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Energy Systems Environmental Restoration Program
ORNL Environmental Restoration Program

**Site Characterization Plan for Groundwater in Waste Area
Grouping 1 at Oak Ridge National Laboratory, Oak Ridge, Tennessee**

Date Issued—July 1994

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Energy Division
Oak Ridge National Laboratory

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ABBREVIATIONS

ARAR	applicable or relevant and appropriate requirement
BGS	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
CDI	chronic daily intake
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
CFR	<i>Code of Federal Regulations</i>
CH	core hole
CWA	Clean Water Act of 1977
DB	detention basin
DCE	dichloroethene
DOE	U.S. Department of Energy
DOE-ORO	U.S. Department of Energy-Oak Ridge Operations
DQO	data quality objective
EB	equalization basin
EPA	U.S. Environmental Protection Agency
ER	environmental restoration
<i>Fed. Regist.</i>	<i>Federal Register</i>
FFA	Federal Facilities Agreement
FS	feasibility study
FY	fiscal year
IDW	investigation-derived waste
LLW	low-level liquid waste
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MH	manhole
NCP	National Contingency Plan
NEPA	National Environmental Policy Act of 1969
NERP	National Environmental Research Park
NRC	U.S. Nuclear Regulatory Commission
NTF	North Tank Farm
ORNL	Oak Ridge National Laboratory
ORR	1. Oak Ridge Reservation 2. Oak Ridge Research Reactor
OSHA	Occupational Safety and Health Administration
OU	operable unit
OVM	organic vapor monitor
OSWER	Office of Solid Waste and Emergency Response, U.S. EPA
PARCC	precision, accuracy, representativeness, completeness, and comparability
PCB	polychlorinated biphenyl
PWTP	Process Waste Treatment Plant
QA	quality assurance
QAPjP	quality assurance project plan
QAS	quality assurance specialist
QC	quality control

RCRA	Resource Conservation and Recovery Act of 1976
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
ROD	Record of Decision
RSA	research area
SB	soil boring
SDWA	Safe Drinking Water Act
SHSO	site health and safety officer
SOP	standard operating procedure
STF	South Tank Farm
SWMU	Solid Waste Management Unit
SWSA	Solid Waste Storage Area
TBC	to be considered
TCA	Tennessee Code Annotated
TCE	trichloroethene
TDEC	Tennessee Department of Environment and Conservation
TDS	total dissolved solids
USC	<i>United States Code</i>
UST	underground storage tank
VOC	volatile organic compound
WAG	Waste Area Grouping
WEF	Waste Evaporator Facility
WOC	White Oak Creek

EXECUTIVE SUMMARY

The Waste Area Grouping (WAG) 1 Groundwater Operable Unit (OU) at Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee, is undergoing a site characterization to identify environmental contamination that may be present. Oak Ridge is in Anderson and Roane counties, Tennessee, and ORNL is about 7 miles south of the city of Oak Ridge. ORNL was constructed in the early 1940s as part of the efforts during World War II to construct an atomic bomb. The research, production, fabrication, maintenance, and decontamination facilities that were constructed and operated as part of that effort have resulted in various sorts of environmental contamination throughout the Oak Ridge area.

The 150-acre WAG 1 is contained within the ORNL security area. It includes all of the former ORNL radioisotope research, production, and maintenance facilities; former waste management areas; and some former administrative facilities. This document, *Site Characterization Report for Groundwater in Waste Area Grouping 1 at Oak Ridge National Laboratory, Oak Ridge, Tennessee*, identifies areas of concern with respect to WAG 1 groundwater and presents the rationale, justification, and objectives for conducting this continuing site characterization.

This report summarizes the operations that have taken place at each of the areas of concern in WAG 1, summarizes previous characterization studies that have been performed, presents interpretations of previously collected data and information, identifies contaminants of concern, and presents an action plan for further site investigations and early actions that will lead to identification of contaminant sources, their major groundwater pathways, and reduced off-site migration of contaminated groundwater to surface water.

Site characterization activities performed to date at WAG 1 have indicated that groundwater contamination, principally radiological contamination, is widespread. An extensive network of underground pipelines and utilities have contributed to the dispersal of contaminants to an unknown extent. In addition, numerous spills and pipeline leaks and the long and varied history of activities at specific facilities at ORNL complicates contaminant migration pathways analysis and source identification. The general absence of radiological contamination in surface water at the perimeter of WAG 1 is attributed to the presence of pipelines and underground waste storage tank sumps and dry wells distributed throughout WAG 1 which remove more than about 40 million gal of contaminated groundwater per year.

One contaminant plume is currently known to be directly discharging off-WAG to surface water and indirectly discharging via plume leakage to storm drains. These are the largest known groundwater contaminant discharges to surface water at WAG 1. An early action is described which is designed to immediately terminate those discharges and intercept the plume at several locations along its length. Identifying the source for the plume is one of the primary objectives of the activities described in this report. Other areas of concern will undergo either exploratory investigation or monitoring to more fully describe the nature and

extent of contamination and migration pathways which are also important report objectives. The approximate locations, numbers, target analytes, and sampling frequency of samples to be collected are described for each area of concern.

In addition to groundwater elevation and quality data acquisition from new wells, the rationale and justification for a monitoring and sampling program to provide a minimum data record are described. The monitoring and sampling program will be an ongoing, long-term effort to determine changing conditions over time.

The Field Sampling Plan, the Field Quality Assurance Project Plan, and the Laboratory Quality Assurance Plan are also included. The Field Sampling Plan describes the objectives of data collection and the quality assurance documentation required to meet those objectives. The Quality Assurance Project Plans include the procedures that will be followed by the field samplers and laboratory to obtain reliable and defensible data. They also provide for surveillances and audits and establish corrective actions to be employed in the event that activities are not consistent with quality assurance objectives.

The Health and Safety Plan and Waste Management Plan for the WAG 1 groundwater site characterization will be prepared in accordance with 29 CFR 1910.120 and will contain an evaluation of potential hazards associated with the wastes disposed of from exploration, sampling, and monitoring. It will also describe personnel decontamination procedures designed to ensure that hazardous and/or radioactive material encountered in the investigated area does not leave that area.

1. INTRODUCTION

1.1 REGULATORY INITIATIVE

The framework for remedial action on the Oak Ridge Reservation (ORR) is provided by the ORR Federal Facility Agreement (FFA). The U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the Tennessee Department of Environment and Conservation (TDEC) entered into this Agreement to comply with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and coordinate remediation activities undertaken on the ORR pursuant to CERCLA, the Resource Conservation and Recovery Act of 1976 (RCRA), and the National Environmental Policy Act of 1969 (NEPA).

The general purposes of the FFA are to

- establish a procedural framework and schedule for developing, implementing, and monitoring appropriate response actions at the ORR in accordance with CERCLA, RCRA, NEPA, appropriate guidance and policy, and Tennessee state law;
- coordinate response actions under CERCLA with closure, postclosure care, and corrective measures under way or planned under RCRA and applicable state laws, in such a manner as to maximize flexibility and preclude redundant activity;
- minimize the duplication of investigative and analytical work and documentation and ensure the quality of data management; and
- expedite response actions with a minimum of delay.

1.2 ORR ENVIRONMENTAL RESTORATION PROGRAM

To address contamination of the ORR as a whole, the ORR has been partitioned into waste area groupings (WAGs) and operable units (OUs), which can be prioritized to achieve the most effective and rapid investigation and cleanup possible. An OU is defined as a unit for which a Remedial Investigation/Feasibility Study (RI/FS) will be performed, including any interim actions and/or removal actions. OUs may be redefined and work schedules adjusted as investigations progress and new data become available.

The following guidelines are basic to Environmental Restoration (ER) Program planning and implementation:

- Emphasis is placed on integrating ongoing activities and historical information into the overall effort.
- Considerable attention and importance has been paid to coordinating and integrating the activities of other major programs with the ER Program in order to ensure that adequate resources are available, data are provided in a consistent format to satisfy multiprogram

needs, and technical issues and remediation technologies are communicated throughout the ER Program so that consistent approaches are applied.

- Remedial action schedules for the OUs are dynamic and can be revised per mutual agreement of DOE, EPA, and TDEC and appropriate public involvement.
- OUs may be redefined or reprioritized as the investigation progresses per mutual agreement of DOE, EPA, and TDEC and appropriate public involvement.
- Work at the OUs will be managed to minimize waste and to prevent the recontamination of OUs previously remediated.

A fundamental goal of cooperative efforts among DOE, EPA, and TDEC is that remedial action be emphasized. This goal recognizes that no reasonable amount of investigation can resolve all uncertainty and that once remedial actions are initiated they must be able to accommodate divergence from original hypotheses. This approach promotes earlier remedy selection, flexibility for remedial action, and contingencies to react to new information discovered during investigations.

The ORR remedial actions will be conducted using a "lead agency" strategy to minimize duplication of effort and maximize oversight productivity. The lead agency is designated as the responsible agency for overseeing and coordinating the activities in accordance with the Agreement. The regulators will provide support within the oversight role to the lead agency.

DOE-Oak Ridge Operations (DOE-ORO), as the lead agency for the ORR, provides the on-scene coordination to plan and implement response action under the National Contingency Plan (NCP). Lead agency duties include

- overseeing and managing ORR remedial activities pursuant to the FFA and the site management plan;
- serving as primary contact and coordinator with the regulators for the purposes of implementing the Agreement and the site management plan; and
- ensuring availability of resources required to implement the site management plan.

EPA and TDEC are participating in the Agreement as working partners in initiating the remedial action work at Oak Ridge and in a regulatory oversight role. In this capacity, they will provide regulatory opinions and counsel to the lead agency. The regulators will assist the lead agency by attending working meetings, providing timely response to action items, and providing timely review and concurrence, where applicable, of ORR remedial documentation and/or activities. EPA, DOE, and TDEC will each designate project managers to coordinate the implementation of the Agreement and the ongoing regulatory oversight duties and shall notify each other in writing of the designation.

The Energy Systems ER Division has been designated as integrating contractor for the DOE ER Program. The primary purpose of the integrating contractor role is to ensure that all participants in the Oak Ridge ER Program approach and conduct their tasks in a technically consistent and operationally similar manner to ensure a common focus for technical and administrative management. On the ORR, the primary contractors to DOE as

of the date of this document are Energy Systems; Radian Corporation; Ebasco Services, Inc.; and MK-Ferguson, in Oak Ridge. The specific ER Program responsibilities of each of these prime contractors are defined in the DOE ER Program Management Plan (DOE 1991a) and the DOE D&D Program Management Plan (DOE 1991b).

1.3 WAG 1 ER PROGRAM

To facilitate characterization and remediation of contaminated areas, Oak Ridge National Laboratory (ORNL) has been divided into WAGs. WAGs are either geographically contiguous or hydrologically constrained areas. WAG 1 encompasses the main plant area of ORNL and has been further divided into OUs. These currently identified OUs include the Gunitite and Associated Tanks OU, the Surface Impoundments OU, the Pipeline and Storm Sewer Network Leakage OU, the Groundwater OU, and the Flood Plain Soils OU.

Activities described in this report will be carried out as an additional site characterization phase. Phase I site characterization activities in WAG 1 are described in the Site Characterization Summary Report (BNI 1992). Phase I of the RI was planned as a broad scope investigation to provide information so that appropriate OUs could be identified and to provide the technical foundation to support additional OU-specific investigations. Data collected during Phase I and the activities described in this report will be used to characterize WAG 1 groundwater contamination and evaluate remedial alternatives. These data will also be used in support of the other OU RIs in WAG 1.

1.4 INTENT AND SCOPE OF THIS REPORT

Based on data collected during Phase I of the WAG 1 Groundwater RI, this report describes data necessary to further characterize WAG 1 groundwater and evaluate remedial alternatives to prevent the off-site migration of contaminants and control or eliminate sources of groundwater contamination. In addition to the description of groundwater data, this report describes data needs associated with anthropogenic features. As discussed below, these data are needed (1) because of extensive development and current and historical activities at WAG 1 that are known or strongly suspected to be contributing to groundwater contamination, and (2) because of at least seasonal interactions between groundwater and sumps, underground pipelines, and other structures (e.g., valve pits, filter pits, etc.).

The purpose of this report is to provide a rationale and prioritization for groundwater data acquisition, monitoring, and remedial actions to be performed during implementation of environmental restoration at WAG 1. It is intended to serve as a strategy document for performing these actions. Data acquisition is anticipated to enhance our understanding of the nature, extent, and fate of groundwater contamination. This understanding will improve our ability to select and implement the most appropriate and effective groundwater remedial actions.

In many instances, limited data are available to quantitatively describe the nature and extent of contamination as a basis for additional data acquisition. This document thus includes a description of the apparent state of WAG 1 groundwater contamination at the present time.

1.5 SPECIAL PROBLEMS

Many locations considered for subsurface drilling in this report for WAG 1 are likely to encounter radioactively contaminated conditions, and preparations for drilling under such conditions must be made before drilling. Also, the extensive underground process waste and low-level liquid waste (LLW) pipeline network and overhead utility lines may limit flexibility in choosing drilling sites; and drilling may alter the existing vertical distribution of contamination by introducing contaminants to depths currently not contaminated. Close on-site health physics monitoring and work crew training and preparation for such eventualities must be made prior to drilling.

1.6 OVERALL PROJECT OBJECTIVES

The goal of this report is to provide the necessary data on the nature and extent of groundwater contamination with an acceptable level of uncertainty to support the selection of remedial alternatives and to identify additional data needs for future RI phases. Primary objectives are

1. To collect data to identify and characterize contaminant migration pathways. These data will be used for assessment of remedial alternatives for prevention of off-site migration of contaminants found in groundwater via movement of contaminated groundwater off-WAG or via discharge of contaminated groundwater to surface water which subsequently moves off-WAG.
2. To identify sources of groundwater contamination and evaluate remedial actions which could be implemented to control or eliminate these sources.
3. To conduct groundwater monitoring in support of other OUs in WAG 1 (e.g., Surface Impoundments OU, Gunitite and Associated Tanks OU, and Pipeline and Storm Sewer Network Leakage OU) and the ORNL Groundwater OU.

The activities focus on known or suspected areas that are comparatively more highly contaminated. Areas that are comparatively much less contaminated and do not appear to pose a serious environmental threat are not addressed.

1.7 IDENTIFICATION OF POTENTIAL CLASSES OF REMEDIAL TECHNOLOGIES

As stated in the previous section, one objective of Phase II of the WAG 1 Groundwater RI is to prevent off-site migration of contaminants in groundwater. Remedial technologies which may be used to accomplish this goal include trenches and subsurface drains to intercept

contaminated groundwater; installation and operation of pumping wells to contain contaminant plumes; in-situ zeolite treatment; and lining of underground storm sewers to prevent infiltration of contaminated groundwater into the sewers and subsequent discharge to surface waters. Groundwater which is intercepted and/or pumped from wells would be treated in the Process Waste Treatment Plant (PWTP) and/or the Waste Evaporator.

The second objective of the RI is control or elimination of sources of groundwater contamination. Technologies which may be used to accomplish this goal are pumping of contaminated groundwater in source areas, in-situ vitrification of contaminated soils, cryogenic freezing of contaminated areas, hydraulic isolation of contaminated areas (e.g., by installation of grout curtains or sheet pilings) and excavation of contaminated soils which may be serving as secondary sources of groundwater contamination.

Data needs for evaluating these alternatives are (1) the locations of sources and pathways; (2) the levels of contamination in source areas and contaminant plumes; (3) the areal extent of source areas and contaminant plumes; (4) the isotopic composition of the contamination; and (5) the relative contribution of the contaminant discharges to off-site risk.

1.8 DATA NEEDS FOR THE BASELINE RISK ASSESSMENT

Most of any off-site public exposure to ORNL contaminants results from surface water, which is the major transport mechanism for contaminant fluxes to off-site receptors. Other potential transport mechanisms (e.g., the food chain, the air pathway, and direct groundwater transport) currently are not primary sources of off-site fluxes. Data are being collected on surface water contamination at the 7500 Bridge on White Oak Creek (WOC) as part of WAG 2 activities. This is the integration point between WAG 1 groundwater and surface water and is being used to assess the contribution of WAG 1 to off-site public exposure to contamination. No data need be collected under the WAG 1 Phase II Groundwater RI for the off-site baseline risk assessment.

1.9 PROJECT SCHEDULE

Data acquisition and analysis for the activities described in this report are scheduled to begin in February 1995 and be completed in March 1997. Reporting of those results to regulatory agencies is scheduled for December 1997. Routine monitoring and sampling are scheduled to be ongoing activities independent of data acquisition and analysis from new locations described in this report.

1.10 DATA QUALITY OBJECTIVES

Data quality objectives (DQOs) are the endpoints in the formulation of a set of constraints needed to design a study. They are qualitative and quantitative statements that

specify the quality of the data required to support decisions during remedial response activities. The DQO process follows the "observational approach," which is aimed at characterizing the site, interpreting/predicting expected conditions and deviations from expected conditions, and formulating decision rule statements to guide site activities. DQOs are determined based on the end uses of the data to be collected. For example, sufficient data may have to be collected to characterize the site, evaluate remedial alternatives, determine design criteria, perform the baseline risk assessment, or monitor site conditions or remedial action effectiveness. DQOs apply to all types of data collected, not just to the analytical data from a laboratory. The level of detail and data quality needed varies based on the intended use of the data. The variability of site characteristics makes it impossible to apply a generic set of DQOs to all CERCLA activities.

DQOs are established before data collection; this section summarizes them, and they are further discussed in Chap. 7. The DQO development process has been integrated with the project planning process, and the results are incorporated into the different sections and chapters of this report. The DQO process results in a well-conceived sampling and analysis plan. The plan details the chosen sampling and analysis options and methods of documenting decisions made during the RI process. Decisions about how to implement the RI are based on historical records, the training and experience of the investigation team members, or through established analytical quality control (QC) procedures. DQOs have been specified for each data collection activity associated with this investigation. All investigation activities will be conducted and documented to ensure that sufficient data of known quality will be collected to support sound decisions concerning site characterization, feasibility studies, risk assessment, and remedial actions.

1.10.1 DQO Stage 1: Identifying Decision Types

The RI is initiated with the first stage of the DQO process. This stage should be repeated whenever (1) new data on either the operational history or the site environment are received by the primary data users or (2) the objectives or the requirements of the investigation are redefined. This stage comprises the following tasks: identifying and involving data users, evaluating available information, developing a conceptual model, and specifying objectives and decision rules.

1.10.1.1 Identifying and involving data users

The DQO development process involves planning RI activities by data users. Data users and decision makers can be identified as either primary or secondary. Primary and secondary data users are involved in making decisions throughout the RI/FS activities. Primary data users are involved in ongoing RI/FS activities. In the Phase II RI, primary data users are the WAG 1 ER Groundwater OU Project Manager, the ORNL Groundwater OU technical coordinator, the WAG 1 ER Program Manager, the Energy Systems ER Division technical support contractor, and the ORNL Risk Assessment Team Leader. The WAG 1 ER Groundwater OU Project Manager has the primary responsibility for incorporating DQOs into the planning and implementation activities.

Secondary data users obtain information to support their activities through RI/FS deliverables. Secondary data users provide input to the primary data users during the DQO development phases of the RI/FS activities. Secondary data users include, but are not limited to, the EPA Region IV administrator or designee, the TDEC DOE Oversight Environmental Restoration Section Manager or designee, and DOE.

1.10.1.2 Evaluating available information

The operational history and the environmental sampling performed to date have been evaluated in the preparation of this report. The operational history and current status of each site within WAG 1 are described in Chap. 2. A description and an interpretation of environmental data collected to date are included in Chaps. 3 and 6.

Decisions about which areas within WAG 1 should be investigated and how they should be investigated were based on the operational history, the environmental information available, and the overall project objectives as described in Section 1.6. The criteria below were applied to each area to determine whether further investigations were needed.

1. Does the operational history of the area indicate that it may be contaminated?
2. Do the environmental data available indicate that the area is contaminated?
3. Have the nature and extent of contamination been determined by existing information?
4. Is additional information needed on the contaminants that may exist in groundwater?

1.10.1.3 Developing a conceptual site model

From a review of operational history and existing environmental samples and their analyses, a conceptual model of groundwater flow and transport has been developed for WAG 1. The conceptual model is described in Chap. 3.

1.10.1.4 Remedial investigation objectives, decision rules, and analytical data uncertainty

The overall objectives for the WAG 1 investigation are summarized in Sect. 1.6. Briefly, these objectives are to (1) identify and characterize groundwater contaminant migration pathways and evaluate remedial alternatives for preventing off-site migration of contaminants via these pathways, (2) identify sources of groundwater contamination and evaluate remedial alternatives to control or eliminate these sources, and (3) conduct groundwater monitoring in support of other OUs. Expected conditions, deviations from expected conditions, and decision rules for each of these overall objectives are discussed below.

For the investigation of contaminant migration pathways, the expected conditions are that contamination is present in discrete migration pathways from sources to discharge areas (i.e., seeps and springs). The deviation from expected conditions is that contamination is not found in the anticipated pathways. Decision rules are as follows:

- If contamination is found, then perform further exploration and sampling to characterize the pathway and determine the possible source of the contamination.
- If a pathway and a source are verified, then develop preliminary remedial actions and determine data needs to evaluate these remedial actions.
- If contamination is not found, then no further action will be taken.

Assuming that contaminant levels in migration pathways would be expected to be orders of magnitude higher than background levels, the probabilities of false positives and false negatives (i.e., inferring the presence of a pathway when one is not present or inferring the lack of a pathway when one is present) are very low. Thus, for this objective there is a relatively high acceptable level of uncertainty in the data.

For the investigation of sources of groundwater contamination, the expected conditions are that highly contaminated areas (e.g., contaminated soil or groundwater, pipeline leaks) are present in WAG 1 which are sources of contaminant plumes. Contamination in these source areas is expected to be significantly greater than that found in the plumes. Deviations from these expected conditions are that contamination is present but not at high enough levels for the area to be a source; or that contamination is not found in the area. Decision rules for the source investigation are as follows:

- If a source is identified, develop preliminary remedial actions and data needs to evaluate these remedial actions.
- If contamination is found, but not at high enough levels to be a source, then develop further exploration plans to identify the source.
- If contamination is not found, then no further action will be taken in the area.

Source investigations focus on limited areas of WAG 1 where available data suggest the potential for the presence of a source(s). A source(s) would be anticipated to exhibit contaminant levels considerably higher than surrounding locations. Thus, the probability of inferring the presence of a source(s) when it is not present or the absence of a source(s) when it is present is very low, and for this objective there is a relatively high acceptable level of uncertainty in the data.

Expected conditions for the groundwater monitoring objective are that contamination will continue to be found at levels comparable to historic levels. Deviations from these expected conditions are that contaminant levels will increase or decrease. Monitoring decision rules are as follows:

- If contaminant levels increase, then continue monitoring and develop plans to identify the source of the contamination and potential remedial actions.
- If contaminant levels decrease, then attempt to identify the reason for the decrease. Continue monitoring until levels fall below background.

Because of the temporally limited data which have been collected, there is a relatively high level of uncertainty regarding levels of groundwater contamination within WAG 1. In

addition, preliminary analysis of these temporally limited data indicates a potential seasonality to the analytical results. Until a larger data base is obtained, analytical fluctuations with the precipitation year cannot be adequately described. Results of groundwater monitoring will be used to minimize this uncertainty.

Monitoring will be coordinated with other OUs in order to assist in the development of remedial actions for these OUs and evaluate the effectiveness of these remedial actions when implemented.

Individual objectives for each area of concern within WAG 1 are described in Chap. 6 and Chap. 7.

1.10.2 DQO Stage 2: Identifying Data Uses and Needs

Identifying data uses and needs follows the development of the objectives and conceptual model developed for the site. It involves the following steps:

- identifying data uses;
- identifying data types;
- identifying data quality needs;
- identifying data quantity needs;
- evaluating sampling and analysis options;
- reviewing precision, accuracy, representativeness, completeness, and comparability (PARCC) parameter information; and
- applying PARCC parameter information.

1.10.2.1 Identifying data uses

At each of the areas within WAG 1, the potential remedial actions were considered in designing the Sampling and Analysis Plan. The information required to characterize the site, evaluate the potential remedial actions, and the data required to conduct the feasibility study are included in the sampling and analysis activities.

1.10.2.2 Identifying data types

Several types of data are required for the WAG 1 RI, including records, reports, and recollections by present and former employees on the operational history of the units in the area; observations by the scientists and engineers conducting the investigation; geophysical measurements; groundwater elevation data and laboratory analyses of groundwater samples. Chapter 2 summarizes records and reports on the history of units in the area. Observations used in WAG 1 study include those by the scientists who conduct the surveys to locate seeps and springs and those by scientists, engineers, and operators who operate the drilling rigs. These observations must be documented in such a way that they can be substantiated and traced to the observer. The procedures to be followed to ensure adequate documentation are described in Chaps. 7 and 8 and in the Laboratory Quality Assurance Project Plan (QAPjP)

approved by the Analytical Projects Office (APO). The environmental samples to be analyzed in a qualified, licensed laboratory include soil and groundwater. Details of the laboratory sampling and analysis requirements are given in Chaps. 7 and 8 and in the Laboratory QAPjP.

1.10.2.3 Identifying data quality needs

Data quality needs vary with the types of data to be collected. QC is least strict for historical records and most strict for laboratory analyses. Data types with other data QC include observations by the field sampling and analysis team, geophysical measurements taken in area surveys, and geohydrologic measurements. Chapter 8 includes detailed information on the data quality controls required for each type of data collected in this investigation.

QC is least strict on historical data. These records and reports, prepared from the 1940s to the 1970s on the past operations of the site, are believed to be accurate; however, no verification or control procedures are known to have existed when they were prepared. Recollections of present and former employees may not be as accurate as written records but are often the only source of information about the early operation of ORNL. These data are the foundation of RIs; their quality dictates the quality requirements of additional data that will determine the nature and extent of contamination in the OU.

Observations of field conditions require some quality controls, which are detailed in the Field QAPjP (see Chap. 8). Observations will be used to locate seeps and springs in the WAG 1 perimeter.

The QC associated with laboratory analyses is generally equivalent to Level 4, as established by EPA, or Level D, as established by the Hazardous Waste Remedial Action Program. Details of Level D QC requirements will be included in the Laboratory QAPjP.

1.10.2.4 Identifying data quantity needs

Data quantity needs in the WAG 1 study apply to the numbers of borings from which observations on the nature of the subsurface environment will be made and from which samples of soil and groundwater will be collected. The borings are considered to be sufficient to describe the nature and extent of groundwater contamination and to determine contamination migration pathways. In both instances, the numbers and locations of data points are based on the requirements to obtain a representative value for the measurement desired, considering the variability of the instruments to be used and the site conditions.

1.10.2.5 Evaluating sampling and analysis options

Sampling and analysis options to meet data requirements must be evaluated for technical and economic feasibility. This has been done for each of the data types required to meet the objectives for this project. The quality assurance (QA) documentation for data collection activities is detailed in the Field QAPjP (Chap. 8). Laboratory QA is the responsibility of the laboratory, as delineated in the Laboratory Quality Assurance Plan approved by the APO.

1.10.2.6 Reviewing and utilizing PARCC parameter information

The PARCC of all data proposed must be accounted for in the final data evaluation effort. This includes operational histories, field observations, and laboratory analyses. The sampling program was designed so that data of sufficient quantity would enable a reasonable, accurate evaluation of the nature and extent of contamination and its fate in the environment. If all data are not received as requested, that accuracy of the evaluation is jeopardized. The QA documentation required to verify that all data can be accounted for is described in the Field and Laboratory QAPjPs.

1.10.3 DQO Stage 3: Designing the Data Collection Program

The third and final stage of the DQO process involves applying the information gathered in the first two phases, drawing conclusions about the environmental conditions of the site under investigation, and making recommendations about data needed to complete the purposed activities. The third stage includes three steps:

- assembling data collection components,
- developing data collection documentation, and
- reporting data and presenting interpretation.

1.10.3.1 Assembling data collection components

Assembling data collection components includes developing (1) the objectives for each unit to be sampled, (2) a plan for sampling all relevant media, (3) a schedule for collecting these samples, and (4) a plan for interpreting and reporting the data to be collected. Section 7.3 presents the objectives for sampling each unit in this study and recommends sampling to meet these objectives.

1.10.3.2 Developing data collection documentation

Data collection documentation is included herein. This report includes a Field Sampling Plan and a Field QAPjP. In addition, a Laboratory QAPjP, a Health and Safety Plan, and a Waste Management Plan and a Security Plan will be prepared for this project but are not included in this report.

1.10.3.3 Reporting and interpreting data

Data reporting and interpretation for the investigation follows the requirements of the FFA, up to and including the Record of Decision (ROD). A community relations plan has been prepared for the ORR ER Program. The documents required by the FFA and a brief description of their contents and purpose in the RIs of the ER Program are as follows:

Site Descriptions. This document is a brief summary of historical and operational information on all known Solid Waste Management Units (SWMUs) at WAG 1. Information

on waste characteristics and release data is also included, along with the regulatory status and media of concern for each site. Information was gathered from interviews with past and present employees, construction and process drawings, and reports written.

Preliminary Assessment/Site Inspection. These investigations, which are usually presented in one report, are intended for those units whose histories indicate a potential for contaminant releases. Samples are collected and analyzed for the potential contaminants indicated in the site descriptions. If contaminants are found, the site becomes a candidate for an RI and falls under the jurisdiction of CERCLA.

Remedial Investigation Work Plan. This is the first of several documents required for an RI. It includes a summary of existing environmental data, a history of operations, and a plan for sampling and analysis to characterize the site and design an acceptable remediation system.

Remedial Investigation Report. This report includes the conclusions drawn from the field investigation and site characterization data on the nature, extent, and migration pathways of contamination at the site under investigation and the relative risk posed by the site according to the information obtained.

Feasibility Study. The primary objective of the FS is to analyze the remedial action for the site under investigation. Remedial alternatives on the ORR are limited by the radiological constituents of the contamination and by security considerations necessitated by the nature of the disposed materials; consequently, the most probable remedial alternative is sometimes known before the initiation of the RI. The FS determines which of a limited number of remedial options is best for the site or how best to implement the only feasible alternative.

Record of Decision. A ROD is required in order to document the completion of the remedial selection process. The ROD will provide the final resolution for mitigating risks to human health and the environment with the best available technology. A ROD is also appropriate for an interim action which is limited in scope and addresses only areas or media that will be followed by a final OU ROD. Interim actions could be required to protect human health and the environment from an imminent threat in the short term while a final remedial solution is being developed. Because it would not be feasible to determine the final remedial action of a site before sources have been controlled, the implementation of final RODs will take much longer than implementation of RODs for interim actions.

At WAG 1 tentative plans are to issue RODs for all source OUs, and issue a final ROD after all sources have been controlled as much as technically feasible and groundwater contamination and remediation have been addressed. This documentation process will allow quicker actions to control sources than might otherwise be possible.

According to the FFA, documents are designated as "primary" or "secondary." Primary documents are the RI work plan, the RI report, and the RODs. These documents contain recommendations and conclusions that require approval of DOE, EPA, and TDEC before being implemented. Secondary documents are any additional reports that do not require DOE

or regulator approval. Generally speaking, they do not include proposals or recommendations for additional data collection activities. All of these documents will be prepared based on the information obtained in the RI, which will meet the data requirements of all of the studies required for the remediation of the site.

1.11 QUALITY ASSURANCE

1.11.1 Program Planning and Implementation

The overall planning and implementation of QA and QC activities of this project are governed by ES/ER/TM-4/R2 (*Environmental Restoration Quality Program Plan*), which addresses the guidance in EPA's *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans* (EPA-600/4-83-004 [QAMS-005/80]) and the specifications of the Energy Systems Quality Procedures Manual, the American Society of Mechanical Engineers document *Quality Assurance Program Requirements for Nuclear Facilities* (ASME NQA-1), and applicable DOE orders.

1.11.2 Project-Specific Planning

The ER Quality Program Plan (ES/ER/TM-4/R2) will be supplemented by the Field QAPjP and the Laboratory QAPjP. The format and requirements of these project-specific QAPjPs are based on the elements of QAMS-005/80 and will integrate other elements of the ER Quality Program Plan as needed.

2. HISTORY AND CURRENT CONDITIONS

2.1 GEOGRAPHIC INFORMATION

WAG 1 is located within the ORNL main plant area. It is bounded on the north by Bethel Valley Road, on the south by WOC, and on the west by First Creek. The eastern boundary follows Fifth Creek in the north but extends east to include Solid Waste Storage Area (SWSA) 2 and Buildings 4501 and 4508. The location of WAG 1 in relation to other ORNL WAGs is shown on Fig. 2.1.

2.2 BACKGROUND INFORMATION

The original objective of the ORNL site was to produce gram quantities of plutonium. The site initially included a nuclear reactor, a chemical separations plant, a number of large underground tanks, and a variety of support facilities. The nuclear reactor (Building 3001), referred to as the "Graphite Reactor" was air cooled and was the first nuclear reactor with production capacity. The Radiochemical Processing Pilot Plant (Building 3019), originally referred to as the "Hot Pilot Plant" was constructed to dissolve the irradiated fuel elements from the Graphite Reactor and to develop the bismuth phosphate precipitation method for separation of the plutonium.

The Isotopes Area, located in the east-central portion of WAG 1, was among the earliest radioisotope production areas at ORNL. Isotopes Area facilities prepared radioisotopes for commercial, medical, and research purposes from the late 1940s and early 1950s until the 1980s. All production activity ceased in the area in the early 1990s. During its period of operation, activities varied both among and within the individual facilities. Limited documentation is available of the activities performed and the wastes generated in these facilities, and most of the information which does exist is anecdotal.

From the beginning, the management of radioactive waste required classification of the waste into categories. Management requirements depended upon both the level and type (alpha or beta emitting) of radioactivity in the waste and the volume of waste. The names of the categories and the division between the categories have changed over time reflecting, in part, the gradual change from individual plants developing their own systems to categories that are consistent across all DOE facilities. Despite the changes in the names used for a category and the divisions between categories, the early categories are generally recognizable and can be related to current categories. Initially, liquid wastes were divided into three main categories: metal wastes, radiochemical wastes, and process wastes (Browder 1949).

