.00/GW-103	78.80/GW-243	52.60/GW-243	45.90/GW-243	35.60/GW-243	46.00/GW-243	34.20/GW-243
VANADIUM, mg/L	0.050/GW-226	0.210/GW-242	0.023/GW-257	0.054/GW-531	0.073/GW-086	0.072/GW-644	0.021/GW-364
DISSOLVED VANADIUM, mg/L	0.007/GW-101	0.009/GW-277	-	-	0.007/GW-520	2.10/GW-243	-
VINYL ACETATE, µg/L	1.00/GW-127	3.00/GW-007	7.00/GW-123	-	2.00/GW-043	6.00/GW-118	2.00/GW-370
	-	3.00/GW-010	-	-	2.00/GW-054	-	-
	-	3.00/GW-021	-	-	2.00/GW-056	-	-
	-	-	-	-	2.00/GW-057	-	-
	-	-	-	-	2.00/GW-063	-	-
	-	-	-	-	2.00/GW-227	-	-
	-	-	-	-	2.00/GW-309	-	-
	-	-	-	-	2.00/GW-313	-	-
	-	-	-	-	2.00/GW-364	-	-
	-	-	-	-	2.00/GW-520	-	-
	-	-	-	-	2.00/GW-602	-	-
VINYL CHLORIDE, µg/L	28.00/GW-229	3400.00/GW-014	2400.00/GW-027	510.00/GW-046	970.00/GW-624	180.00/GW-624	26.00/GW-053
XYLENES, µg/L	6.00/GW-229	-	-	-	-	-	-
ZINC, mg/L	5.10/GW-103	2.40/GW-276	0.430/GW-291	0.20/GW-531	4.60/GW-243	20.00/GW-615	4.00/GW-243
DISSOLVED ZINC, mg/L	8.60/GW-103	2.60/GW-243	0.140/GW-291	0.760/GW-308	2.60/GW-243	5.50/GW-243	4.20/GW-243
ZIRCONIUM, mg/L	0.051/GW-103	0.055/GW-242	0.020/GW-248	-	-	-	-
DISSOLVED ZIRCONIUM, mg/L	0.047/GW-103	0.028/GW-276	0.011/GW-325	-	-	-	-
	0.047/GW-104	-	-	-	-	-	-

*Data Source: H&R Technical Associates.

*Blank indicates chemical was not analyzed for or was never detected.

*Rads less than the counting error were considered not detected.

Note: Produced by programs maxmin.prp and maxass on 25JUN93 using preliminary OREIS data files.

Table A.4 Trace metal concentrations that exceed maximum contaminant levels in 1991

Metal	MCL/ Screening Level ^a	Well Number	Location ^b	1991 quarterly concentration ^c (mg/L)			
				1	2	3	4
Aluminum	8.3	GW-080	BG	<i>d</i>	16	<i>d</i>	<i>d</i>
		GW-086	OLF	<i>d</i>	11	<i>d</i>	<i>d</i>
		GW-243	S3	750	NS ^e	790	790
		GW-364	OLF	24	13	<i>d</i>	<i>d</i>
		GW-531	OLF	26	13	NS	NS
		GW-623	BG	<i>d</i>	21	<i>d</i>	<i>d</i>
		GW-644	OLF	<i>d</i>	<i>d</i>	<i>d</i>	38
		GW-655	BG	<i>d</i>	<i>d</i>	13	<i>d</i>
Barium	1.0	GW-101	S3	<i>d</i>	2.4	NS ^e	NS
		GW-122	S3	8.2	8.4	NS	NS
		GW-243	S3	10	NS	8.3	5.3
		GW-526	S3	7.8	7.9	9	<i>d</i>
		GW-615	S3	360	390	390	380
		GW-537	OLF	2	1.8	2.1	<i>d</i>
		GW-287	BG	NS	NS	1.6	<i>d</i>
Beryllium	0.0066	GW-119	BG	<i>d</i>	<i>d</i>	<i>d</i>	0.03
		GW-243	S3	0.058	<i>d</i>	0.08	0.066
		GW-615	S3	0.03	0.03	0.03	0.3
Boron	1.1	GW-052	BG	1.3	NS	NS	NS
		GW-056	BG	<i>d</i>	1.2	<i>d</i>	<i>d</i>
		GW-125	S3	<i>d</i>	<i>d</i>	<i>d</i>	1.4
		GW-225	OLF	<i>d</i>	<i>d</i>	1.3	<i>d</i>
		GW-227	OLF	<i>d</i>	<i>d</i>	1.4	<i>d</i>
		GW-243	S3	3.2	NS	1.5	<i>d</i>
		GW-291	BG	2.1	4.2	NS	NS
		GW-615	S3	1.4	<i>d</i>	<i>d</i>	4.4
		GW-684	EXP	NS	1.4	<i>d</i>	<i>d</i>
		GW-705	EXP	NS	2.9	2.2	2.3
Cadmium	0.01	BCK 9.40	EXP	<i>d</i>	<i>d</i>	1.4	<i>d</i>
		GW-243	S3	1.6	NS	4	2.2
		GW-615	S3	0.14	0.13	0.035	<i>d</i>
		GW-042	BG	0.023	<i>d</i>	0.058	0.02
Chromium	0.05	GW-080	BG	<i>d</i>	<i>d</i>	<i>d</i>	0.011
		GW-243	S3	0.31	NS	0.31	0.19
		GW-615	S3	<i>d</i>	0.17	<i>d</i>	<i>d</i>
		GW-063	OLF	0.13	<i>d</i>	<i>d</i>	<i>d</i>
		GW-644	OLF	<i>d</i>	<i>d</i>	<i>d</i>	0.44
		GW-053	BG	<i>d</i>	<i>d</i>	0.44	<i>d</i>
		GW-057	BG	<i>d</i>	0.71	NS	NS
		GW-080	BG	<i>d</i>	<i>d</i>	<i>d</i>	0.28
		GW-621	BG	<i>d</i>	0.063	0.095	0.13
		GW-623	BG	0.25	0.44	<i>d</i>	<i>d</i>

Table A.4 (continued)

Metal	MCL/ Screening Level ^a	Well Number	Location ^b	1991 quarterly concentration ^c (mg/L)			
				1	2	3	4
Cobalt	0.012	GW-086	OLF	0.023	0.019	NS	NS
		GW-118	BG	<i>d</i>	<i>d</i>	0.05	0.05
		GW-119	BG	<i>d</i>	<i>d</i>	0.05	0.05
		GW-226	OLF	0.028	0.14	NS	NS
		GW-243	S3	1.3	NS	1.3	1.8
		GW-364	OLF	0.017	<i>d</i>	<i>d</i>	<i>d</i>
		GW-526	S3	<i>d</i>	<i>d</i>	0.05	0.05
		GW-531	OLF	0.018	<i>d</i>	<i>d</i>	<i>d</i>
		GW-537	OLF	<i>d</i>	<i>d</i>	0.05	<i>d</i>
		GW-615	S3	0.5	0.5	0.5	5
		GW-644	OLF	<i>d</i>	<i>d</i>	<i>d</i>	0.038
		GW-655	BG	<i>d</i>	<i>d</i>	0.05	<i>d</i>
		GW-705	EXP	NS	0.05	<i>d</i>	<i>d</i>
Copper	0.44	GW-080	BG	<i>d</i>	<i>d</i>	<i>d</i>	0.7
		GW-243	S3	1.4	NS	0.9	1.2
		GW-615	S3	1.6	0.77	0.4	4
		GW-705	EXP	NS	0.7	<i>d</i>	<i>d</i>
Iron	13.91	GW-053	BG	<i>d</i>	<i>d</i>	16	<i>d</i>
		GW-080	BG	<i>d</i>	17	<i>d</i>	<i>d</i>
		GW-086	OLF	<i>d</i>	16	NS	NS
		GW-118	BG	<i>d</i>	24	28	32
		GW-119	BG	<i>d</i>	20	<i>d</i>	<i>d</i>
		GW-163	BG	<i>d</i>	14	NS	NS
		GW-226	OLF	20	82	NS	NS
		GW-343	BG	<i>d</i>	<i>d</i>	<i>d</i>	110
		GW-364	OLF	31	19	<i>d</i>	<i>d</i>
		GW-531	OLF	32	14	NS	NS
		GW-615	S3	20	25	15	<i>d</i>
		GW-623	BG	<i>d</i>	17	<i>d</i>	<i>d</i>
		GW-644	OLF	<i>d</i>	<i>d</i>	<i>d</i>	74
		GW-705	EXP	NS	230	16	<i>d</i>
		GW-710	EXP	NS	NS	NS	14
		GW-711	EXP	NS	NS	NS	15
Lead	0.05	GW-615	S3	<i>d</i>	1.3	<i>d</i>	<i>d</i>
		GW-005	OLF	0.079	<i>d</i>	NS	NS
		GW-520		0.057	<i>d</i>	<i>d</i>	<i>d</i>
		GW-531	OLF	0.066	<i>d</i>	NS	NS
		GW-644	OLF	<i>d</i>	<i>d</i>	<i>d</i>	0.16
		GW-053	BG	<i>d</i>	<i>d</i>	0.058	<i>d</i>
		GW-054	BG	<i>d</i>	<i>d</i>	<i>d</i>	0.073
		GW-080	BG	<i>d</i>	<i>d</i>	<i>d</i>	0.21
		GW-623	BG	0.074	0.56	<i>d</i>	<i>d</i>
		GW-705	EXP	NS	0.25	<i>d</i>	<i>d</i>