Metal wastes, while radioactive, contained primarily uranium with small quantities of plutonium or thorium. These elements are long-lived radionuclides and are fissionable source material. Waste containing uranium, plutonium, and/or thorium with activity $>3.7 \times 10^6$ Bq/L

Fig. 2.1. Oak Ridge National Laboratory Waste Areas

ORNL-DWG 93M-12556

● WAG 10 Hydrofracture Study Area

Area Groupings [from DOE (1992)].

(100 nCi/mL) would now be classified as transuranic waste. In the late 1940s, approximately 1500 gal/week (5677 L/week) of metal waste were being generated and collected from a variety of facilities throughout the laboratory (Browder 1949). This waste was collected and stored until a process could be developed by which to recover the uranium and other transuranic elements (Browder 1949).

Radiochemical waste contained primarily fission product radionuclides that have half-lives significantly shorter than the metal waste radionuclides. Radiochemical liquid wastes have been referred to as "hot" chemical wastes (Browder 1949) and intermediate-level wastes (Coobs and Gissel 1986) in the past; in most cases, they are now referred to as low-level liquid waste. In the late 1940s, approximately 30,000 gal/week (113,550 L/week) of radiochemical waste were being generated (Browder 1949). Radiochemical waste was discharged from process vessels in laboratory and Radiochemical Processing Pilot Plant cells into "hot" drains via "hot" sinks or glove boxes (Browder 1959; Mannes Schmidt and Witkowski 1962). Radiochemical wastes contained ^{137}Cs and ^{90}Sr with relatively long half-lives (about 30 years) in addition to other radionuclides with short half-lives (i.e., ^{131}I , 8 d; ^{141}Ce , 28 d; ^{143}Ce , 33 h; ^{103}Ru , 41 d; ^{140}Ba , 12.8 d; ^{140}La , 40 h), as well as various metals and small amounts of organics (Binford and Orifi 1979). The wastes usually originated as nitrate solutions, although some wastes were acidic chlorides or other corrosives. The acidic solutions were generally neutralized by the addition of solid sodium hydroxide before the wastes were sent to the Gunite tanks (Huang et al. 1984).

Process waste was, theoretically, nonradioactive or it had very low activity (Browder 1949). Current guidance classifies process waste as containing total beta-gamma activity not to exceed 10,000 Bq/L (0.27 $\mu\text{Ci/L}$). It is derived from cooling water, laboratory sinks other than "hot" sinks, and floor drains outside facilities devoted to "hot" work. In the late 1940s, approximately 2 to 4 million gal/week (7.6 to 15.1 million L/week) of process waste were being generated (Browder 1949).

A fourth category referred to as "warm waste" was in use during early operations (Browder 1949). Warm waste was moderately radioactive and represented a transition between process waste and radiochemical waste. Depending on the level of radioactivity present, warm waste was handled as either radiochemical waste or process waste.

An extensive system of underground utilities has been constructed and modified over the history of the facility. This system includes LLLW and process waste transfer lines whose purpose was to transport wastes from their generation points to treatment, storage and disposal facilities within the main plant area and in Melton Valley. Locations of the underground utilities are shown on the ORNL Area Atlas; however, because of poorly documented modifications which have been made to the system, this Atlas is incomplete.

Numerous underground tanks (see Fig. 3.2) have been installed during the operational history of the facility. The purpose of these tanks was to store wastes generated during site activities. This system of tanks includes six 170,000-gal (643,450-L) capacity Gunite tanks in the South Tank Farm (STF), Gunite and stainless steel tanks in the North Tank Farm (NTF),

and other waste collection and storage tanks located adjacent to waste-generating facilities in WAG 1.

The Gunitite tanks were originally constructed to store all of the radioactive liquid (radiochemical and metal) wastes generated by ORNL site operations, which was originally planned to have a 1-year operating period (Browder 1962). However, even before the Graphite Reactor first went critical on November 4, 1943, expansion of the scope of work had required that the period of operation be extended initially to 3 years. Because of the expanding requirements for managing the radioactive waste liquids, the capacity of the tanks was inadequate for permanent storage and it became necessary to consider disposal of some portion of the waste. Various approaches were used to manage the increasing volumes of waste with the Gunitite tanks remaining the central facility for most of the waste management activities at ORNL into the 1970s.

The first waste management approach was to separate the different waste streams as much as practical and to concentrate the radioactive components in the liquids by precipitation (Browder 1949). The large Gunitite tanks in the STF were used for the precipitation process with the smaller Gunitite tanks in the NTF used either for the storage of metal waste or the collection of waste for characterization before transfer to the appropriate system. At that time the tanks in the STF were connected and operated in three pairs. The three tanks on the north side of the tank farm (W-5, W-7, and W-9) received the waste stream and overflowed to the corresponding tanks to the south (W-6, W-8, and W-10, respectively). Tanks W-5 and W-6 were used for the collection and treatment of the radiochemical waste stream while Tanks W-7, W-8, W-9, and W-10 were used for the collection and treatment of the metal waste stream. The precipitation step was found to concentrate most of the radionuclides in the precipitate that formed a sludge at the bottom of the tank and significantly reduced the level of activity in the remaining liquid (supernatant). The supernatant would then be discharged to a 1,500,000-gal (5,667,500-L) settling basing that was completed in July 1944 where the supernatant was diluted with large volumes of process waste before discharge into White Oak Creek.

In 1945, the precipitation of radiochemical waste was discontinued (Browder 1949). Instead, Tanks W-5 and W-6 were used to collect and hold the radiochemical waste to allow radionuclides with short half-lives to decay and significantly reduce the total radioactivity of the waste. Tanks W-5 and W-6 were used to hold the radiochemical waste for about 1 month on average, after which it was discharged to the settling basin for dilution with process waste (Browder 1949). Tanks W-7, W-8, W-9, and W-10 continued to be used to collect metal waste. However, the original piping for the transfer system was modified so that waste in any one tank in the STF could be transferred to any other tank (Mynatt and Webster 1963). Tank W-9 was used as the initial collection tank for metal waste, which was then transferred to either Tank W-7 or W-10 for precipitation. The supernatant from the precipitation was transferred to the radiochemical waste system. At this time, Tank W-8 was only used for the temporary storage of metal waste.

Starting in 1949, the radiochemical waste stream was treated by concentration using a pot-type evaporator. This operation was conducted in the Waste Evaporator Facility (WEF) (Building 3506), which was constructed on the western side of the STF. The WEF was the first liquid waste evaporator at ORNL and operated from June 1949 until June 1954. During this period, the evaporator processed a total of 11,650,000 gal (44,095,250 L) of radiochemical waste (Browder 1959). An estimated 432,000 gal (1,635,120 L) of concentrated radiochemical waste were returned to storage in the Gunit tanks while the evaporated aqueous phase was discharged to the settling basin for mixing with the process waste stream.

In 1950, further expansion of ORNL required additional modifications in the waste management system to handle the increased waste volumes and levels of radioactivity. In order to better manage the waste, underground stainless steel tanks were installed near each building or area that was a source of radiochemical or metal waste. These tanks permitted better collection and segregation of the waste types as well as sampling and measurement of waste volumes and rates of accumulation from each source. Tanks W-1A, W-13, W-14, and W-15 in the NTF were installed at this time.

From 1952 to 1957, a metal recovery plant extracted approximately 130 tons (132,080 kg) of uranium from the accumulated metals waste in storage in the Gunit tanks. Residual waste from the metals recovery process was incorporated into the radiochemical waste stream.

Starting in 1952, some radiochemical waste was discharged directly into the ground using a series of pits and trenches (Browder 1962; Mannes Schmidt and Witkowski 1962). In 1954, the use of the WEF was discontinued in favor of using the pits and trenches. Gunit Tanks W-5, W-6, and W-8 in the STF were once again used for holding the radiochemical waste to permit the decay of the short half-life radionuclides (Browder 1959). The waste was then pumped from these tanks to the disposal pits and trenches. Tanks W-7, W-9, and W-10 continued to be used for the precipitation and storage of metal waste.

In 1965, a new evaporator was placed in operation. Radiochemical waste was initially accumulated from the various collection tanks into Tank W-5. Tank W-5 also continued to receive the supernatant from precipitation of the metal waste in Tanks W-7 and W-10. The radiochemical waste was transferred to the evaporator for concentration. The concentrated radiochemical waste was returned to Tanks W-6 or W-8 for holding until disposal to pits and trenches while the evaporated aqueous phase was discharged to the settling basin. Disposal of the radiochemical waste to pits and trenches continued until 1966 when routine disposal of the waste using the hydrofracture technique was initiated. With this technique, the waste was mixed with a cement grout and injected into shale at a depth of about 1000 ft.

Continuous improvements and modifications to the ORNL waste management system eventually eliminated the need for most of the older tanks. Tanks W-1, W-2, W-3, W-4, W-13, W-14, and W-15 in the NTF were removed from service in the late 1950s or early 1960s (Coobs and Myrick 1986). The liquid waste was removed from the tanks when they were removed from service. Any sludge in the tanks as well as a small volume of residual liquid remained in the tank. The large Gunit tanks in the STF were removed from service in the

late 1970s (Coobs and Myrick 1986). Accumulated sludge precipitated from solution as well as residual solutions remained in these tanks until they were cleaned by sluicing in 1982 and 1983; however, some liquid and sludge remain (Weeren 1984; Coobs and Myrick 1986). The sluicing operation used a mixture of bentonite and water that was pumped from a feed tank through a sluicer nozzle to impinge on and resuspend the sludge in the tank being sluiced. The resuspended sludge was pumped from the tank and through a grinder to break up oversized particles. It was then recycled to the feed tank. This operation was continued until the sludge concentration in the feed tank approached about 15% by weight. At this point the sluicing operation would stop and the slurry was pumped from the feed tank to storage at the Melton Valley Storage Tanks. The slurry was stored there until it could be prepared for final disposal at the New Hydrofracture Facility (Weeren 1984). Except when it was sluiced, Tank W-10 was used for the feed tank. Tank W-9 was used as a feed tank during the sluicing of Tank W-10 (Weeren 1984). An estimated 2,195,400 lb (995,646 kg) of sludge were removed from the tanks and transferred to the New Hydrofracture Facility.

The WEF (Building 3506) was constructed in 1949 and housed the first liquid waste evaporator at ORNL (Manneschmidt and Witkowski 1962; Coobs and Myrick 1986). The facility received the LLLW streams from ORNL laboratories and other processing areas. Operations at this facility were suspended in 1954. The concentrated waste was returned to storage in the Gunit tanks while the evaporated phase was discharged to the settling basin for mixing with the process waste stream. Subsequently, an experimental incinerator for radioactive wastes was located in the large cell, and experimental equipment was used to develop fission product purification processes (Horton 1984; Coobs and Myrick 1986). The building went through extensive decontamination before its use as an incinerator facility. Most of the former process equipment was removed after the facility became inactive (Simpson 1984; Coobs and Myrick 1986). Presently, the building exterior doors are normally locked, and the building and grounds are posted as radiation/contamination zones with access restrictions.

The Fission Product Pilot Plant, built in 1948, was first called the ^{106}Ru tank arrangement. It was used in the fission product recovery development program for the separation of curie quantities of various radionuclides, including ruthenium, strontium, and cesium, from liquid waste (Horton 1984; Coobs and Myrick 1986). The waste came from the ORNL laboratories and from the Canadian Chalk River cleanup operation. Its initial construction consisted of a concrete pad with tanks surrounded by stacks of concrete blocks three rows deep, with a tent surrounding the pad. The facility was modified several times from 1950 to 1951 (Horton 1984) and it was abandoned in 1958 when it was replaced by the Fission Product Development Laboratory (Coobs and Myrick 1986). Shortly after operations ceased at the Fission Product Pilot Plant, the building was entombed in a concrete shell, which remains to this date (Coobs and Myrick 1986).

2.3 RELEASES

Historically, numerous contaminant releases have occurred in WAG 1. Because of the complex and variable nature of the operations carried out at ORNL, and because of the

secrecy surrounding many of these operations, complete written documentation of all releases is not available.

One hundred sixty-seven SWMUs have been identified and classified in WAG 1. The SWMUs are individually described in the ORNL "Contaminated Sites Summary Sheets" (ORNL 1990). ORNL identified these SWMUs as potential sources of contamination that might pose a threat to human health or the environment. Table 2.1 gives a short description of each SWMU. A detailed discussion of the characteristics of the SWMUs is presented in the "Site Characterization Summary Report" for WAG 1 (BNI 1992) prepared as part of Phase I of the RI.

Pursuant to a RCRA permit issued prior to the initiation of the WAG 1 RI, 27 SWMUs were classified as requiring no further investigation. Fourteen were listed for decommissioning and demolition under the DOE surplus facilities program. The remaining 126 SWMUs, shown on Fig. 2.2, include inactive underground waste storage tanks, waste burial grounds, surface impoundments, LLLW lines and leak sites, active underground waste storage tanks, and mercury spill sites.

Descriptions of 35 sites where LLLW line leaks have occurred at ORNL can be found in Grimsby (1986). Twenty-three of the leak sites are located in WAG 1, with 20 of the 23 sites being concentrated in the 3000 and 3500 blocks which are divided by Central Avenue.

**Table 2.1. Solid waste management units (SWMUs)
in Waste Area Grouping 1**

SWMU	Description of unit ^a
1.1	Mercury-contaminated soil (3503)
1.2	Mercury-contaminated soil (3592)
1.3	Mercury-contaminated soil (4501)
1.4	Mercury-contaminated soil (4508)
1.5A	LLLW lines and leak sites, south of Building 3020
1.5B	LLLW lines and leak sites, east of Building 3020
1.5C	LLLW lines and leak sites, west of Building 3082
1.5D	LLLW lines and leak sites, north of Building 3019
1.5E	LLLW lines and leak sites, southwest corner of Building 3019
1.5F	LLLW lines and leak sites, between W-5 and WC-19
1.5G	LLLW lines and leak sites, underneath Building 3047
1.5H	LLLW lines and leak sites, general isotopes area (3037, 3038, 3034)
1.5I	LLLW lines and leak sites, Building 3092 area
1.5J	LLLW lines and leak sites, underneath Building 3026
1.5K	LLLW lines and leak sites, between WC-1 and W-5
1.5L	LLLW lines and leak sites, ORR water line (Building 3085)
1.5M	LLLW lines and leak sites, Building 3028
1.5N	LLLW lines and leak sites, east of Building 2531

Table 2.1 (continued)

SWMU	Description of unit ^a
1.5O	LLLW lines and leak sites, underneath Building 3515
1.5P	LLLW lines and leak sites, Building 3525 to a sump
1.5Q	LLLW lines and leak sites, underneath Building 3550
1.5R	LLLW lines and leak sites, sewer near Building 3500
1.5S	LLLW lines and leak sites, abandoned line, Central Ave. area
1.5T	LLLW lines and leak sites, Building 4508, North
1.5U	LLLW lines and leak sites, Building 3518, West
1.5V	LLLW lines and leak sites, northwest of SWSA 1
1.5W	LLLW lines and leak sites, Building 3503, ground contamination
1.6	Contaminated surfaces and soil from 1959 explosion in 3019 cell
1.7	Contamination at base of 3019 stack
1.8	Graphite reactor storage canal overflow (3001/3019)
1.9	ORR decay tank rupture site (3087)
1.10	Storage pads (3503/3504)
1.11	Decommissioned waste holding basin (3512)
1.12	Waste holding basin (3513)
1.13	Equalization basin (3524)
1.14	Process waste pond (3539)
1.15	Process waste pond (3540)
1.16	Sewage aeration pond (east) (2543)
1.17	Sewage aeration pond (west) (2544)
1.18	Coal pile settling basin (2545) ^b
1.19	Low Intensity Test Reactor pond (3085W)
1.20	3517 filter pit (Fission Product Development Laboratory) (3517)
1.21	Fission Product Development Laboratory LLLW transfer line
1.22	Isotopes ductwork/3110 filter house
1.23A	Inactive LLLW collection/storage tank W-1
1.24A	Inactive LLLW collection/storage tank W-3
1.25A	Inactive LLLW collection/storage tank W-13
1.26A	Inactive LLLW collection/storage tank W-5
1.27	Inactive LLLW collection/storage tank W-11
1.28	Inactive LLLW collection/storage tank W-1A
1.29	Inactive LLLW collection/storage tank WC-1
1.30A	Inactive LLLW collection/storage tank WC-15
1.31A	Inactive LLLW collection/storage tank TH-1
1.32	Inactive LLLW collection/storage tank TH-4
1.33	Active LLLW collection tank 2026A
1.34	Active LLLW collection tank W-2
1.35	Active LLLW collection tank W-3
1.36	Inactive LLLW collection tank WC-4
1.37A	Inactive LLLW collection tank WC-5

Table 2.1 (continued)

SWMU	Description of unit ^a
1.38	Active LLLW collection tank WC-7
1.39A	Active LLLW collection tank WC-10
1.40	Active LLLW collection tank WC-19
1.41	Inactive LLLW collection tank WC-12
1.42A	Inactive LLLW collection tank WC-16
1.43A	LLW collection tank (W-21) ^b
1.44	LLW collection tank (W-23) ^b
1.45A	LLW concentrate storage tank (C-1)
1.46	SWSA 1 (2524)
1.47	SWSA 2 (4003)
1.48	LLW evaporator (2531) ^b
1.49	Neutralization facility ^b
1.50	PCB storage area (2018W) ^b
1.51	Process Waste Treatment Plant (3544) ^b
1.52	Sewage Treatment Plant (2521) ^b
1.53	Septic tank for Building 3000 (3078) ^b
1.54	Waste oil storage tanks (2525) ^b
1.55	Septic tank for Building 6506 (5507) ^b
1.57	Site nonradiological wastewater treatment plant ^b
1.58	Former waste pile area
1.59	Old incinerator site ^b
1.60	Buried lead near north portal ^b
1.61A	Waste accumulation area (1503) ^b
1.62	Waste Evaporator Facility (3506)
1.63	Transfer canal and dissolver pit (3505)
1.64A	Active LLLW collection tank S-223
1.65A	Active LLLW collection tank F-201
1.66	Inactive LLLW collection tank W-11
1.67A	Inactive LLLW collection tank 4501-C
1.68	Inactive filter house seal tank 3002-A
1.69A	Active LLLW collection tank N-71
1.70	Active LLLW collection tank LA-104
1.71	Inactive LLLW collection tank H-209
1.72	Inactive tank 3001 suspect
1.73	Inactive LLLW collection tank 3001-B
1.74	Inactive LLLW collection tank 3003-A
1.75	Inactive LLLW collection tank 3004-B
1.76	Inactive LLLW collection tank 3013
1.77	Active LLLW collection tank L-11
1.78	Inactive LLLW collection tank T-30
1.79	3001 storage canal

Table 2.1 (continued)

SWMU	Description of unit ^a
1.80A	Acid storage tank (3505A)
1A.1A	Graphite Reactor Building 3001 ^c
1A.2A	Low Intensity Test Reactor (3005) ^c
1A.3	ORR (3042) ^c
1A.4	⁶⁰ Co storage garden (3029) ^c
1A.5	Fission Product Development Laboratory (3517)
1A.6	Fission Product Pilot Plant (3515)
1A.7	Metal Recovery Facility (3505) ^c
1A.8	Storage garden (3033)
1A.9	⁹⁰ Sr power generators (3028) ^c
1A.11	Ceramic Processing Laboratory (4608) ^c
1A.12	High-Level Chemical Development Laboratory (4507)
1A.13	Remote coating furnace loop (4508) ^c
1A.14	Transuranium Research Laboratory 45 (5506) ^c
1A.15	High-Level Radiochemical Analytical Laboratory (3019B)
1A.16	ORR heat exchanger (3087) ^c
1A.17	Off-gas filter house (3121)

^aAcronyms used in the table: LLW = low-level waste, LLLW = low-level liquid waste, ORR = Oak Ridge Research Reactor, PCB = polychlorinated biphenyl, SWSA = solid waste storage area.

^bNo further investigation.

^cSurplus facility.

Source: BNI (1992).

WAG1 01F313.DGN
9/23/92

Fig. 22. WAG 1 Solid Waste Mana

3. THE GROUNDWATER SYSTEM

This chapter describes the current understanding of the groundwater system at WAG 1, the interaction of groundwater with underground utilities and pipelines, and the conceptual model for flow and transport.

WAG 1 is underlain by complexly interbedded limestone, siltstone, and shale rocks of the Chickamauga Group which strike northeast-southwest and dip about 35° southeast, consistent with the regional structural setting. Detailed geologic mapping of ORNL was first performed by Stockdale (1951) who subdivided the Chickamauga Group into 8 subunits lettered A through H. Subsequent subsurface explorations have provided additional detail to Stockdale's work. Hatcher et al. (1992) first related Stockdale's A through H subunits to recognized formations in Virginia. However, since those relations have not yet been formally accepted, Stockdale's A through H designations will be used in this report.

Groundwater at WAG 1 is under water table conditions. Recent data analysis suggests the presence of very localized partially confining conditions which may be related to the presence of low permeability (e.g. shale-dominated) bedrock lithologies. The presence of cavitate bedrock in some areas of WAG 1 complicates flow analyses to an undetermined extent. Building sumps and underground tanks and pipelines also complicate the flow system.

3.1 FLOW CONDITIONS AND CONTROLS

Solomon et al. (1992) describe the Chickamauga Group groundwater system at WAG 1 as an aquitard in which flow is dominated by fractures. The aquitard generally has lower permeability and yield than the adjacent Knox/Maynardville aquifer. Fairly large volumes of water may be stored in fractures, but only limited amounts of water are transmitted through them. Aside from pervasive bedding plane fractures, two steeply dipping, cross-cutting, orthogonal fracture sets are oriented roughly normal and parallel to geologic strike (30–50° NW and 40–65° NE respectively). The occurrence of these fractures likely accounts for observed groundwater flow paths parallel to geologic strike and oblique to the hydraulic gradient. The presence of solution cavities in limestone-rich bedrock Units C, D, and G also results in localized cavity flow systems.

The stormflow zone is a 1- to 2-m-deep interval beneath the ground surface which approximately coincides with the root zone. This zone is reported to account for about 90% of active subsurface flow in ORR aquitards (Solomon et al. 1992). However, because of extensive development in WAG 1, stormflow is considered to occur in only limited areas with topographic relief and an absence of development in the northern part of the WAG. In developed areas, precipitation is mostly diverted to surface water by storm sewers and underground pipeline trenches.

An estimated 40 million gal/year of groundwater is artificially removed by underground liquid waste storage tank sumps and dry wells and the process waste pipeline system, particularly in the southern portions of the WAG. This water is directed to the PWTP; thus, an extensive pump and treat system that removes contaminated groundwater operates within the WAG. This value is only an estimate and represents nearly 15 in./year of groundwater removal, which is about one-half of all runoff from the basin on a unit area basis. Groundwater removal by building sumps undoubtedly contributes even more.

Analysis of process waste manhole flow, radiological, and precipitation data shows that contaminant flux from groundwater through parts of the process waste system is directly related to precipitation and/or groundwater elevation, indicating that contaminants reside within groundwater or in the vadose zone immediately above the water table, and water table rise results in the mobilization of contaminants. Characteristics of the vadose zone vary across WAG 1. In low-lying areas near surface water bodies, the water table surface coincides closely with surface water, and the vadose zone is absent. The vadose zone thickens away from surface water bodies; and on the topographic high in the northern part of the WAG, perched groundwater develops seasonally in the comparatively thick residual soils. In low-lying and developed areas, much of the precipitation that enters the vadose zone is intercepted by underground pipeline trenches and discharges directly to surface water.

Analysis of water elevation data indicates that water is generally below the elevation of bedrock in the hilltop area underlain by Units C and D. Perched water is considered to develop above bedrock seasonally, which infiltrates fairly rapidly. Units E and G bedrock is perennially beneath the water table, and water elevations vary little seasonally. Likely because of the greater clastic content in Unit F than in adjacent Units E and G, Unit F bedrock is perennially above the water table. This characteristic may explain apparently anomalous, strike-parallel flow related to Unit F discussed below.

The water table surface generally coincides with the shape of the land surface. Solomon et al. (1992) report that about 98% of the flow occurs in depths <30 m, and flow path lengths are from tens to hundreds of meters to local surface drainageways for discharge. Although no compelling evidence exists to support the presence of deep, long subsurface flow paths, limited data could be interpreted to support such phenomena. These phenomena are discussed in Chap. 6.

Comparison of groundwater elevation data and engineering design drawings of underground tanks used for temporary storage of liquid low-level and process waste indicates that many tanks would be partly to completely beneath the water table in the absence of dry wells adjacent to the tanks. Where present, groundwater around the tanks is considered to flow toward the dry wells which undoubtedly also serve to create local groundwater depressions. Water is pumped from the dry wells as needed to the PWTP. Limited dry well pumping data indicate that pumping is not always strongly related to rainfall.

Figure 3.1 shows the general configuration of the water table surface at WAG 1. The apparent groundwater mound in the north-central portion of WAG 1 is considered to possibly

Fig. 3.1. WAG 1 general water table surface configuration including well and geologic unit locations.

represent local perched water and may not be representative of actual groundwater conditions. The presence of cavities and preferred flow pathways locally alters flow patterns in the shallow portion of the aquitard from what would be anticipated from analysis of the water table configuration. The extent to which local flow is altered is not known because they are not resolvable with the current distribution of piezometers and wells. However, several studies in and around WAG 1 have determined that significant localized effects occur.

Core hole straddle packer tests in WAG 1 indicate that hydraulic head generally increases with depth. Anomalous zones of low head at depth have been suggested to represent potential off-WAG discharge pathways. This phenomenon is discussed in Sect. 6.4.9.3. Because of suspected equipment malfunctions or incomplete isolation of the test interval, the results are subject to overinterpretation.

Results of core hole flow meter testing indicate that the overwhelming majority of the rock mass is not involved in water transmission, and only discrete intervals at the roughly 0.24- to 3.5-m scale (Moore and Toran 1992) are pervious intervals actively involved in water transmission. Although these estimates include data from bedrock units other than those underlying WAG 1, it is reasonable to assume they can be approximately applied to WAG 1.

3.1.1 Recharge and Discharge

The WAG 1 aquitard is influenced by recharge at two scales: regionally from the adjacent ridges and locally from the topographic high underlain by Units C and D. It is considered that the elevated hydraulic head values in Units C and D reflect pressure influences from adjacent Chestnut Ridge. The extensive cavity system, especially in Unit D, should allow water to readily drain from those units; but the maintenance of perennially elevated head in the cavity system suggests influences from Chestnut Ridge, perhaps combined with lenticular cavities where flow is controlled by small, variably connected fractures. Thus, even though flow rates may be small, pressure in the groundwater system at depth, combined with local recharge from infiltration, results in elevated head.

Most local recharge occurs on undeveloped areas of high ground underlain by Units C and D. Most precipitation in undeveloped flat-lying areas of WAG 1 is likely intercepted by underground pipeline and utility trenches. This has been suggested as an explanation for lower water table fluctuations in WAG 1 than elsewhere on the ORR (Moore, Huff, and Ketelle 1987). Developed areas likely contribute little to recharge where precipitation is diverted by storm sewers. Discharge is to local surface water drainages in the form of seeps and springs or pipeline bedding material.

Comparison of well hydrographs and precipitation data indicates rapid (often within hours) groundwater response to precipitation. A slow water level decline (over a nominal several day period) to normal levels occurs until the next activating precipitation event. Piezometers near surface water bodies respond more quickly to precipitation than do those away from surface water. Adjacent rock and interface well pairs respond similarly to

precipitation suggesting deep aquifer pressure response to precipitation is not solely from localized infiltration but may be from more regional effects.

3.1.2 Lateral and Vertical Gradients

In general, lateral hydraulic gradients in the shallow flow system at WAG 1 range from about 0.001 to 0.15 ft/ft toward the southeast to southwest. In September 1991, gradients in the northern portion of the WAG averaged 0.067 ft/ft and generally decreased to the south to an average 0.029 ft/ft.

Gradients in the northern portion of the WAG are generally steeper in the spring than in the fall because of large increases in groundwater elevations in recharge areas relative to the rest of the WAG. The average gradient in the northern portion of the WAG was 0.073 ft/ft in April 1991 vs 0.067 ft/ft in September 1991. In the southern portion of the WAG, the gradient in April (0.030 ft/ft) was virtually the same as the gradient in September (0.029 ft/ft).

The general potential gradient in bedrock (from deep core hole packer test intervals) was about 0.03 ft/ft toward the south and southwest. These potential gradient directions generally agree with potential gradient directions for shallow groundwater, and suggest that groundwater recharge occurs to the north of the WAG and that groundwater discharges along the WOC drainage system.

Because of localized development of secondary porosity features such as cavities and fractures, the piezometric contours and lateral gradients discussed above indicate only potential directions of flow. Preferred flow pathways may depart significantly from flow pathways indicated by general lateral hydraulic gradients in WAG 1.

Well pairs for which hydraulic head measurements were available were used to calculate vertical gradients. Upward vertical gradients were observed in six well pairs (540/811, 610/825, 815/816, 825/826, 875/885, and 807/808) during monitoring in April and September 1991. These well pairs are all near streams, indicating that streams are likely discharge areas for groundwater in WAG 1. Downward vertical gradients were observed in three well pairs (820/821, 878/883, and 1100/1101). Well pair 820/821 is located near SWSA 2 in a groundwater recharge area. The downward vertical gradient observed in well pair 1100/1101, to the north of impoundment 3513, may be due to leakage from this impoundment. The strongest downward gradient was observed in well pair 878/883 near impoundment 3540, but this downward gradient reflects the anomalously low heads observed in well 883 during April and September 1991 and may reflect only localized conditions.

Piezometric head measurements were successfully obtained in 37 of 38 packer test intervals in eight core holes (CH-1, CH-3, CH-6, CH-7A, CH-9, FT-10, CH-11A, and CH-12). Piezometric head measurements were used to calculate vertical gradients and construct head potential graphs for the core holes. The data show an overall upward head potential within the bedrock aquifer at WAG 1, indicating that WAG 1 is predominantly a groundwater

discharge area. However, within some core holes, downward potential gradients exist over short intervals, especially in Units D, E, and F in the west-central portion of the WAG.

3.1.3 Anthropogenic Features

Extensive development at ORNL in WAG 1 has left little of the natural flow field intact. Terrain modifications, stream rerouting, and facility construction and abandonment are incompletely documented, and many details of past activities and their effect on groundwater flow will likely never be known with a great deal of certainty. This section describes the effect of anthropogenic features on groundwater to the extent documented and strongly suspected.

It is suspected that a significant percentage of infiltrating precipitation that would normally reach the water table is diverted through the bedding and backfill material of the pipeline network, but the suspicion has not been substantiated quantitatively. The diverted water likely discharges to surface water.

3.1.3.1 Underground utilities and pipelines

An extensive network of underground pipelines and utilities exists at ORNL. Utility corridors are generally coincident with roadways, while process waste and LLLW pipelines serving user facilities are more irregularly distributed. Figure 3.2 shows the general layout of the process waste and LLLW pipeline network; the general locations of major underground liquid waste storage tanks are also shown.

Because of the presumed higher permeability of pipeline trench backfill material than the surrounding undisturbed soil or saprolite, pipeline trenches are considered to be preferred flow and transport pathways that likely serve to alter the rate and direction of groundwater contaminant migration. Localized data indicate the presence of contaminants within pipelines and pipeline trenches; limited data suggest the potential for hundreds of feet of migration.

Soil contamination resulting from historic process waste and LLLW pipeline outleakage can be a secondary source of groundwater contamination. Contaminants likely initially seeped into the soil around the trench when the leaks were active and are remobilized when the soils are resaturated. The bulk of the contamination may remain in the trench and surrounding soil in the near vicinity of the leak or migrate undetermined distances within the trench.

Comparison of process waste pipeline invert and groundwater elevation data indicates that process waste pipelines serving facilities along Hillside Avenue and in the vicinity of the North and South tank farms are above the water table. In contrast, shallow temporary piezometers installed in pipeline trenches (BNI 1992) indicate that the trenches in the NTF contain seasonal perched water under high base conditions. Within the STF and north of Building 3517, the temporary piezometers were continually dry.

Fig. 3.2. General layout of process waste and low-level liquid waste pipeline system including locations of major liquid waste storage tanks.

A comparison of estimated manhole invert elevations and estimated high and low base groundwater elevation data indicates that invert elevations of manholes on the eastern portion of WAG 1 (manholes 112, 114, 190, and 234) are near or below the water table at least seasonally. It is known that groundwater enters the process waste system between manholes 112 and 114, probably from a combination of cracked piping and contributions from an abandoned process or potable water line near the Unit D/E contact and may receive inleakage from the hillside area. Measured flow data from 1991 indicate a weekly average inleakage of 10,781 gal/d (7.5 gal/min). Manhole 190 is perennially beneath the water table.

Ford, Holder, and Jones (1992) report that total fugitive (groundwater) process waste collected and treated in the PWTP during fiscal year (FY) 1992 exceeded 40 million gal (110,000 gal/d). From the process waste pipeline system this groundwater is reported to be derived principally from north of manhole 112, between manholes 112 and 114, and from pumping station 1. Fugitive process waste is also collected from the WC-8 tank dry well and the WC-10 tank farm dry well.

Undoubtedly, the principal cause for radiological contamination in the sanitary sewer impoundments (BNI 1992) is inleakage from process waste and/or LLLW pipelines to sanitary sewer pipelines. The extent of pipeline system interaction is not known. Seepage of contaminated groundwater into the storm sewer system in the western portion of WAG 1 was described by Ketelle and Lee (1992), but that seepage has not been characterized further.

Delineation of those portions of pipeline systems that contribute to individual outfall discharges is not well known. National Pollutant Discharge Elimination System outfall sampling also likely obtains samples directly from pipe discharges only and ignores seepage from the pipeline trench backfill material.

3.1.3.2 Underground tanks

Figure 3.2 shows the locations of the principal underground waste storage tanks at WAG 1 which are inactive but could contribute to groundwater contamination. These tanks temporarily stored wastes from generator facilities prior to pumping to the LLLW treatment plant. BNI (1992) summarizes operational histories of selected tanks and tank farms.

Monthly inactive tank liquid levels for FY 1992 are reported by Ford, Holder, and Jones (1992). Increases in those levels may be assumed to be due to groundwater inleakage. Monthly radiological (gross beta) and pumping data from selected tank dry wells are also reported. Both liquid level and dry well radiological data are available only for tank WC-17. Liquid levels in tank WC-17 remained relatively constant throughout FY 1992 (Ford, Holder, and Jones 1992). This is consistent with results of a video survey of the tank in late 1992 which showed inleakage into the bottom of the tank. The level of the liquid in the tank may correspond with the pumping capacity of the sump pump. Seasonal variations in the radiological content of the dry well water are not apparent.

Dry wells TH-1, TH-2, and TH-3, W1-A, WC-1, and WC-15 and WC-17 are also sampled for radiological content. The values show no apparent seasonality. Dry well WC-1 commonly has from about 3 million pCi/L to more than 4 million pCi/L concentrations, and the others are generally in the hundreds of thousands of picocuries per liter.

Comparison of engineering drawings of underground storage tanks and water elevation data from nearby piezometers indicates that, with the exception of the north and south tank farms, the base of most underground tanks is beneath the areal water table elevation. Tank dry wells are designed to remove groundwater from around the tanks. As such, local groundwater depressions undoubtedly exist in the immediate vicinity of the dry wells.

Various estimates have been made regarding groundwater leakage to the process waste and LLLW systems including underground storage tank dry wells. Mynatt and Webster (1963) estimated an average 26,500 gal/d (18 gal/min) drainage from the STF collection dry well. Daily discharge data for the WC-8 and WC-9 tank dry wells are available for much of the time period between 1987 and the first half of 1992. During that period daily average pumping volumes varied from 5000 to 51,500 gal/d (3.5 to 36 gal/min) for the WC-9 tank dry well and from 11,500 to 45,000 gal/d (8 to 31 gal/min) for the WC-8 tank dry well. By comparison, Ford, Holder, and Jones (1992) report daily averages ranging from 133 to 168,400 gal (0.1 to 117 gal/min) for the WC-9 dry well and from 0 to 30,800 gal (21 gal/min) for the WC-8 dry well in FY 1992. Average daily FY 1992 leakage to the vault for LLLW tank T-30 adjacent to Building 4507 and LLLW tank W-1A in the NTF varied from 0.1 to 10 gal and 1 to 450 gal respectively.

In contrast, the LLLW system was estimated to receive an annual average 600 gal/d (0.4 gal/min) (Parrot 1990) from generating facilities which is negligible compared to the amount received by the process waste system. Estimates of groundwater leakage to LLLW tanks can be made from daily pumping data of out-of-service tanks. In 1991, an average 106 gal/d (0.07 gal/min) was pumped from Tank W-1A which was taken out of service in 1986. Data from January through most of June 1992 for tanks WC-11 through 14 (taken out of service in 1991) indicate a daily average of 81.7 gal/d (0.057 gal/min) is removed. For the same time period, a weekly average 22.2 gal/d (0.015 gal/min) is derived from tanks WC-5 and WC-6. Pumping volumes for all these tanks are strongly rainfall dependent. An analysis of recent historic and current LLLW system groundwater leakage is being performed by Waste Management and Remedial Actions Division staff and will provide additional detail to these estimates.

3.1.3.3 Building sumps

Many buildings at WAG 1 have basement sumps. As part of site characterization data acquisition, BNI (1992) report results of sampling in 21 sumps in 10 buildings in early 1991. Building sump pumping rates are known for only the two sumps in Building 3042 (23,040 gal/d annual average) which is an undetermined combination of process waste from the Oak Ridge Research Reactor, groundwater from the Building 3085 area pump house, and local groundwater leakage. Other building sumps pump unknown amounts of water because

building sumps are inaccessible, their locations unknown, and no monitoring is performed. Similar to underground storage tanks, however, local groundwater depressions likely exist in the immediate vicinity of many building sumps, but the areal distribution of existing piezometers fails to resolve the depressions.

Comparison of the areal configuration of the water table with nine estimated building sump elevations was performed by BNI (1992). That comparison indicated that sumps in Buildings 3042, 3033, 4501 and 3106 potentially affect the water table. Sumps in Buildings 2533, 3500, 3085, 2531, and 3534 were estimated to be near or above the water table.

3.1.4 Observed Flow Paths

Observed flow pathways at WAG 1 are limited to one unintentional interception of a contaminant plume and a tracer test strongly influenced by artificial gradients. A potential trichloroethene (TCE) plume south of Building 2026 may describe a third pathway, but the plume is insufficiently characterized at present to describe a flow pathway. Contaminant migration near the Units F/G contact from WAG 3 may be extrapolated to WAG 1 with some confidence (see Sect. 6.4.9).

The unintentional plume interception was in the drilling of core hole CH-8, and the plume is commonly referred to as the CH-8 plume. From analysis of historic groundwater data in the area and sampling in both First Creek and storm sewers, Ketelle and Lee (1992) described a narrow, stratabound plume oriented parallel to geologic strike and oblique to the hydraulic gradient. The source of the plume is not known but is suspected to be from the Building 3019 area or from north of the NTF area.

Huff (1985) describes results of a dry weather tracer test performed in a bedrock cavity located immediately north of Building 3019. The cavity was identified beneath a break in a LLLW line. Although dye was detected in sanitary and storm sewer lines, the predominant migration direction was along geologic strike toward the Building 3042 sumps. Dye migrated about 137 m (450 ft) to the Building 3042 sump within 48 h (>2.8 m/h). Although it may be assumed that the sumps altered the natural gradient, the extent to which the sumps altered the natural flow direction is not known. Attempts to find evidence of westerly movement of dye into First Creek had negative results.

Stueber et al. (1981) describe the migration of radionuclides from SWSA 3 through a small cavity along geologic strike. The cavity is present at the geologic contact of Units G and F. Migration distance to discharge in the Northwest Tributary is about 640 m (2100 ft).

Limited observations of flow pathways could be interpreted to indicate that all flow in the shallow portion of the aquitard is along geologic strike. Strike-parallel flow is clearly operative in WAG 1, but it is not well-understood in detail and is not considered to be the principal flow mechanism. Rather, gradient-normal flow, which may occur in detail in a trellis pattern through strike and dip-set fractures, is considered to constitute the bulk of the flow; however, the local importance of underground pipelines and utilities, sumps, and underground

tank dry wells, as well as possible recharge from leaking water supply lines, cannot be overemphasized when considering flow pathways.

3.2 AQUIFER PROPERTIES

3.2.1 Overburden

Direct measurements of total porosity of the overburden materials at WAG 1 are not available. Moore (1988) reported a total porosity of 0.30 to 0.50 for clayey materials in the stormflow zone (i.e., shallow interval where unsaturated flow occurs) on the ORR. Davis et al. (1984) reported a mean total porosity in shaley saprolite in trench walls at WAG 6 of 0.50.

Due to the high clay content of the overburden, effective porosity (porosity through which water is capable of moving) is probably much lower than total porosity. However, no site-specific data on effective porosity have been collected from WAG 1. Moore (1989) reported an average effective porosity of 0.0042 in the vadose zone of undisturbed soil on the ORR. Solomon et al. (1989) estimated the effective porosity of overburden materials near three abandoned surface impoundments in WAG 1 to be about 0.018.

Saturated hydraulic conductivity values have been estimated for three piezometers and well points completed above the overburden/bedrock interface in WAG 1: piezometer 588 (near Building 3001), well point 721 (near WOC, just outside the southwestern boundary of WAG 1), and well point 722 (adjacent to WOC in the southwestern corner of WAG 1). The values were 1.97×10^{-4} cm/s, 2.6×10^{-6} cm/s, and 1.27×10^{-4} cm/s for piezometer 588, well point 721, and well point 722 respectively. These relatively low values are consistent with observations regarding the composition of overburden materials, which consist primarily of native clay-rich soils (residuum, alluvium, or colluvium) or clay-rich fill materials.

Hydraulic conductivity estimates were made from two temporary piezometers (01.SB208 and 01.SB224) which were constructed near buried pipelines. The values in these piezometers were about 1 to 4×10^{-4} cm/s, comparable to other overburden values. However, these piezometers may not have intercepted the backfill materials surrounding the pipelines. In addition, data from only two piezometers is probably not sufficient to characterize hydraulic conductivities in pipeline backfill materials at WAG 1.

3.2.2 Bedrock

Primary porosity is probably almost absent from Chickamauga Group bedrock at WAG 1. Therefore, groundwater movement likely occurs along secondary porosity features (e.g., fractures, solution channels, and cavities). Total porosity and effective porosity have not been measured for the Chickamauga in Bethel Valley. DeLaguna et al. (1968) reported porosity values ranging from 3.9×10^{-3} to 1.5×10^{-2} in samples of unfractured Chickamauga rock collected from depths >2000 ft in a core hole in Melton Valley. Moore (1989) estimated the effective porosity of ORR bedrock to range between 1×10^{-5} and 1×10^{-3} . Moore and Toran

(1992) estimated matrix porosity to be 9.6×10^{-3} , fracture porosity to be 5.0×10^{-4} , and effective fracture porosity to be 3.5×10^{-4} for the groundwater zone of ORR aquitards. However, these data may not be directly applicable to the Chickamauga in WAG 1.

Hydraulic conductivity values for bedrock aquifer materials at WAG 1 have been estimated using slug test methods and packer test methods. The values are highly variable, ranging from 1×10^{-9} cm/s to 1×10^{-2} cm/s, with a geometric mean of 8.8×10^{-6} cm/s.

No consistent relationship exists between geologic unit and hydraulic conductivity values. Although the different rock units have different mean hydraulic conductivity values, there is significant overlap of ranges and standard deviations. Some of the highest hydraulic conductivity values are found in Unit D; however, there is a high probability that intervals with low hydraulic conductivity values will also be encountered in that unit. This relationship suggests that preferred flow pathways (i.e., highly transmissive secondary porosity features) are relatively widely spaced and are separated by comparatively nontransmissive intervals. However, it is not possible to identify all preferred flow pathways based on existing hydraulic conductivity data. Locations for which hydraulic conductivity data are available are not distributed evenly across WAG 1 and most data are from depths <100 ft.

There is an overall decrease in hydraulic conductivity with depth. This is probably due to a decrease in the frequency of open fractures with depth. However, high or low hydraulic conductivity values are possible at almost any depth. Within the uppermost depth range (from 0 to 100 ft), fewer than 10% of hydraulic conductivity values are $<10^{-7}$ cm/s. The percentage of hydraulic conductivity values which are $<10^{-7}$ cm/s increases steadily with depth. In the 400–500-ft depth range, 67% of hydraulic conductivity observations are in this category. Conversely, the number of hydraulic conductivity values that are $>10^{-5}$ cm/s decreases with depth. For example, more than 40% of the hydraulic conductivity values in the 0–100-ft depth range are in the 10^{-5} to 10^{-4} cm/s category. There are no values in this category in the deepest depth range. The categories that include hydraulic conductivity values in the 10^{-3} to 10^{-4} cm/s range and values $>10^{-3}$ cm/s show a similar trend.

The foregoing analysis shows that most zones of high hydraulic conductivity occur at relatively shallow depths. Therefore, most groundwater flow in WAG 1 probably occurs at these relatively shallow depths in zones dominated by high hydraulic conductivity values. Some localized zones of high hydraulic conductivity values do occur at depths >300 ft. Most of the active groundwater flow in deeper intervals probably occurs in these high hydraulic conductivity zones.

Anisotropy, a ratio of hydraulic conductivities along different axes, is likely to occur on a local scale in WAG 1. Anisotropy near individual fracture zones may range up to several orders of magnitude because of preferred orientation (usually parallel to geologic strike) of transmitting fractures. Over larger areas, however, the changes in anisotropy are not known.

3.3 GROUNDWATER GEOCHEMISTRY

Geochemical analyses of groundwater samples from 14 core hole packer test intervals and from 15 groundwater monitoring wells in WAG 1 indicate that groundwater is stratified. In general, pH increases with depth. Specific conductance also increases with depth, indicating that total dissolved solids (TDS) also increase with depth (BNI 1992).

With one exception, the data plot into three groups: a calcium-bicarbonate to calcium-magnesium-bicarbonate type, a sodium-bicarbonate type, and a sodium-chloride type. The exception is the sample from piezometer 548, which is an upgraded piezometer screened across the overburden/bedrock interface. The groundwater in this sample plotted as a calcium-chloride type water. This water chemistry was not identified in any other groundwater samples included in this evaluation and could be the result of contamination from surface water runoff or other sources.

The three groundwater types were distributed according to the elevation of the sampling interval. The calcium-bicarbonate to calcium-magnesium-bicarbonate type waters occurred in the shallower sampling intervals from about 725 to 850 ft above mean sea level (MSL); the sodium-bicarbonate type waters were found in the intermediate sampling intervals from about 625 to 725 ft MSL; and the sodium-chloride type waters were found in two samples at elevations below 550 ft MSL. Boundaries between groundwater types probably vary somewhat across WAG 1 due to groundwater recharge.

A third sample of sodium-chloride type water was collected from an elevation of approximately 650 ft MSL in CH-9. Borehole flowmeter data (Moore and Young 1992) indicate that groundwater enters the borehole at a depth of 338 ft below ground surface (BGS) (elevation 447 ft MSL) and flows upward. Water flows out of the borehole at a depth of 135 ft BGS (elevation 650 ft MSL). Both of these intervals in CH-9 were sampled and the samples both contained sodium-chloride type water. Upward flow from the deeper to the shallower interval suggests that the chemistry of the water in the shallower interval may be affected by borehole circulation and that the shallower interval was not sufficiently purged prior to sampling. Further evidence of mixing between the deep and shallow zones in this core hole is that the shallow sample has the lowest specific conductance and highest alkalinity of the three sodium-chloride type samples and that it contains 1.2 mg/L bromide compared with 3.5 mg/L bromide in the deep sample.

The presence of three water types is typical of the ORR and suggests stratification of the groundwater. The chemistry of the shallow calcium-bicarbonate and calcium-magnesium-bicarbonate water is common worldwide, especially in limestone and dolomite aquifers. The sodium-bicarbonate chemistry of waters at intermediate depths is typical of ion exchange wherein calcium from groundwater recharge replaces sodium on exchange sites on clays in aquifer materials. This chemistry can also reflect mixing of sodium-chloride and calcium-bicarbonate waters with subsequent precipitation of calcium carbonate to form calcite. Numerous calcite veins and infillings found in core holes suggest that precipitation may be an important process in WAG 1. The sodium-chloride water found at depth is similar to

oilfield brines found elsewhere in the eastern United States (MacFarlane and Hathaway 1987; Bloch and Key 1981; Gott and Hill 1953 as referenced in BNI 1992). Oil-stained vugs were observed in several rock cores from WAG 1. In addition, the two deepest groundwater samples collected from WAG 1 (318 to 330 ft BGS in CH-9 and 318 to 331 ft BGS in CH-6) contain relatively high concentrations of bromide and fluoride, typical of oilfield brines.

Further evidence of stratification is the distribution of tritium in groundwater at WAG 1. Tritium is common in surface water and shallow groundwater as a result of long-term operations at ORNL. With little exception, tritium is present only in very low concentrations in samples from deep packer test intervals. If significant mixing of deep and shallow groundwater were occurring, tritium concentrations in the deeper zone should be similar to concentrations in the shallower zone.

3.4 BOUNDARIES

If one considers that the stratified aquitard described in Sect. 3.3 describes a shallow system through which most of the groundwater movement occurs, then it is reasonable to assume that the perennial surface water drainages at the WAG boundary (First Creek, Fifth Creek, and WOC) describe the discharge boundary for the shallow groundwater flow system to the west, east, and south respectively. Results of straddle packer testing in Units A and B to the north of WAG 1 indicate generally low permeability (in contrast to Unit C) and increasing hydraulic head with depth which suggests a discharge setting from adjacent Chestnut Ridge. These conditions in Units A and B are interpreted to represent a northern boundary for WAG 1.

The stratified aquitard may also describe a vertical boundary at about elevation 550 ft below which active groundwater movement relevant to WAG 1 ER activities does not occur. Results of core hole straddle packer testing have identified zones of low hydraulic head at depth which could be interpreted to support an interpretation that discrete zones of active groundwater movement could exit WAG 1; but uncertainties exist regarding the reliability of these data (e.g., equipment malfunction, poor packer seating). The presence of ^{137}Cs and tritium in core hole CH-9 at a depth of about 300 ft is not well-explained but could indicate groundwater flow from the shallowest portions of the aquitard to depth. Similarly, continually low heads in well 883 could indicate deeper flow paths exist than currently thought.

3.5 CONCEPTUAL MODEL

The WAG 1 groundwater flow conceptual model is that the WAG is the groundwater discharge area for the Knox Group aquifer underlying the adjacent Chestnut Ridge recharge area. The maintenance of elevated hydraulic head in Units C and D, despite the presence of cavities in those units, is considered to reflect hydraulic influences from the Knox which are transmitted through the relatively impermeable Units A and B. Local recharge occurs on the WAG 1 hilltop area underlain by Units C and D where the water table is generally beneath

bedrock. Perched water develops seasonally but apparently infiltrates rapidly to the water table. Groundwater elevation is perennially above bedrock in Units E and G, and fluctuation below bedrock is not observed. Presumably because of its comparatively greater clastic content that adjacent units, Unit F bedrock is perennially above the water table which may partially explain apparent strike-parallel flow near Unit F.

The groundwater system is thus envisioned to contain local recharge on the hilltop area which discharges through the overlying geologic units to surface water. Seasonal water table rise is a system-wide, piston-like response to precipitation. Throughout much of the WAG, significant amounts of discharging groundwater are intercepted by the extensive underground process waste pipeline and liquid waste tank storage network which is then sent to the PWTP for treatment.

The greatest flux of contaminants through groundwater to this network occurs during periods of elevated water table in response to precipitation. It is partly because of this network that contaminated WAG 1 groundwater is generally not detected in adjacent surface water bodies. The extent of surface water contamination would be anticipated to be much greater in the absence of this network.

Although cavities are known to occur in Unit G, the influence of these cavities on flow and transport is not known. The available data for WAG 1 Unit G bedrock piezometers indicate no piezometers were constructed in cavities. While drilling logs indicate the presence of fracturing in several of those piezometers, their hydraulic conductivity estimates do not differ significantly from those without fracturing. Air rotary drilling methods used in WAG 3 piezometer installation to the west of WAG 1 would not identify cavities. However, Stueber et al. (1981) indicate that off site migration of ^{90}Sr is along small, presumably strike-parallel cavities in Unit G near the geologic contact with Unit F.

The occurrence of stratabound groundwater flow at WAG 1 has been described by Ketelle and Lee (1992). Observations of stratabound flow were made in Melton Valley (Webster 1976) and in WAG 3 (Stueber et al. 1981). Stratabound flow has also been suggested to occur in Chestnut Ridge (Lee and Ketelle 1987), in a groundwater dye tracer test in Bear Creek Valley (Lee et al. 1989), and by the configuration of the S-3 Pond plume at the Y-12 plant (Geraghty and Miller 1990).

A simplified block diagram (Fig. 3.3) illustrates the basic components of the process as it is currently envisioned. The bulk of groundwater movement is envisioned to be essentially confined within discrete geologic strata. The direction of movement is determined by the hydraulic gradient within the stratum from a point of observation to the nearest surface water drainage. Comparatively minor stratum outleakage occurs with the local or site-wide hydraulic head profile. Vertical outleakage continues until another stratum is encountered through which stratabound flow can occur. Groundwater flow and contaminant migration are thus envisioned to occur in a trellis-like pattern. The scale at which the trellis movement is not resolved but simply resembles gradient-driven flow is not known but likely varies by bedrock unit.

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Fig. 3.3. Idealized block diagram of the stratabound pathway concept.

Stratabound flow is considered to occur most commonly in homogeneous, comparatively thick (on the order of about 1 m), limestone strata within which laterally extensive fractures can develop. As such, stratabound flow would not be expected to occur in thin bedded (nominally up to several centimeters thick) rocks with a mixed carbonate and clastic composition which do not contain laterally extensive fractures. Because the bulk of ORNL facilities are underlain by thin bedded rocks of Units E and G, stratabound flow is not considered to be the only flow and transport mechanism at WAG 1. However, strata do occur in these units which have the potential for stratabound flow development, and that mechanism must be considered to occur at least locally.

The underground process waste pipeline system and underground tank sumps and dry wells remove an amount of groundwater equal to approximately one-half of all expected runoff from an area the size of WAG 1, although this is only an estimate. The fractions of this water derived from bedrock groundwater, shallow subsurface flow, and leaking water supply lines are not known. However, estimates of expected recharge to the bedrock system from infiltration are considered to be only a few inches per year. Thus, the extensive pump and treat system that operates in WAG 1 significantly alters natural flow conditions.

4. POTENTIAL RECEPTORS AND EXPOSURE PATHWAYS

4.1 INTRODUCTION

The primary purpose of a risk assessment is to provide relevant information for environmental decision making. Risk assessment under CERCLA has two main goals: to determine the need for action at a site and to establish remedial goal options for consideration in the feasibility study. The need for action is established through the process of identifying pathways and contaminants of concern at a site and subsequently calculating risk on the basis of a set of exposure assumptions. In the feasibility study, the primary use of a risk assessment is to determine remedial goal options that will serve as a baseline for the amount of risk reduction afforded by implementation of the alternatives identified by the feasibility study if action is necessary. In order to achieve this task, reasonable land use scenarios must be identified for the on-source and off-source components of the risk assessment.

In this section, characterization of the human and ecological populations that may be affected by the WAG 1 Groundwater OU are considered. The receptor assessment aims to identify those individuals or populations with a current or future potential for exposure to contaminants originating from the site. The exposure pathway assessment identifies the routes by which a receptor might be exposed. Assessments will be used to evaluate risk posed by contaminants in source OUs that move through the shallow groundwater to surface water. Pathways to be included in the assessment are ingestion, inhalation, and dermal contact of the surface water. Risk characterization will be conducted using data from ongoing monitoring efforts and the WAG 1 remedial investigation. Groundwater data will be collected to determine which source OUs are contributing to contaminants found in the surface water. This information will also be used in an integration point assessment to prioritize the source OUs for remedial actions.

The risk assessment strategy for source OUs is designed to assist the ER program by focusing actions on sites that are a high risk priority for either on-site or off-site exposures and to provide adequate risk baselines for measuring the potential effectiveness of proposed remedial alternatives. Most of any off-site public exposure to ORNL contaminants results from surface water, which is the major transport mechanism for contaminant fluxes to off-site receptors. Other potential transport mechanisms (e.g., the food chain, the air pathway, and direct groundwater transport) are not currently primary sources of off-site fluxes. The integration point assessment is designed to actively use monitoring, surveillance, compliance, and RI data to evaluate the off-site risk from a variety of sources that contribute to the surface water integrator OU. The data will be used to establish a baseline for evaluating the risk at different points within the integrators, to identify and prioritize source areas within the context of the integrator, and to establish the degree of risk reduction a source control action can potentially achieve.

Residential pathways will be evaluated for the off-source assessment of risk from the source OUs. Selection of the off-source receptor point in the WOC floodplain at the WAG 1 boundary is consistent with what was established in the preliminary risk assessment report (IAHS 1990). The results of the WOC floodplain receptor will be used to evaluate the no-action alternative and combined with information obtained in the feasibility study to evaluate the amount of risk reduction obtained by any in-situ options for the FS. This will serve as a baseline for the relative degree of risk reduction in the future for implementation of the various options. Data from Phase II of the site characterization activities will be used in conjunction with data from ongoing site-wide monitoring programs to provide input for integration point assessments. These risk assessments will address current and future on-source OU and off-source OU exposures and will support (1) Records of Decision for interim or final actions and (2) removal actions.

4.1.1 Human Populations and Exposure Pathways

An exposure pathway is the means by which contamination from any contaminated media is transported 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.

The WAG 1 Groundwater OU is located within the ORNL site and is part of the DOE ORR (which covers approximately 35,000 acres). WAG 1 is an area of 150 acres that includes most of the original research and development facilities and associated waste management units. WAG 1 Groundwater OU is situated in an industrial area and no residences or drinking water sources are currently located on the site. Security precautions currently limit the presence of persons in this controlled area; consequently, the potential for human exposure to contaminants is limited. Employment at the ORNL site (as of January 1992) consisted of approximately 5000 full-time on-site personnel, the majority of which work in the main ORNL complex. Because most of the source areas have been closed and intrusive activities are limited, exposure to the on-site worker is generally limited to a small group of maintenance-type workers and future sampling and remediation workers. Given the extensive development of the main plant area, it is expected that WAG 1 will maintain an industrial land use classification in the future.

Nine public water supply systems serve about 91,500 people within a 32-km (20-mile) radius of the ORR. The intake for Kingston, located on the Tennessee River, is about 0.6 river km (0.37 miles) above the confluence of the Clinch and Tennessee rivers and about 34.1 river km (21.3 miles) below the White Oak Dam outfall. Kingston withdraws approximately 9% of its average daily supply from the Tennessee River. Sixteen public groundwater supplies are located within a 32-km (20-mile) radius of ORNL. Of these sources, the closest to ORNL is the Allen Fine Spring supplying the Dixie-Lee Utility District in Loudon County. This groundwater source, about 11 km (6.8 miles) southeast of ORNL, serves 6700 people with an average of 1,500 m³ (53,000 ft³) of water per day. Private single-family wells are common in adjacent rural areas not served by public water supply. Most of the residential wells, other than those adjacent to the City of Oak Ridge, are south of the

Clinch River. These wells are hydrologically isolated from impacts originating from the ORR because of the Clinch River. The nearest resident is approximately 3.7 km (2 miles) from the WAG 1 boundary.

All drainage and effluents from WAG 1, as well as from other WAGs, discharge to WOC and therefore, to White Oak Lake. Under normal flow conditions and during precipitation events, waterborne radioactivity and radioactively contaminated sediments can be carried through White Oak Dam and discharged to the Clinch River. WAG 1 has been a historical contributor of ^{90}Sr and ^{137}Cs to the overall contaminant inventory in the WOC watershed.

4.1.1.1 On-site potential human receptors and exposure pathways

An industrial future land use for the on-source assessment of risk at WAG 1 is the most appropriate given EPA guidance. This location meets the definition for areas that are defined as industrial sites under the future land use condition; the term “on-site” strictly means buildings and their associated infrastructure for purposes of the baseline risk assessment. Selection of an industrial scenario is consistent with the NCP and EPA guidance. *Risk Assessment Guidance for Superfund* (EPA 1989) states that “an assumption of future residential land use may not be justifiable if the probability that the site will support residential use in the future is exceedingly small.”

For future on-site land use, a reasonable maximum exposure risk assessment will be done based on industrial exposure at the source OUs. All water used on the ORR is imported from the Clinch River. Well yields are low in WAG 1 and are considered insufficient to serve as a reliable potable water supply currently and in the future. Because groundwater is not usable as a source of potable water at WAG 1, risk from groundwater within the site boundaries will not be assessed for the purposes of supporting specific remedial decisions. It will be assumed that future industrial receptors will continue to import their water from off-site. The emphasis for risk assessment and for remedial decisions will be on source control for groundwater contamination within the WAG 1 plant boundaries because the groundwater discharges to surface water in WOC.

4.1.1.2 Off-site potential human receptors and exposure pathways

The greatest potential for off-site human exposure is believed to be from surface water runoff and shallow groundwater discharge into WOC. The contaminants found in these integrators affect downstream surface water bodies, including the Clinch River. These water bodies are used for domestic and industrial water supply, fishing, recreation, and irrigation.

Under the current land use conditions, an integration point assessment will be used to evaluate potential exposure to off-site receptors. In brief, this assessment is designed to evaluate off-site human health risk from exposure to contaminants from the source OU (i.e., WAG 1 Groundwater OU). Conservative (residential) exposure parameters will be used to evaluate risk from ingestion of and dermal contact with surface water and for inhalation of

VOCs in the water at the WOC Dam. Contributions from the WAG 1 Groundwater OU will be ranked relative to other source OUs in the WOC watershed based on their flux contributions of contaminants of concern.

For future off-site land use, modeled results could be used to evaluate future 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, and (5) external exposure to radionuclides in soil. The point of residential exposure pathway assessment for future land use is the WOC floodplain at the WAG 1 boundary as previously established in the Preliminary Risk Assessment Report.

4.1.2 Ecological Populations and Exposure Pathways

Previous ecological assessments of the WOC watershed indicate that severe effects are not occurring in the aquatic habitats of WAG 2 and a diverse and productive aquatic community is present. However, reference stream surveys of aquatic biota indicate that there is some evidence for effects on fish reproduction and on benthic invertebrate community composition. Toxicity tests that have been performed for surface water have not indicated toxicity to *Ceriodaphnia dubia* or to larval fathead minnows in 7-d exposures. As ongoing studies within the scope of WAG 2 and the Biological Monitoring and Abatement Program continue, any contaminant migration originating from WAG 1 that can be linked to detrimental environmental effects will be targeted for remedial action.

4.2 HUMAN HEALTH RISK ASSESSMENT METHODOLOGY

The integration point assessment is a flux-based risk assessment. Flux is an important concept for source control because of the number of actual and potential sources of contaminants that exist on the ORR and the variability in flow rates of the different surface water systems that transport these contaminants to the surface water integrator OUs and eventually to the Clinch River. Source control actions taken at areas that have high fluxes of integrator contaminants of concern are the quickest means to reduce off-site exposure to levels that are as low as reasonably achievable.

An important objective during early phases of a large investigation is to assimilate available information from existing programs in order to estimate fluxes and mass balances of contaminants within the integrator system. The information is then used to assess fluxes within the watershed and compare them with fluxes that input into public access areas in order to differentiate between various contaminant sources at the ORR. Mass balance information is important to describe the accumulation of contaminants within a system where inputs and outputs are known and to assess the net impact of a reach or source area. The integration point assessment provides a means for communicating this information in terms of risk to the public and to risk managers. It also provides an important risk link between the source control and integrator OUs so that the effects of source control actions can be evaluated in the integrator.

4.2.1 Exposure Assessment Method

CERCLA and the Superfund Amendments and Reauthorization Act of 1986 establish a national program for responding to releases of hazardous substances into the environment. To help meet CERCLA's mandate to protect human health and the environment from current and potential threats posed by uncontrolled hazardous substance releases, EPA's Office of Emergency and Remedial Response has developed a human health evaluation process as part of its remedial response program. The purpose of the remedial process is to identify and reduce, control, or eliminate risks to human health and the environment.

The purpose of a risk assessment is to provide interested parties (e.g., managers, regulators, workers, and the general public) with an evaluation of the human and environmental health threats posed by hazardous waste sites. Risk assessment is a four-stage process that converts site-specific contaminant data (collected from sampling efforts) into a quantitative value that can be compared directly with risk-based standards. Data collection and evaluation are the first stage of this process. During this stage, analytical and other site-specific data are used to characterize the nature and extent of contamination. The second stage, an exposure assessment, involves the calculation of exposures based on the contaminant concentrations estimated from the analytical data, fate and transport models, and information collected on the demography and behavior of receptor populations. The third stage, toxicity assessment, involves the collection of information concerning the toxic characteristics of each contaminant. The results of the toxicity assessment (and subsequent uncertainty analyses) are combined with the exposure estimates to quantitatively or qualitatively evaluate the potential risks to human and environmental health posed by each contaminant of potential concern at a site in the fourth stage, risk characterization.

In order to derive a reliable estimate of exposure to be used in the risk characterization stage, it is essential to accurately determine representative constituent concentrations in the respective contaminated media at the site. For example, consider estimating exposure resulting from the ingestion of contaminants in water. The chronic daily intake (CDI) due to ingestion of contaminated water would be calculated using the following equation:

$$CDI = \frac{RC \times IR \times EF \times ED}{BW \times AT} ,$$

where

the intake concentration is in milligrams per liter per day,

RC = representative concentration in water (mg/L),

IR = ingestion rate (L/d),

EF = exposure frequency (d/year),

ED = exposure duration (years),

BW = body weight (kg),

AT = averaging time (period, in days, over which dose is averaged).

With the exception of the representative concentration, all of the variables in the above equation tend to be estimated by generic values recommended by EPA. Toxicity values for a given chemical are also constant across hazardous waste sites. The representative concentration is entirely site-specific and is probably the most important variable used to determine the threat to human and environmental health posed by individual hazardous waste sites. A representative concentration cannot be derived without reliable analytical data and a competent sampling plan.

The representative concentration is not necessarily the maximum concentration that was measured or that could be contacted by a receptor at any one time, rather, it is regarded as a reasonable estimate of the concentration likely to be contacted over time and likely to be typical, or representative, of the contamination levels across the site. Because of the uncertainty associated with any such estimate, the 95% upper confidence limit on the arithmetic average (the arithmetic mean) is used. However, exceptions to this rule do exist when there is considerable variability in measured or modeled values. For these cases, the calculated upper confidence limit will be high, and could be above the maximum detected or modeled value. Thus, the maximum detected or modeled value should be used. For some sites, where a screening level analysis is sufficient for characterizing potential exposures, calculation of the upper confidence limit on the mean is not required, and the maximum detected or modeled concentration should be used as an estimate of the exposure concentration (i.e., the representative concentration).

When the list of potential contaminants of concern and their representative concentration have been determined, the health risk is then calculated. Risks are estimated by multiplying the CDI (as calculated in the example above) by health risk factors available from the EPA. The results are quantitative estimates of the increased risk of getting cancer from carcinogenic chemicals in the soil and the risk of adverse health effects from noncarcinogenic chemicals in the soil, air, groundwater, etc. These risk estimations can then be used to aid in the prioritization of waste sites and/or in the assessment of remedial alternatives.