Table A.4 (continued)

Metal	MCL/ Screening Level ^a	Well Number	Location ^b	1991 quarterly concentration ^c (mg/L)			
				1	2	3	4
Manganese	2.4	GW-101	S3	<i>d</i>	6.2	NS	NS
		GW-226	OLF	13	16	NS	NS
		GW-243	S3	200	NS	210	210
		GW-309	RS	3.1	3.4	3.6	2.4
		GW-531	OLF	2.5	<i>d</i>	NS	NS
		GW-615	S3	21	20	20	24
Mercury	0.002	GW-243	S3	0.071	NS	0.0023	
		GW-005	OLF	0.0097	<i>d</i>	NS	<i>d</i>
Molybdenum	0.023	GW-117	BG	0.027	0.031	0.028	0.037
		GW-118	BG	<i>d</i>	<i>d</i>	0.1	0.1
		GW-119	BG	<i>d</i>	<i>d</i>	0.1	1.0
		GW-243	S3	1.0	NS	1.0	1.0
		GW-348	S3	NS	0.049	<i>d</i>	<i>d</i>
		GW-526	S3	<i>d</i>	<i>d</i>	0.1	0.1
		GW-537	OLF	<i>d</i>	<i>d</i>	0.1	<i>d</i>
		GW-615	S3	1.0	1.0	1.0	1.0
		GW-655	BG	<i>d</i>	<i>d</i>	0.1	<i>d</i>
		GW-695	EXP	NS	0.092	0.072	0.044
Nickel	0.18	GW-705	EXP	NS	0.1	<i>d</i>	<i>d</i>
		GW-119	BG	<i>d</i>	<i>d</i>	<i>d</i>	1.0
		GW-226	OLF	<i>d</i>	0.19	NS	NS
		GW-243	S3	19	NS	20	19
		GW-615	S3	1.0	1.0	1.0	1.0
		GW-705	EXP	NS	0.19	<i>d</i>	<i>d</i>
Strontium	0.88	GW-069	BG	0.97	0.91	<i>d</i>	<i>d</i>
		GW-101	S3	1.1	6.6	NS	NS
		GW-118	BG	2.7	2.2	1.9	<i>d</i>
		GW-119	BG	1.2	1.1	0.94	<i>d</i>
		GW-122	S3	19	24	NS	NS
		GW-211	EXP	3.2	3.4	NS	NS
		GW-225	OLF	1.2	1.4	1.3	1.0
		GW-243	S3	12	NS	12	11
		GW-344	BG	1.7	1.8	1.6	1.5
		GW-371	BG	NS	NS	1.6	1.5
		GW-526	S3	10	11	12	1.1
		GW-537	OLF	2.4	2.3	2.7	<i>d</i>
		GW-601	OLF	1.6	<i>d</i>	1.6	1.4
		GW-602	OLF	1.9	2.0	2.1	2.0
		GW-615	S3	320	360	370	340
		GW-623	BG	<i>d</i>	2.2	<i>d</i>	<i>d</i>
		GW-644	OLF	3.5	2.8	4.1	3.5
		GW-647	OLF	1.3	1.2	1.4	1.3
		GW-710	EXP	NS	NS	NS	8.9
		GW-711	EXP	NS	NS	NS	12
		GW-712	EXP	NS	NS	NS	2.7

Table A.4 (continued)

Metal	MCL/ Screening Level ^a	Well Number	Location ^b	1991 quarterly concentration ^c (mg/L)			
				1	2	3	4
Thorium	<0.2	GW-118	BG	<i>d</i>	<i>d</i>	2	2
		GW-119	BG	<i>d</i>	<i>d</i>	2	2
		GW-243	S3	20	NS	20	2
		GW-526	S3	<i>d</i>	<i>d</i>	2	2
		GW-537	OLF	<i>d</i>	<i>d</i>	2	<i>d</i>
		GW-615	S3	20	20	20	20
		GW-655	BG	<i>d</i>	<i>d</i>	2	<i>d</i>
		GW-705	EXP	NS	NS	2	<i>d</i>
		GW-710	EXP	NS	NS	NS	0.4
Uranium	0.01	GW-005	OLF	0.062	0.022	NS	NS
		GW-052	BG	0.061	NS	NS	NS
		GW-058	BG	0.028	<i>d</i>	0.016	0.032
		GW-061	BG	0.025	0.025	0.08	0.034
		GW-101	S3	0.044	0.045	NS	NS
		GW-226	OLF	0.088	0.056	NS	NS
		GW-227	OLF	0.118	0.085	0.034	0.024
		GW-243	S3	36.9	NS	44	40
		GW-615	S3	0.414	0.35	0.38	0.38
		GW-621	BG	<i>d</i>	<i>d</i>	0.018	<i>d</i>
		GW-654	BG	<i>d</i>	<i>d</i>	<i>d</i>	0.174
		GW-683	EXP	NS	0.039	0.088	0.032
		GW-684	EXP	NS	0.038	0.081	0.032
		GW-694	EXP	NS	0.047	0.23	0.139
		GW-706	EXP	NS	<i>d</i>	0.11	0.13
		SS-1	EXP	0.029	0.029	0.04	0.047
		SS-4	EXP	0.04	0.041	0.09	0.067
		SS-5	EXP	0.032	0.039	0.061	NS
		BCK 0.63	EXP	0.02	0.02	0.036	0.042
		BCK 4.55	EXP	0.024	0.023	0.04	0.056
		BCK 9.40	EXP	0.098	0.081	0.1	0.12
		BCK 11.97	EXP	0.166	0.147	0.15	0.13
Vanadium	0.064	GW-119	BG	<i>d</i>	<i>d</i>	<i>d</i>	0.5
		GW-243	S3	0.5	NS	0.5	0.5
		GW-615	S3	0.5	0.5	0.5	5
		GW-644	OLF	<i>d</i>	<i>d</i>	<i>d</i>	0.072

Table A.4 (continued)

Metal	MCL/ Screening Level ^a	Well Number	Location ^b	1991 quarterly concentration ^c (mg/L)			
				1	2	3	4
Zinc	0.14	GW-080	BG	<i>d</i>	<i>d</i>	<i>d</i>	0.17
		GW-119	BG	<i>d</i>	<i>d</i>	<i>d</i>	0.63
		GW-210	EXP	2.1	5.1	NS	NS
		GW-243	S3	3.1	NS	3.3	3.2
		GW-364	OLF	0.17	<i>d</i>	<i>d</i>	<i>d</i>
		GW-366	OLF	0.3	0.18	<i>d</i>	<i>d</i>
		GW-535	OLF	<i>d</i>	0.26	NS	NS
		GW-615	S3	<i>d</i>	0.96	0.2	20
		GW-621	BG	<i>d</i>	<i>d</i>	<i>d</i>	0.21
		GW-623	BG	0.17	1.2	<i>d</i>	<i>d</i>
		GW-644	OLF	<i>d</i>	<i>d</i>	<i>d</i>	0.23
		GW-705	EXP	NS	0.52	<i>d</i>	<i>d</i>

^aMaximum contaminant level (Mg/L); values represent the maximum total concentration (in mg/L) that would be expected in uncontaminated, unfiltered groundwater samples collected from monitoring wells located upgradient from waste management sites at the Y-12 Plant.

^bLocation abbreviations:

BCK = Bear Creek Kilometer

BG = Bear Creek Burial Grounds

EXP = exit pathway (Maynardville Limestone and Bear Creek)

OLF = Oil Landfarm

RS = Rust Spoil Area

S3 = S-3 Site

SPI = Spoil Area I

^cTotal (unfiltered) concentrations.