The human health evaluation methodology used in this remedial investigation follows the *Risk Assessment Guidance for Superfund* (EPA 1989), the *Superfund Exposure Assessment Manual* (EPA 1988a), and the *Health Effects Assessment Summary Tables* (EPA 1992). The *Guidance for Data Useability in Risk Assessment* (EPA 1990) was used in the selection of contaminants and appropriate contaminant concentrations.

4.2.2 Integration Point Assessment Method

The integration point assessment is performed at a chosen point using standard EPA guidance for calculating the concentration term (EPA 1989). Surface water pathways are assessed at the point with the assumption of residential land use of the water. This would entail using standard risk assessment parameters, which are available in EPA guidance factors and in the open literature, for these pathways. Primary pathways to be assessed include

ingestion of surface water, dermal contact while showering, and indoor inhalation of contaminants resulting from water use. The risk at this point is then compared with action levels of excess cancer risk of 1×10^{-4} and to the noncarcinogenic hazard index of 1. Action under CERCLA is generally warranted if either action level is exceeded. The next step is to use contaminant fluxes and risk to identify the primary contributors to the risk at the integration point.

Generally, the results generated by a risk assessment are driven by only a few high-priority contaminants. Determination of high-priority contaminants can be achieved by selecting those comprising 90% of the total risk at the integration point. For those identified contaminants that drive the risk, the annual fluxes for each should be quantified to the degree possible at the integration point and at the major sources. The spatial resolution of the sources is dependent upon the amount of source data available.

The flux data for each of the sources are then used with the integration point flux data to rank the relative importance of the different sources within the context of the integration point. Given the generalized cancer risk equation for multiple substances

$$\text{Risk}_T = \sum \text{Risk}_i$$

where

Risk_T = the total cancer risk, expressed as a unitless probability; and
 Risk_i = the risk estimate for the i^{th} substance.

The equation for the calculation of carcinogenic effects for the flux-based risk assessment at each of the sources is

$$\text{Risk}_{sf} = \left(\frac{\sum \left[\text{Risk}_i \left(\frac{\text{Flux}_{is}}{\text{Flux}_{ip}} \right) \right]}{\text{Risk}_T} \right) 100 \quad ,$$

where

Risk_{sf} = percentage of risk at the integration point which originates at the identified source,
 Flux_{is} = flux of the i^{th} substance originating at the identified source,
 Flux_{ip} = flux of the i^{th} substance identified at the integration point.

Similarly, the standard equation for calculation of noncarcinogenic effects is

$$\text{Hazard Index}_i = \sum \frac{E_i}{\text{RfD}_i}$$

where

E_i = exposure level (or intake) for the i^{th} toxicant,
 RfD_i = reference dose for the i^{th} toxicant.

E and RfD are expressed in the same units and represent the same exposure period (i.e., chronic, subchronic, or shorter term).

The calculation for the flux-based risk assessment of noncarcinogenic effects is

$$\text{Hazard}_{\text{sf}} = \left[\frac{\sum \left(\frac{E_i \text{ Flux}_{\text{is}}}{\text{RfD}_i \text{ Flux}_{\text{ip}}} \right)}{\text{Hazard Index}_i} \right] 100$$

where

$\text{Hazard}_{\text{sf}}$ = percentage of the hazard index at the integration point that originates at the identified source.

The total contribution of WAG 1 to off-site risk will be quantified according to this methodology. Additionally, individual sources within WAG 1 will be addressed as discrete sources. Currently, the plume associated with CH-8 is the primary active transport pathway within WAG 1 and it will be assessed individually. As additional discrete sources within the WAG 1 boundaries are identified, their contributions will also be assessed.

4.2.3 Uncertainty in the Risk Assessment Process

All problems relating to protecting environmental quality and human health are subject to uncertainty. However, issues related to groundwater contamination typically are more uncertain than those arising from other environmental media groundwater assessments need to address a longer and more technically complex set of causal relationships linking human activities that contaminate groundwater to human exposure and, ultimately, to potentially adverse health effects. Characterizing contaminant sources, transport processes, and exposure levels for groundwater contamination can involve more uncertainty than is generally the case for other environmental concerns.

Specific source control areas that pose a threat of major release or sites that are situated in exceedingly complex groundwater regimes where numerous source terms can not be

differentiated may have to be modeled. The modeling results can be used to show the need to mitigate a potential off-site risk or to confirm the role they are suspected to play in releases to the environment. The modeling results should be within the context of the larger scale integration point assessment, and its impact on selected integration points should be compared with other releases for which more information is known.

Because of the dynamic nature of the ORR watershed systems and fiscal restraints in data collection, it is recognized that significant amounts of uncertainty are necessarily present in performance of these integration point assessments, especially if modeled results are used. Uncertainties are inherent in the flux determination process because of difficulties in actually measuring the flux and the temporal variability of fluxes in both short- and long-term time frames. Temporal variability is caused by the affects of climate and human actions at the sources as well as the relationships between mass balances and hydrologic conditions. Conditions related to extensive development within WAG 1 introduce another source of uncertainty: many details of past construction and terrain modifications are incompletely documented and have disrupted the natural flow field.

However, given a bias for action at sites on the ORR, the uncertainty present in the process should not preclude source control activities. The integration point assessment is designed to use risk to identify sources that are clear off-site contributors of high priority contaminants. These sites can then be addressed in an expedited manner with actions that are interim or final in nature. Consistent implementation of this process can assist in meeting goals of reducing off-site exposures to levels that are as low as reasonably achievable and in cleaning the watershed systems within the plant boundaries to acceptable risk levels.

4.2.4 Current Land Use

Current land use for the WAG 1 area is government control of the land. Currently, groundwater at the site is not used as a potable or an industrial water source. Therefore, there are no completed exposure pathways for on-site exposure scenarios from contaminants in WAG 1 groundwater.

4.2.5 Future Land Use

If the government released control of the land in the future, the potential exposure scenarios for groundwater in WAG 1 could change. Two possible land use scenarios for the area are industrial and residential. Under the residential use scenario, it is assumed that the above-mentioned exposures could occur. Under an industrial use scenario, it is likely that groundwater would not be used.

Residential risk assessment calculations for carcinogens in WAG 1 groundwater wells are provided based on Reasonable Maximum Exposure (RME) variables for the ingestion and inhalation of groundwater pathways. The residential groundwater risk calculations rely on two primary sources for concentration data used to calculate the concentration term; the RCRA

compliance data collected for the WAG 1 perimeter groundwater quality monitoring wells and the groundwater data collected by BNI (1991).

Historical analytical data are available for groundwater wells in WAG 1 that have been monitored for compliance with DOE Order 5400.1. Most of the 26 compliance wells in WAG 1 have been sampled 8 times since December of 1988. For the sampling event of October 1989, the concentration data for wells 812 and 825 have been swapped for calculating the risk since indications are that the analytical data were transposed in the lab.

In addition, four groundwater sampling events were completed at WAG 1 for the Site Characterization Summary Report, these included

- initial background sampling of wells outside the WAG boundary in June 1990
- low base flow sampling of wells and piezometers within WAG 1 in late September through early October 1990
- high base flow storm sampling in late February 1991
- high base flow sampling from March to May 1991.

In addition, samples were collected from selected wells, deep coreholes, piezometers, and temporary borehole piezometers to evaluate conditions of new SWMUs, pipeline trenches, and the contaminant plume intersected by corehole 008, the location of highest groundwater risk in WAG 1. Corehole 008 was sampled in August and September 1991.

The above-mentioned data sets were merged for determining the risk values for each well individually. Contaminant screening was then performed in a series of steps to reduce the number of chemicals of potential concern for WAG 1 groundwater:

- eliminating the chemicals that were never detected in a well,
- identifying the oral carcinogens,
- assigning values to remaining non-detects, and
- calculating the risk.

Representative concentrations for use in the risk assessment calculations were determined by taking the minimum of the maximum observed concentration and the upper 95th confidence limit based on either a normal or lognormal distribution. The RME exposure variables and equations used for the calculations are provided in Tables 4.1 and 4.2. Table 4.3 shows the results of the analysis by contaminant type and the total risk for all locations possessing a risk greater than 1×10^{-4} .

Table 4.1. Groundwater inhalation residential exposure scenario, surface water pathway

Variable	Value used	Explanation/source
$\text{Chronic daily intake (mg/kg-d)} = \frac{[(\text{CW} \times \text{IR} \times \text{K} \times \text{EF})/(\text{AT})] \times [(\text{ED}_c/\text{BW}_c) + (\text{ED}_a/\text{BW}_a)]}{\text{Intake (pCi)} = \text{CW} \times \text{IR} \times \text{K} \times \text{EF} \times \text{ED}}$		
CW = Concentration in water	Chemical-specific (mg/L; pCi/L)	Concentration is derived from sample data
IR = Inhalation rate	0.15 m ³ /d	Inhalation rate while showering (0.6 m ³ /h) for all age groups (EPA 1989), assuming a 15-min shower
K = Volatilization factor	0.5 L/m ³	(EPA 1989)
EF = Exposure frequency	350 d/year	(EPA 1991a)
ED _c = Exposure duration	6 years	Two-part (child and adult) residential exposure for a 30-year duration (EPA 1991a)
ED _a	24 years	
BW _c = Body weight	15 kg	Child (EPA 1991a)
BW _a	70 kg	Adult (EPA 1989)
AT = Averaging time	365 d/year × 70 years	Averaging time for carcinogens (EPA 1989; EPA 1991a)

Table 4.2 Groundwater ingestion residential exposure scenario, surface water pathway

Variable	Value used	Explanation/source
$\text{Chronic daily intake (mg/kg-d)} = [\text{CW} \times \text{IR} \times \text{EF}/\text{AT}] \times [(\text{ED}_c/\text{BW}_c) + (\text{ED}_a/\text{BW}_a)]$ $\text{Intake (pCi)} = \text{CW} \times \text{IR} \times \text{EF} \times [\text{ED}_c + \text{ED}_a]$		
CW = Concentration in water	Chemical-specific (mg/L; pCi/L)	Concentration is derived from sample data
IR = Ingestion rate	2 L/d	(EPA 1989; EPA 1991a)
EF = Exposure frequency	350 d/year	(EPA 1991a)
ED _c = Exposure duration	6 years	Two-part (child and adult) residential exposure for a 30-year duration (EPA 1991a)
ED _a	24 years	
BW _c = Body weight	15 kg	Child (EPA 1991a)
BW _a	70 kg	Adult (EPA 1989)
AT = Averaging time	365 d/year × 70 years	Averaging time for carcinogens (EPA 1989; EPA 1991a)

Table 4.3. Relative WAG 1 groundwater risk by well and contaminant group

Well	Organics	Transuranics	Metals	Rad	Total risk
CH-8		1.2E-03		2.4E-1	2.4E-01
875				1.4E-2	1.5E-02
814	9.2E-03				9.4E-03
539				8.6E-3	8.8E-03
818	7.4E-03				7.4E-03
819	7.4E-03				7.4E-03
545	6.1E-3			2.5E-4	6.4E-3
812		1.3E-4	2.5E-4	6.0E-3	6.4E-3
598	5.4E-3			3.7E-4	5.8E-3
597	4.1E-3				4.2E-3
590				3.0E-3	3.1E-3
874				2.0E-3	2.0E-3
1102				1.5E-3	1.8E-3
543	1.8E-3				1.8E-3
553	1.2E-3				1.5E-3
885				1.2E-3	1.4E-3
809	6.8E-4		6.1E-4		1.3E-3
601				1.0E-3	1.0E-3
881					9.7E-4
608			3.1E-4	6.5E-4	9.6E-4
1103	6.8E-4			2.6E-4	9.4E-4
1104				9.0E-4	9.1E-4
825	8.1E-4				9.0E-4
571				7.4E-4	8.5E-4
538			7.5E-4		8.3E-4
603			5.4E-4	2.1E-4	7.8E-4
589			2.1E-4	4.9E-4	7.3E-4
CH-9	6.4E-4				7.3E-4
1101				6.4E-4	7.2E-4

Table 4.3 (continued)

Well	Organics	Transuranics	Metals	Rad	Total risk
588	1.3E-4			4.6E-4	6.9E-4
1100	3.9E-4			2.4E-4	6.3E-4
564				5.9E-4	5.9E-4
549			4.2E-4	1.6E-4	5.8E-4
550			3.0E-4	2.3E-4	5.5E-4
572			1.6E-4	3.9E-4	5.5E-4
566			1.3E-4	3.8E-4	5.1E-4
541	1.0E-4		1.0E-4	2.8E-4	4.4E-4
593	1.8E-4		1.8E-4	2.3E-4	4.3E-4
830	2.2E-4				4.0E-4
876				3.9E-4	4.0E-4
611			3.5E-4		3.9E-4
806			2.7E-4	1.2E-4	3.9E-4
602	1.2E-4		2.4E-4		3.9E-4
613				3.7E-4	3.7E-4
596	1.4E-4	1.0E-4			3.4E-4
540			3.2E-4		3.2E-4
CH-11A				3.0E-4	3.1E-4
807			2.5E-4		2.9E-4
813			1.8E-4		2.9E-4
884				2.0E-4	2.7E-4
536			1.7E-4		2.6E-4
808			2.2E-4		2.4E-4
829			2.0E-4		2.3E-4
824			1.8E-4		2.1E-4
827			1.5E-4		1.9E-4
828			1.7E-4		1.9E-4
533			1.4E-4		1.8E-4

Table 4.3 (continued)

Well	Organics	Transuranics	Metals	Rad	Total risk
CH-6			1.4E-4		1.8E-4
811			1.4E-4		1.7E-4
CH-7A	9.0E-5		6.3E-5	1.7E-4	1.7E-4
618			1.4E-4		1.6E-4
810			1.4E-4		1.6E-4
546			1.0E-4		1.5E-4
554			1.2E-4		1.4E-4
622			1.1E-4		1.3E-4
604	1.5E-5		7.1E-5	2.9E-5	1.2E-4
634			1.0E-4		1.2E-4
816			9.4E-5	2.3E-5	1.2E-4
873			9.1E-5	2.6E-5	1.2E-4
877	7.8E-5			4.3E-5	1.2E-4
579			9.6E-5	1.7E-5	1.1E-4
610			1.1E-4	1.1E-4	1.1E-4
623			9.8E-5		1.0E-4
563				1.0E-4	1.0E-4

5. IDENTIFICATION OF INVESTIGATION REQUIREMENTS

5.1 IDENTIFICATION OF ARARs

CERCLA was passed by Congress and signed into law on December 11, 1980 (Pub. L. 96-510) to provide for "liability, compensation, cleanup, and emergency response for hazardous substances released into the environment and the cleanup of inactive waste disposal sites." The Superfund Amendments and Reauthorization Act, adopted on October 17, 1986 (Pub. L. 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 applicable or relevant and appropriate requirements (ARARs) is the assumption that protection of human health and the environment is ensured.

The purpose of this report is to supply a preliminary list of available federal and state chemical- and location-specific ARARs that might be considered for cleanup of WAG 1 which includes shallow groundwater flow, to a depth of 100 ft, in the main plant fenced area. The areas where the groundwater flows into the tributaries of WOC, as well as WOC itself, are addressed as part of WAG 2 and are not included in this operable unit.

Although many of the sites contributing to the contamination of WAG 1 may be RCRA-permitted facilities and contain RCRA-listed or -characteristic waste, it is impossible to determine the exact source of the contaminants identified in environmental media at WAG 1. Therefore, pursuant to the NCP (53 *Fed. Regist.* 51444), if the lead agency cannot ascertain, using available site information, manifests, storage records and vouchers, the source of these RCRA-listed wastes, the RCRA regulations may not be legally applicable to remedial actions taken at WAG 1; they would, however, be relevant and appropriate (53 *Fed. Regist.* 8763). However, if any of the contaminants exhibit the RCRA toxicity characteristic, the RCRA regulations would definitely be legally applicable. RCRA ARARs pertain, for the most part, to specific types of actions or facilities and will be addressed more thoroughly as remedial alternatives are developed during the feasibility study.

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 FFA Sects. I(A)(3) and III(A)(2) and the Secretary of Energy Notice 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; however, the federal and state regulations protecting environmental resources that may be identified at a site during a NEPA assessment are discussed in Sect. 5.1.3.

Title I, Sect. 111(c)(6), of CERCLA mandated that the Occupational Safety and Health Administration (OSHA) promulgate standards for regulation of employee health and safety during hazardous waste operations at RCRA or CERCLA sites and during emergency response to hazardous substance releases. The final regulations for "Hazardous Waste Operations and Emergency Response" (29 CFR 1910) have appeared in 54 *Fed. Regist.* 9294 (Final Rule, March 6, 1989). These regulations are designed to protect workers involved in cleanup operations at uncontrolled hazardous waste sites and to provide worker protection during initial site characterization and analysis, monitoring activities, materials handling activities, training, and emergency response. These regulations do not apply to those workers who would not be exposed.

Federal construction activities involving no potential for hazardous substance exposure are covered by the OSHA standards in 29 CFR 1926 ("Federal Service Contracts") and 29 CFR 1910 ("General Industry"). DOE also addresses occupational safety in DOE Orders 5480.11 ("Radiation Protection for Occupational Workers"), 5480.4 ("Environmental Protection, Safety, and Health Protection Standards"), 5483.1A ("Occupational Safety and Health Program for Contractors at Government Owned, Contractor Operated Facilities"), 5480.9 ("Construction Safety and Health Program"), and 5480.10 ("Contractor Industrial Hygiene Program"). ARARs apply to those federal and state regulations that are designed to protect the environment and do not generally apply to occupational safety regulations. EPA requires compliance with the OSHA standards in Sect. 300.150 of the NCP, not through the ARARs process. Therefore, neither the regulations promulgated by OSHA nor the DOE Orders related to occupational safety are addressed as ARARs; these regulations appear in site-specific Health and Safety Plans for WAG 1.

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 *Fed. Regist.* 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 *Fed. Regist.* 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.

5.1.1 Chemical-specific ARARs

"Chemical-specific requirements set health- or risk-based concentration limits or discharge limitations in various environmental media for specific hazardous substances, pollutants, or contaminants" (53 *Fed. Regist.* 51437). These requirements generally set protective cleanup levels for the chemicals of concern in the designated media or indicate a safe level of discharge that may be incorporated when considering a specific remedial activity.

As stated in the NCP (55 *Fed. Regist.* 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.

In the NCP, EPA states the preference for SDWA MCLs and nonzero MCLGs or other health-based standards, criteria, or guidance for cleanup of Class I and Class II groundwater at CERCLA sites (55 *Fed. Regist.* 8732). Alternate concentration limits may also be used when active restoration of the groundwater to MCLs or nonzero MCLGs is not practicable (55 *Fed. Regist.* 8754). For Class III groundwaters, EPA establishes remediation levels based on specific site conditions, the beneficial use of the groundwater, and environmental receptors (55 *Fed. Regist.* 8732). Federal MCLs/MCLGs and action levels for chemicals of concern at WAG 1 are listed in Table 5.1. Contaminants of concern were identified from site characterization activities which were conducted under Phase I of the WAG 1 Groundwater RI. Results of these activities were reported in the Site Characterization Summary Report for WAG 1 (BNI 1992).

Table 5.1. Applicable or Relevant and Appropriate Requirements for WAG 1 groundwater nonradiological contaminants of concern

Analyte	SDWA MCL ^a (µg/L)	Analyte	SDWA MCL ^a (µg/L)
Beryllium	4	Vanadium	NA ^b
Cadmium	5	Trichloroethene	5
Chromium	100	1,1-dichloroethene	7
Cobalt	NE ^b	1,2-dichloroethene	70/100 ^c
Copper	1,300 ^d	Vinyl chloride	2
Lead	15 ^d	Benzene	5
Mercury	2	Toluene	1,000
Nickel	100	Ethylbenzene	700
Silver	50 ^d	Xylenes	10,000

^aSDWA MCL = Safe Drinking Water Act maximum contaminant level.

^bNA = none available; NE = not established.

^ccis = 70 µg/L, trans = 100 µg/L.

^dAction level.

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 where such goals or criteria are relevant and appropriate under the circumstances of the release. Although MCLGs and water quality criteria are nonenforceable guidelines, Congress elevated them to a higher status by specifically mentioning them in CERCLA. At present, EPA is planning to use the SDWA MCLs for remedial action compliance for carcinogens that have an MCLG of zero and any nonzero MCLG for systemic toxicants (55 *Fed. Regist.* 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 *Fed. Regist.* 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 WAG 1, the federal action level for lead is neither legally applicable nor relevant and appropriate at this time. However, 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 would be considered TBC guidance for remediation of lead-contaminated groundwater. Tennessee has issued a rule, *Hazardous Substance Site Remedial Action* (Chap. 1200-1-13, effective February 19, 1994), which mandates that specific criteria for domestic water supply as promulgated by the Water Quality Control Board, or federal MCLs and action levels established under the Federal SDWA be considered as chemical-specific ARARs for cleanup of contaminated groundwater classified for drinking water at remedial action sites. The TDEC Underground Injection Control regulations currently classify all groundwater of the state for domestic water supply except for certain exclusions (TDEC 1200-4-6-.05).

Chapter 1200-5-1 of the Rules of the TDEC, as amended effective January 1993, lists MCLs for public water systems which are identical to the federal MCLs in effect at that time; therefore, they are not repeated here.

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 (TDEC Proposed Rule 1200-4-3-.04 to .08). A draft of the proposed rule, dated May 28, 1993, was issued for public comment in June 1993; a final version is expected by late 1994. Chapter 1200-4-3-.07 of the proposed rule lists four classifications for groundwater: Class A, current or future source of water supply; Class B, current or future source of water supply, but which will not support all uses as a water supply due to contamination; Class C, not a current or future source of water supply for drinking or other beneficial use; and Class D, groundwater which flows to the surface of the ground or mixes with surface water.

Groundwater in Class D can also be identified as A, B, or C. According to this classification scheme, it appears that contaminated groundwater at ORR would be classified as Class B and/or Class D. The water quality criteria (WQC) for Class B groundwater, proposed at Chap. 1200-4-3-.08, would be the criteria for Class A groundwater (i.e., criteria established in 1200-4-3-.03, with the exception of those for fish and aquatic life) except where a groundwater use is shown to be impaired in accordance with 1200-4-3-.09(2)(c). Chapter 1200-4-3-.09 details steps to be taken to have groundwater registered as Class B, and includes a requirement for submittal of monitoring data, remediation history and plans, hydrogeologic studies, study of current and potential land uses, risk assessments, and permit applications. If the state Commissioner grants the petition for registration as Class B groundwater, water quality criteria for the contaminants of concern, as well as other permit conditions, will then be negotiated. The WQC for Class D groundwater would be the criteria established for the surface water body into which the groundwater flows and would apply at the point of influence of the groundwater into the surface water body. Although many comments have been received on the draft rule, necessitating revisions before final promulgation, it is expected that the substantive provisions of the draft rule will remain as given in the proposed rule (Moss 1993). Final determination of ARARs for WAG 1 groundwater will depend on the chosen groundwater classification, and will be addressed further in future phases of the RI.

Possible contamination of groundwater with petroleum byproducts from the USTs will also need to be addressed. The Tennessee UST Board promulgated regulations for release response and corrective action for USTs on April 15, 1990; these are found in the Rules of the TDEC, Chapters 1200-1-15-.05 to 1200-1-15-.07. The regulations closely parallel the federal 40 CFR 280 regulations, although the state regulations only apply to USTs containing petroleum products. The Rule mandates investigation and confirmation of a release from USTs and delineates requirements for corrective action and closure of the USTs. Chapter 1200-1-15-.06(6) addresses investigations for groundwater cleanup. Chapter 1200-1-15-.06(7)(e)(1) mandates that groundwater contaminated by benzene or total petroleum hydrocarbons (TPHs) from USTs must be cleaned up to meet levels listed in Appendix 3 of the Rule; the levels vary depending on whether the water is classified as "drinking water supply" or "non-drinking water supply." These cleanup levels are given in Table 5.2 of this report. Determination of groundwater classification is done as part of the *Environmental Assessment (EA)* for the site (see paragraph below). These UST regulations are considered legally applicable to corrective actions/closure of the WAG 1 USTs and cleanup of any contaminated groundwater at the site, and will be analyzed further during the feasibility study (FS) phase of this CERCLA action.

In January 1994, TDEC Division of UST issued revisions to its UST Handbook, including *Environmental Assessment Guidelines* and *Corrective Action Plan (CAP) Guidelines* documents to assist in these cleanup activities. These non-promulgated guidelines are considered "to-be-considered" (TBC) guidance for this CERCLA remedial action. The CAP guidance discusses cleanup levels and corrective actions based on the groundwater classification. The EA guidance document lists a three-step process for classifying the groundwater and requires the

Table 5.2. Chemical-specific cleanup levels for petroleum underground storage tank contamination of soil and groundwater (ppm)^a

	Drinking water	Non-drinking water
Groundwater		
Benzene	0.005	0.070
TPH ^b	0.100	1.0
Soil		
BTX ^c		
($>10^{-4}$ cm/sec) ^d	10	50
(10^{-4} - 10^{-6} cm/sec) ^d	50	250
($<10^{-6}$ cm/sec) ^d	100	500
TPH		
($>10^{-4}$ cm/sec) ^d	100	250
(10^{-4} - 10^{-6} cm/sec) ^d	250	500
($<10^{-6}$ cm/sec) ^d	500	1000

^aRules of the Tennessee Department of Environment and Conservation (TDEC), Chapter 1200-1-15-.06(7)(e), April 15, 1990.

^bTPH = Total petroleum hydrocarbons.

^cBTX = Benzene, toluene, and xylene.

^dSoil permeability levels.

placement of one upgradient and three downgradient monitoring wells as part of the investigative procedure for release response. However, remediation of contaminated groundwater is being addressed under the CERCLA ORNL groundwater OU, and groundwater monitoring is being implemented under the Groundwater OU RI. Therefore, the requirements for monitoring wells as part of the investigative procedure is not considered TBC guidance. A Corrective Action Plan (CAP) must be prepared and will provide information detailing the three most technologically feasible and reliable corrective action options that were evaluated. An EAR-CAP for UST-2026 has been submitted to the state of Tennessee.

The TDEC Division of Superfund has issued a final rule, *Hazardous Substance Site Remedial Action* (Chap. 1200-1-13, effective February 19, 1994), governing cleanup of remedial action Superfund sites in the state of Tennessee. Chapter 1200-1-13-.08 of the rule lists procedures for the development and usage of remediation goals for hazardous substance remediation. The rule allows for final remediation goals to be established, subject to Department approval, using either ARARs, background concentrations, site-specific risk assessment, or a combination of ARARs, background concentrations, and site-specific risk assessment.

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 or reference concentrations for systemic toxicants, and carcinogenic slope factors for carcinogens or Office of Drinking Water Health Advisories (EPA 1988b) for drinking water contaminants. The reference doses, reference concentrations, and carcinogenic slope factors are available through the Integrated Risk Information System (EPA 1991b) and the *EPA Health Effects Assessment Summary Tables* (EPA 1992), and would be considered TBC guidance.

5.1.2 Radiation-specific ARARs

Very few applicable standards are available for the cleanup of radioactively contaminated CERCLA sites. The Atomic Energy Act of 1954 and its amendments delegated authority for control of nuclear energy to DOE, the U.S. Nuclear Regulatory Commission (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. DOE regulations for handling and cleanup of radioactive materials are outlined in a series of internal DOE Orders that are legally binding to DOE contractors but are not considered by EPA to be ARARs. The DOE Orders, however, are functionally equivalent to the NRC requirements, and include all "appropriate" requirements from the NRC regulations. Sections of the NRC regulations may be considered relevant and appropriate or TBC guidance in situations where no DOE Order exists which clearly addresses a specific situation at a site to ensure protection of human health and the environment. For the purposes of development of ARARs, DOE Orders will be treated as TBC guidance.

EPA-promulgated MCLs for radionuclides in community water systems 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 repropose for ²²⁶Ra and ²²⁸Ra, beta emitters, and photon emitters on July 18, 1991. Final promulgation of the concentration limits is not expected until April 1995. These concentration limits, listed in Table 5.3 for radionuclides of concern at WAG 1, would be relevant and appropriate for cleanup of radionuclide-contaminated groundwater at WAG 1.

Subpart H of EPA's 40 CFR 61 addresses atmospheric radionuclide emissions from DOE facilities and may be applicable to airborne emissions during cleanup of WAG 1. EPA has issued a final National Emissions Standard for Hazardous Air Pollutants rule (54 *Fed. Regist.* 51654, December 15, 1989) that limits emissions of radionuclides to the ambient air from all

Table 5.3. Applicable or Relevant and Appropriate Requirements for WAG 1 groundwater radiological contaminants of concern

Analyte	Current SDWA MCL ^a	Proposed SDWA MCL ^{a,b}
Gross alpha, pCi/L	15	15
Gross beta, mrem/year	4	4
Tritium, pCi/L	20,000	60,900
⁹⁰ Sr, pCi/L	8	42
Natural uranium, µg/L		20
²²⁶ Ra, pCi/L	5 ^c	20
²²⁸ Ra, pCi/L	5 ^c	20
All other manmade radionuclides, ^d mrem/year	4	4

^aSDWA MCL = Safe Drinking Water Act maximum contaminant level.

^bProposed rule, July 18, 1991 (56 *Fed. Regist.* 33050); final rule expected in April 1995.

^c²²⁶Ra + ²²⁸Ra.

^dIf two or more manmade radionuclides are present, the sum of their annual dose equivalent to the total body or to any organ shall not exceed 4 mrem/year. Other manmade radionuclides detected in WAG 1 groundwater include ¹³⁷Cs, ⁹⁹Tc, ¹⁴⁷Pm, ⁶³Ni, and ⁶⁰Co.

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). This national emissions standard will be addressed as an action-ARAR during selection of remedial alternatives.

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 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. In addition, effluent releases to surface water must not result in exposures to aquatic organisms that exceed an absorbed dose of 1 rad/day. DOE proposed this Order for codification under 10 CFR 834 on March 25, 1993 (58 *Fed. Regist.* 16268); final rule expected July 1994. When promulgated, these standards will then become legally applicable to cleanup at WAG 1.

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 WAG 1. The DOE Orders will be addressed in detail following selection of remedial alternatives for WAG 1.

The EPA Office of Radiation and Indoor Air 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 guidance when the radionuclide contamination at WAG 1 is more clearly defined.

5.1.3 Location-specific ARARs

Location-specific requirements "set restrictions upon the concentration of hazardous substances or the conduct of activities solely because they are in special locations" (53 *Fed. Regist.* 51394). In determining the use of location-specific ARARs for selection of remedial actions at CERCLA sites, one must investigate the jurisdictional prerequisites of each of the regulations.

Geologic formations. ORR, located in the Valley and Ridge Physiographic Province of eastern Tennessee, is characterized by gently to moderately sloping ridges and valleys (Rogers et al. 1989). A variety of geologic formations of sedimentary origin underlie ORR. The most important formations are the Rome Formation and the Conasauga, Knox, and Chicamauga groups. The bedrock consists of highly faulted and folded sedimentary units with ridges underlain by limestones, siltstones, sandstones, and dolostones. Shales and carbonate formations underlie the valleys (Energy Systems 1990a). There are no indications of salt-dome formations, salt-bed formations, or underground mines on or near the ORNL site (Lee 1991).

Faults. The White Oak Mountain and Copper Creek thrust faults transect ORR. These faults extend from the surface to the geologic basement at ~426 m. The Copper Creek Fault is a single fault that transects the ORNL reservation. ORNL is located ~1.5 km southeast of the southeast dip of the Copper Creek Thrust (Davis et al. 1984). Minor seismic activity has been recorded in the region, but no surface rupturing associated with any of the faults within ORR has been recorded (Chance 1986). The faults on ORR are ancient (pre-Holocene) and are stable (Ketelle 1991). The possibility of fault movement is considered extremely unlikely (Chance 1986); therefore, the seismic regulations would not be ARAR for WAG 1.

Wetlands and floodplains. ORR is located within the Clinch River drainage basin and is bounded on the south and west by the Clinch River. Each of the three DOE facilities is located in a different sub-basin of the Clinch River. Gullies as well as seasonal and permanent streams drain into WOC (ORNL). Creek flow is interrupted by settling basins and/or retention ponds, including White Oak Lake at ORNL. Portions of ORNL are located within 100- and 500-year floodplains. Many wetland areas occur on the ORR. If any remedial alternatives are selected for WAG 1 that would impact floodplains, the requirements found in EO 11988, 40 CFR 264.18(b), and 10 CFR 1022 would provide ARARs. If wetlands are affected, consideration should be given to EO 11990, 10 CFR 1022, the Clean Water Act of 1977 (CWA) Sect. 404, and 40 CFR 230 for applicable requirements.

Aquatic resources. There are no known designated wilderness areas, wildlife refuges, or scenic rivers on or near WAG 1 such that remedial action would likely impact these. There are a number of water resources on ORR, some natural and some man-made. At ORNL,

seasonal streams and tributaries flow into White Oak Creek before discharge into the Clinch River. The Clinch River itself forms part of the western and southern boundaries of ORR. Melton Hill Reservoir also forms part of the southern boundary. The Clinch River, Poplar Creek with its various tributaries and forks, and White Oak Creek have all been classified by TDEC for a variety of uses, including fish and aquatic life and wildlife. The provisions of the Tennessee Water Quality Control Act (TCA 69-3-101 et seq.) would provide ARARs should any remedial actions at WAG 1 cause, or be likely to cause, harm to wildlife or aquatic life in these waters.

Slightly over 5000 acres of ORR have been designated as a DOE National Environmental Research Park (NERP), which also includes Research Areas (RSAs) located both within and outside of the NERP. There are several RSAs in close vicinity (<0.05 km) to ORNL, including RSA No. 25, carbon monoxide monitoring, and RSA No. 37, biomass demonstration plots (Parr and Pounds 1987).