^dLess than the Maximum Contaminant Level

*NS = Not sampled

Source: HSW 1992

Table A5. Nitrate concentrations that exceed 10 mg/L in 1991^a

Sample Point ^b	Location ^c	Nitrate concentration (as N) (mg/L) ^d	
		1990	1991
GW-243	S3	6230	7322
GW-615	S3	9690	6758
GW-101	S3	2200	1967
GW-537	OLF	819	1321
GW-526	S3	845	786
GW-616	S3	274	492
GW-122	S3	770	439
GW-085	OLF	185	139
GW-345	S3	398	85
GW-225	OLF	97	82
GW-601	OLF	29	66
GW-706	EXP	NS	43
GW-694	EXP	NS	30
GW-227	OLF	17	25
GW-315	SPI	16	16
GW-309	RS	18	15
GW-683	EXP	NS	13
GW-052	BG	28	12
GW-307	RS	18	12
GW-369	OLF	11	12
GW-061	BG	11	11
GW-684	EXP	NS	11
SS-1	EXP	89	47
SS-4	EXP	31	16
SS-5	EXP	29	10
BCK 11.97	EXP	308	68
BCK 9.40	EXP	31	18

^aMaximum Contaminant Level (MCL) for drinking water^bAbbreviations:

BCK = Bear Creek Kilometer (Surface-water Sampling Station)

SS = Spring

^cLocation abbreviations:

BG = Bear Creek Burial Grounds WMA

EXP = Exit pathway (Maynardville Limestone and Bear Creek)

OLF = Oil Landfarm WMA

RS = Rust Soil Area

S3 = S-3 Site

SPI = Spoil Area I

^dAnnual Average nitrate concentration (as N) in milligrams per liter (mg/L); NS = Not sampled.

Source: HSW 1992.

Table A.6 Average VOC concentrations in groundwater for 1991

Analyte	Average VOC concentration (µg/L)									
	GW-040 ^a BG ^b	GW-042 ^a BG	GW-053 ^a BG	GW-056 ^a BG	GW-063 ^a OLF ^b	GW-064 ^a OLF	GW-071 ^a BG	GW-072 ^a BG		
Acetone	0 ^c	0	0	0	0	0	29	0		
Benzene	0	0	0.4	0	0	0	275	0		
Bromoform	0	0	0	0	0	0	d	0		
Carbon Tetrachloride	0	0	0	0	0.8	3.5	d	0		
Chlorobenzene	0	0	0	0	0	0	d	0		
Chloroethane	0	0	0	0	0	0	d	0		
Chloroform	0	0	0	0	0.4	0	2	0		
1,1-Dichloroethane	0	0	13.5	0	0	0	625	14		
1,2-Dichloroethane	0	0	0.5	0	0	0	d	0		
1,1-Dichloroethene	0	0	3	0	0	0	15	0		
1,2-Dichloroethene	0	0	17.8	1	0	9	42.5	0		
4-Methyl-2-Pentanone	0	0	0	0	0	0	d	0		
Methylene Chloride	0	0	0	0	0	0	d	1.5		
Tetrachloroethene	0	0	0	0	0	0	440	0		
Toluene	0.4	0	0	0	0	0	d	0		
1,1,1-Trichloroethane	0	3.7	0.5	0	0	1	220	0		
Trichloroethene	0	0	0	0	28.5	97.7	450	0		
Vinyl Acetate	0	0	0	0	0	0	0	0		
Vinyl Chloride	0	0	14.8	0	0	0	d	0		
Summed VOCs	0.4	3.7	50.5	1	29.7	111.2	(2,098.5) ^c	15.9		

Table A.6 (continued)

Analyte	Average VOC concentration ($\mu\text{g/L}$)							
	GW-082 ^a BG	GW-089 ^a BG	GW-117 ^a BG	GW-118 ^a BG	GW-119 ^a BG	GW-122 ^a S3 ^b	GW-123 ^a S3	GW-125 ^a S3
Acetone	0 ^c	0	0	0	0	0	0	11.5
Benzene	0	0	0	0.7	0	0	0.2	0
Bromoform	0	0	0	0	0	0	0	0
Carbon Tetrachloride	0	0	0	0	0	0	0	0
Chlorobenzene	0	0	0	0	0	0	0	0
Chloroethane	0	11.8	0	0	0	0	0	0
Chloroform	0	0	0	0	0	0	0	0
1,1-Dichloroethane	0	8.5	1.8	0	5.2	0	0	0
1,2-Dichloroethane	0	0	0	0	0	0	0	0
1,1-Dichloroethene	0	0	0	0	0	0	0	0
1,2-Dichloroethene	37.5	0	0	0	0	0	0	0
4-Methyl-2-Pentanone	0	0	0	0	0	0	0	0
Methylene Chloride	0	0	0	0	0	0	0	0
Tetrachloroethene	0	0	13.8	0	2.2	0.5	0	0
Toluene	0	0	0	0	0	0	0	0
1,1,1-Trichloroethane	0	0	0	0	0	0	0	0
Trichloroethene	0	0	4	0	0	0	0	0
Vinyl Acetate	0	0	0	2	0	0	0	0
Vinyl Chloride	0	2.7	0	0	0	0	0	0
Summed VOCs	37.5	23	19.6	2.7	7.4	0.5	0.2	11.5

Table A.6 (continued)

Analyte	Average VOC concentration ($\mu\text{g/L}$)							
	GW-225 ^a OLF ^b	GW-226 ^a OLF	GW-227 ^a OLF	GW-243 ^a S3	GW-291 ^a BG	GW-306 ^a RS ^b	GW-307 ^a RS	GW-308 ^a RS
Acetone	21	0	0	950	0 ^c	0	0	0
Benzene	<i>d</i>	0.7	0	<i>d</i>	0	0	0	0
Bromoform	<i>d</i>	0	0	<i>d</i>	0	0	0	0
Carbon Tetrachloride	6	0	0	<i>d</i>	0	1.5	2	2.5
Chlorobenzene	<i>d</i>	7	0	<i>d</i>	0	0	0	0
Chloroethane	<i>d</i>	2	0	<i>d</i>	0	0	0	0
Chloroform	3.3	0	0	35.5	0	0	0	0
1,1-Dichloroethane	<i>d</i>	1.5	0	<i>d</i>	0	0	3.5	2
1,2-Dichloroethane	<i>d</i>	0	0	<i>d</i>	<i>d</i>	0	0	0
1,1,1-Dichloroethene	4.2	1.5	0	<i>d</i>	0	0	0	0
1,2-Dichloroethene	<i>d</i>	32.5	0	<i>d</i>	11	8.5	8	5.5
4-Methyl-2-Pentanone	<i>d</i>	0	0	<i>d</i>	0	4	0	0
Methylene Chloride	32	0	0	260	0	0	0	0
Tetrachloroethene	4.5	0	0	6,066.7	620	0	0.5	0.9
Toluene	6	0	0	35	0	0	0	0
1,1,1-Trichloroethane	2.5	0	0	25	3	2	2	2.5
Trichloroethene	355	4.5	7.7	<i>d</i>	90.5	68	45.5	45.5
Vinyl Acetate	<i>d</i>	0	0	<i>d</i>	0	0	0	0
Vinyl Chloride	<i>d</i>	0	0	<i>d</i>	0	0	0	0
Summed VOCs	(434.5) ^f	49.7	7.7	(7,372.2)	724.5	84	61.5	58.9

Table A.6 (continued)

Analyte	Average VOC concentration ($\mu\text{g/L}$)									
	GW-309 ^a RS	GW-310 ^a RS	GW-311 ^a RS	GW-312 ^a RS	GW-313 ^a SPI ^b	GW-314 ^a SPI	GW-315 ^a SPI	GW-348 ^a S3 ^b		
Acetone	0 ^c	0	0	0	0	0	0	0		
Benzene	0	0	0	0	0	0	0	0		
Bromoform	0	0	0	0	0	0	0	0		
Carbon Tetrachloride	0	0	3	0	0	0	0	0		
Chlorobenzene	0	0	0	0	0	0	0	0		
Chloroethane	0	0	0	0	0	0	0	0		
Chloroform	0	0	0.5	0	0	0	0	0		
1,1-Dichloroethane	0	0	0	0	0	0	0	0		
1,2-Dichloroethane	0	0	0	0	0	0	0	0		
1,1,1-Dichloroethene	0	0	0	0	0	0	0	0		
1,2-Dichloroethene	7.7	27	0	0	33.7	40.7	17.5	0		
4-Methyl-2-Pentanone	0	0	0	2.5	0	0	0	0		
Methylene Chloride	0	0	0	0	0	0	0	0		
Tetrachloroethene	1.3	3	0	0	11.3	15	23.8	0		
Toluene	0	0	0	0	0	0	0	0		
1,1,1-Trichloroethane	0	0	0	0	0	0	0	0		
Trichloroethene	9.8	50	28.5	70.5	5	5.2	9	0.2		
Vinyl Acetate	0	0	0	0	0	0	0	0		
Vinyl Chloride	0	0	0	0	0	0	0	0		
Summed VOCs	18.8	80	32	73	50	60.9	50.3	0.2		

Table A.6 (continued)

Analyte	Average VOC concentration (µg/L)								GW-623 ^a BG
	GW-364 ^a OLF	GW-365 ^a OLF	GW-366 ^a OLF	GW-367 ^a OLF	GW-369 ^a OLF	GW-601 ^a OLF	GW-615 ^a S3		
Acetone	0 ^c	0	0	0	0	0	120.5	0	
Benzene	0	0	0	0	0	0	0	0	
Bromoform	0	0	0	0.5	0	0	0	0	
Carbon Tetrachloride	0	0	0	0	0.5	4	0	0	
Chlorobenzene	0	0	0	0	0	0	0	0	
Chloroethane	0	0	0	0	0	0	0	17	
Chloroform	0	0	0	0	0.4	0	0	0	
1,1-Dichloroethane	4.5	4.7	0	0	0	0	0	1,495.2	
1,2-Dichloroethane	0	0	0	0	0	0	0	0	
1,1-Dichloroethene	4.5	13	0	0	0	0	0	290	
1,2-Dichloroethene	10.5	48.7	0	0	0	0.8	0	300.5	
4-Methyl-2-Pentanone	0	0	0	0	0	0	0	0	
Methylene Chloride	0	0	0	0	0	0	2	0	
Tetrachloroethene	0	1	0	0	0	0.5	0	10,450	
Toluene	0	0	0	0	0	0	0	226.7	
1,1,1-Trichloroethane	2	5.5	0	0	0	0.6	0	235	
Trichloroethene	13.8	28.3	0.3	18	43	162.5	0	6,775	
Vinyl Acetate	0	0	0	0	0	0	0	0	
Vinyl Chloride	0	1.3	0	0	0	0	0	80.5	
Summed VOCs	35.3	102.5	0.3	18.5	43.9	168.4	122.5	19,869.9	

Table A.6 (continued)

Analyte	Average VOC concentration ($\mu\text{g/L}$)							
	GW-624 ^a BG	GW-626 ^a BG	GW-627 ^a BG	GW-629 ^a BG	GW-653 ^a BG	GW-683 ^a EXP ^b	GW-684 ^a EXP	GW-685 ^a EXP
Acetone	0 ^c	0	0	0	0	0	0	0
Benzene	4	0	0	0	0	0.1	0	0
Bromoform	0	0	0	0	0	0	0	0
Carbon Tetrachloride	0	0	0	0	0	0	0	0
Chlorobenzene	0	0	0	0	0	0	0	0
Chloroethane	0	0	0	0	0	0	0	0
Chloroform	0	0	0	0	0	0	0	0
1,1-Dichloroethane	36	5	1	7	0	0	0	0
1,2-Dichloroethane	4	1.5	0	0	0	0	0	0
1,1,1-Dichloroethene	12	88	0	0.5	0	0	0	0
1,2-Dichloroethene	565	123	0	0	9.3	0	0	2.7
4-Methyl-2-Pentanone	0	0	0	0	0	0	0	0
Methylene Chloride	0	0	0	0	0	0	0	0
Tetrachloroethene	105.5	185.8	5.5	92.5	3	0	0	0.2
Toluene	0	0	0	0	0	0	0	0
1,1,1-Trichloroethane	10.5	74.2	0	0	0	0	0	0
Trichloroethene	114	232.3	0	9.5	0.3	0	0.2	0.5
Vinyl Acetate	0	0	0	0	0	0	0	0
Vinyl Chloride	104.5	0	0	0	0	0	0	0
Summed VOCs	955.5	709.8	6.5	109.5	12.6	0.1	0.2	3.4

Table A.6 (continued)

Analyte	Average VOC concentration ($\mu\text{g/L}$)									
	GW-694 ^a EXP	GW-695 ^a EXP	GW-703 ^a EXP	GW-704 ^a EXP	GW-706 ^a EXP	BCK 9.44 ^a EXP	SS-1 ^a EXP	SS-4 ^a EXP		
Acetone	60	14	0 ^c	0	0	0	0	0		0
Benzene	0.3	0	0	0	0	0	0	0		0
Bromoform	0	0	0	0.3	0	0	0	0		0
Carbon Tetrachloride	0.3	0	0	1.2	0	0	0	0		0
Chlorobenzene	0.3	0	0	0	0	0	0	0		0
Chloroethane	0	0	0	0	0	0	0	0		0
Chloroform	0	0	0	0.1	0	0	0	0		0
1,1-Dichloroethane	0.3	0	0	0.3	0	0	0	0		0
1,2-Dichloroethane	0	0	0	0	0	0	0	0		0
1,1-Dichloroethene	2	0	0	4.7	0	0	0	0		0
1,2-Dichloroethene	12.7	0	0	0.7	3.7	6.8	0.7	0		0
4-Methyl-2-Pentanone	0	0	1.7	0	0	0	0	0		0
Methylene Chloride	0	0	0	0	0	0	0	0		0
Tetrachloroethene	0.7	0	0	0	0	0.6	1.5	6.8		0
Toluene	0	0	0	0	0	0	0	0		0
1,1,1-Trichloroethane	0.7	0	0	1	0	0	0	0		0
Trichloroethene	18.3	1.7	23.7	69.7	2.3	0	1.3	0		0
Vinyl Acetate	0	0	0	0	0	0	0	0		0
Vinyl Chloride	0	0	0	0	0	0	0	0		0
Summed VOCs	95.6	15.7	25.4	78	6	7.4	3.5	6.8		

(Footnotes follow on next page.)

Table A.6 (continued)

^aWell number^bLocation abbreviations:

BG = Bear Creek Burial Grounds Waste Management Area

EXP = exit pathway (Maynardville Limestone and Bear Creek)

OLF = Oil Landfarm Waste Management Area

RS = Rust Spoil Area

S3 = S-3 Site

SPI = Spoil Area I

^c0 = Not detected, anomalous, or false positive result^dNot detected at an elevated analytical detection limit^e() = Data considered qualitative because of elevated analytical detection limits

Source: HSW 1992

Table A.7 Mean gross alpha activities that exceed 15 pCi/L in 1991

Sample point ^a	Location ^b	Mean gross alpha activity (pCi/L) ^c	
		1990	1991
GW-243	S3	8,205 ± 386	10,115 ± 332
GW-615	S3	307 ± 79	477 ± 90
GW-101	S3	96 ± 49	72 ± 37 ^e
GW-005	OLF	31 ± 2	32 ± 2 ^e
GW-226	OLF	20 ± 2	26 ± 2 ^e
GW-227	OLF	25 ± 2	16 ± 2
GW-052	BG	40 ± 4	31 ± 4
GW-061	BG	<i>d</i>	16 ± 2
GW-694	EXP	NS	43 ± 3
GW-710	EXP	NS	32 ± 21
GW-706	EXP	NS	29 ± 3
GW-711	EXP	NS	24 ± 22
GW-683	EXP	NS	20 ± 2
SS-1	EXP	31 ± 4	19 ± 2
SS-4	EXP	53 ± 5	25 ± 2
SS-5	EXP	53 ± 5	16 ± 2
BCK 0.63	EXP	18 ± 3	16 ± 2
BCK 4.55	EXP	16 ± 3	16 ± 2
BCK 9.40	EXP	43 ± 5	49 ± 3
BCK 11.97	EXP	77 ± 6	57 ± 3

^aAbbreviations:

BCK = Bear Creek Kilometer (Surface-water Sampling Station)

SS = Spring

^bLocation abbreviations:

BG = Bear Creek Burial Grounds Waste Management Area

EXP = Exit pathway (Maynardville Limestone and Bear Creek)

OLF = Oil Landfarm WMA

S3 = S-3 Site

^cNS = Not sampled^dLess than 15 pCi/L.^eMean activity calculated from 1990 and 1991 data

Source: HSW 1992

Table A.8 Mean gross beta activities that exceed 50 pCi/L in 1991

Sample Point ^a	Location ^b	Mean gross beta activity (pCi/L) ^c	
		1990	1991
GW-243	S3	60,750 $\pm$ 1,345	45,068 $\pm$ 592
GW-615	S3	554 $\pm$ 173	868 $\pm$ 162
GW-345	S3	244 $\pm$ 6	50 $\pm$ 4
GW-315	SPI	55 $\pm$ 3	73 $\pm$ 3
GW-537	OLF	354 $\pm$ 48	233 $\pm$ 18
GW-085	OLF	57 $\pm$ 3	64 $\pm$ 3
GW-227	OLF	69 $\pm$ 3	62 $\pm$ 3
GW-052	BG	120 $\pm$ 8	51 $\pm$ 5
GW-694	EXP	NS	108 $\pm$ 4
GW-706	EXP	NS	95 $\pm$ 4
GW-683	EXP	NS	53 $\pm$ 3
SS-1	EXP	177 $\pm$ 9	106 $\pm$ 4
SS-4	EXP	125 $\pm$ 8	60 $\pm$ 3
BCK 11.97	EXP	610 $\pm$ 16	235 $\pm$ 5
BCK 9.40	EXP	159 $\pm$ 9	82 $\pm$ 3

^aAbbreviations:

BCK = Bear Creek Kilometer (Surface-water Sampling Station)

SS = Spring

^bLocation Abbreviations:

BG = Bear Creek Burial Grounds Waste Management Area

EXP = exit pathway (Maynardville Limestone and Bear Creek)

OLF = Oil Landfarm Waste Management Area

S3 = S-3 Site

SPI = Spoil Area I

^cNS = Not sampled

Source: HSW 1992

APPENDIX B

REQUIRED DETECTION LIMITS

Table B.1. Contract required detection limits—inorganics

Element	Water ($\mu\text{g/L}$)	Soil/Sediment (mg/kg)
Aluminum (Al)	80	20
Antimony (Sb)	2	6
Arsenic (As)	2	1
Barium (Ba)	5	20
Beryllium (Be)	1	0.5
Cadmium (Cd)	2	0.5
Calcium (Ca)	500	500
Chromium (Cr)	8	1
Cobalt (Co)	6	5
Copper (Cu)	6	2.5
Iron (Fe)	80	10
Lead (Pb)	2	0.5
Magnesium (Mg)	100	500
Manganese (Mn)	5	1.5
Mercury (Hg)	0.1	0.1
Nickel (Ni)	15	4
Potassium (K)	2,000	500
Selenium (Se)	2	0.5
Silver (Ag)	3	1
Sodium (Na)	1,000	500
Thallium (Tl)	2	1
Vanadium (V)	5	5
Zinc (Zn)	20	2

Table B.2. Practical quantitation limits—volatile organics

Compound	Groundwater ($\mu\text{g/L}$)	Low soil/sediment ($\mu\text{g/kg}$)
Chloromethane	5	5
Bromomethane	5	5
Vinyl chloride	5	5
Chloroethane	5	5
Methylene chloride	5	5
Acetone	5	5
Carbon disulfide	5	5
1,1-Dichloroethene	5	5
1,1-Dichloroethane	5	5
1,2-Dichloroethene (total)	5	5
Chloroform	5	5
1,2-Dichloroethane	5	5
2-Butanone (MEK)	5	5
1,1,1-Trichloroethane	5	5
Carbon tetrachloride	5	5
Bromodichloromethane	5	5
1,1,2,2-Tetrachloroethane	5	5
1,2-Dichloropropane	5	5
cis-1,3-Dichloropropene	5	5
Trichloroethene	5	5
1,1,2-Trichloroethane	5	5
Dibromochloromethane	5	5
Benzene	5	5
trans-1,3-Dichloropropene	5	5
Bromoform	5	5
2-Hexanone	5	5
4-Methyl-2-pentanone (MIBK)	5	5
Tetrachloroethene	5	5
Toluene	5	5
Chlorobenzene	5	5
Ethylbenzene	5	5
Styrene	5	5
Xylenes, total	5	5

Table B.3. Energy Systems environmental analysis procedures for biota

Parameter	Energy Systems procedure	EPA method	Lowest concentration reported (LCR) (mg/kg)
Gamma-ray spectrometry of fish	EC-4150		Procedure in preparation ^a
Metals in Fish, AA	EC-4250	600-4-81/055 ^b	See below
Pu isotopes in fish	EC-4360		20 pCi/kg (ORNL) 4 pCi/Kg
PCBs in fish and animal tissue	EC-4400	600-4-81/055 ^b	0.1
⁹⁰ Sr in fish	EC-4600		100 pCi/kg (ORNL) 200 pCi/kg
⁹⁹ Tc in fish	EC-4630		Procedure in preparation ^a
U (total) in vegetation	EC-4700		0.5
U isotopes in animal tissue	EC-4800		Procedure in preparation ^a
Procedures for atomic absorption			
Metals in fish, furnace AA	EC-4250	600/4-81-055 ^a	
Cd			0.01
Cr			0.05
Cu			0.10
Ni			0.50
Pb			0.05

^aEnvironmental Monitoring Plan for the Oak Ridge Reservation, Energy Systems, April 1992.

^bInterim Methods for the Sampling and Analysis of Priority Pollutants in Sediments and Fish Tissue," EPA, Rev. October 1980.

APPENDIX C

**ENVIRONMENTAL RESTORATION PROGRAM
SITE-SPECIFIC HEALTH AND SAFETY PLAN**

SITE-SPECIFIC HEALTH AND SAFETY PLAN
FOR

Site Name: Bear Creek Valley Operable Unit 4

Prepared by: _____
(Signature) (Date)

Reviewed by: _____
Environmental Restoration (Signature) (Date)

Reviewed by: _____
Health Physics (Signature) (Date)

Reviewed by: _____
Industrial Hygiene (Signature) (Date)

Reviewed by: _____
Industrial Safety (Signature) (Date)

Approved by: _____
HAZWOPER Coordinator (Signature) (Date)

1. SITE DESCRIPTION

The Bear Creek Valley (BCV) Operable Unit 4 (OU 4) Site is located within the U. S. Department of Energy Oak Ridge Reservation in Anderson County, Tennessee. (*See Site Map*).

The BCV OU 4 Site comprises all groundwater in BCV. The BCV OU 4 Site receives contaminants from nine source areas (formerly identified as SWMUs) associated with the Y-12 Plant, including two construction spoil areas, liquid waste percolation ponds, a sanitary landfill, an oil landform, a hazardous-chemical disposal/storage area, a solid-waste burial area, and two ponds used to capture any oil that might seep from the burial grounds. In addition, ORNL has listed a contaminated-metal scrapyard as existing within the Bear Creek watershed. The area is bounded to the north and south by Pine Ridge and Chestnut Ridge, respectively, and has an elevation of 975 ± 50 ft above MSL. It is underlain by the Maynardville Limestone and Nolichucky Shale formations. Environs surrounding the BCV OU 4 include hickory forest, grasslands, devegetated areas, and developed locations, with the forests serving as habitat for many species. Weather patterns in the area are temperate, with warm, humid summers and cool winters. Average annual temperature is approximately 58°.

2. SITE HISTORY

Nine source areas exist within the confines of Bear Creek Valley and have contributed contaminants to the BCV OU 4 Site. Because each SWMU operated for different operational periods and were each used for the disposal of various waste materials, a brief synopsis of each can be found in Sects. 2.2 and 2.3 of the RI Plan.

While the facilities are, or were, the original sources of contamination, secondary sources now exist in the soils and aquifer matrix as well as in sediments and floodplain deposits of Bear Creek. These secondary sources may continue to release contaminants into Bear Creek surface water and groundwater even after upstream releases from the SWMUs are eliminated.

An all inclusive list of contaminants of concern is not available; however, the following table represents the primary contaminants of concern historically identified that potentially are present within the nine source areas.

3. SITE MAP

T-004	S-3 Ponds
T-006	Oil Retention Pond #1
T-009	Oil Retention Pond #2
T-014	Oil Land Farm
D-101	Sanitary Landfill 1
D-106	Rust Spoil Area
D-107	Spoil Area 1
D-024	Burial Grounds
D-024+HC	Hazardous Chemical Disposal Area - Boneyard/Burnyard

Revision No.: _____
Revision Date: _____

C-5

C-6

Revision No.: _____
Revision Date: _____

Organics	Inorganics	Metals	Miscellaneous
tetrachloroethylene	nitrate	aluminum	gross alpha (U and Np-237)
trichloroethylene	sulfate	barium	gross beta (Tc-99 Sr-90 & H3)
1,2-dichloroethylene		cadmium	americium-241
1,1,1-trichloroethane		chromium	radium
1,1-dichloroethane		iron	strontium-89
1,1-dichloroethylene		mercury	
vinyl chloride		manganese	
acetone		lead	
chloroform		uranium	
2-butanone			
carbon tetrachloride			
methylene chloride			

4. HEALTH AND SAFETY HAZARD EVALUATION

[Place an X in each () to indicate presence of hazard]

4.1 Physical hazards

☒ Heat stress	☒ Cold stress	☐ Noise
☐ Confined space	☐ Enclosed space	☐ Heavy lifting
☒ Tripping/Falling	☒ High voltage	☐ High pressure water
☐ Oxygen deficient	☐ Explosive/flammable	☐ Vibration

4.2 Construction hazards

☐ Trenching	☐ Excavating	☐ Heavy equipment op.
☐ Demolition	☐ High Work	☐ Welding/Cutting
☐ Ladders	☐ _____	☐ _____

4.3 Chemical hazards

☒ Organic chemical	☒ Inorganic chemical	☒ Carcinogen
☐ Corrosive	☐ Reactive	☒ OSHA specific
☐ Mutagen	☐ Teratogen	substances