In addition to the NERP and its associated RSAs, DOE has also designated areas on ORR as DOE-NERP Reference Areas and DOE-NERP Natural Areas. None of these, however, appears to be located on or near ORNL (Parr and Pounds 1987). 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.

Rare, endangered and threatened species. There do not appear to be any state- or federally-listed rare, endangered, or threatened plant or animal species on or near WAG 1 (Kroodsmma 1987). If a site survey reveals the presence of any federal-listed endangered or threatened species which might be impacted by remedial actions at WAG 1, the provisions found in the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.), 50 CFR 492, and the Fish and Wildlife Coordination Act (16 U.S.C. 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.) or the Tennessee Rare Plant Protection and Conservation Act of 1985 (TCA 11-26-201 et seq.) may provide ARARs.

Historic sites and archaeological findings. According to the National Historic Preservation Act (NHPC) of 1966, WAG 1 is deemed a "historic property" [16 U.S.C. 470-h-2; NHPC Sect. 110 (a)(2)(A)]. Any prehistoric or historic district, site, building structure, or object included in, or eligible for inclusion in, the National Register of Historic Places is considered a historic property and a cultural resource. All undertakings at a property must comply with the requirements of the Historic Sites Act (HSA) (16 U.S.C. Sect. 461), the National Historic Preservation Act (NHPA) as amended (16 U.S.C. Sect. 470), the Archeological and Historic Preservation Act (16 USC Sect. 469), and Executive Order (EO) 11593, entitled "Protection and Enhancement of the Cultural Environment" (May 13, 1971). An "undertaking" means any project, activity, or program that can result in changes in the character or use of historic properties, if any such historic properties are located in the area of potential effects.

If there are historic properties that the undertaking may affect, the Federal agency head or a designee with authority over a specific undertaking shall assess the effects, in accordance with NHPA Section 106, by Applying the Criteria of Effect (36 CFR Part 800). If an effect is found, the Agency Official, in consultation with the State Historic Preservation Officer (SHPO), shall apply the Criteria of Adverse Effect [36 CFR Sect. 800.9(b)] to determine whether the effect of the undertaking should be considered adverse. An undertaking has an adverse effect on a historic property if the integrity of the property's location, design, setting, materials, workmanship, feeling, or association is diminished. If any remedial action taken for the WAG 1 groundwater is considered to be an undertaking with adverse effects, a Memorandum of Agreement (MOA) signed by all parties involved will declare how the effects will be taken into account [36 CFR Sect. 800.5(e)(4)].

NHPA Sect. 110(b), governed by 36 CFR Part 800, requires agencies to document historic properties that may be destroyed or altered as a result of Federal actions or assistance. The documentation may include architectural, engineering, historical, oral historical, and archeological documents. NHPA Sect. 106 provides information used in determining what types of documentation to need to be provided.

A reconnaissance to assess adverse impacts to cultural resources located within ORNL was conducted in compliance with the NHPA, NEPA, and EO 11593 (May 13, 1971). According to *An Archaeological Reconnaissance and Evaluation of the Oak Ridge National Laboratory, Oak Ridge Reservation, Anderson and Roane Counties, Tennessee*, all habitable areas within WAG 1 have been destroyed. Although early historic Indian (Cherokee) sites probably exist in the general area, none are recorded for the project area. No additional archaeological investigations are recommended for the existing WAG areas, and therefore it is not presumed that properties would be discovered during implementation of an undertaking. However, if any remedial action is taken that would cause irreparable harm loss, or destruction to significant archaeological resources, the provision of the Archaeological Resources Recovery Act (16 U.S.C. 469-a-c) may be applicable.

5.1.4 Action-specific ARARs

Performance, design, or other action-specific requirements set controls or restrictions on particular kinds of activities related to the management of hazardous waste (52 Fed. Regist. 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 are established under RCRA, CWA, SDWA, the Clean Air Act, and the Toxic Substances Control Act of 1976. Action-specific ARARs for WAG 1 will be developed during selection of remedial alternatives in the feasibility study phase.

5.2 IDENTIFICATION OF PRELIMINARY REMEDIAL ACTION GOALS

This report applies to site characterization activities for Phase II of the WAG 1 Groundwater OU RI. Phase II is one phase of an anticipated long-term, multi-phase RI for WAG 1. The primary objectives of the RI are to identify groundwater contaminant sources, describe the principal contaminant migration pathways, and conduct ongoing groundwater monitoring to describe temporal changes in the distribution of groundwater contaminants and in support of remediation activities in other OUs in WAG 1. Future RI phases in WAG 1 will identify specific data necessary to evaluate remediation action alternatives.

5.3 IDENTIFICATION OF POTENTIAL CLASSES OF REMEDIAL TECHNOLOGIES

Phase I of the RI identified areas of radiologically contaminated groundwater and limited areas of nonradiological contamination of groundwater with volatile organic compounds and metals in WAG 1. Contaminated soil, which may serve as a secondary source of groundwater contamination, was also identified. Chapter 6 of this report contains a discussion of the groundwater and soil contamination found in various areas of WAG 1.

As stated in the previous section, the primary goal of Phase II of the WAG 1 Groundwater RI is to prevent off-site migration of contaminants in groundwater. Remedial technologies which may be used to accomplish this goal include trenches and subsurface drains to intercept contaminated groundwater; installation and operation of pumping wells to contain contaminant plumes; and lining of storm sewers to prevent infiltration of contaminated groundwater into the sewers and subsequent discharge to surface waters.

A secondary goal of the RI is control of sources of groundwater contamination. Technologies which may be used to accomplish this goal are pumping of contaminated groundwater in source areas and excavation of contaminated soils which may be serving as secondary sources of groundwater contamination.

6. NATURE AND EXTENT OF CONTAMINATION AND SITE DATA NEEDS

This section describes the nature and extent of contamination at WAG 1 as it is currently understood. Data gaps and additional data needed to describe groundwater contamination more completely are also noted. The description relies upon data reported by BNI (1992) and other limited historical data, and it focuses on groundwater and soils contamination which may serve as secondary sources of groundwater contamination. Accounts of additional historical contamination are based on information presented in Grimsby (1986) and known or suspected historical operations that took place in buildings and facilities, pipeline leaks, and accidental spills. Additional data needs and proposed actions follow the description of the nature and extent of contamination.

BNI (1992) provides a detailed accounting of WAG 1 groundwater, soils, and surface water contamination. Radionuclides are the major groundwater contaminants at WAG 1 both in terms of areal distribution and contaminant levels. Hazardous constituents typically occur in more limited areas (e.g., adjacent to underground fuel tanks). Underground pipelines, sumps, and tank dry wells affect the distribution of contaminants.

Because activities contributing to groundwater contamination at WAG 1 have been numerous and varied over a long time, a presentation of the overall condition of groundwater contamination is confusing at best. As a result, major areas of contamination are treated as individual areas of concern, and points of overlap between areas are identified. To further simplify the presentation and facilitate comparison among areas, the indicator radiological analytes gross alpha, gross beta, and tritium are emphasized. Specific radionuclides are discussed when they contribute to the description of the nature and extent of contamination. Similarly, only those nonradiological analytes that contribute to an understanding of the nature and extent of contamination are discussed. In groundwater these analytes include the volatile organic compound (VOC) TCE and its degradation products [1,2-dichloroethene (1,2-DCE) and vinyl chloride] and the metals cadmium, chromium, beryllium, mercury, and lead. The occurrence of nonradiological soil contaminants is variable and addressed on a case-by-case basis. Tables 6.1 and 6.2* contain proposed RCRA action levels for soil and SDWA MCLs for groundwater respectively for contaminants of concern in WAG 1.

Only those areas with comparatively more significant or widespread contamination are described. This site characterization is not intended as a full accounting of contamination at WAG 1 but is intended to identify and prioritize areas for interim remedial actions, and resources will be directed at those areas on a priority basis. Numerous isolated locations that are considerably less contaminated would receive a low priority ranking beyond monitoring, but should analysis of such monitoring data determine more significant or widespread contamination than presently understood, modifications can be made in subsequent phase

*Because of the length and number of the tables in Chap. 6, they appear at the end of the chapter.

investigations. In addition, because of overlap between areas, early actions will undoubtedly affect conditions in areas peripheral to the initiating area. The extent of this effect on peripheral areas cannot be realistically predicted at present.

In general, gross alpha and gross beta groundwater contamination in any piezometer or well is inversely related to groundwater elevation. This relationship suggests that increased volumes of water during high base conditions serve to dilute contaminant levels. In contrast, tritium concentrations are commonly directly related to groundwater elevations, which suggests that tritium is mobilized during the rainy season. In both cases, the flux of contaminants through groundwater will be shown to be greater during high base than low base conditions because of accompanying increased groundwater movement.

WAG 1 groundwater is a part of the much larger Groundwater OU, and agreements have been reached as to which groundwater responsibilities lie with WAG 1 and which are part of more general issues to be addressed by the Groundwater OU. Because most WAG 1 groundwater contamination is considered to be contained within the upper portions of the aquifer, the nominal upper 100 ft of the aquifer is the responsibility of WAG 1. Deeper groundwater flow issues (e.g., long off-site flow paths, depth of active flow) lie with the Groundwater OU. Exceptions will be the instrumentation of core holes CH-2 and CH-7A in WAG 1 discussed in Sects. 6.4.10 and 6.5.1.

Because surface water in and around WAG 1 leads to WAG 2 (WOC south of the Haw Ridge water gap) the Groundwater OU will assume responsibility for WAG 1 surface water. Issues related to groundwater underflow of surface water in WAG 1 will remain the responsibility of WAG 1.

6.1 SOILS

In general, soils are most highly contaminated in the vicinity of the NTF and STF, the 3513 and 3524 impoundments, and Building 3019 (BNI 1992). Lesser contaminant levels occur in the Isotopes Area and near the thorium tank farm. Relatively localized areas of contamination are commonly related to pipeline leaks or spills.

Background radiological contaminant levels from reference soil sampling reported in BNI (1992) indicate as much as 34 pCi/g gross beta, 56 pCi/g gross alpha, and 0.22 pCi/g tritium. ^{137}Cs , ^{99}Tc , and total radioactive strontium (^{89}Sr plus ^{90}Sr) were detected in small amounts. Metals and hazardous constituents were detected in varying amounts. Because the list of those analytes is long, the amount that a WAG 1 sample value exceeded the reference value is described in the sections below. Table 6.1 contains reference and RCRA action level soil contaminant values.

Beryllium concentrations in both WAG 1 and reference soils often greatly exceed RCRA action levels, and it is difficult to judge what actually constitutes manmade beryllium contamination in WAG 1. Klaassen et al. (1986) report that beryllium in the environment

largely results from coal combustion, but it is also used in nuclear reactions. The relative contribution of these two mechanisms to beryllium soil contamination is not known, but since coal combustion has and does occur both regionally and locally, that mechanism is considered to be the principal cause for the contamination. Deposits from vehicle brake linings may also contribute.

6.2 GROUNDWATER

Extensive areas of WAG 1 groundwater are contaminated with radiological and nonradiological constituents. Radionuclides are the principal groundwater contaminant. Contamination generally appears to be confined to the upper portions of the aquitard. Evidence to support the potential for contaminant migration to greater depths is discussed below, as is the potential for off-WAG migration by groundwater underflow of surface water.

Background radiological contaminant levels from reference sampling (BNI 1992) indicate about 4 pCi/L gross alpha, 5 pCi/L gross beta, and between about 1000 and 2000 pCi/L tritium. SDWA MCLs are 15 pCi/L (gross alpha), 4 mrem/year (gross beta) and 20,000 pCi/L (tritium). Table 6.2 compares these levels. Although different geologic units in WAG 1 may have slightly different amounts of naturally occurring radionuclides, gross alpha and beta maximum reference values are useful for evaluating contaminant levels. BNI (1992) describes the difficulties in accurately determining what constitutes radiological contamination at WAG 1, and the maximum reference values and MCLs were used only as guides. VOCs, base/neutral/acid-extractables, metals, and pesticides and herbicides were either not detected or were detected in relatively low concentrations at isolated locations.

6.3 SURFACE WATER

Historical surface water radiological contamination data for First Creek, Fifth Creek, Northwest Tributary, and WOC surrounding WAG 1 indicate negligible to low levels of contamination compared with WAG 1 groundwater contamination. Contaminant discharges to WOC downstream of the PWTP outfall are obscured by plant discharges. Assuming that groundwater at WAG 1 discharges to adjacent surface water bodies, the generally low surface water contaminant levels compared to groundwater within the WAG supports the concept that contaminated groundwater is being effectively captured by pipelines, sumps, and underground tank dry wells. Adsorption, radioactive decay, travel distance, and dilution in surface water also contribute to apparent differences between groundwater and surface water contaminant concentrations.

6.4 AREA-SPECIFIC CONTAMINATION

This section describes known areas of contamination in WAG 1 based on analysis of site data and/or historical activities. In most cases, these areas comprise the most significant or

widespread contamination, and some are considered to contain contaminant sources. The analyses to be performed from proposed subsurface investigations in each of these areas are listed in Sect. 6.6

6.4.1 Building 3001/3019 Area

This area includes Buildings 3001 and 3019, the 3001/3019 storage canal, and the "3019 Hot Bank," which is the slope located north of Building 3019 (Fig. 6.1^{*}). Building 3001 is one of the oldest buildings at ORNL and houses the Graphite Reactor. Building 3019 includes the main portion of the Radiochemical Processing Plant and houses a High Radiation Level Analytical Facility.

Buildings 3001 and 3019 are connected by the 3001/3019 storage canal. The canal is a belowground concrete structure which is 7 ft wide, 11.5 ft deep, and 101 ft long. It is covered with a concrete lid and soil and has a capacity of 62,000 gal. The canal was used for underwater transfer of spent fuel from the graphite reactor and was in operation from 1943 to 1963. The canal was then used for storage of radioisotopes until 1990 when a leak was discovered and removal of the stored material was initiated (ORNL 1990). Remediation of the canal under RCRA has been accelerated. As part of the remedial process, sludge containing cobalt crystals was removed from the canal. As a result of the sludge removal, the rate of leakage from the canal is reported to have increased.

Also included in this area is the 3019 Hot Bank which is the slope located north of Building 3019. The slope has been contaminated by a combination of emissions from the Building 3019 stack and LLLW line leaks in the area. Most of the contamination at the Hot Bank is believed to be limited to surface or near-surface soils, but some contamination may have infiltrated to groundwater or been transported along pipelines that cross the area.

In addition to the facilities described above, there are other potential sources of contamination in the area, including filter houses, underground ductwork, tanks, and pipelines.

Environmental sample data for the 3001/3019 potential source area are limited mostly to surface and near surface soil samples. No water quality wells and only a limited number of piezometers are located within the area. The piezometers are completed at the top of the bedrock, and during most of the year do not provide sufficient quantities of water for sampling. Some groundwater data from wells located outside the immediate vicinity may indicate contamination from Building 3001/3019 sources. Screening level water samples have been collected from one temporary pipeline trench piezometer located at a former pipeline leak site. These data are discussed briefly below.

Table 6.3 summarizes indicator radiological data from groundwater and soil samples collected from the 3001/3019 area. The data indicate that three areas of contamination exist:

^{*}The legend for Figs. 6.1–6.4 and 6.6–6.12 appears on p. 6-5.

NOTES

1. ALL COORDINATES ARE BASED ON THE ORNL GRID SYSTEM. THE ANGLE OF DECLINATION OF THE ORNL GRID TO TRUE NORTH IS TAKEN FROM THE APPROXIMATE CENTER OF THE WAG.

LEGEND

	WAG 1 BOUNDARY
	PAVED ROAD
	FENCE
	PERENNIAL STREAM
	WATER BODY
	BUILDING WITH NUMBER
	WATER QUALITY WELL
	FLUSH MOUNT PIEZOMETER
	STICK-UP PIEZOMETER
	SUMP LOCATION (FROM ORNL MAIN ATLAS)
	TANK SUMP
	SOIL BORING
	SOIL BORING W/ TEMPORARY PIEZOMETER
	PROPOSED TANK SUMP SAMPLING LOCATION
	NEW WELL POINT
	NEW PIPELINE TRENCH PIEZOMETER
	CORE HOLE
	NEW WELL
	STOCKDALES (1951) COREHOLE 33
	CHICKAMAUGA GROUP (UNIT C AND D CONTACT)

6/12/75

Legend for Figs. 6.1-6.4 and 6.6-6.12.

Fig. 6.1. Building 3001/3019 area.

(1) site of an past pipeline leak southwest of Building 3019, (2) site of past pipeline leak north of Building 3019, and (3) the 3019 Hot Bank.

Soil boring SB132 is located at the site of a series of historic LLLW pipeline leaks that occurred southwest of Building 3019. Samples from this boring contained up to 16,005 pCi/g gross beta and 1043 pCi/g gross alpha. In addition, samples from this location contained elevated concentrations of several other radionuclides including ^{137}Cs , total radioactive strontium, ^{60}Co , ^{238}Pu , $^{239/240}\text{Pu}$, and ^{147}Pm . Concentrations were greatest in samples collected from the 10–12-ft interval, which is nominally 5 ft below the estimated pipeline invert elevation.

The historical pipeline leak site north of Building 3019 was sampled at borings SB130. Samples from this location contained elevated activities of gross beta (up to 1855.8 pCi/g) and gross alpha (up to 3104 pCi/g). Radionuclides found in these samples include ^{241}Am , ^{60}Co , ^{137}Cs , ^{152}Eu , ^{238}Pu , $^{239/240}\text{Pu}$, and ^{244}Cm . Highest concentrations were found in samples collected in the 10–12-ft depth interval, also below estimated pipeline invert elevations.

Soil samples collected at the 3019 Hot Bank also contain contamination. For example, gross beta activities in samples from boring SB126 were as high as 6171 pCi/g, and gross alpha activities from the same location were as high as 1904 pCi/g. The most predominant radionuclides detected in Hot Bank soils were ^{137}Cs and total radioactive strontium. Most of the contamination on the Hot Bank appears to be limited to the upper 6 ft of soil.

Soil samples were collected from other areas near 3001/3019, including the storage canal, pipelines, and buried tanks sites. With the exception of one boring, gross beta and gross alpha activities in samples from these borings were generally at or near background levels. However, because some of the borings (e.g., the storage canal borings) could not be advanced deep enough to allow sampling below the probable contaminant depth, it is possible that contaminants could have been missed. The location where contamination was detected is boring SB258, where soils in the 2–4-ft depth range contained elevated activities of gross beta and strontium. The source of this contamination is not known, but may be associated with buried pipelines in the area.

Very little groundwater quality data are available for the 3001/3019 area. The only groundwater sampling locations in the area are piezometers 573 and 582. During the recent RI (BNI 1992), screening-level groundwater samples were collected from these locations. Results from these analyses indicate that groundwater at piezometer 582, located south of 3019, contains elevated gross beta activities. However, it is important to note that samples from these locations are not considered to provide a complete or reliable representation of groundwater quality at the 3001/3019 area because the piezometers were constructed at the bedrock/soil interface, and the water table is beneath that depth. The piezometers, therefore, are constructed in seasonally perched water.

Other incidental data provide additional indications that groundwater contamination may exist at the site. For example, soil samples collected from the two historic pipeline leak sites

(SB132 and SB130) were wet at depths greater than about 10 ft BGS. This depth interval is greater than the depth at which the formerly leaking pipelines are believed to be buried, and is also the interval at which soil samples containing the greatest amounts of contamination were found. Based on available data from nearby piezometers, depths to groundwater in the area are typically >25 ft. Therefore, the wet soils encountered in the soil borings may indicate perched water table conditions, possibly associated with leaky pipelines or with water moving along relatively permeable pipeline trench backfill material.

A temporary piezometer was installed in borehole SB132 to provide information on water quality in the perched zone. Screening-level water samples collected from the piezometer contained elevated activities of gross beta (up to 20,000 pCi/L) and gross alpha (up to 110 pCi/L). Water levels in the piezometer have been quite variable (ranging from 11.65 to 15.2 ft BGS), suggesting that periodic, fairly rapid, pulses of flow may occur. These pulses are probably responsible for most of the flow in the trenches. Concentration data for the SB132 piezometer indicate that as the pulses occur, contaminant concentrations decrease, probably as a result of dilution. This indicates that there is some direct communication between the trench and infiltrating water; the infiltration may occur directly on the ground, or from secondary sources such as building gutter discharges or leaking storm drains.

Potential contaminant source areas in the 3001/3019 area include known historic pipeline leaks (mostly north and southwest of Building 3019), unknown historic leaks (floor drains, tanks, etc.), the historical canal leak, and leaching from hot bank soils. There are several potential mechanisms by which contamination may migrate from the 3001/3019 area to other parts of the WAG. Because of its position near the northern, upslope, upgradient portion of WAG 1 and its operational history, the 3001/3019 area is recognized as a potential source area for much of the contamination found in WAG 1 groundwater, including contamination in core hole CH-8, the NTF, the Isotopes Area, and other areas of the WAG.

Most historical leaks at 3001/3019 are believed to have occurred in unsaturated soil. In this situation, the clayey soils retard the downward migration of contamination. Contamination may be retarded for long periods of time, with periodic releases occurring when contaminants are periodically mobilized either because of a rising water table or downward infiltration. The net result is that there are areas of unsaturated soil in the 3001/3019 area that would continue to be constant or periodic sources of groundwater contamination.

One area in which a direct release to groundwater may have occurred is north of Building 3019 where a cavity was discovered during excavation of the leaking pipeline. Waste is believed to have migrated into the cavity where it interacted directly with groundwater. The potential for contaminant migration along pipelines was clearly demonstrated by the results of a dye tracer test conducted following discovery of the pipeline leak (Huff 1985). The test results demonstrated that a hydraulic connection exists between the cavity and the Building 3042 sump and underground pipelines in the area.

The pipeline network at 3001/3019 is believed to have a large impact on the transport of contaminated groundwater. There is a large, complex array of buried pipelines leading from

the 3001/3019 area. These lines extend to much of the WAG, including the areas south of 3001/3019 (e.g., NTF, Isotopes Area), First Creek, and Fifth Creek. As a result, the pipeline system may conceivably transport contaminants from the 3001/3019 area to virtually any other part of WAG 1.

The predominant groundwater gradient direction at 3001/3019 area is southward with eastward and westward components present. Groundwater in the area may also migrate as stratabound flow, in which groundwater travels primarily along fractures or dissolution features in geologic strata. Dissolution features are known to occur in the Unit D beneath the 3001/3019 area. Stratabound flow appears to be an important transport pathway that results in migration of contaminants in the eastward or westward (along geologic strike) directions.

An aggressive subsurface exploration program will be performed in the 3001/3019 area. The emphasis of the program is to determine the vertical and areal extent of contamination in the area. It will test hypotheses about the presence of a sizable volume of contaminant contained within a localized cavity system(s) in Unit D vs localized contamination related to specific historic pipeline leaks. Both conditions are candidates as a CH-8 plume source and possibly other contamination within the WAG which is a secondary objective of the program. A tertiary objective is to determine the extent that pipeline trenches in the area are transmitters of contamination.

As shown in Fig. 6.1, bedrock wells will be installed adjacent to piezometers 560, 573, and 582, and soil borings SB130 and SB132. New bedrock wells will be installed west of Building 3137, northwest of the NTF, south of Building 3019 in Hillside Drive, and adjacent to a LLLW transfer line at the corner of Hillside Drive and Third Street. Four temporary piezometers will be installed in pipeline trenches southeast of Building 3001 and north of the NTF to investigate eastward and southward migration in pipeline trenches.

Piezometer 573 and a new bedrock piezometer near SB132 and SB130 are in locations very near historic pipeline leaks that may have contaminated groundwater. A new well south of the hot tank would seek to identify contaminants in that area. Piezometer 582 is downgradient from the 3001 canal, and piezometer 560, currently in a nonwater bearing portion of bedrock, is in a position near a possible southwest migrating pathway from a Building 3019 contaminant source that could also be used in CH-8 plume source investigations. Bedrock wells south of Building 3019 will be near a major PWT transfer pipeline and south of the storage tank, respectively. These will look at more localized areas of contamination near Building 3019. The well at the southeast corner of Hillside Drive and Third Street will look at both localized areas and more widespread contamination. Comparison of water elevations with the adjacent interface piezometers would also provide information about perched water.

It must be presumed that significant quantities of contaminant will be encountered during drilling, and decisions about the potential use of the boring in remedial design will need to be made. Because of the possible presence of secondary soil contamination in the area, soil

auger drilling will sample and analyze for contamination as field screening dictates. The temporary piezometers in pipeline trenches would address potential migration from the area to the east.

A core hole near piezometer 583 into Unit D will seek to locate a potential contaminant pool south of Building 3019 at depth. The investigation would also be related to the CH-8 plume source investigation. The most desirable exploration method is core drilling which provides high resolution subsurface control. It is anticipated that such exploration to a depth of about 150 ft would proceed by advancing the hole in controlled increments with the ability to set casing during drilling to avoid creating an artificial contaminant pathway and to allow drilling to proceed. At present, values on the order of a factor of 5 to 10 above previous values will trigger casing installation.

If significant contamination is identified in these activities, installation of an additional piezometer(s) is foreseeable as part of a follow-on RI phase. Criteria for piezometer siting would include (1) areal and vertical contaminant characterization and (2) ability to remove contaminants by pumping if limited pump and treat is selected as the preferred remediation option.

Temporary piezometers in pipeline trenches southeast of the area would address pipeline migration pathways from the area to the east for which there are currently no data. The precise location for the temporary piezometers would be determined in conjunction with ORNL Waste Management and Engineering divisions staff who are knowledgeable about pipeline locations.

6.4.2 Underground Tanks

This section describes groundwater contamination associated with major underground liquid waste storage tanks. In WAG 1, Gunite and associated tanks are considered to be a separate OU. Because the NTF and STF constitute the major tank storage areas, they are treated separately. In addition, remedial investigation/feasibility studies activities are under way to address closure of the NTF and STF. The remaining tanks are then treated together. The approximately 80 × 230 ft contiguous area to the east of the STF which contains one 1500-gal capacity Gunite tank and six small stainless steel tanks is not part of the STF OU. The principal objective of investigations in the NTF and STF is to determine the relationship between tank and groundwater elevations.

Figure 3.2 shows the locations of the major inactive underground liquid waste storage tanks in WAG 1, some of which may be potential sources of groundwater contamination. Under normal circumstances leaks from those tanks beneath the water table would contribute greatly to groundwater contamination, but tank sumps and dry wells appear to capture groundwater contaminants and inhibit migration away from the tanks. Dry wells are pumped periodically or as needed to the PWTP or LLLW system for treatment.

During their operation, the tanks were used for temporary storage of low-level, process, and mixed liquid wastes. They were taken out of service because they were no longer needed. Because they concentrated large quantities of wastes (for decades in many cases) and many historic pipeline leaks near the tanks are reported, the tanks are considered to constitute major potential primary and secondary sources of groundwater contamination in WAG 1.

6.4.2.1 North Tank Farm

Tanks in the NTF (Fig. 6.2) were installed in the 1940s and early 1950s to receive LLLW principally from Building 3019 but also from Building 2026. Tanks are either stainless steel or Gunitite construction, and all are inactive either because of leaks or because they are no longer needed. Because of inleakage, tank liquid levels are monitored, and liquids are periodically pumped to the LLLW system. The NTF has long been a major liquid waste transfer and storage area at WAG 1. Because several pipeline leaks are known to have occurred during its history, it is recognized as a potentially significant source of groundwater contamination.

The NTF is serviced by a sump system which collects liquids (groundwater or tank outleakage) at the base of each tank. The liquids drain to a common sump in the south central part of the tank farm and then drain by gravity past the west side of the STF to the PWTP for treatment and eventual discharge.

Groundwater data are available only from the periphery of the tank farm which are likely not to be representative of groundwater conditions within the tank farm or the excavations immediately around the tanks. Gross beta analytical data are obtained monthly from the W-1A tank dry well and from the dry well in the southern part of the farm where all the individual tank sumps drain. Radiological contamination is significant in these dry wells (hundreds of thousands of picocuries per liter), but it is uncertain what portion of this contamination, if any, is derived from groundwater.

Analytical results from soil boring SB26 (Table 6.4), which encountered saturated conditions in the 15-ft sample, are interpreted to be representative of groundwater conditions. Significantly less to essentially no contamination was found in the unsaturated soil samples. Nonradiological contamination in the 15-ft sample was not detected above reference values. An anomalously high 212,000 $\mu\text{g/kg}$ of beryllium in the 0-5-ft sample is not understood.

Soil boring SB26 is located just north of tank W-1 which has an estimated depth to the bottom of the tank of 13 ft. This suggests that groundwater elevation is below the bottom of tank W-1, and it is assumed that dry wells at other tanks also effectively maintain groundwater levels near the bottom of the tanks. Results from other soil borings in the NTF indicate that contamination is generally in close proximity to tank locations and that contamination generally increases with depth.

Despite the absence of groundwater analytical data from the NTF, its history of operation and proximity along geologic strike from core hole CH-8 has made it a candidate

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Fig. 6.2. North tank farm area.

source area for the CH-8 plume. Alternatively, leaks from LLLW or process waste pipelines from the Building 3019 area to the NTF could be the source.

To evaluate these scenarios, a comparison was made of the radionuclides found in CH-8, in SB26, and from temporary piezometer SB132 in a process waste pipeline trench on the southwest corner of Building 3019. The comparison indicates that the suite of radionuclides as well as their concentrations are similar for all three locations. For example, ^{90}Sr was the most abundant radionuclide found at each location, and gross alpha and ^{238}U were found at all locations. Overall, contaminant suites are most similar between SB132 and CH-8, and contaminant concentrations were most similar between CH-8 and SB26. These results suggest that both the NTF area and Building 3019 areas are potential sources of CH-8 contamination and/or that 3019 is a source of NTF contamination.

Because of the proximity of the NTF slightly south of the CH-8 plume, assuming the level of water in tank sumps and dry wells is representative of groundwater elevation in the immediate vicinity of that location, and assuming that tank sumps effectively capture contaminants in the near vicinity of the tanks, the NTF is not considered to be a candidate source area for CH-8 contamination. However, these assumptions are not confirmed, and essentially no data are available to describe the potential migration of NTF contaminants either through pipelines or groundwater to the west or south.

The data acquisition program for the NTF is designed to describe the configuration of the water table in the immediate vicinity of tank excavations and to determine the effectiveness of tank dry wells in removing contaminants. These data will be used to support decision making for NTF remediation alternative selection.

Six drive points (at the locations shown on Fig. 6.2) will describe the elevation of tanks with respect to the water table and the radius of influence of tank dry wells on the water table configuration. Those located near tanks will be located on the opposite site of the tank from the dry well to describe the configuration of the water table surface immediately around the tank and to compare contaminant concentrations with those in the tank dry wells. The drive point location near the center of the NTF and outside of the tank excavation pits will be used to compare water elevations and contaminant concentrations with those inside the pits. The drive point located along the northern edge of the NTF will be used to compare groundwater elevations and contaminant concentrations upgradient of the NTF with those within the tank excavation pits. After an initial evaluation of the presence of contaminants in the drive point wells, pressure transducers and data loggers will be used to obtain water elevation data from the drive points and tank dry wells to reduce waste generation. Sampling will be performed during high base, low base, and high base storm conditions.

Similarly, with knowledge about the amount of water transmitted through the NTF common sump, in combination with monthly radiological content of the water currently being collected, estimates about the flux of contaminated groundwater being captured by the sump system can be made. Consideration will be given to the feasibility of installing a flow metering device in the NTF common sump.

6.4.2.2 South Tank Farm

The 130 × 200 ft STF (Fig. 6.3) contains six large buried Gunitite storage tanks that are approximately 50 ft in diameter and 12 ft in height with a 170,000-gal capacity. They were constructed within a pit excavated into the underlying bedrock. Old photographs suggest the excavation may be about 5 ft into bedrock. The backfill material around each of the tanks is a 3-ft layer of 2-in. crushed stone surrounding the tank from the base to the top. A dry well and sump system similar to that described for the NTF consists of a concrete pad at the base of each tank and a gutter system that drains water from each pad to one of six individual dry wells. The dry wells in turn drain to a common sump for pumping to the PWTP. In the event of a leak, the liquid was intended to flow through the crushed stone to the concrete base then drain to the sump system. The system was draining an estimated average of 26,500 gal/d in the early 1960s (Mynatt and Webster 1963) as a result of groundwater inleakage into the sump system.

The Gunitite tanks were originally built for permanent storage of radioactive liquid waste produced by the plutonium pilot plant. They were to receive waste from the building drains uphill to the north and to overflow from one tank to the next toward the south. As the laboratory grew, the storage tanks became inadequate to handle the volume of liquid waste being generated. The waste was precipitated in the tank by raising the pH with sodium hydroxide; the supernatant was decanted to waste holding basin 3513 and subsequently discharged to WOC. This practice changed in 1949 when a new evaporator was developed to handle the effluent. The use of each tank continued to change over the years as laboratory operations evolved.

Video inspections of Gunitite tanks W5, W6, and W8 conducted during or soon after rain events indicated that all three tanks receive inleakage of stormwater from the top. The remainder of the Gunitite tanks, except possibly tank W-7, are also expected to have similar inleakage.

Soil samples from 12 soil borings drilled between 1990 and 1991 provide data on soil contamination in the STF (BNI 1992). No groundwater samples have been collected within the STF.

Table 6.5 lists the gross alpha, gross beta, and tritium concentrations for soil samples collected within the STF. The primary radionuclides found in STF samples were ⁹⁰Sr and ¹³⁷Cs both of which are beta emitters. As a result, gross beta activities in soil samples from the STF were significantly higher than gross alpha activities. Samples from nine borings exceeded the highest reference gross beta activity. The highest gross beta activity (34,831 pCi/g) was detected in a sample from boring SB183 which is situated near a process waste pipeline that extends from Building 3515. Other locations where samples with high gross beta activities (>1000 pCi/g) were collected include boring SB19 (1394 pCi/g), located next to tank W-10; boring SB20 (1791 pCi/g), located near tank W-7 and next to a process waste pipeline; boring SB182 (17,047 pCi/g), located next to Building 3515 and near a process

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Fig. 6.3. South tank farm area.

waste pipeline; and boring SB213 (5204 pCi/g), located near a group of process waste pipelines in the southeast portion of the tank farm.