4.4 Ionizing radiological hazards

☐ Internal exposure	☒ External exposure

4.5 Nonionizing radiological hazards

☐ UV	☐ RF	☐ Microwave
☐ Laser		

4.6 Biological/Vector hazards

☒ Wildlife	☒ Plants	☐ Medical waste
☐ Bacterial	☒ Parasites	

5. PREVIOUS SAMPLING RESULTS

Contaminant	Source (Water, Sediment, Sludge, Soil, Air, etc.)	Quantity or Concentration
tetrachloroethylene	water	.005 (mg/L)
trichloroethylene	water	.005 (mg/L)
1,2-dichloroethylene	water	.005 (mg/L)
1,1,1-trichloroethane	sediment	38 ($\mu\text{g/kg}$)
1,1-dichloroethane	sediment	16 ($\mu\text{g/kg}$)
vinyl chloride	sediment	13 ($\mu\text{g/kg}$)
Acetone	soil	.49 (mg/kg)
chloroform	sediment	21 ($\mu\text{g/kg}$)
carbon tetrachloride	surface water	11 ($\mu\text{g/l}$)
methylene chloride	sediment	130 ($\mu\text{g/kg}$)
nitrate	water	1,950 (mg/L)
sulfate	water	109 (mg/L)
aluminum	sediment	78,000 ($\mu\text{g/g}$)
barium	sediment	1,500 ($\mu\text{g/g}$)
cadmium	sediment	70 ($\mu\text{g/g}$)
chromium	sediment	140 ($\mu\text{g/g}$)
iron	sediment	84,200 ($\mu\text{g/g}$)
mercury	sediment	20 ($\mu\text{g/g}$)
manganese	sediment	16,000 ($\mu\text{g/g}$)
lead	sediment	386 ($\mu\text{g/g}$)
uranium	sediment	315 ($\mu\text{g/g}$)
gross alpha (U and Np-237)	sediment	44 (pCi/g)
gross beta (Tc-99, Sr-90 and H3)	sediment	110 (pCi/g)
americium-241	sediment	.2 (pCi/g)
strontium-89	water	1.3 (mg/L)

6. CONTAMINANTS

- 6.1 Chemical:** tetrachloroethylene
PEL/TLV* : 25 ppm IDLH: 500 ppm
STEL: 200 ppm LEL: NA
Action level: Not given in research literature (NG)
Route of exposure: Inhalation, ingestion, contact
Monitoring equipment: PID/OVM
Symptoms/effects of exposure: Irritated eyes, nose and throat, nausea
- 6.2 Chemical:** Trichloroethylene
PEL/TLV* : 25 ppm IDLH: 1000 ppm
STEL: 200 ppm LEL: (77°F) 8%
Action level: NG
Route of exposure: Inhalation, ingestion, contact
Monitoring equipment: PID/OVM
Symptoms/effects of exposure: Irritated eyes, nausea, tremors
- 6.3 Chemical:** 1,2-dichloroethylene
PEL/TLV* : 200 ppm/200 ppm IDLH: 4000 ppm
STEL: NG LEL: 5.6%
Action level: NG
Route of exposure: Inhalation, ingestion, contact
Monitoring equipment: PID/OVM
Symptoms/effects of exposure: Irritated eyes, respiratory system, CNS
- 6.4 Chemical:** 1,1,1-trichloroethane
PEL/TLV* : 350 ppm IDLH: 1000 ppm
STEL: 450 ppm LEL: 7.5%
Action level: NG
Route of exposure: Inhalation, ingestion, contact
Monitoring equipment: PID/OVM
Symptoms/Effects of exposure: Irritated eyes, headaches, poor equi, CNS
- 6.5 Chemical:** 1,1-dichloroethane
PEL/TLV* : 100 ppm IDLH: 4000 ppm
STEL: 250 ppm LEL: 5.6%
Action level: NG
Route of exposure: Inhalation, ingestion, contact
Monitoring equipment: PID/OVM
Symptoms/Effects of exposure: Skin irritant, depression CNS

* OSHA, NIOSH, or ACGIH Standard, whichever is most restrictive

- 6.6 Chemical:** Vinyl chloride
PEL/TLV* : 5 ppm IDLH: NG
STEL: NG LEL: 3.6%
Action level: NG
Route of exposure: Inhalation
Monitoring Equipment: PID/OVM
Symptoms/Effects of exposure: Weakness, abdominal pain, bleeding
- 6.7 Chemical:** Chloroform
PEL/TLV* : 2 ppm IDLH: 1000 ppm
STEL: 2 ppm LEL: NA
Action level: NG
Route of exposure: Inhalation, ingestion, contact
Monitoring equipment: PID/OVM
Symptoms/Effects of exposure: Dizziness, nausea, irritates eyes and skin
- 6.8 Chemical:** Carbon tetrachloride
PEL/TLV* : 2 ppm IDLH: 300 ppm
STEL: 2 ppm LEL: NA
Action level: NG
Route of exposure: Inhalation, absorption, ingestion, contact
Monitoring equipment: PID/OVM
Symptoms/Effects of exposure: Nausea, vomiting, skin irritant, CNS
- 6.9 Chemical:** methylene chloride
PEL/TLV* : 500 ppm IDLH: 5000 ppm
STEL: NG LEL: 14%
Action level: NG
Route of exposure: Inhalation, ingestion, contact
Monitoring equipment: PID/OVM
Symptoms/Effects of exposure: Fatigue, weakness, sleepiness, nausea, irritates eyes and skin

* OSHA, NIOSH, or ACGIH Standard, whichever is most restrictive

- 6.10 Chemical: Nitrate**
PEL/TLV* : NG
STEL: NG
Action level: NG
Route of exposure: NG
Monitoring equipment:
Symptoms/Effects of exposure: NG
IDLH: NG
LEL: NG
- 6.11 Chemical: Barium**
PEL/TLV* : 0.5 mg/m³
STEL: NG
Action level: NG
Route of exposure: Inhalation, ingestion, contact
Monitoring equipment: Sampling pump and filter
Symptoms/Effects of exposure: Irritated eyes, skin, skin burns
IDLH: 1100 mg/m³
LEL: NA
- 6.12 Chemical: Cadmium**
PEL/TLV* : 0.1 mg/m³
STEL: NG
Action level: NG
Route of exposure: Inhalation, ingestion
Monitoring equipment: Sampling pump and filter
Symptoms/Effects of exposure: Coughing, chills, muscle aches
Special medical monitoring:
IDLH: 50 mg/m³
LEL: NA
- 6.13 Chemical: Chromium**
PEL/TLV* : 1 mg/m³
STEL: NG
Action level: NG
Route of exposure: Inhalation, ingestion
Monitoring equipment: Sampling pump and filter
Symptoms/Effects of exposure: Dermal sensitivity
Special medical monitoring:
IDLH: NG
LEL: NA
- 6.14 Chemical: Mercury**
PEL/TLV* : .005 mg/m³
STEL: NG
Action level: 0.025 mg/m³
Route of exposure: Inhalation, ingestion, skin or eye contact
Monitoring equipment: Jerome Mercury Analyzer
Symptoms/Effects of exposure: Cough, chest pain, indecision, irritability, weak, headache
Special medical monitoring: Urinalysis
IDLH: 10 mg/m³
LEL: NA

* OSHA, NIOSH, or ACGIH Standard, whichever is most restrictive

- 6.15 Chemical: Lead**
PEL/TLV* : 0.05 mg/m³ IDLH: 700 mg/m³
STEL: NG NA
Action level: NG
Route of exposure: Inhalation, ingestion, skin or eye contact.
Monitoring Equipment: Sampling pump and filter
Symptoms/Effects of exposure: Weakness, abdominal pain, irritates eyes, hypertension
Special medical monitoring: Bioassay
- 6.16 Chemical: Uranium**
PEL/TLV* : 0.5 mg/m³ IDLH: 20 mg/m³
STEL: NG LEL: Unknown
Action level: NG
Route of exposure: Inhalation, absorption, contact, ingestion
Monitoring equipment: Alpha particle detection meter
Symptoms/Effects of exposure: Irritated skin, eyes, nose, and throat, headache and irritability
Special medical monitoring: Whole-body dosimetry

* OSHA, NIOSH, or ACGIH Standard, whichever is most restrictive

7. TASK BREAKDOWN**7.1 Description: surface water sampling**

Level of Personal Protective Equipment: Primary: D Contingency Upgrade or downgrade as needed

Type of work: Intrusive (X) Nonintrusive (X)

Engineering controls: None required

Administrative controls: Occupational Safety and Health Administration 40-hr health and safety training, as specified in 29 *CFR* 1910.120, shall be required for all employees engaged in hazardous waste operations. Personnel will be required to have annual 8-hr refresher training courses. Managers and supervisors shall receive an additional 8 hours of instruction. All classroom training shall be supplemented with 24-hr on-site orientation and instruction under an experienced and qualified individual.

Personal Protective Equipment:

	Primary	Contingency
1. Respiratory protection: none required	Y() N(X)	Y() N()
2. Protective clothing: splashproof tyvek	Y(X) N()	Y() N()
3. Head protection: hardhat	Y(X) N()	Y() N()
4. Eye protection: safety glasses with side shields	Y(X) N()	Y() N()
5. Foot protection: steel-toed butyl rubber boots	Y(X) N()	Y() N()
6. Hand Protection: gloves - latex	Y(X) N()	Y() N()
7. Hearing protection: none required	Y() N(X)	Y() N()
8. Tape-up required: around boots and gloves	Y(X) N()	Y() N()

7.2 Description: groundwater sampling

Level of Personal Protective Equipment: Primary: D Contingency:

Type of work: Intrusive () Nonintrusive (X)

Engineering controls: None required

Administrative controls:

Occupational Safety and Health Administration 40-hr health and safety training, as specified in 29 *CFR* 1910.120, shall be required for all employees engaged in hazardous waste operations. Personnel will be required to have annual 8-hr refresher training courses. Managers and supervisors shall receive an additional 8 hours of instruction. All classroom training shall be supplemented with 24-hr on-site orientation and instruction under an experienced and qualified individual.

Personal Protective Equipment:

		<u>Primary</u>		<u>Contingency</u>	
1.	Respiratory protection: none required	Y()	N(x)	Y()	N()
2.	Protective clothing: splashproof tyvek	Y(x)	N()	Y()	N()
3.	Head protection: hardhat	Y(x)	N()	Y()	N()
4.	Eye protection: safety glasses with side shields	Y(x)	N()	Y()	N()
5.	Foot protection: steel-toed rubber boots	Y(x)	N()	Y()	N()
6.	Hand protection: gloves- latex	Y(x)	N()	Y()	N()
7.	Hearing protection: earplugs	Y(x)	N()	Y()	N()
8.	Tape-up required: none required	Y()	N(x)	Y()	N()

7.3 Description: site survey**Level of Personal Protective Equipment:**

Primary D Contingency

Type of work:

Intrusive ()

Nonintrusive (x)

Engineering controls:

None required

Administrative controls:

Occupational Safety and Health Administration 40-hr health and safety training, as specified in 29 *CFR* 1910.120, shall be required for all employees engaged in hazardous waste operations. Personnel will be required to have annual 8-hr refresher training courses. Managers and supervisors shall receive an additional 8 hours of instruction. All classroom training shall be supplemented with 24-hr on-site orientation and instruction under an experienced and qualified individual.

Revision No.: _____
Revision Date: _____

Personal Protective Equipment:

1. Respiratory protection:
2. Protective clothing:
3. Head protection:
4. Eye protection:
5. Foot protection:
6. Hand protection:
7. Hearing protection:
8. Tape-up required:

<u>Primary</u>	<u>Contingency</u>
Y() N(x)	Y() N()
Y() N(x)	Y() N()
Y() N(x)	Y() N()
Y() N(x)	Y() N()
Y() N(x)	Y() N()
Y() N(x)	Y() N()
Y() N(x)	Y() N()
Y() N(x)	Y() N()

8. MONITORING REQUIREMENTS

<u>Instrument</u>	<u>Task(s)</u>	<u>Monitoring frequency</u>	<u>Action guidelines</u>
8.1 Direct Reading Instruments			
LEL meter	_____	_____	_____
O ₂ meter	_____	_____	_____
Calorimetric indicator tubes	_____	_____	_____
Photoionization Detector (PID)	<u>7.1-7.3</u>	<u>Continuously</u>	<u>Background +</u> <u>for > 1 min.</u>
Flame Ionization Detector (FID)	<u>7.1-7.3</u>	<u>Continuously</u>	<u>Background +</u> <u>for > 1 min.</u>
Alpha meter	<u>7.1-7.3</u>	<u>As deemed</u>	<u>ALARA</u>
Beta/Gamma meter	<u>7.1-7.3</u>	<u>As deemed</u>	<u>ALARA</u>
Area radiation monitors	_____	_____	_____
Perimeter radiation monitors	_____	_____	_____
Noise meter	_____	_____	_____
Jerome mercury analyzer	<u>7.1-7.3</u>	<u>Continuously</u>	<u>0.025 mg/m³</u>
8.2 Personnel Monitoring			
Whole-body dosimetry	<u>7.1-7.3</u>	<u>On job site</u>	<u>2 mR/h</u>
Extremity dosimetry	_____	_____	_____
Whole-body count	<u>7.1-7.3</u>	<u>Start/Stop of job</u>	_____
Urinalysis/Bioassay	<u>7.1-7.3</u>	<u>Start/Stop of job</u>	_____
		<u>Baseline/Annual</u>	_____
Chemical air sampling	_____	_____	_____
	_____	_____	_____
	_____	_____	_____
	_____	_____	_____
Radiation air sampling	_____	_____	_____

9. HAZARD ANALYSIS**9.1 CHEMICALS****Tasks 7.1-7.3**

Specific labeling requirements of site-generated waste: Water purged from the monitoring wells, investigation-derived wastes, and decon water will be generated, labeled, handled, and temporarily stored according to Y-12 requirements.

Chemical-specific disposal requirements: Personnel and equipment decontamination water and investigation-derived groundwater shall be drummed and sent to the Y-12 West End Treatment Plant for treatment and disposal; protective clothing shall be drummed for disposal by the Y-12 waste management personnel. Final disposition of the wastes will be based on analytical results.

9.2 FIRE/EXPLOSION**Tasks: N/A**

Are flammable liquids present?

No

Description _____

Location _____

Quantity _____

Containment/Storage method _____

For welding, cutting, or brazing is a welding permit required?

N/A

9.3 CONFINED/ENCLOSED SPACES**Tasks: N/A**

Confined/enclosed space entry required (low/high risk)?

No

Operations safety work permit required?

No

Standard operating procedure required?

No

9.4 IONIZING RADIATION

Tasks: 7.1-7.5

Applicable detailed checklist?

NA

Primary contaminating isotope(s): Uranium, gross alpha, gross beta, radium
americium-241, strontium-89
(Isotopes may be present but expected only at low
levels)

Location on site Sediment, surface water

Containment/storage method decon water, purged water, and investigation-derived wastes

Radiation type Alpha/Beta/Gamma (may be present but expected only
at low levels)Dose rate (maximum) ? _____ mR/h @ _____ meter(s)
(average) ? _____ mR/h

Worker dose limit 2 _____ mR/h (SAIC employees limited to 500 mR/yr)

Contamination level
(fixed) 5000 dpm/100 cm²
(removable) 1000 dpm/100 cm²Airborne contamination
concentration _____ mCi/ml (Airborne concentrations exceeding limits in Table 1,
Attach. 1 of DOE Order 5480.11 will require the use of
appropriate PPE.)

Water contamination potential? Yes

Unrestricted airborne
contamination release potential? Yes

Radiation work permit required? No

Health Physics coverage Intermittent

Special task operation
requirements _____ Welding/cutting/brazing
 _____ Grinding/chipping
 _____ Hydraulic/air hammer operation
 _____ Dusty conditions (sweeping, vacuuming,
 etc.)
 _____ Equipment decontamination/free release

9.5 NONIONIZING RADIATION

Tasks: 7.1

High-Voltage (> 100 Kv) electrical transmission lines nearby? N/A

Location, distance, and voltage: No digging, excavation, or intrusive sampling will be conducted.

Radiofrequency radiation sources (AM and/or FM broadcast towers, r-f sealers) nearby?

No

Location and distance:

Microwave sources in use on site?

No

Location and description: _____

Lasers in use nearby?

No

Location and laser class: _____

Are workers potentially exposed to sunlight (ultraviolet radiation)? Yes

Are ultrasound sources in use on site?

No

Location: _____

9.6 ELECTRICAL HAZARDS

Tasks: 7.1

Electrical shock hazard?

Yes/No

_____ Voltage

_____ Current

Location of hazard: No drilling or boreholes will be installed, however, a submersible pump may be used to obtain groundwater samples. Electrical lines will be inspected for frayed or cut sections and be repaired if damaged, accordingly.

9.7 TEMPERATURE EXTREMES

Tasks: 7.1-7.6

Temperature extremes (hot/cold)?

_____ Average daily high temperature (during work shift)

_____ Average daily low temperature (during work shift)

_____ Average wind speed MPH

_____ Temperature WBGT °C

Yes/No

°F/°C

°F/°C

cloudy/sunny

Work load:

☒ Light☐ Moderate☐ Heavy

Work/Rest regimen:

_____ % work

_____ % rest

Threshold Limit Value_

Precautions (*specify*): The work schedule has not been determined; therefore, the potential for temperature extremes cannot be evaluated. However, excessive temperature extremes are not anticipated.

Cooling/heating equipment needed: None.

9.8 NOISE

Tasks: 7.1

Noise extremes?

Yes__ No x

Sound level

_____ dB(A)

Noise source(s): Submersible pump; low noise levels expected.

Noise above 85 dB(A) (hearing protection required)

Yes_ No xPrecautions(*specify*):

9.9 VIBRATION

Tasks: None

Vibration extremes?