In contrast to the NTF, gross beta activities were highest in samples collected from depths of 6 ft or less. A total of eight samples from depths >10 ft were collected from five borings; gross beta activities exceeded 1000 pCi/g in one of these samples. In addition, a sample from the 22–23.1-ft interval at boring SB20 contained 607 pCi/g gross beta.

²⁴¹Am and isotopes of uranium and plutonium were found at elevated levels in some soil samples from the STF. Samples from five borings contained gross alpha activities that exceeded the highest reference activity (56 pCi/g). The highest gross alpha activities were found in samples from boring SB20 (near tanks W-7, W-9, and process waste pipelines); boring SB182 (near Building 3515 and process waste pipelines); and boring SB213 (near process waste pipelines in the southeast corner of the STF).

In addition to soil boring data, information about a LLLW pipeline leak discovered in the summer of 1993 suggest that another source of contamination may be present. The leak was discovered along Central Avenue in a LLLW line north of tank W-5. High levels of soil contamination were found in the excavation when repairing the leak. The duration of the leak is not known, but it may have been active for a number of years. It is possible that contamination from the leak has leached to groundwater and is impacting groundwater quality in the STF.

The data indicate that significant amounts of contamination exist in shallow soil at the STF. However, information about the nature of the tank/groundwater interactions is not known. Groundwater contamination at the STF may have been derived from historical leaks in pipelines, or from contaminants migrating along pipeline trenches. The soil data suggest that much of the contamination occurs in shallower soils, indicating that contaminants were derived from pipelines to the tanks. However, there are isolated occurrences of contamination found at deeper intervals.

As described above, the STF is contained within a pit that was excavated into bedrock. The major factor affecting groundwater within the pit is likely to be the tank sump system. If the sump system is effective, groundwater within the pit is at least partially contained. Depending upon the effectiveness of the dry well and sump system, some contaminated groundwater may migrate out of the tank farm through pipeline trenches or within the groundwater flow system. Data regarding hydrogeologic conditions within the tank farm are needed to evaluate these scenarios and to evaluate the effectiveness of the dry well system.

Similar to the NTF, the STF data acquisition program is designed to assess groundwater/tank interactions within the excavation pit surrounding the tanks and to compare these data with data from nearby piezometers around the tank farm. Also, the distribution of contaminants in these locations will provide some indication of the likely migration pathways for groundwater contamination. If significant amounts of contamination are found, additional followup studies may be needed to further evaluate the transport pathways.

Four drive points will be installed in the STF area at locations shown in Fig. 6.3. These well points will be driven to the top of bedrock and will be situated away from any known buried pipelines. The three well points on the north side of the tanks will provide water elevation and quality data for comparison with similar data from tank dry wells on the opposite side of the tanks. These will describe hydrologic and concentration gradients on opposite sides of the tanks. This configuration assumes that groundwater flow to the excavated pit is from the north. The fourth drive point will be between Building 3515 and tank W-10 will describe hydrologic and concentration gradients between the building and the tank sump.

Similar to the NTF, drive point wells and dry wells will be instrumented with pressure transducers and external data loggers to reduce waste generation. Sampling will be performed during high base, low base, and high base storm conditions. Monthly sampling of the common STF sump in the southwest corner of the tank farm and possible installation of a flow metering device will describe flow volumes to calculate contaminant flux.

The data from the wellpoint near W-5 will also be compared to analytical data for the soils excavated from the pipeline leak site adjacent to the north boundary of the STF. Similarities in isotopic compositions between the groundwater and soil samples may indicate that the pipeline leak is the source of some of the groundwater contamination in the STF.

6.4.2.3 Remaining tank farms and isolated tanks

Remaining tanks at WAG 1 include WC-5, 6, 7, and 9 and TH-1 through TH-3 in the thorium tank farm; WC-10 through WC-17 serving the 4500N area; W-11 and W-12, and W-19 and W-20 southeast of the STF; W-16 through 18 northeast of the STF; TH-4 southwest of Building 3550, and WC-1 in the Isotopes Area.

Tanks W-11 and TH-4 are Gunitite construction and the others are stainless steel. WC-9, WC-10, and W-16 are the only remaining active tanks. All are constructed on bermed and graded concrete pads and presumably backfilled with an undetermined combination of rock or excavated saprolite. Dry wells at the lowest part of the tank pad collect water which is pumped periodically from the tank. In the tank farms, individual tank sumps drain to a common sump and dry well.

Monthly liquid tank level data are obtained by Waste Management Division staff and maintained on a computer data base. In those cases (e.g., WC-17) where a sump pump discharges accumulated groundwater near the base of the tank, monthly sump pumping estimates are made based on the rated pumping capacity of the pump and the amount of time the pump operates. The accuracy of the estimate is admittedly subject to question. In the case of WC-17, the relatively constant tank liquid level is attributed to sump pump operation. That the liquid level is maintained at about 300 gal may reflect the elevation of the pump. Camera inspection of the tank after it was emptied showed considerable inleakage into the bottom of the tank. Tank inleakage was also identified in WC-15 when a sudden loss of tank contents, approximately 500 gal of low to moderately contaminated liquid, occurred in August

1993. WC-15 and WC-17 are serviced by a common sump pump that maintains liquids in both tanks at similar elevations. In those cases where tanks and tank sump dry wells are emptied monthly by pumping, the rate at which the tanks or dry wells refill is not known.

No wells or piezometers are in sufficiently close proximity to any of the surplus tanks to accurately estimate the groundwater elevation in the near vicinity of the tanks. However, because groundwater elevation is generally close to the elevation of bedrock and excavations of many tanks can be presumed to have been close to that depth, tank bottoms can be expected to be below normal groundwater elevation at some and certainly below high base groundwater elevation in many cases.

A considerable but unquantified amount of groundwater is considered to be captured from underground tank sumps and dry wells. The presence of these tanks is therefore a possible component of the overall WAG 1 groundwater removal and treatment system that reduces apparent contaminant levels in surface water. In conjunction with knowledgeable Waste Management Division staff, the acquisition of reliable dry well water elevation, refilling rate, and radiological data from selected tank dry wells will allow the flux of contaminant removal to be calculated. These data will be used to describe groundwater/tank interactions to more adequately evaluate remediation options than at present. Recommendations for the locations for monitoring and sampling frequency would be made with input from Waste Management Division staff but would include perhaps as few as three to four locations considered to be representative of conditions throughout the underground tank system.

6.4.3 Isotopes Area

The Isotopes Area is located in the central part of WAG 1, north of Central Avenue, south of Hillside Avenue, and west of Fifth Street. Figure 6.4 shows locations of buildings, wells, soil borings, manholes, and sumps in the Isotopes Area.

During the production of radioisotopes for many years, numerous spills and pipeline leaks have occurred in the Isotopes Area, and it contains both radiological and nonradiological contaminants. Contamination in the general Isotopes Area is also from leaks and spills during operations in the 1950s and 1960s, and contamination is known to occur beneath Building 3047 that is at least partly discharging into the process waste pipeline network in the area.

East-flowing seepage of ^{90}Sr and ^{137}Cs contaminated groundwater into the foundation excavation for Building 3047 is anecdotally reported during building construction in the early 1960s. Neither the extent of contamination nor the volume of the seep are known, but the source was apparently commonly considered at the time to be from the Hillside area. Grimsby (1986) reports significant contamination obtained from piezometers within and near the building in the early 1970s. Inleakage to abandoned process waste pipelines is known to occur, and pipeline in-situ form lining in the mid-1980s was not performed on those portions of the pipeline to allow this capturing effect to continue. Water captured in these pipelines is treated in the PWTP.

Elevated levels of gross alpha, gross beta, and tritium were detected in groundwater samples from Isotopes Area wells and sumps (Table 6.6). The highest levels of gross alpha and tritium in Isotopes Area wells were found in the low base sample collected from well 608 in November 1991. Well 608 is located approximately 50 ft south of Building 3033, between Buildings 3037 and 3038. Alpha-emitting radionuclides detected above background levels in well 608 included ^{228}Th (8.7 pCi/L), ^{230}Th (2.6 pCi/L), ^{232}Th (4.3 pCi/L), and ^{224}Cm (108 pCi/L). The highest gross beta activity in Isotopes Area wells was detected in the March 1991 high base sample collected from well 598, which is located about 50 ft west of Building 3092. Beta-emitting radionuclides detected in this sample included total radioactive strontium (124 pCi/L) and ^{63}Ni (346 pCi/L).

Levels of gross alpha, gross beta, and tritium (including the highest tritium activity detected in WAG 1) which were from two to four orders of magnitude higher than those detected in Isotopes Area wells were found in a water sample collected from the Building 3033 sump. Beta-emitting radionuclides found in this sample included ^{137}Cs (599,000 pCi/L), ^{152}Eu (15,500 pCi/L), ^{154}Eu (8440 pCi/L), ^{155}Eu (2290 pCi/L), ^{57}Co (5790 pCi/L), ^{60}Co (2070 pCi/L), and ^{22}Na (3060 pCi/L). The volume of water pumped by the sump is not known but has been estimated to be about a couple of hundred gallons per day.

The reported presence of ^{22}Na and ^{57}Co are suspect from that sump because those radionuclides were produced in Building 3030 for the cyclotron program. Production essentially ceased in the early 1980s, and in the intervening years, ^{57}Co and ^{22}Na would have gone through 4 and nearly 13 half-lives respectively. Concentrations in the thousands of picocuries per liter today are noncredible for ^{57}Co and suspect for ^{22}Na .

A water sample collected from the Building 3106 sump contained moderately high gross alpha and gross beta activities. The tritium activity in this sample was about four times the maximum reference level.

Elevated levels of gross alpha, gross beta, and tritium were detected in samples collected from soil borings in the Isotopes Area (Table 6.7). The highest levels of gross alpha (1890 pCi/g) and gross beta (3218 pCi/g) were found in the 4–6-ft interval in SB160 at the site of a suspected pipeline leak in Central Avenue. Alpha-emitting radionuclides detected in this sample included ^{234}U (185 pCi/g), ^{235}U (25 pCi/g), and ^{238}U (1383 pCi/g). Beta-emitting radionuclides found in this sample included ^{63}Ni (133 pCi/g) and ^{147}Pm (10.4 pCi/g). Elevated gross beta activities in soil borings SB148 and SB149 were associated with the Building 3028 leak area. Samples from soil borings SB150, SB152, and SB153 which were collected at sites of suspected or known past pipeline leaks contained elevated gross beta activities. The second highest gross beta activity detected in Isotopes Area soil borings (2830 pCi/g) was from the 12–14-ft depth interval in SB40, located directly north of tank WC-1. Beta-emitting radionuclides found in this sample included ^{90}Sr (886 pCi/g), ^{137}Cs (390 pCi/g), and ^{60}Co (100 pCi/g). These elevated activities were likely the result of a leak from tank WC-1 evidenced by the dispersed surface contamination in the surrounding area.

Table 6.8 is a summary of nonradiological contaminants found in Isotopes Area wells. Metals detected in groundwater samples from these wells included beryllium, cadmium, chromium, and lead. These metals were present at levels below to slightly above SDWA MCLs. The VOCs 1,2-DCE and TCE were detected in groundwater samples from well 598, located west of Building 3092. This well contained the highest concentration of TCE in WAG 1 (210 $\mu\text{g/L}$ in the low base sample collected in October 1990).

Beryllium, chromium, and lead were detected above background but well below RCRA action levels in Isotopes Area soil borings. TCE was detected in one soil sample from the 12-14-ft interval in SB40.

A study of process system flows and radiological monitoring data in Isotopes Area manholes indicates that the flux of gross beta through MH114 is one to two orders of magnitude higher than through MH112. It appears that this additional gross beta activity is entering the process system between the two manholes. As there are no processes discharging to the process system between MH112 and MH114, the source of this beta activity is generally considered to be contaminated groundwater which is being intercepted by an abandoned line exiting MH114 toward the north. MH114 is approximately along geologic strike with the Building 3033 sump. Possible sources of the radiological contamination of groundwater in the sump and in the process system could be uphill in the 3019 or 3042 areas. Contaminants could be transported down dip with groundwater in Unit D, discharge upward to Unit E, and move along strike to the east in a mirror image of the CH-8 plume. Alternatively, there could be a source to the west in the Building 3026 area, a localized pipeline leak, or a combination of sources. This contamination could ultimately be intercepted by the process system and be treated in the PWTP, move off-WAG in permeable pipeline trench backfill, and/or underflow Fifth Creek.

Data acquisition for the Isotopes Area seeks to address the issues of contaminant source and possible underflow of Fifth Creek. In all cases, isotopic comparisons will be used to test alternate hypotheses about contaminant source.

The 30331 sump was resampled in April 1993. This sample will be analyzed for tritium, gross alpha, gross beta, and alpha and beta-emitting radionuclides. The primary purpose of sampling this sump was to confirm the presence of contamination found in previous sampling and to determine the presence or absence of ^{90}Sr and ^{137}Cs . In addition, within the limits of data resolution, the bottom of the Building 3033 sump could be very close to the Unit E stratum through which the CH-8 plume migrates. If so, the contamination in the sump may not necessarily be from a local source but could be from another location to the west or northwest. At present, the available data provide no indication that anything other than a local source is responsible for the contamination. However, the data cannot rule out the possibility of a remote source.

Radioanalytical sampling in manholes MH114 and MH233 would be compared with results from the Building 3033 sump to determine contaminant source locations. Because these manholes are known as groundwater catchment features, analysis for BTEX and TPH

will be used in monitoring of petroleum underground storage tanks (USTs). A core hole located to the west of Building 3038 and targeted to the CH-8 plume stratum will address issues of both eastward, mirror image migration of the CH-8 plume, and isotopic comparison with other samples would also address the issue of contaminant source in the Isotopes Area. Sampling in Stockdale core hole 33 would address possible contaminant underflow of Fifth Creek from the Isotopes Area. Sampling of piezometer 598 will be used to monitor radiological and VOC contamination.

6.4.4 CH-8 Plume

The so-called CH-8 contaminant plume was identified in early 1992 as an apparently narrow, westward migrating, strike-parallel plume which discharges off-WAG to First Creek (Fig. 6.5). Gross beta contaminant levels in CH-8 are among the highest measured in WAG 1, and ^{90}Sr constitutes the majority of the beta activity. Analytical data indicate that a part of the plume seeps into a storm sewer near the northeast corner of Building 2013 and discharges to First Creek via outfall 341. The plume also seeps into an abandoned storm sewer line which parallels First Street and discharges via outfall 342.

Sampling of piezometer 535 to the west of First Creek in conjunction with CH-8 plume investigations in November 1991 revealed gross alpha, gross beta, and tritium values of 116, 322, and 647 pCi/L respectively, which was suggested (BNI 1992) to represent underflow of First Creek. No source for the contamination is known or suspected to be to the west of First Creek. In the absence of data to determine the isotopic composition of the piezometer 535 contamination, it must be presumed that the CH-8 plume is underflowing First Creek.

Similarly, routine sampling of outfall 247 in November 1992 revealed more than 1700 pCi/L gross beta activity, more than 1400 pCi/L of which was attributable to ^{90}Sr ; however, seven sampling events from March 1991 through June 1992 revealed an absence of contamination in that outfall, and a sample in March 1993 also showed no contamination. The samples with elevated values were not obtained during periods of particularly high precipitation which might indicate high contaminant flux, and analyses before and since show a lack of contamination. A field reconnaissance survey of the outfall area in May 1993 showed an absence of activity, and the elevated values are considered to be anomalous.

Available indicator radiological data from isolated intervals in CH-8 are in Table 6.9. Data for wells and piezometers within the plume, First Creek, and outfalls 341 and 342 are in Table 6.10. The data indicate relatively stable contaminant levels over the brief period of record with the exception of increasing tritium concentrations in well 812 and piezometer 539. Increasing tritium at these locations may be interpreted to indicate the presence of a separate tritium source or that the plume is evolving and tritium is migrating ahead of other radioisotopes. Because there are no known or suspected tritium sources in the vicinity of well 812 or piezometer 539, the latter interpretation is favored.

Data to further characterize the CH-8 plume have not been obtained. The source of the plume is undoubtedly east of CH-8, and the current conceptual model shows upward leakage

Fig. 6.5. Interpreted configuration of the CH-8 plume.

into Unit E from the Building 3019 area above Unit D where significant quantities of contaminant may reside. Alternatively, or perhaps in combination, leaking pipelines in the NTF area could be a source. Isotopic comparisons, described in Sect. 6.4.2.1, indicate that both areas are potential sources, but at present the data are insufficient to be more definitive.

An aggressive plume characterization, interception, and source identification program will be performed for the CH-8 plume as an early interim action. The program utilizes data to be obtained from the Building 3001/3019 area, the NTF, and the Isotopes Area described above. Consideration was given to possible dual use in CH-8 source identification in the siting of many of those wells and core holes. Basic components of the program include source identification, plume interception, and investigation of underflow of First Creek.

Early action plume characterization and removal activities described in the paragraphs that follow are included only to provide a comprehensive and coherent presentation of activities related to CH-8. These early actions, however, are not part of this report. Rather, they are part of the CH-8 early action Engineering Evaluation/Cost Assessment to be prepared.

Plume characterization activities are designed to support early action remedial design. Eight to ten bedrock weathering interface wells will be installed along the southern plume boundary and across the plume axis to describe the plume areal configuration and to assist in identifying locations for plume interception trenches described below. Two such wells will be installed downgradient of the trenches to monitor interceptor trench effectiveness. A nominal 100 to 150 ft core hole located west of Building 2069 will intersect the contaminated stratum at depth to investigate down dip migration. Semi-annual monitoring of piezometer 535 will continue to address underflow of First Creek, and similar sampling of piezometer 539 and well 812 will be used to monitor interceptor trench effectiveness.

Early action remediation is designed to (1) immediately halt plume seepage into the storm sewer system, (2) intercept the plume at several locations to prevent new such seepage from developing, and (3) identify the source of the plume. Based on analyses of First Creek outfalls 341, 342, and storm sewer locations, the plume is known to be seeping into the storm sewer system. One location is an abandoned portion of the system on the eastern side of First Street which apparently (according to the ORNL Atlas) has a portion of pipeline which continues to the east toward piezometer 539. This pipeline discharges to First Creek via outfall 342. Manholes to the north of Building 2013 also receive plume seepage which, after joining with other parts of the storm sewer system, ultimately discharges to First Creek via outfall 341.

The pipeline near First Street will be videoed to determine where the seepage is occurring, and the pipeline will be lined to prevent further seepage. The manholes north of Building 2013 will be lined and interceptor trenches constructed to the north of the manholes to prevent further seepage in the area. Preliminary conceptual design for the interceptor includes a french drain which would direct water passively captured in the trench to the

PWTP for treatment. Quarterly monitoring of Outfalls 341 and 342 will be performed until such time as it is determined that they are no longer discharging contaminants.

Because the plume is in an area of groundwater discharge, two additional passive interceptor trenches are planned at locations across the plume axis to further control seepage. The precise locations for the trenches will be determined after characterization wells more definitively describe the plume, but at present one is envisioned in the vicinity west of Building 2069 and the other is envisioned between Buildings 2011 and 2018. They, too, will contain french drains which will direct captured water to the PWT system for discharge. Bedrock weathering interface monitoring wells will be installed to the west of each extraction trench.

Contaminant removal is also planned for CH-8 because of its high levels of contamination and presumed location near the source. This will be accomplished by low-volume pumping from the Westbay installation sampling ports to the PWT system along Third Street. Semi-annual sampling of the CH-8 Westbay installation will continue until the contaminant removal system is operational to maintain a continuous record, monitor changes in concentration at different phases of the water year, and provide baseline conditions for comparison after initiation of the early action.

In all cases, contaminant removal is designed to minimally perturb the natural groundwater system. It is considered likely that the groundwater flow system and presumed distribution of contaminants may be sensitive to more aggressive removal options (e.g., larger scale pumping) which could lead to possibly undesirable results. At present, the degree and areal distribution of contamination is insufficiently characterized to anticipate the effects of system perturbations. With the exception of minor extraction from CH-8, the plume removal system would simply provide preferred groundwater discharge galleries for the existing discharging system.

Selection of the contaminant removal and treatment option for plume interception is to obtain immediate results with a proven and in-place technology. As the interception system matures and monitoring results are analyzed, the removal and treatment option is likely to be reevaluated in lieu of alternatives such as in-situ remediation technologies.

It is known that historic problems have occurred with a concrete-encased LLLW pipeline on the eastern side of Third Street. To investigate the possibility that the CH-8 plume source is related to this line, three temporary piezometers will be installed near the pipeline in a north-south orientation running across the presumed plume axis. Additional plume source investigations are described in the sections above. Sample analyses from wells and core holes will be compared to describe the levels and compositions of contamination. Depending on the analytical results, source removal or immobilization options will be considered to augment those remedial actions already under way.

6.4.5 Oak Ridge Research Reactor (Building 3042) Area

The Oak Ridge Research Reactor (ORR) was placed in service in March 1958 and was shut down in 1987. The reactor shielding pools and associated equipment are located within the main building (3042). Heat removal systems are located within adjacent buildings. Containment ducts and filter pit areas are contaminated with ^{137}Cs , ^{90}Sr , and ^{60}Co . Figure 6.6 shows the locations of buildings, wells, soil borings, and sumps.

The primary cooling loop for the ORR, consisting of two parallel 24-in. pipelines, extends underground northeastward to the main circulating pumps in Building 3085. A third perforated pipeline has been installed in gravel backfill in the bottom of the pipe chase for the primary cooling loop. The lowest point of the pipe chase is at elevation 798.53 ft MSL in the ORR basement. The perforated pipeline collects groundwater, which then flows by gravity from the lowest point of the pipe chase to the ORR building sump. The ORR sump consists of two sumps, an inner (shallow) sump with a bottom elevation of approximately 785 ft MSL and an outer (deep) sump with a bottom elevation of about 773 ft MSL. The groundwater collected in the pipeline in the primary cooling loop pipe chase goes to the outer (deep) sump where it is commingled with process waste from the ORR building and pumped to the process waste system. Average flow from the outer (deep) sump is approximately 16 gal/min; however, the contribution of groundwater to this total flow is unknown. The inner (shallow) sump collects groundwater from foundation drains under the ORR building. This water is pumped from the sump to a storm drain for discharge to Fifth Creek. Six additional sumps are located along the pipe chase between the ORR and Building 3085. Groundwater collected in these sumps is pumped to the process waste system.

Activities of gross alpha, gross beta, and tritium which were above reference levels have been detected in groundwater samples collected from 3042 Area wells (Table 6.11). The highest gross alpha activity (125 pCi/L) in 3042 area wells was found in the low base sample collected from interface well 596 in November 1991. Well 596 is located about 50 ft north of Building 3042. Alpha-emitting radionuclides detected above background in this sample included ^{241}Am (20.4 pCi/L), ^{228}Th (2.9 pCi/L), ^{230}Th (2.7 pCi/L), ^{232}Th (3.9 pCi/L), and ^{238}U (1.3 pCi/L). The highest gross beta level (552 pCi/L) was detected in the high base sample from well 589 collected in May 1991. Beta-emitting radionuclides which were found above reference levels in this sample included total radioactive strontium (284 pCi/L) and ^{137}Cs (67 pCi/L). Other beta-emitting radionuclides which were above background levels in samples from 3042 area wells were ^{226}Ra , ^{228}Ra , and ^{99}Tc . The highest tritium activity in 3042 area wells (61,750 pCi/L) was in the low base sample collected from well 603 in November 1991.

Higher levels of radiological contamination than were found in 3042 area wells were observed in the water sample collected from the 3042 sump (30421) in August 1993 (Table 6.11). The gross alpha activity was 23.2 pCi/L and the gross beta activity was 4590 pCi/L in this sample. The bulk of the beta-emitting activity was accounted for by ^{137}Cs (1863 pCi/L), ^{60}Co (1809 pCi/L), and ^{134}Cs (864 pCi/L).

Fig. 6.6. Oak Ridge Research Reactor (ORR) area.

These results differ from those reported by BNI (1992) by more than two orders of magnitude. The vast difference is believed to have been a result of sampling locations. On the basis of an interview with the technician who obtained the BNI (1992) sample, the source of the sample was the outer (deep) sump, which is not representative of groundwater. However, written documentation of where the sample was taken does not exist.

Levels of gross alpha and gross beta ranging from below to slightly above reference levels were detected in soil samples from borings SB142 and SB257 in the 3042 area (Table 6.12). The maximum tritium activity detected in these borings was from the 4–5.9-ft interval in SB257 (1.17 pCi/g).

Nonradiological contaminants detected above background levels in 3042 area wells included TCE, beryllium, cadmium, chromium, and lead (Table 6.13). The highest levels of beryllium and lead in the wells were detected in the sample collected from well 603 in November 1991. The highest concentrations of cadmium and chromium were found in the sample collected from well 589 in November 1990. The sample collected from the 3042 sump contained about five times the maximum concentration of lead found in 3042 area wells (2230 $\mu\text{g/L}$).

Beryllium, cadmium, chromium, and lead were detected in 3042 area soil borings. However, they were detected at levels below maximum reference concentrations.

Results of a dye test reported by Huff (1985) indicated that groundwater was flowing eastward, along geologic strike, to the ORR sump from the area of a LLLW line break between Building 3019 and Building 3074. A cavity in the limestone bedrock was observed in the excavation for the line break. Fluorescein dye which had been injected into this cavity was observed in the inner (upper) ORR sump within 48 h. The injection point for the dye was at an elevation of about 820 ft MSL and the collection point for groundwater in the sump was at about 785 ft MSL. Therefore, there was an hydraulic gradient from the injection point to the sump of approximately 35 ft over a distance of 450 ft. This gradient is produced by pumping of water which maintains a groundwater depression in the vicinity of the sump. Therefore, radiological contamination detected in water samples from the ORR sump may be moving from the Building 3001/3019 area along cavities and solution features in Unit D. Contaminants may also be collected in the sump from leaks in nearby underground lines.

Actions for the ORR seek to determine the sources and migration pathways to the ORR sump. The inner (upper) 3042 sump will be sampled and isotopic analyses of the sample will be conducted to determine the radiological fingerprint of the sump sample. The isotopic composition of the contamination will be compared to isotopic analyses of samples collected in the 3019 area to determine if contaminants in the sump are derived from the Building 3019 area.

Drilling of a bedrock well immediately to the south of piezometer 588 will seek to obtain groundwater data between the ORR and the Building 3001/3019 area. Comparison of the

analytical results with those from the ORR sump and wells in the Building 3001/3019 area will provide information about source areas and migration pathways.

6.4.6 Surface Impoundments (3524, 3513, 3539, and 3540)

The four inactive impoundments in this area were used for settling and/or emergency storage of LLLW waste and as settling basins as part of the process waste system. These impoundments still contain water and sludges. Figure 6.7 shows the locations of the impoundments, piezometers, wells, and soil borings discussed in this section.

The unlined waste detention basin (DB) 3513 was constructed in 1944. In some places the bottom of the basin is within 1 ft of limestone bedrock. During its operational life (1944 to 1976) the DB received the supernatant outflow from the STF LLLW tanks; later, water treated in the original PWTP was held in the DB before being discharged to WOC. Nonradiological contaminants detected in water samples from the DB include chromium, lead, and selenium. Radiological contaminants detected in the water are ^{137}Cs and ^{90}Sr ; nonradiological contaminants in sludge samples from the DB included mercury and, possibly, selenium. Radiological constituents detected in the sludge samples are ^{60}Co , ^{137}Cs , ^{90}Sr , ^{154}Eu , ^{238}Pu , ^{239}Pu , ^{241}Am , and ^{244}Cm .

The equalization basin (EB) 3524 was originally built in 1945 as two adjacent, unlined ponds for emergency storage of LLLW. In 1957 the earthen dike between the two ponds was removed to create a larger EB for the original PWTP. The basin was further enlarged in 1961 to a final capacity of 1 million gal. Perimeter rock exposures and bedrock pinnacles are seasonably visible in the EB, and the expanded, western half of the basin shows clear evidence of simple cut-and-cover construction with an absence of a well-defined perimeter berm. It is thus very likely that excavation was to bedrock and that fissures and cavities allow for outleakage. The EB was removed from service in 1989, although it is still available for emergency overflows from the current process waste system. Analyses of sludge samples from the EB in 1984 found ^{137}Cs , ^{90}Sr , ^{241}Am , ^{60}Co , and ^{154}Eu . VOCs detected in sediment samples and in samples of the water directly overlying the sludge in 1986 were benzene, chloroform, and methylene chloride.

The process waste ponds 3539 and 3540 were constructed in 1964 with compacted clay liners as a surge basin system designed to receive and discharge process waste streams from the Building 4500 area. The ponds were removed from service in 1990. VOCs detected in samples of water directly overlying the sludge in these ponds were methylene chloride and chloroform. Sludge samples collected in 1986 contained slightly elevated levels of methylene chloride and 1,2-*trans*-DCE. Total radioactivity in the ponds has been estimated to be <10 Ci.

Table 6.14 is a summary of radiological contamination detected in groundwater samples from wells in the DB (3513) area. Gross alpha, gross beta, and tritium were detected above maximum background (reference) levels in wells 877, 1102, 1103, and 1104 in the DB area. Highest gross alpha (120 pCi/L) and gross beta (2200 pCi/L) activities in the DB area wells were detected in samples from well 1102 in February 1991 during high base storm conditions

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Fig. 6.7. Surface impoundments.

and in June 1992 during high base conditions respectively. The highest activities of manmade beta-emitting radionuclides in the DB area were ^{90}Sr (1020 pCi/L) and ^{228}Ra (308 pCi/L) in the sample from well 1102 in February 1991. This well is located to the south of and hydraulically downgradient of the DB. The highest tritium activities were observed in samples collected from well 1104 in February 1991 during high base storm conditions (79,500 pCi/L) and in April 1991 during high base conditions (50,950 pCi/L). This well is to the west of the DB and downgradient of the EB.

Radiological contamination detected in groundwater samples from EB (3524) area wells is summarized in Table 6.15. Elevated gross alpha, gross beta, and tritium activities were detected in groundwater samples from these wells. The highest tritium activities in the Impoundments Area (827,670 pCi/L to 912,000 pCi/L) were detected in samples from the 875/885 well pair, which is located directly south and hydraulically downgradient of the EB. Tritium activities in samples from other downgradient wells (874, 876, 1100, and 1101) ranged from 104,000 to 404,000 pCi/L, except for the sample from well 1100 in May 1991 (2540 pCi/L). Tritium activities in the closest upgradient well (579) were two orders of magnitude lower than activities in the downgradient wells in samples collected in February 1991 and April 1991 (7280 and 3330 pCi/L respectively). The highest gross alpha (74 and 287 pCi/L) and gross beta (2710 and 5710 pCi/L) activities in the EB area were detected in the high base storm samples collected in February 1991 from wells 874 and 875 respectively. Isotopes contributing to the gross alpha activity in the February 1991 sample from well 875 included ^{234}U and ^{230}Th . Manmade beta-emitting radionuclides which were detected in the February 1991 sample from well 875 were ^{90}Sr , ^{228}Ra , and ^{147}Pm . The data indicate that radiological contamination is most prevalent in shallow interface wells than in the bedrock well downgradient of the EB.

A water sample collected from the temporary piezometer installed in SB189, located in a process waste pipeline trench west of the EB, contained a gross beta activity of 34,000 pCi/L. Only a small portion of this beta activity was accounted for by gamma spectroscopy. The activity found in this sample may be related to ^{63}Ni contamination detected in soil samples from this boring.

Gross alpha, gross beta, and tritium activities only slightly elevated above reference levels were detected in groundwater samples from wells in the area of the 3539/3540 impoundments (see Table 6.16). Tritium activities ranged from 1710 to 3020 pCi/L, except in the April 1991 sample from well 882 (10,400 pCi/L). Gross alpha and gross beta activities showed little evidence of contamination in this area, ranging from below their respective MCLs to slightly above reference levels. The elevated gross alpha and gross beta activities detected in well 877 may have been due to contamination from the 3513 and/or 3524 areas.

In general, significant radiological contamination was found downgradient (south) of the EB and DB and was not found in the 3539/3540 area. The highest levels of contamination occurred in samples collected during high base storm conditions. This contamination consisted primarily of high levels of tritium, moderately high levels of gross beta (predominantly ^{90}Sr and ^{228}Ra) and moderately low levels of gross alpha.

Elevated levels of gross alpha, gross beta, and tritium were detected in soil borings in the DB and EB areas (see Tables 6.17 and 6.18). Principal alpha-emitting radionuclides detected were ^{234}U , ^{235}U , and ^{238}U ; principal beta emitters were ^{137}Cs , total radioactive strontium, and ^{147}Pm . Gross alpha and gross beta in 3539/3540 area borings were detected at levels below or near background (see Table 6.19). With the exception of gross alpha and gross beta in SB189, elevated levels of radiological contaminants in Impoundments Area soil borings are likely due to leakage from the impoundments or lines associated with the impoundments. SB189 was completed as a temporary piezometer in a process system pipeline trench. Levels of gross beta in soil samples from this boring were one to two orders of magnitude higher than in other Impoundments Area borings. Nickel-63 accounted for most of the gross beta activity in SB189. This isotope was not detected in soil samples from any of the other borings in the Impoundments Area. The soil contamination found in SB189 may be the result of a leak in the process system pipeline near the boring. Alternatively, the contamination may be the result of leakage from the EB or a leak in a pipeline in the Isotopes Area, the NTF, and/or the STF and migration of contaminants through permeable pipeline trench backfill materials.