Yes__ No_x

Vibration frequency

____ 1

Precautions (*specify*): _____**9.10 SANITATION**

Tasks: 7.1-7.6

Potable water required?

No

Nonpotable water used?

No

Eating, drinking, and smoking permitted?

Yes

Where? Only in an area located outside the exclusion zone as designated by the Site Health and Safety Officer.

Toilet facilities required?

Yes

Location and number: Specified by plant personnel at time of check-in.

Washing facilities required?

Yes

Location: Specified by plant personnel at time of check-in.

Change rooms required?

Specify:

No

9.11 ILLUMINATION

Tasks: None

Additional illumination needed?

NA

9.12 SAFETY HAZARDS

Site posted information/notification required? No

Site posting required? Yes

Site guard required? No

Access control required? Yes

Entry/exit logs required? No

Escape routing/posting required (include site map)? Yes

Compressed gas cylinders? No

Location: _____

Storage: _____

10. EMERGENCY PREPAREDNESS

Evacuation route (*map attached*):

EMERGENCY CONTACTS: All emergency services at the Bear Creek Valley OU 4 Site are to be contacted by first calling the Plant Shift Superintendent (PSS) at Commercial extension, 574-7172; from Y-12, extension 4-7172. In the event that the PSS is not available, emergency services may be reached at the telephone numbers shown below.

Facility Personnel**PSS****Project Engineer****Contract Engineer****Program Health & Safety Coordinator****Industrial Hygiene****Industrial Safety****Health Physics****Plant Disposal****Quality Assurance****Phone****574-7172****Steve V. Walker (615) 576-5364****Larry M. (615) 576-4018****Rudy Weigel (615) 241-2487****Wes James (615) 574-3897****Dave Gauss (615) 574-8070****Chris Smith (615) 576-1176****Hugh Newsom (615) 576-5810****Emergency Assistance Service****Police****Ambulance****Fire****Hospital****Doctor****Phone****Y-12 extension, 911; commercial extension 574-7272****Y-12 extension, 911; commercial extension 576-1890****Y-12 extension, 911; commercial extension 576-1890****Methodist Medical Center of Oak Ridge, 481-1190 or 911****Methodist Medical Center of Oak Ridge, 481-1190 or 911**

Health Information Services

Methodist Medical Center of Oak Ridge, 481-1190 or 911

Directions to Oak Ridge Methodist Medical Hospital: from

Y-12 Plant, turn left onto Scarboro Road, travel approximately 0.25 mile and turn right onto Lafayette Road. Travel approximately 1.75 miles to the Oak Ridge Turnpike. Turn right. The Methodist Hospital is immediately to the left. See attached hospital location map.

11. RECORD KEEPING REQUIREMENTS

(Mark with an X as appropriate)

	<u>Required</u>
Hazardous Chemicals	
Area monitoring	<u> X </u>
Personnel monitoring	<u> </u>
Oxygen Level Measurements	<u> X </u>
Flammability Measurements	<u> </u>
Ionizing Radiation	
Worker dose	<u> X </u>
Contamination levels	<u> </u>
Airborne contamination level	<u> </u>
Radiation work permit	<u> </u>
Nonionizing Radiation	
UV level measurements	<u> </u>
Microwave level measurements	<u> </u>
Laser power level measurements	<u> </u>
Biological	
Personnel exposure monitoring	<u> X </u>
Electrical	
Tag-out records	<u> </u>
Temperature extremes	
WBGT measurements	<u> </u>
Daily temperature/wind speed	<u> </u>
Noise	
Area monitoring	<u> </u>
Personnel monitoring	<u> </u>
Vibration	
Source measurements	<u> </u>
Illumination	
Area foot-candle measurements	<u> </u>
Personnel Medical Monitoring	<u> X </u>
Safety/Emergency Response	
OSHA accident records	<u> X </u>

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Revision No.: _____
Revision Date: _____

Accident/incident reports
Personal Protective Equipment
Inspection of: Clothing
Respirators
Gloves
Boots
Waste Disposal Manifests
Spill Incident Reports
Training of Employees

X

X

X

X

X

X

X

APPENDIX D

EXAMPLES OF PROJECT-SPECIFIC FIELD FORMS

MMES: ERP LAB

Sample No.: _____ **Project No.:** _____
Location: _____ **Station:** _____
Sample Media: _____
Sample Type: _____
Analysis: _____
Preservative: _____ **Volume:** _____
Rad Screen: _____ **Units:** _____
Sample Date/Time: _____
Comments: _____
_____ **Collector:** _____

SAMPLE LOG SHEET

PROJECT NAME: _____

PROJECT NO: _____

SAMPLE ID NUMBER: _____

DATE COLLECTED (MM/DD/YY): _____

TIME: _____

SAMPLING LOCATION CODE: _____

DESCRIPTION: _____

SAMPLING POINT CODE: _____

DESCRIPTION: _____

NORTHING: _____ EASTING: _____ ELEVATION: _____

SAMPLE DEPTH CODE: _____ : _____ TO _____ BELOW LAND SURFACE

SAMPLE MEDIA CODE: _____ DESCRIPTION: _____

WEATHER: _____ ACTIVITIES IN AREA: _____

FIELD OBSERVATIONS: _____

FIELD MEASUREMENTS	READING	UNITS	SERIAL NO.	LAST CALIB.
RADIOACTIVITY:				
TEMPERATURE:				
PH:				
CONDUCTIVITY:				
REDOX:				
DO:				
ORGANIC VAPORS:				
TURBIDITY:				
Other _____ :				

SAMPLE TYPE:

☐

GRAB

☐

SPATIAL COMPOSITE

☐

TIME COMPOSITE

☐

QC TRIP BLANK

☐

QC RINSATE

☐

QC FIELD BLANK

☐

OTHER (SPECIFY) _____

SAMPLE COLLECTED: ☐ YES ☐ NO SAP SAMPLING PROCEDURE WAS FOLLOWED? ☐ YES ☐ NO

IF SAP WAS NOT FOLLOWED, SPECIFY WHAT DEVIATIONS WERE NECESSARY AND WHY:

SAMPLE NUMBER:

[illegible]

SAMPLE ID'S:
SITE SKETCH:

RINSATE:

TRIP BLANK:

FIELD BLANK:

FIELD DUPLICATE:

RECORDED BY:

(SIGNATURE)

QA CHECK BY:

(SIGNATURE)

TASK TEAM ACTIVITY LOG SHEET

PROJECT NAME:

PROJECT NO:

Date (mm/dd/yy): ____/____/____

Page of

Task Team Members:

Narrative (include time and location):

Daily Weather Conditions: A.M. _____
P.M. _____

P.M. _____

RECORDED BY: _____
(Signature)

(Signature)

QA CHECKED BY: _____
(Signature)

(Signature)

GROUND WATER PURGE SHEET

PROJECT NAME: _____

PROJECT NO: _____

DATE (mm/dd/yy): _____

TIME: ____:____

WELL ID NUMBER: _____

WELL LOCATION: _____

DEPTH OF SCREENED INTERVAL(toc notch): _____ ft. to _____ ft

INNER CASING: TYPE: _____ ID: _____ inches

WELL VOLUME CALCULATION $V_c = 3.142 \times (di/2)^2 \times (TD-H)$ _____ $V_f = 3.142 \times [(dH/2)^2 - (do/2)^2](TD - S \text{ or } H)(P)$ _____NOTE: If $S > H$ use S , If $S < H$ use H $V_t = (V_c + V_f)(7.48)$ _____

WHERE:

 V_c = Volume of water in well casing, cu.ft. V_t = Total volume, gal do = outside of diameter of well casing, ft. TD = total depth of well from top of well casing, ft. H = depth to water, ft., from top of well casing S = depth to base of seal, ft., from top of well casing P = estimated porosity of filter pack (for most Ottawa, Morie #1 sand or glass beads this value is estimated at a range of 30 to 35%) V_f = Volume of water in filter pack, cu.ft. di = inside diameter of well casing, ft. dH = diameter of borehole, ft.PURGE METHOD: ☐ Bailer ☐ Bladder Pump ☐ Pump Type _____MINIMUM PURGE VOLUME = $V_t \times 3$ PURGE VOLUME: _____ GAL.SAMPLE METHOD: ☐ Bailer ☐ Bladder Pump ☐ Other (specify) _____

NOTE: IF WELL HAS A DEDICATED PUMP, IT IS TO BE USED.

SITE CONDITIONS DURING PURGING: _____

FIELD OBSERVATIONS: _____

S&A PLAN SAMPLING PROCEDURE FOLLOWED: ☐ YES ☐ NO IF NO, WHY
WAS A DEVIATION NECESSARY: _____

RECORDED BY: _____

(Signature)

QA CHECKED BY: _____

(Signature)

PURGE LOG

D-8

[illegible]

PROJECT NO:

[illegible]

DECONTAMINATION

PROJECT NAME:

PROJECT NO:

[illegible]

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