Nonradiological contaminants detected in Impoundments Area wells included TCE, 1,2-DCE, vinyl chloride, cadmium, chromium, and lead (see Tables 6.20, 6.21, and 6.22). Metals (cadmium, chromium, and lead) were generally found at concentrations which were below maximum background and/or MCLs. VOCs (TCE, 1,2-DCE, and vinyl chloride) were detected at low levels which were slightly above their respective MCLs.

Nonradiological contaminants detected in soil included chromium and lead (see Table 6.23). These metals were present below or near maximum background concentrations and well below RCRA action levels.

Seepage of contaminated water from the EB and DB impoundments is apparently a major source of tritium, ^{90}Sr , and ^{228}Ra contamination of groundwater in WAG 1. Video inspection of a 24-in. storm sewer to the west of the EB in December 1992 revealed numerous inleaking joints, particularly in that portion of the storm sewer on the northwest side of the EB. All of the observed flow in the storm sewer was derived from inleakage which is subsequently pumped back into the EB. Because most of the leaks were from the EB side (east) of the pipeline and a head potential exists from the EB to the pipeline, it is reasonable to assume that the pipeline inleakage is derived at least partly from seepage from the EB. Sampling of the inleaking water has not been performed.

Radiological contaminants have been found in overburden, interface, and bedrock wells. Contaminants should move southward (downgradient in the overburden and down-dip in bedrock), eventually discharging to WOC. Contaminants may also be migrating in pipeline backfill materials. Given the relatively short half-life and slow transport velocity in groundwater of ^{228}Ra , it should undergo significant decay before it reaches WOC. Therefore, tritium and ^{90}Sr are the primary contaminants which could reach WOC and be transported off-WAG.

The following actions will be performed in the Impoundments Area:

- consideration will be given to determine the need for an interim, early action separate from this report to retard the migration of contaminants from the impoundments to groundwater. Discussions will begin during scoping meetings held to initiate the RI/FS process for the Surface Impoundments OU. Considered actions might include the feasibility of installing a temporary liner or implementing other source control technology before closure or accelerating the final closure schedule where feasible;
- sampling of groundwater twice yearly in wells 874, 875, 885, 876, and 1104 downgradient of the EB and wells 1102, 1103, and 1104 downgradient of the DB; these samples will be analyzed for gross alpha, gross beta, and tritium;
- resampling of groundwater in the temporary piezometer in SB189; this sample will be analyzed for gross alpha, gross beta, tritium, and isotopics to confirm the observation of elevated gross beta activity in the December 1991 sample and to determine whether ^{63}Ni is present in the groundwater at this location.

The impoundments will eventually be closed. After closure, monitoring of downgradient wells for gross alpha, gross beta, and tritium should continue during high base and high base storm conditions to determine the effects of closure on radiological contamination of groundwater and on discharge of contaminants to WOC. No monitoring of nonradiological contaminants is necessary because VOCs should volatilize within hours of entering WOC and metals are present at levels below MCLs.

6.4.7 Solid Waste Storage Areas 1 and 2

Figures 6.8 and 6.9 show wells, piezometers, and soil borings in SWSAs 1 and 2 respectively. Wastes were stored in these areas in the early to mid 1940s. SWSA 1 received solid wastes, and SWSA 2 received both solid and liquid wastes. Some time after 1946, the wastes and contaminated soil were removed from SWSA 2 and transferred to SWSA 3, but some objects may remain in SWSA 2. Both areas are grassed, and SWSA 1 is fenced.

In 1990 geophysical surveys were performed to investigate subsurface objects in SWSAs 1 and 2. Five areas with geophysical anomalies were identified in SWSA 1, and seventeen were identified in SWSA 2. The nature of the objects is not known but could include portions of a waste transfer line in the case of SWSA 1 and storage tanks and vehicles in the case of SWSA 2. The extent to which these remaining objects may contribute to groundwater contamination is not known, but much higher iron concentrations in downgradient piezometer 622 (17,700 $\mu\text{g/L}$) than upgradient locations suggests the potential that buried objects are impacting the groundwater.

Indicator radiological data from SWSAs 1 and 2 are given in Tables 6.24 and 6.25. For SWSA 1, the relatively complete historical data for many wells indicate generally stable contaminant concentrations over time and between high and low base groundwater conditions. Gross alpha and beta concentrations are generally below reference levels, and tritium values range between about 1000 and 2500 pCi/L. The highest tritium concentrations in bedrock

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Fig. 6.8. Solid Waste Storage Area (SWSA) 1.

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Fig. 6.9. Solid Waste Storage Area (SWSA) 2.

wells 828 and 947 suggest the possibility of flow paths below the water table surface. In addition, piezometer 571 contains several radionuclides (e.g., $^{239}\text{Pu}/^{240}\text{Pu}$, ^{228}Ra), which could suggest westward migration of contaminants from SWSA 1. Nonradiological contamination is generally below to only slightly above MCLs and reference values.

SWSA 1 soils radiological data (not tabulated) are generally below or only slightly above reference levels. The exception is SB63 which contained 2166 pCi/g gross beta from the 0–1.8-ft sample. $^{239}\text{Pu}/^{240}\text{Pu}$ was also detected (below reference levels) from that location. The absence of similar contamination from nearby soil borings SB61 and SB62 indicates that SB63 contamination is very localized, and no major areas of soil contamination are present.

Table 6.25 for SWSA 2 indicates that tritium contamination is prevalent throughout much of the area, with the highest concentrations within and southwest of SWSA 2—suggesting southwestward migration. Slightly higher gross alpha and beta in the downgradient piezometer also suggest minor radiological migration. This is corroborated by the presence of radiological contamination in Fifth Creek outfall 165 that serves a small segment of a storm sewer from Fifth Street. Because no other source for the outfall 165 contamination is apparent, it is presumed to be coming from discharging groundwater from SWSA 2. The data from adjacent bedrock wells 820 (about 20 ft deep) and 821 (about 80 ft deep) indicate that contamination decreases with depth. With the exception of iron in piezometer 622 above reference values, nonradiological contamination is at or below MCLs and reference sampling results. No soils data are available from SWSA 2.

Monitoring will be performed in SWSAs 1 and 2. To augment reduced environmental compliance monitoring of the WAG 1 water quality wells, wells 827, 828, 829, 946, and 947 and piezometer 571 will be sampled in SWSA 1. Piezometer 622 and well 822 will be monitored in SWSA 2. Monitoring will be performed during high and low base conditions, and sampling coordination will be arranged with environmental compliance monitoring to maximize efficiency.

6.4.8 Pipelines

Because pipelines, particularly process waste pipelines, are known to collect significant amounts of contaminated groundwater, available flow and radiological data from process waste manholes which are monitored monthly were analyzed. Figure 3.2 shows the locations of process waste manholes for which radiological data are available. The purpose of the analysis was to investigate possible relationships with groundwater elevation. A description of the results of Phase 1 RI temporary piezometer installation in pipeline trenches follows the description of the process waste manhole analysis.

Performance of the process waste manhole analysis relied on monthly process waste flow and radiological data and underground tank level and dry well radiological data acquired and provided by ORNL Waste Management Division staff. Because these data are collected for purposes other than groundwater studies and may not represent a suitably high degree of accuracy, the absolute data values are emphasized less than apparent trends in the data.

Irregularities in process waste production in facilities served by any manhole and periodic tank pumpage seriously complicates the analysis.

Groundwater elevation data are those contained in BNI (1992), and piezometers were selected to be representative of both recharge and discharge locations. Precipitation data are from Walker Branch Stations RG1 and RG3, and surface water stage data are for First Creek and Northwest Tributary collected by the Office of Environmental Compliance and Documentation. Thus, the data are from several unrelated programs and projects at ORNL.

Because the data were collected at various frequencies, the analysis was conducted on summaries of the monthly frequencies. No attempt was made to validate the data beyond that conducted by the data custodians. The data generally cover the time period from 1985 through 1992, but most of the data series are incomplete for the entire time period. When short data records correlated highly with longer data records, a surrogate was used to increase the data density. For example, some of the groundwater data from some piezometers correlated highly with stage data from creeks, and the use of the surrogate creek data greatly increased the number of groundwater data points available for analysis.

The analysis considered the dependence of several variables on an observation to determine causal relationships. When plotted, dependence is observed as a diagonal, straight line pattern to the data. An absence of such a straight line pattern indicates an absence of dependence. Total contaminant flux through the process waste pipeline system at any location was calculated by multiplying monthly manhole flow rate and radiological data. The principal objective of the analysis was to determine if flow or contaminant flux through process waste manholes was related to either precipitation or groundwater elevation which would provide some indication of the interaction between the process waste pipeline system and groundwater. Complicating the analysis is the variable generation of process waste liquids from user facilities around ORNL.

Efforts to relate tank levels to precipitation and groundwater elevations were generally unsuccessful. The typical pattern observed was a steady increase over time followed by a precipitous drop which is undoubtedly from pumping.

With the exception of several potentially outlier data points, a relatively weak relationship between process waste pipeline flow and precipitation is apparent in MH229. No other manholes exhibited dependence. However, dependence between manhole contaminant flux and precipitation is apparent at PS1, MH149, MH229, and MH234. Dependence between manhole contaminant flux and groundwater elevation is apparent at PS1, MH114, MH149, MH229, and MH234. That contaminant flux at MH114 is not dependent on precipitation is probably because the pipelines to that manhole are in Unit D where a lag between precipitation and aquifer response is likely.

Dependence between manhole contaminant flux and precipitation and/or groundwater elevation supports the concept that contaminant mobilization occurs principally during periods of elevated water table despite apparently lower concentrations due to dilution. It also

suggests that contaminants residing in groundwater or in the vadose zone immediately above the water table are mobilized above the bedrock weathering interface in response to water table rise.

BNI (1992) reports the installation of nine temporary piezometers in pipeline trenches. Water level monitoring and sampling was performed between November 1991 and March 1992. Estimated well depths and high and low base groundwater elevations indicate that only two (SB187 and SB208) of the nine piezometers (and trenches) are seasonally below or very near the water table elevation. However, monitoring data indicate that all but two of the piezometers (SB195 and SB197) contained water in at least one monitoring event during the monitoring period, and four piezometers contained water during each monitoring event. Because of the time period of monitoring, these conditions can be considered to generally represent high base conditions.

Maximum radiological content data for the temporary piezometers indicate negligible to significant radiological contamination in all piezometers which contained water. Contamination in SB187, apparently located in a storm sewer, suggests the possibility of pipeline crossover or leakage from a process waste or LLLW line to the storm sewer system. Significant concentrations in SB132 are likely related to a process waste line leak in the area, and concentrations in SB189 could result from along-line migration or outleakage from the 3524 EB. The general absence of radiologic contamination in soil borings near piezometers SB189 and SB197 suggests that along-line migration occurs. Hydraulic conductivity estimates in piezometers SB208 and SB224 of 3.71×10^{-4} and 1.24×10^{-4} cm/s are comparable to average hydraulic conductivity values for interface piezometers. Alternatively, generally uniform contaminant concentrations in soil borings in the vicinity of SB195 suggests more diffuse areal contamination.

Compared to contaminant concentrations in underground tank dry wells, the level of contamination in pipeline trenches is comparatively small. However, although tank dry wells tend to capture contaminated groundwater, pipeline trenches may tend to distribute contamination.

The identification of ^{63}Ni , an unusually occurring radioisotope, in several soil borings and temporary piezometers provides some qualitative insight into migration within pipeline trenches. ^{63}Ni was detected during the Phase 1 RI in samples from six soil borings and one piezometer in WAG 1. The highest activities of ^{63}Ni were found in borings SB182 and SB183 near Building 3515 and in temporary piezometer SB189 to the west of the EB (3524). Lower ^{63}Ni activities were found in SB194, located east of Building 3517; SB174, south of Building 3503; and SB160, in Central Avenue southwest of Building 3038. ^{63}Ni was also detected in a groundwater sample collected from piezometer 598, located in the Isotopes Area between Buildings 3026 and 3092. The ^{63}Ni found in the Isotopes Area may have originated in the Low Intensity Test Reactor, where it has been found in the core and in the heat exchangers. It may have migrated downhill in permeable pipeline backfill material.

The ^{63}Ni found in SB182 and SB183 near Building 3515 may be the result of past pipeline leaks in the area. Boring SB194 is located near a process waste pipeline which originates at Building 3515. The ^{63}Ni found in this boring may have migrated from the Building 3515 area in the process waste pipeline trench. Boring SB174 is also located near a process waste pipeline. The process waste pipeline adjacent to temporary piezometer SB189 is connected to the process line originating at Building 3515 via MH117. Therefore, the ^{63}Ni found in temporary piezometer SB189 may also have originated in the Building 3515 area and migrated to SB189 in pipeline trench backfill. Alternatively, the ^{63}Ni found in SB189 could have resulted from leakage from the EB (3524). The ^{63}Ni found in SB174 may also have a source at Building 3515 as this boring is located near a process waste pipeline connected to the line from that building. Assuming that a potential source for the ^{63}Ni found in most of the soil borings was derived from Building 3515 pipeline leaks, then migration along pipeline trenches would be measured in hundreds of feet and is to various parts of the pipeline system.

To trace possible migration pathways for ^{63}Ni in pipeline trench backfill, it would be necessary to drill numerous borings in pipeline trenches and install temporary piezometers in these borings. Many of these borings would have to be performed in contaminated areas with potentially high risk of exposing workers to radiological contamination. Due to the many pipelines which are located in the areas which would need to be investigated, identifying these migration pathways would be expensive both in terms of time and money. Therefore, such an investigation will not be conducted.

With the exception of the limited data pertaining to contaminant migration in pipeline trenches within WAG 1, further resolving migration pathways within WAG 1 is considered to be an essentially hopeless endeavor. Pipeline routes and system interconnections are only generally known, and the map atlas is over 10 years old. Rather than attempting to unravel WAG interior pathways, sampling of trench backfill near pipeline discharge locations at surface water bodies which either coincide with a WAG boundary or are within the WAG will be performed. Identified excursions can then be traced back on a case-by-case basis via atlas information and/or camera to locate the source. Decisions about the most appropriate remediation option can also then be made on a case-by-case basis pending results of the investigation. In conjunction with the pipeline trench sampling, a seep and spring inventory and selective sampling program will be implemented. Because BNI (1992) reports such an investigation at First Creek related to the CH-8 plume investigations, the program need be implemented only at Fifth Creek and WOC. Because seep and spring data would be obscured by PWTP discharges, seep and spring sampling in WOC downstream of the PWTP discharge would not be needed.

6.4.9 Unit F

Because Stueber et al. (1981) describe strike-parallel flow and contaminant transport in Unit F from SWSA 3, consideration is given to such flow in WAG 1. Three areas of contamination in or immediately outside of WAG 1 could describe strike-parallel flow related to Unit F.

6.4.9.1 Piezometer 536 and Well 810

Table 6.26 contains water elevation and indicator radiological data for piezometers and wells potentially related to low levels of radiological contamination in piezometer 536 and well 810 (Fig. 6.10). Nonradiological contamination is absent. Contaminant levels are within to barely above background concentrations, but the data are of concern because the presence of contamination in piezometer 536 and well 810 could be interpreted to suggest possible migration along Unit F from WAG 1 and underflow of First Creek. No information suggests the possibility of a spill in the area to account for the contamination.

The data in Table 6.26 indicate an absence of either a hydraulic or concentration gradient from piezometers or wells in WAG 1 toward piezometer 536 or well 810. Very close control on the elevation of First Creek in the vicinity of Unit F indicates a reverse hydraulic potential from the creek to well 810. These data essentially preclude WAG 1 as a source of contamination in piezometer 536 and well 810. Rather, hydraulic and concentration gradients do exist from piezometer 533 toward piezometer 536 and well 810 which indicates an eastward migrating plume. Because strike-parallel flow has been documented within Unit F in SWSA 3, the most logical explanation for the source of piezometer 536 and well 810 contamination is from SWSA 3 where a hydraulic gradient exists. If this is the case, it suggests that the Northwest Tributary is an incomplete groundwater discharge surface water body and that First Creek is the ultimate discharge location for eastward migrating groundwater.

The data indicate that contamination in piezometer 536 and well 810 is not derived from WAG 1 but from an eastward migrating plume with a possible source area in SWSA 3. In addition, a hydraulic potential beneath First Creek into WAG 1 does not exist. Therefore, contamination in piezometer 536 and well 810 is not a WAG 1 groundwater issue but a Bethel Valley Groundwater OU issue and will be addressed by the Bethel Valley OU. Because existing data are relatively complete to describe changes in water elevation and radiological contamination in piezometer 536 and well 810, no further monitoring or sampling will be performed as part of this site characterization report.

6.4.9.2 Building 2533 Sump Plume

Table 6.27 contains indicator radiological data for piezometers and sumps which appears to describe another contaminant plume in the vicinity of Unit F (Fig. 6.10). The data indicate the presence of a plume originating in the vicinity of the Building 2533 sump and migrating in a southwesterly direction. The plume exhibits highly elevated concentrations of tritium and gross beta; nearly 75% of the gross beta activity in the Building 2533 sump is ^{137}Cs .

The plume appears to terminate in Unit F. Piezometer 567 to the south of Unit F in the apparent plume migration direction does not exhibit radiological contamination. Radiological contamination slightly above background levels in piezometer 541, about 650 ft to the west in Unit F, could represent strike parallel migration since no other apparent source for that contamination (especially ^{137}Cs) is in the area, but the data are insufficient to substantiate such migration.

Fig. 6.10. Contamination associated with Unit F.

Soil boring radiological data (see Table 6.28) indicate nominally one order-of-magnitude elevated gross beta values over background for SB181. Because SB078 (near the apparent high concentration portion of the plume) does not exhibit similar elevated values, it is considered unlikely that the SB181 (located near or outside of the apparent eastern border of the plume) contamination is related to the plume. The nature of the SB181 contamination is unknown, but the data show no relationship between the groundwater plume and soil contamination.

Facility monitoring by Energy Systems personnel indicates no activities in Building 2533 could serve as an ongoing source, but assumed intermittent sump pump operation is likely to be the cause of plume development. The recent identification of a leak in a LLLW line north of the STF which feeds the Building 2533 evaporator is considered to be a likely source. The pipeline has been leaking for an undetermined period of time, but leaks into and migration along the pipeline backfill material are possible. Both the Building 2533 sump water and soil surrounding the leak contain the beta emitters ^{155}Eu , ^{154}Eu , ^{152}Eu , ^{60}Co , and ^{137}Cs in considerable amounts. The alpha emitters $^{239/240}\text{Pu}$, ^{238}Pu , and ^{244}Cm present in the soil is apparently not present in the Building 2533 sump. Alternatively, the extremely high contaminant concentrations suggest some relation to a former leak from a process waste pipeline in the area. The data are currently insufficient to confidently identify a source.

After possible source areas are discussed with knowledgeable personnel, drive points can be installed along suspected pipelines in an attempt to identify a source. Pending results of those studies further source reduction measures can be considered. Semi-annual sampling of the sumps in Buildings 2533 and 2531 and piezometers 564, 566, and 567 during high and low base conditions will be ongoing. Isotopic comparison between the Building 2533 sump and soil samples around the LLLW pipeline leak will support source investigations along the pipeline trench.

6.4.9.3 Core hole CH-9

Sampling in two straddle packer test intervals in CH-9 (Fig. 6.10) revealed the presence of ^{137}Cs (about 17 pCi/L) and tritium (about 18,000 to 30,000 pCi/L) and minor nonradiological contamination. One explanation for the contamination in core CH-9 is down-dip migration within Unit F. Such migration is potentially significant because, contrary to the current conceptual model of the flow field, it would indicate the presence of long deep flow paths actively involved in contaminant migration.

Table 6.29 contains radiological and VOC data and estimated head values from the two CH-9 straddle packer test intervals. Data from piezometers located up dip from the CH-9 contaminated intervals are also included.

The lower CH-9 contaminated interval (from about 314- to 327-ft depth) is within Unit F and has elevated tritium concentrations. The data from well 886 (screened in Unit F) do not indicate contaminant migration from that location to depth. Temporal differences between the piezometer 565 and CH-9 contaminant data prohibit definitive comparisons; however,

neither exhibit a head gradient to the CH-9 interval. Toluene and acetone are also absent from well 886. Data are not available from other nearby surface locations (e.g., south of the STF) to identify another source.

The upper CH-9 contaminated interval (about 126 to 138 ft deep) is within Unit G and would project to a surface location about 10 m south of the 3524 EB. Insufficient data are available to describe the head potential from that area to the CH-9 upper contaminated interval. The generally upward head profile from CH-9 packer testing indicates water moves up the hole, and radiological contamination can be considered to be dispersed throughout the hole.

As stated in Sect. 3.3, flow meter testing in CH-9 by Moore and Young (1992) determined that water entered the hole in the vicinity of 338 ft depth and exited the hole at 135 ft. Geochemical sampling of the contaminated intervals indicates that the waters are of the sodium chloride type which has been interpreted to represent deep and older water (e.g., BNI 1992). Mixing between the time the hole was drilled and straddle packer tested may render these results subject to question for the upper interval. These data suggest that the upper interval contaminants are derived from the lower interval. The presence of significantly higher tritium concentrations in the upper interval, however, is inconsistent with that interpretation.

Analysis of the data provides no reasonable explanation for the presence of contaminants at depth in CH-9. The absence of contamination in other packer tested intervals suggests that contaminants were not introduced to the hole by the straddle packer equipment. The data do indicate, however, that the open condition of CH-9 is serving as an artificial contaminant migration pathway.

Because of the comparatively great depths to the contaminated intervals, contamination in CH-9 comes under the responsibility of the Groundwater OU and is not a WAG 1 groundwater issue. However, the OU should consider CH-9 as a candidate for a Westbay multiport sampling installation to prohibit continued mixing of contamination throughout the hole and to monitor changes in contaminant concentration over time.

No other locations in WAG 1 exhibit contamination in Unit F, but the available data suggest that Unit F may be at least a partial barrier to gradient-normal flow and a strike-parallel transmitter of contaminants. The data do not presently support the hypothesis that Unit F is a pathway for contaminant migration to depth.

6.4.10 Localized Areas of Contamination

6.4.10.1 Well 830

Grimsby (1986) describes the area near well 830 (Fig. 6.11) as an ILW line break in the early 1970s which resulted in leakage to WOC. Historic data in Table 6.30 show that tritium is by far the most prevalent contaminant. Nonradiological contaminant data for groundwater

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Fig. 6.11. Localized areas of contamination.

are not available. Soil samples in the area exhibit considerable gross beta contamination likely associated with pipeline leaks, but the soil samples do not exhibit the tritium contamination present in well 830. These data suggest that secondary contaminant sources are not present in the area. WOC sediment sampling radiological contamination at CS-3 described in BNI (1992) cannot be attributed to the well 830 area because other upstream sources may be responsible for the streambed contamination.

No data exist to determine whether contamination from the vicinity of well 830 is seeping into WOC. Data are also insufficient to determine how contamination in well 830 has changed over time, but since nearly two tritium half-lives have expired since the reported pipeline leak, it can be presumed to be significantly reduced.

Seep and spring sampling in the vicinity of well 830 will be performed to determine if contaminants are reaching the creek. If no contamination is found, and no information is uncovered to suggest an ongoing release, only continued monitoring of well 830 will be performed.

6.4.10.2 Piezometer 584

Piezometer 584 (Fig. 6.11) is located at the intersection of Central Avenue and Fourth Street, south-southwest of Building 3026. Results of Close Support Laboratory analyses of a sample collected from this piezometer in December 1991 indicated the presence of significant radiological contamination (see Table 6.31). The highest gross alpha (6611 pCi/L) and gross beta (1,346,395 pCi/L) in WAG 1 groundwater were detected in this sample. This piezometer was resampled in April 1993; and the sample has been submitted for laboratory analyses of gross alpha, gross beta, tritium, and isotopics.

Piezometer 584 is located near several LLLW pipelines which run parallel to Central Avenue. A likely source of the contamination detected in this piezometer is historical leaks in these pipelines or in pipelines to the north associated with Building 3026. During recent construction of the new LLLW pipeline along Central Avenue, significant leakage of ^{137}Cs into the process waste system is reported to have occurred near piezometer 584.

Pending results of laboratory analyses of the most recent sample, samples will be collected from piezometer 584 twice yearly during high base and high base storm conditions. These samples will be analyzed for gross alpha and gross beta.

6.4.10.3 Piezometer 590

Piezometer 590 (Fig. 6.11) is located north of Central Avenue, directly west of Building 3026 and east of the site of the former Building 3024. Table 6.32 summarizes radiological contamination detected in a groundwater sample from piezometer 590 and soil samples from SB165 and SB241. The groundwater sample, collected during low base conditions in November 1991, contained elevated gross alpha and tritium activities and a high gross beta activity (5278 pCi/L). Soil samples from boring SB165, one of five borings performed to

investigate reported leaks associated with Building 3026, contained elevated activities of gross beta and tritium. A relatively high gross beta activity (1084 pCi/g) was detected in the sample from the 4–5.5-ft interval in SB241. The purpose of this boring was to investigate possible soil contamination from a leak in tank WC-4.

Possible sources of the radiological contamination found in piezometer 590 are leaks from Building 3026 and from tank WC-4. In addition, Grimsby (1986) reported numerous leaks and spills associated with the former Building 3024, located to the west of piezometer 590. However, Building 3024 was in a nonradiological area, and the source is suspected to be former pipeline leaks. These releases may also be sources of the groundwater contamination in the area.

Samples will be collected twice yearly from piezometer 590 during high base and high base storm conditions. These samples will be analyzed for gross alpha, gross beta, and tritium.

6.4.10.4 Piezometer 593

Piezometer 593 (Fig. 6.11) is located to the south of Building 3525 along Fourth Street. Table 6.33 is a summary of radiological contamination found in a groundwater sample from piezometer 593 and in soil samples from borings south of Building 3525. Elevated gross alpha and gross beta activities (114 pCi/L and 128 pCi/L respectively) were observed in the high base sample collected from piezometer 593 in February 1991. Levels of gross alpha and gross beta in the borings were all below maximum reference levels. Grimsby (1986) reports that leaks have occurred in low-level waste lines discharging water into a ventilation duct which in turn feeds a sump located near Building 3525. These leaks may be a source of the contamination detected in piezometer 593.

A sample will be collected from piezometer 593 once yearly during high base storm conditions. This sample will be analyzed for gross alpha and gross beta.

6.4.10.5 Core hole 7A

Core hole 7A is located in the northwestern part of WAG 1 north of Building 2009, between Buildings 2026 and 2007 (see Fig. 6.11). It was drilled to a total depth of 184.6 ft BGS in Unit C of the Chickamauga Group in 1991. Chickamauga Unit D was encountered at 28 ft BGS and Unit C was penetrated at 147.6 ft BGS.

Fractured intervals in Unit D which have been identified on geophysical logs of CH-7A occur at 49 to 51, 66 to 67, 72 to 73, 89 to 90, and 162 to 163 ft BGS. Shifts in the temperature and differential temperature logs are noted in these intervals, with the most dramatic shifts occurring at 49 to 51 and 89 to 90 ft. These temperature shifts are inferred to show active groundwater flow in these fractured intervals. A 1-ft cavity was encountered while drilling at approximately 90 ft BGS.

Packer tests, which included piezometric head measurements and hydraulic conductivity tests, were completed in six intervals in CH-7A. Piezometric heads and hydraulic conductivities for the packer test intervals are summarized in Table 6.34. In general, Unit D in CH-7A appears to be a zone of low piezometric head. The lowest head was observed in the interval from 84 to 91 ft BGS. This interval contains the 1-ft cavity which was encountered at 90 ft and the fractured interval from 89 to 90 ft identified on geophysical logs. The presence of a cavity, indications of active groundwater flow on temperature logs, detection of low levels of contamination, and the low head imply that this interval may include a significant groundwater discharge zone in Unit D. The relatively low hydraulic conductivity estimated for this interval (6.0×10^{-5} cm/s) may not be accurate, and should be retested. The highest hydraulic conductivities in CH-7A, 10^{-2} and 10^{-3} cm/s, were observed in the 124–131-ft and 117–124-ft intervals respectively.

Groundwater samples were collected from two of the packer test intervals: 84 to 91 and 70 to 77 ft BGS. Results of analyses of these samples for radiological and nonradiological parameters are shown in Table 6.35. Gross beta and tritium activities slightly above maximum reference levels were observed in the 84–91-ft interval. Gross alpha and gross beta activities elevated slightly above maximum reference levels were detected in the sample from 70 to 77 ft. Concentrations of VOCs (tetrachloroethene, TCE, chloroform, and toluene) above maximum reference levels were also measured.

A Westbay multi-port system will be installed in this core hole in order to isolate multiple zones and characterize groundwater flow/contaminant migration pathways in Unit D. Measurements of piezometric head, aquifer tests to estimate hydraulic conductivities, and collection of samples for analyses of radiological and VOC contamination will be performed in the isolated zones. Packer intervals which should be constructed and reasons for isolating these intervals are as follows:

- 45 to 55 ft BGS because this depth range contains the fractured zone with active groundwater flow at 49 to 51 ft BGS identified on geophysical logs;
- 85 to 95 ft BGS because this zone includes the cavity encountered while drilling at 90 ft, the fractured interval with active groundwater flow detected at 89 to 90 ft BGS on geophysical logs, and the sample interval which exhibited low levels of radiological and VOC contamination;
- 116 to 131 ft BGS because this range comprises the two packer test intervals which had the highest estimated hydraulic conductivity values in CH-7A.

6.4.10.6 Mercury contamination of soil

Four sites in the southeastern part of WAG 1 (Fig. 6.12) have been grouped into a Mercury Spill Soils OU: Building 4501, Building 4508, an area beneath the roadway just south of Building 3503, and an area immediately to the south of Building 3592.

In 1954, ton quantities of mercury were used in Building 4501 for about 6 months to operate a small pilot plant for lithium separation (OREX process). During these operations,

Fig. 6.12. Mercury contaminated soils area.

spills occurred that were cleaned up; but some mercury was able to escape through cracks in the concrete floor and contaminate soil under the building. Soil samples collected in 1983 from locations around the building had mercury concentrations ranging from 0.05 to 465 ppm (ORNL 1990). In 1991, soil samples were collected from four soil borings which were advanced under Building 4501. Concentrations of mercury in these samples ranged up to 12,600 $\mu\text{g}/\text{kg}$ in the sample from 2 to 4 ft BGS in SB203. Elevated concentrations of mercury ranging up to 16.7 $\mu\text{g}/\text{L}$ were also detected in water samples collected from four sumps in the building in 1990. Mercury was not detected in groundwater samples from downgradient piezometers (618, 623, and 626) or core hole CH-4. Therefore, it appears that groundwater contaminated with mercury from the Building 4501 spills is being captured by the building sumps and treated in the PWTP. The sumps will be monitored twice yearly for mercury concentrations.

Research activities in Building 4508 are reported to have used <100 lb of mercury; however, there have been no reports of spills (ORNL 1990). Mercury was not detected in soil samples from four soil borings around Building 4508, nor in a water sample collected from the building sump. A mercury concentration of 0.33 $\mu\text{g}/\text{L}$ was detected in a groundwater sample collected from well 824, located south of the building, in March 1991. This concentration is slightly above the maximum reference level of 0.20 $\mu\text{g}/\text{L}$, but well below the MCL of 2.0 $\mu\text{g}/\text{L}$. The source of the mercury found in well 824 may or may not be soils under Buildings 4508 or 4501, and this well will be monitored twice yearly for mercury.

During the 1950s and early 1960s, substantial quantities of mercury were used in Building 3503 in the spent fuel reprocessing program known as PUREX. No information is available on the amount of possible losses of mercury during these operations. Mercury concentrations reported from analyses of soil samples collected from various locations around Building 3503 in 1983 ranged from 0.8 to 25 ppm (ORNL 1990). The contaminated soils are located just south of the building. A relatively low mercury concentration of 560 $\mu\text{g}/\text{kg}$ was observed in the soil sample collected from the 4–6-ft depth interval in SB173. Mercury was not found in groundwater samples from piezometer 601 or wells 879 and 881, located hydraulically downgradient of Building 3503. Water is currently being pumped from tank sumps in the thorium tank farm south of Building 3503 and treated in the PWTP. Groundwater which may be contaminated with mercury in this area is probably being captured and treated by this system. In addition, relatively high activities of gross alpha (2839 pCi/g) and gross beta (2996 pCi/g) were found in the soil sample from 2 to 3.3 ft BGS in SB174. Because of the low levels of mercury found in soils, the presence of radiological contamination in the area, and the likelihood that contaminated groundwater is being captured and treated in the PWTP, additional exploration or remedial activities for mercury contamination of soils in this area will not be performed as part of this site characterization. Samples collected from piezometer 601 as part of monitoring for radiological contamination (see Sect. 6.4.10.9) should be analyzed for the presence of mercury.

In 1956, work carried out in Building 3592 supported the lithium separation project in Building 4501, and approximately 60,000 lb of mercury was used. Accurate estimates of the amount of mercury lost during these operations are not available but operating personnel

reported that about 2000 to 3000 lb were lost to spills and leaks. Analyses of soil samples taken from various locations around Building 3592 in 1983 showed mercury concentrations ranging from 4.1 to 320 ppm (ORNL 1990). Table 6.36 summarizes analyses of soil samples for mercury from SB175 and SB176. Concentrations of mercury exceeded the RCRA action level of 20,000 $\mu\text{g}/\text{kg}$ in the 1–2-ft and 2–4-ft samples from SB175. Elemental mercury was visible in the soil from 2 to 3.25 ft BGS during sampling of SB175. Concentrations of mercury observed in samples from SB176 did not exceed the RCRA action level.

Actions that will be performed at this site include:

- hand-augering of soil borings and collection of soil samples to ascertain the extent of mercury contamination of soils;
- installation of a piezometer and collection of groundwater samples to determine whether groundwater in the area is contaminated with mercury;
- if groundwater is contaminated with mercury, the contaminated soils will be hydraulically isolated (e.g., by repaving the area) to prevent further movement of mercury from the soil into groundwater.

Given the relatively small volume of contaminated soil, consideration should also be given to excavating and disposing of mercury-contaminated soil south of Building 3592 in order to prevent future groundwater contamination. However, complicating factors may be the presence of a process waste pipeline and low levels of radiological contamination of soils in the potential excavation area (see Table 6.36).

6.4.10.7 Piezometer 553

Piezometer 553 (Fig. 6.11) is located near the southwest corner of the steam plant (Building 2519) adjacent to a diesel UST which has been removed since sampling. Table 6.37 is a summary of radiological and nonradiological contaminants detected in groundwater samples from piezometer 553. Gross alpha, gross beta, and tritium activities which were elevated slightly above maximum reference levels were observed in groundwater samples from this well. The metals beryllium, cadmium, chromium, cobalt, nickel, silver, and vanadium were found in the low base sample at the highest concentrations in WAG 1 groundwater. A possible source of these metals is fallout from atmospheric emissions from coal combustion at the steam plant. The VOCs benzene, toluene, ethylbenzene, and xylenes (BTEX) were also observed at the highest concentrations in WAG 1. These aromatic VOCs may be evidence of a release from the nearby diesel UST.

A groundwater sample will be collected during high and low base conditions from this well and analyzed for metals, BTEX, and total petroleum hydrocarbons (TPH).

6.4.10.8 Area northwest of WAG 1 boundary

This area comprises the northern 2000 part of the Laboratory (see Fig. 6.11). Elevated gross alpha, gross beta, and tritium activities were detected in low base and high base samples

collected from wells in this area in 1990 and 1991 (Table 6.38). Alpha-emitting radionuclides detected above maximum reference levels were $^{228/230/232}\text{Th}$ and $^{234/238}\text{U}$; beta-emitting radionuclides observed above maximum reference levels were $^{226/228}\text{Ra}$ and total radioactive strontium. In general, activities of these radionuclides were higher in the high base samples than in the low base samples.

Nonradiological contaminants detected above maximum reference levels included beryllium, chromium, cobalt, copper, lead, mercury, nickel, silver, vanadium, TCE, and toluene (see Table 6.39). Metals detected above their respective MCLs were beryllium in wells 538, 546, 549, and 572; chromium and lead in well 538; chromium and nickel in well 549; and lead in well 587. TCE was detected above its MCL of 5 $\mu\text{g/L}$ in the well 546 high base sample.

Samples will be collected from wells 538, 549, 572, and 547 during high base storm conditions and analyzed for radiological parameters, metals, and VOCs.

6.4.10.9 Piezometer 601

Piezometer 601 is located in the south-central portion of the WAG, about 50 ft south of Building 3537 (see Fig. 6.11). During drilling of the borehole for this piezometer, a 3-in. PVC underground pipeline originating in the TH-3 tank sump was broken, allowing radiologically contaminated water to come to the surface. About 2 weeks after it was broken, the pipeline was repaired and contaminated soil was excavated and disposed of.

Radiological contamination detected in groundwater samples collected from piezometer 601 is summarized in Table 6.40. Gross alpha, gross beta, and tritium activities above maximum reference levels were detected in the low base sample; elevated gross alpha and gross beta activities were detected in the high base sample. This groundwater contamination may be due to the release of contaminated water from the broken pipeline or it may have a source elsewhere in WAG 1. A groundwater sample will be collected twice yearly from this piezometer and analyzed for gross alpha, gross beta, tritium, and mercury (see Sect. 6.4.10.6).

6.4.11 Tracers

One anticipated byproduct of the additional data obtained as part of this report is further definition of areas of contamination and better insight into groundwater flow paths, especially in cavitose Unit D but also in other locations. These flow paths could be major transmitters of contamination over wide areas in WAG 1. If the data provide the anticipated insight, it is feasible that dye tracing may be performed to further define areas of contamination, describe flow paths, identify source areas, and distinguish between suspected commingling plumes. In addition to a description of flow pathways, dye tracing data could provide estimates of flow velocity and contaminant flux. At present, tracers are anticipated to be dyes, but decisions about the choice of tracers will be made in conjunction with decisions to perform the test(s). Dye tracing may also be performed in other locations in WAG 1 (e.g., the impoundments or tank farms) to support remediation option selection decision making and reduce uncertainty.

6.5 MONITORING

This section describes the monitoring and sampling program that will be performed at existing wells, piezometers, and core holes to more fully understand the nature and extent of contamination and the relationships between contaminant concentrations and other variables (e.g., groundwater elevation, precipitation, time). A base level groundwater elevation monitoring program will be performed to maintain an ongoing record of groundwater conditions.

6.5.1 Core Holes

In 1950 and 1951, 50 core holes were drilled in and around ORNL (Stockdale 1951) to depths of 50 to 250 ft. Most of the holes were drilled in the vicinity of the 3513 and 3524 impoundments and to the west toward SWSA 3. A cursory status review of those core holes was performed as part of the well plugging and abandonment program, but the results of that review are known to be inaccurate, and decisions cannot be made regarding the utility or reliability of those core holes.

Eleven core holes have been drilled within and immediately adjacent to the WAG 1 boundary (Fig. 6.13). Five of these core holes were drilled in 1986 as part of the RAP Program, and the other six were drilled as part of ER Phase 1 remedial investigations for WAG 1. Straddle packer aquifer tests were performed in all core holes except CH-8, to provide estimates of hydraulic conductivity and hydraulic head in the tested interval and allow the tested interval to be sampled. Electromagnetic flowmeter tests were performed on core holes CH-2, CH-3, CH-9, and CH-12 to identify discrete zones of groundwater movement.

Core hole CH-8 contains a Westbay multiport sampling instrument for analysis of the radiological contaminants, and core hole CH-4 contains a mechanical packer to isolate a small hydrocarbon-bearing zone encountered during drilling. Undestroyed and uninstrumented core holes are open throughout their drilled depth and could create artificial contaminant pathways.

Responsibility for WAG 1 core holes lies with the Groundwater OU, and decisions about the fate of the core holes will be made as part of issues relevant to the OU. These issues generally pertain to descriptions of lateral and vertical boundaries and head distributions. Recommendations made here can be used in support of OU decisionmaking. Exceptions are core holes CH-2 and CH-7A which are located in areas of groundwater recharge and which also contain cavities at shallow depth. The currently open condition of CH-7A may also be promoting the vertical distribution of contaminants. Responsibility for these core holes will lie with this WAG 1 site characterization rather than the Groundwater OU.

In addition to WAG 1 core holes, several borings formerly used as water supply wells for fish tanks in aquatic studies performed in Environmental Sciences Division occur to the north of the WAG. Presumably, these wells were drilled into the Knox aquifer, and geophysical logs are being obtained from the borings to determine their usefulness to the Groundwater OU.

Fig. 6.13. WAG 1 core hole locations.

Results of straddle packer testing performed on CH-1 determined the presence of relatively high hydraulic head and low permeability throughout essentially all of Unit A. In large part, these results provide the basis for the current conceptual model that the lower Chickamauga bedrock units provide a valley-wide, low-permeability layer or boundary between the underlying Knox aquifer and the overlying Chickamauga bedrock units. In conjunction with instrumentation of a former fish tank well to the north of Bethel Valley Road, instrumentation of CH-1 would be used to establish the lower Chickamauga as a hydrologic boundary.

In the drilling of CH-2 a cavity was encountered at a depth of 18 ft in Unit D, 62 ft above the Unit C contact. This position compares with a cavity encountered in Unit D in CH-7A, 56 ft above the Unit C contact. Instrumenting the CH-2 cavity will enable analyses of the structural/stratigraphic relationships between cavity development and karst features in differing geologic units to be performed. Instrumenting a deeper zone in Unit B can also support boundary definition efforts in the CH-1 installation.

Moore and Young (1992) encountered a flowing interval at a depth of 12 ft in CH-3 using a flowmeter. This location is immediately below the surface casing and may be related to the casing. Its shallow depth also provides no information about the deeper system. Because nothing else is distinctive about CH-3, it will be plugged and abandoned.

Core hole CH-4 contains a mechanical packer which is isolating naturally occurring hydrocarbons encountered in drilling from the environment. The packer will be removed, and the hole will be plugged and abandoned.

Geophysical logging of CH-5 within the last year has identified an apparent fresh/high total dissolved solids (TDS) interface at depth. Identifying the location where the high TDS water enters the hole can be used in boundary definition. We recommend using the flowmeter to determine where water enters the hole and then instrumenting that interval.

Sodium chloride water was encountered at a depth of about 320 ft in CH-6 at the Unit A/B contact. No hydraulic head or conductivity data were obtained from the interval. Instrumenting this zone would support boundary definition efforts in CH-1 and CH-2.

Recommendations for instrumenting CH-9 and CH-7A are given in Sects. 6.4.9 and 6.4.10 respectively.

The 29–42-ft-deep interval of CH-11A contains low head and low levels of radiological contamination, and Unit F in that hole may contain naturally occurring radionuclides specific to that unit. The relatively shallow depth of Unit F in that hole (about 70 ft) will also allow analyses of flow in that unit at relatively shallow depths. We recommend instrumenting both intervals in support of off-WAG contaminant migration studies.

The rock core and results of straddle packer testing of CH-12 are generally unremarkable, and we recommend plugging and abandoning core hole CH-12.

6.5.2 Existing Wells and Piezometers

In addition to the monitoring and sampling of specific areas described in Sect. 6.4, baseline water monitoring will be performed to provide a reasonable areal distribution of wells and piezometers that will describe the overall configuration of the water table surface. More importantly, however, is that the information about area-specific data can be put into the context of the overall WAG to address issues such as flow and transport mechanisms and contaminant flux out of the WAG. Even without the area-specific data, a continual, periodic record of water elevation change over time is essential to descriptions of the movement of contaminant within and out of the WAG.

Table 6.41 lists all the WAG 1 wells and piezometers from which water elevation and/or water quality data have been obtained. New wells and drive points described in Sect. 6.4 are not included in the listing. Pertinent information about their current and/or historical use is noted, and this information was used to select a subset of all the locations that could meet the needs of continual monitoring.

From an analysis of the information in Table 6.41, a subset of locations was selected (Table 6.42) that provide a wide areal distribution of the WAG, peripheral locations, and critical locations for comparison with area-specific data. Water elevation data need to be obtained monthly from these locations independent of other activities performed at WAG 1 so that as new data are obtained, they can be readily interpreted within the context of the overall WAG. Sampling is being coordinated with existing compliance sampling to maximize sampling benefit and to avoid duplication.

6.6 SUMMARY OF PROPOSED ACTIONS BY AREA

The following summary shows the actions proposed for Phase II of the WAG 1 RI for the major areas of contamination, and it includes references to the sections in Chap. 6 where more detailed discussions of the areas can be found. In addition to the analyses specified below for each major area, analyses for BTEX and TPH will be performed for each new well, drive point, or core hole that is in close proximity or could reasonably be within a flow pathway of an underground fuel storage tank.

3001/3019 Area (see Sect. 6.4.1)

- Action:** Install and sample bedrock wells (1) adjacent to piezometers 560, 573, and 582 and temporary piezometers near SB130 and SB132, (2) in Hillside Drive south of Building 3019 and at southeast corner of Hillside Drive and Third Street, and (3) in the northwestern corner of the NTF and west of Building 3137. Install a core hole into Unit D near piezometer 583.
- Purpose:** To investigate possible presence of significant radiological contamination. Core hole and wells near piezometer 560, in the northwestern corner of the NTF,

west of Building 3137, and near SB132 also used for CH-8 plume source investigation.

Action: Install and sample two temporary piezometers in pipeline trenches along Hillside Drive southeast of Building 3001.

Purpose: To investigate possible eastward contaminant migration in pipeline trench backfill.

Action: Install and sample two temporary piezometers in pipeline trenches between Building 3137 and the NTF.

Purpose: To investigate possible southward contaminant migration in pipeline trench backfill and possible source for CH-8 plume.

Analyses: Gross alpha, gross beta, tritium, isotopics.

North Tank Farm (see Sect. 6.4.2.1)

Action: Measure water levels and sample dry wells and four drive points near the tanks.

Purpose: To describe the water table configuration immediately around the tanks and compare contaminant concentrations with those in the tank dry wells.

Action: Measure water levels and sample one drive point in the center of the NTF, outside of the tank excavations.

Purpose: Compare water level elevations and contaminant concentrations with those inside the tank excavations.

Action: Measure water levels and sample one drive point along the northern edge of NTF.

Purpose: Compare water elevations and contaminant concentrations upgradient of the NTF to those within the tank farm.

Analyses: Gross alpha, gross beta, tritium, isotopics.

South Tank Farm (see Sect. 6.4.2.2)

Action: Measure water levels and sample dry wells and three drive points within the tank excavation to the north of the tanks.

Purpose: To compare groundwater elevations and contaminant concentrations to those in the tank dry wells; to investigate contaminant migration pathways in the vicinity of the STF.

Action: Measure water levels and sample one drive point between Building 3515 and tank W-10.

Purpose: To describe hydraulic and contaminant concentration gradients between Building 3515 and the W-10 tank dry well.

Action: Install flow meter and sample common STF sump.

Purpose: To describe flow volumes and calculate contaminant flux.

Analyses: Gross alpha, gross beta, tritium, isotopics.

Other Tanks (see Sect 6.4.2.3)

Action: Acquire reliable dry well water elevation, refilling rates, and radiological data from selected tanks.

Purpose: To calculate flux of contaminant removal and describe groundwater/tank interactions.

Analyses: Gross alpha, gross beta, tritium, isotopics.

Isotopes Area (see Sect. 6.4.3)

Action: Sample 3033 sump.

Purpose: To monitor radiological contamination; compare isotopics to other sampling locations in Isotopes and Hillside areas as part of source investigation.

Action: Radioanalytical sampling of MH 114 and MH 233.

Purpose: To compare isotopics to those in 3033 sump as part of source investigation.

Action: Sample MH 114 and MH 233 for TPH and BTEX.

Purpose: To monitor petroleum USTs.

Action: Radioanalytical sampling of Stockdale corehole 33.

Purpose: To investigate possible contaminant underflow of Fifth Creek.

Action: Sample piezometer 598 for radiological constituents and VOCs.

Purpose: To monitor radiological and VOC contamination.

Action: Install and sample a core hole west of Building 3038 targeted to the CH-8 plume stratum in Unit E.

Purpose: To investigate the possibility of an eastward mirror image of the CH-8 plume; compare isotopics with other sampling locations within the Isotopes Area as part of source investigation.

Analyses: Gross alpha, gross beta, tritium, isotopics, BTEX, TPH.

CH-8 plume area (see Sect. 6.4.4)

Action: Semiannual radioanalytical sampling of CH-8 Westbay installation until contaminant removal system is operational.

Purpose: To monitor and maintain a continuous record of contaminant concentrations under high and low base conditions.

Actions: Install and sample bedrock wells near piezometer 560, in the northwest corner of the NTF, west of Building 3137, and near temporary piezometer SB132. Install and sample two temporary piezometers in pipeline trenches between Building 3137 and the NTF. Install three temporary piezometers in LLLW pipeline trench along the east side of Third Street west of Building 3137.

Purpose: To investigate source.

Actions: Install eight to ten shallow wells to describe the areal extent of the plume and install one core hole west of Building 2069 to assess down-dip migration. Sample piezometer 535 to assess underflow of First Creek. Monitor piezometer 539 and well 812.

Purpose: To characterize plume.

Actions: Line abandoned storm sewer west of WAG boundary to halt discharge via outfall 342 and line manholes north of Building 2013 to halt discharge via outfall 341. Install gravity-feed seep trench with french drain adjacent to Building 2013 manhole with discharge to PWTP and install two gravity-feed seep trenches with french drains across the plume axis with discharge to PWTP. Perform low-volume pump removal from CH-8 Westbay installation with discharge to PWT system.

Purpose: Early action.

Analyses: Gross alpha, gross beta, tritium, isotopics.

ORR Area (see Sect. 6.4.5)

Action: Radioanalytical sampling of the inner (upper) 3042 sump; BTEX and TPH analyses.

Purpose: To compare the isotopic composition of the sump sample to that of samples collected in the Building 3019 area to assess the possibility of a contaminant source in the 3019 area; petroleum UST monitoring.

Action: Drill and sample a bedrock well immediately to the south of piezometer 588.

Purpose: To obtain information about groundwater elevation and contamination between Building 3042 and the 3001/3019 area; compare analytical results of sampling to results from the 3042 sump and the 3001/3019 area to obtain information about source areas and migration pathways.

Analyses: Gross alpha, gross beta, tritium, isotopics, BTEX, TPH.

Impoundments Area (see Sect. 6.4.6)

Action: Sample wells 874, 875, 885, 876, 1102, 1103, and 1104.

Purpose: To monitor radiological contamination downgradient of the impoundments; provide a baseline for evaluation of future remedial actions.

Action: Radioanalytical sampling of the temporary piezometer in SB189.

Purpose: To confirm elevated gross beta and the presence of ^{63}Ni .

Action: Implement source control.

Purpose: To control outleakage before closure and attenuate a major source of radiological contamination of groundwater and surface water.

Analyses: Gross alpha, gross beta, tritium, isotopics.

SWSAs 1 and 2 (see Sect. 6.4.7)

Action: Sample piezometer 571 and wells 827, 828, 829, 946, and 947 (SWSA 1) and piezometer 622 and well 822 (SWSA 2). Video outfall 165 pipeline for possible lining.

Purpose: To monitor groundwater contamination and possible discharge to Fifth Creek.

Analyses: Gross alpha, gross beta, tritium, isotopics.

Pipelines (see Sect. 6.4.8)

Action: Install drive points and sample groundwater in pipeline trench backfill near pipeline discharge locations at surface water bodies.

Purpose: To identify potential off-WAG contaminant migration pathways.

Analyses: Gross alpha, gross beta, tritium, isotopics.

Building 2533 sump plume (see Sect. 6.4.9.2)

Action: Radioanalytical sampling of the 2531 sump, 2533 sump, and piezometers 564, 566, and 567.

Purpose: To monitor contaminant concentrations in 2533 sump plume.

Action: Install drive points along suspected pipeline trenches.

Purpose: To investigate source.

Analyses: Gross alpha, gross beta, tritium, isotopics.

CH-9 (see Sect. 6.4.9.3)

- Action:** Install and sample a Westbay multiport system.
Purpose: To prevent continued cross-contamination and monitor possible contaminant migration to depth.
Analyses: Gross alpha, gross beta, tritium, isotopics, volatiles, semi-volatiles.

Well 830 (see Sect. 6.4.10.1)

- Action:** Seep and spring sampling in the vicinity of well 830.
Purpose: To determine if contaminants are reaching WOC.
Action: Radioanalytical sampling.
Purpose: To monitor radiological contamination.
Analyses: Gross alpha, gross beta, tritium, isotopics.

Piezometer 584, 590, and 593 (see Sects. 6.4.10.2, 6.4.10.3, and 6.4.10.4)

- Action:** Radioanalytical sampling.
Purpose: To monitor radiological contamination.
Analyses: Gross alpha, gross beta, tritium, isotopics.

CH-7A (see Sect. 6.4.10.5)

- Action:** Install Westbay multiport system to measure piezometric head and collect samples from isolated zones for radiological and VOC analyses.
Purpose: To characterize groundwater flow/contaminant migration pathways in Unit D.
Analyses: Gross alpha, gross beta, tritium, isotopics, volatiles, semi-volatiles.

Mercury-contaminated areas (see Sect. 6.4.10.6)

- Action:** Biannual sampling and analysis for mercury in well 824.
Purpose: To monitor mercury in groundwater from contaminated soils under Building 4501 and/or Building 4508.
Action: Sample four sumps in Building 4501 for mercury.
Purpose: To monitor mercury contamination from contaminated soils under Building 4501.
Action: Sample piezometer 601 for mercury.

Purpose: To monitor possible mercury contamination of groundwater south of Building 3503.

Action: Auger soil borings south of Building 3592 and analyze soil samples for mercury.

Purpose: To determine the extent of mercury contamination of soils around Building 3592.

Action: Install a piezometer south of Building 3592 to sample groundwater for mercury.

Purpose: To determine whether groundwater in the vicinity of Building 3592 is contaminated with mercury.

Analyses: Mercury.

Piezometer 553 (see Sect. 6.4.10.7)

Action: Biannual sampling and analyses for metals, BTEX, and TPH.

Purpose: To monitor elevated metal concentrations; monitor petroleum contamination from diesel UST.

Analyses: BTEX, TPH, metals.

Area northwest of WAG 1 boundary (see Sect. 6.4.10.8)

Action: Sample piezometers 538, 549, 572, and 547 and analyze for radiologicals, metals, and VOCs.

Purpose: To monitor elevated radiological parameters, metals, and VOCs in groundwater.

Analyses: Gross alpha, gross beta, tritium, isotopics, volatiles, semi-volatiles, metals.

Piezometer 601 (see Sect. 6.4.10.9)

Action: Biannual radioanalytical sampling.

Purpose: To monitor radiological contamination.

Analyses: Gross alpha, gross beta, tritium, isotopics, volatiles, semi-volatiles, metals.

Other core holes (see Sect. 6.5.1)

Action: Instrument CH-1.

Purpose: To establish the lower Chickamauga hydrologic boundary.

Action: Instrument CH-2 cavity in Unit D.

Purpose: To analyze structural/stratigraphic relationships of karst development in Unit D; to support boundary definition efforts in the CH-1 installation.

- Action:** Plug and abandon CH-3 and CH-12.
Purpose: No further information is needed.
- Action:** Plug and abandon CH-4.
Purpose: No further information is needed; permanently isolate petroleum hydrocarbon zone and prevent cross-contamination.
- Action:** Flowmeter test and instrument CH-5.
Purpose: To identify the location at which high TDS water enters the hole; boundary definition.
- Action:** Instrument interval in CH-6 where sodium chloride water was found at Unit A/B contact.
Purpose: To support boundary definition efforts in CH-1 and CH-2.
- Action:** Instrument Unit F interval and interval containing low head and low levels of radiological contamination in CH-11A.
Purpose: To support off-WAG contaminant migration studies.
- Analyses:** Head measurements and general geochemistry in CH-5.

Table 6.1. WAG 1 reference levels and RCRA action levels for soil contaminants

Radiological contaminants			Nonradiological contaminants		
Analyte	Maximum WAG 1 reference level ^a (pCi/g)	RCRA action level ^a	Analyte ^b	Maximum WAG 1 reference level (µg/kg)	RCRA action level ^a (µg/kg)
Gross alpha	56	NE	Arsenic	4,600	80,000
Gross beta	34	NE	Beryllium	1,600	200
Tritium	0.22	NE	Cadmium	3,800	40,000
¹³⁷ Cs	0.21	NE	Chromium	41,000	400,000
¹⁵² Eu	NA	NE	Lead	49,600	NE
¹⁵⁴ Eu	NA	NE	Mercury	150	20,000
¹⁵⁵ Eu	NA	NE	Trichloroethene	1	60,000
⁹⁰ Sr	<0.5	NE	1,1-dichloroethene	<6	10,000
²²⁶ Ra	0.98	NE	1,2-dichloroethene	<6	NE
²²⁸ Ra	1.58	NE	Tetrachloroethene	<6	10,000
⁹⁹ Tc	1.53	NE	Vinyl chloride	<12	NE
¹⁴⁷ Pm	<5	NE	Acetone	29	8,000,000
⁶³ Ni	<10	NE	Methylene chloride	30	90,000
⁵⁵ Fe	<10	NE	Benzene	<6	NE
²⁴¹ Am	<0.6	NE	Toluene	4	20,000,000
²⁴² Cm	<0.6	NE	Ethylbenzene	<6	8,000,000
²³⁸ Pu	<0.6	NE	Xylenes	<6	200,000,000
^{239/240} Pu	<0.6	NE			
²³⁴ U	1.29	NE			
^{235/236} U	0.15	NE			
²³⁸ U	1.20	NE			
²²⁸ Th	19.9	NE			
²³⁰ Th	1.87	NE			
²³² Th	1.83	NE			

^aSubpart S proposed rule levels. NE = RCRA action level not established; NA = not analyzed.

Table 6.2. WAG 1 reference levels and maximum contaminant levels for groundwater contaminants

Analyte	Maximum WAG 1 reference level	SDWA MCL ^b
Radiological contaminants ^a		
Gross alpha	3.8	15
Gross beta	5.6	4 mrem/year ^c
Tritium	1,940	20,000
⁹⁰ Sr	<5	8.0
¹³⁷ Cs	<27.8	4 mrem/year ^c
¹⁴⁷ Pm	<50	4 mrem/year ^c
²²⁶ Ra	<1	5 ^d
²²⁸ Ra	<3	5 ^d
⁹⁹ Tc	<30	4 mrem/year ^c
²³⁴ U	<1	NE ^e
^{235/236} U	<1	NE
²³⁸ U	<1	NE
²²⁸ Th	2.43	NE
²³⁰ Th	<1	NE
²³² Th	<1	NE
⁶³ Ni	<100	4 mrem/year ^c
⁶⁰ Co	Not analyzed	4 mrem/year ^c
Nonradiological contaminants^f		
Beryllium	<2	4
Cadmium	5.2	5
Chromium	25.7	100
Cobalt	<4	NE
Copper	9.3	1,300
Lead	25.7	15 ^g
Mercury	0.2	2
Nickel	38.6	100
Silver	<10	50 ^g
Vanadium	5.8	NE
Trichloroethene	<5	5
1,1-dichloroethene	<5	7
1,2-dichloroethene	<5	70/100 ^h
Vinyl chloride	<10	2
Benzene	<5	5
Toluene	<5	1,000
Ethylbenzene	<5	700
Xylenes	<5	10,000

^aUnits are picocuries per liter (pCi/L), except where noted.

^bSDWA MCL = Safe Drinking Water Act maximum contaminant level.

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

^d²²⁶Ra + ²²⁸Ra.

^eNE = MCL not established.

^fUnits are micrograms per liter (µg/L).

^gRCRA maximum concentration limit.

^h_{cis} = 70 µg/L, _{trans} = 100 µg/L.

**Table 6.3. Radiological contamination detected in the
3001/3019 area**

Soils				
Boring	Depth (ft BGS) ^a	Analyte	Activity (pCi/g)	
SB132	10-12	Alpha	1043	
		Beta	16,005	
		Tritium	0.8	
SB130	10-12	Alpha	3104	
		Beta	1856	
		Tritium	0.8	
SB126	0-2	Alpha	1904	
		Beta	6171	
		Tritium	0.4	
SB258	2-4	Alpha	142	
		Beta	550	
		Tritium	0.1 ^b	
Groundwater				
Well	Date	Sample type	Analyte	Activity (pCi/L)
573	5/27/86	Low base	Alpha	1 ^b
			Beta	11
			Tritium	6 ^b
582	4/21/86	High base	Alpha	11
			Beta	512
			Tritium	6 ^b
SB132	12/3/91	High base storm	Alpha	53 ^b
			Beta	8,300
			Tritium	2,000
	2/18/92	High base	Alpha	110
			Beta	20,000
			Tritium	2,200

^aBGS = below ground surface.

^bBelow maximum reference level.

Table 6.4. Radiological contamination detected in North Tank Farm area soil

Boring	Depth (ft BGS) ^a	Analyte	Activity (pCi/g)	Boring	Depth (ft BGS) ^a	Analyte	Activity (pCi/g)
SB24	10.0-15.0	Alpha	10.4 ^b	SB32	6.0-12.0	Alpha	17.9 ^b
		Beta	15.8 ^b			Beta	49.9
SB25	8.0-12.0	Alpha	16.8 ^b		18.0-20.5	Alpha	54.4 ^b
		Beta	16.9 ^b			Beta	21,100
	16.0-17.0	Alpha	1,380	SB34	0.0-6.0	Alpha	17.6 ^b
		Beta	13,300			Beta	47.2
						Tritium	2.63
SB26	0.0-5.0	Alpha	12.6 ^b	SB168	0.0-2.0	Alpha	15.5 ^b
		Beta	20.9 ^b			Beta	46.2
						Tritium	0.47
	11.0-13.0	Alpha	11.8 ^b		6.0-8.0	Alpha	24.0 ^b
		Beta	19.2 ^b			Beta	47.0
						Tritium	0.46
	13.0-15.0	Alpha	9.7 ^b	SB219	4.0-6.0	Alpha	15.5 ^b
		Beta	1,180			Beta	30.1 ^b
						Tritium	0.20 ^b
	15.0-17.0	Alpha	2,570	SB220	0.0-2.0	Alpha	21.3 ^b
		Beta	62,500			Beta	25.2 ^b
						Tritium	0.68
SB29	0.0-4.0	Alpha	26.5 ^b		4.0-5.0	Tritium	0.09 ^b
		Beta	267				
	6.0-12.0	Alpha	14.5 ^b	SB221	0.0-2.0	Alpha	23.6 ^b
		Beta	19.6 ^b			Beta	59.3
						Tritium	0.77
	18.0-19.0	Alpha	688		4.0-6.0	Alpha	32.4 ^b
		Beta	23,200			Beta	213
SB30	6.0-12.0	Alpha	19.8 ^b		6.0-8.0	Alpha	19.4 ^b
		Beta	16.0 ^b			Beta	367
	12.0-16.0	Alpha	22.5 ^b		8.0-8.8	Alpha	30.2 ^b
		Beta	17.0 ^b			Beta	871
						Tritium	0.49
	20.0-20.5	Alpha	40.8 ^b	SB224	8.0-9.5	Alpha	25.0 ^b
		Beta	1,160			Beta	29.1 ^b
						Tritium	0.15 ^b
SB31	4.0-10.0	Alpha	25.7 ^b				
		Beta	175				
	12.0-17.5	Alpha	12.0 ^b				
		Beta	14.3 ^b				

^aBGS = below ground surface.^bBelow maximum reference level.

Table 6.5. Radiological contamination detected in South Tank Farm area soil

Boring	Depth (ft BGS) ^a	Analyte	Activity (pCi/g)	Boring	Depth (ft BGS) ^a	Analyte	Activity (pCi/g)
SB17	0.0-6.0	Alpha Beta	13.0 ^b 15.6 ^b	SB22	0.0-6.0	Alpha Beta Tritium	26.1 ^b 54.6 0.22
SB18	0.0-6.0	Alpha Beta	11.1 ^b 141		19.0-20.3	Alpha Beta	25.1 ^b 52.5
	12.0-16.0	Alpha Beta	19.2 ^b 21.8 ^b	SB182	0.0-2.0	Alpha Beta Tritium	216 17,047 0.1 ^b
SB19	8.0-14.0	Alpha Beta Tritium	30.3 ^b 1,394 0.67	SB183	0.0-2.0	Alpha Beta Tritium	47.2 ^b 1,615 0.16 ^b
	14.0-17.0	Alpha Beta Tritium	22.3 ^b 44.4 0.72		2.0-4.0	Alpha Beta Tritium	180 34,831 0.15 ^b
SB20	0.0-4.0	Alpha Beta Tritium	606 1,791 0.29	SB196	0.0-2.0	Alpha Beta Tritium	48.0 ^b 77.9 0.11 ^b
	4.0-8.0	Alpha Beta Tritium	47.6 ^b 140 0.69	SB197	2.0-4.0	Alpha Beta Tritium	85.5 101 0.20 ^b
	16.0-22.0	Alpha Beta Tritium	23.4 ^b 54.0 0.60	SB213	2.0-4.0	Alpha Beta Tritium	267 4,672 0.65
	22.0-23.1	Alpha Beta Tritium	41.2 ^b 607 1.4		4.0-6.0	Alpha Beta Tritium	223 5,204 0.25
SB21	11.0-17.0	Alpha Beta	26.8 ^b 22.6 ^b	SB249	2.0-4.0	Alpha Beta Tritium	20.5 ^b 25.9 ^b 0.25
	17.0-20.0	Alpha Beta	25.0 ^b 33.0 ^b		6.0-8.0	Alpha Beta Tritium	20.4 ^b 21.9 ^b 0.30

^aBGS = below ground surface.^bBelow maximum reference level.

Table 6.6. Radiological contamination detected in Isotopes Area groundwater

Well (type) ^a	Date	Sample type ^b	Analyte	Activity (pCi/L)	Well (type) ^a	Date	Sample type ^b	Analyte	Activity (pCi/L)
597 (I)	4/86	HB	Alpha	4.4	608 (R)	5/86	HB	Alpha	1.9 ^c
			Beta	178				Beta	56.2
			Tritium	5.8 ^c				Tritium	561 ^c
	1/91	HBS	Alpha	29.0		11/91	LB	Alpha	177
			Beta	208				Beta	307
			Tritium	4,600				Tritium	181,650
	3/91	HB	Alpha	41.3	613 (I)	4/86	HB	Alpha	5.6
			Beta	182				Beta	112
			Tritium	4,980				Tritium	38.6 ^c
	4/91	HB	Alpha	12.3		11/91	LB	Beta	151
			Beta	130				Tritium	54,180
			Tritium	510					
598 (R)	2/91	HBS	Alpha	25.7	615 (I)	7/86	LB	Alpha	0.5 ^c
			Beta	251				Beta	254
			Tritium	7,250				Tritium	13,255
	3/91	HB	Alpha	6.1	616 (I)	5/86	HB	Alpha	3.6 ^c
			Beta	484				Beta	23.9
			Tritium	6,840				Tritium	48.6 ^c
	4/91	HB	Beta	267	30331 (Sump)	3/90	HB	Alpha	631
			Tritium	6,460				Beta	659,000
								Tritium	1,210,000
					31061 (Sump)	3/90	HB	Alpha	183
								Beta	4,330
								Tritium	9,870

^aI = interface, R = bedrock.^bHB = high base, HBS = high base storm, LB = low base.^cBelow maximum reference level.

Table 6.7. Radiological contamination detected in Isotopes Area soil

Boring	Depth (ft BGS) ^a	Analyte	Activity (pCi/g)	Boring	Depth (ft BGS) ^a	Analyte	Activity (pCi/g)
SB40	0.0-4.0	Alpha	25.3 ^b	SB146 (continued)	6.0-8.0	Alpha	24.6 ^b
		Beta	69.1			Beta	26.1 ^b
						Tritium	1.08
	12.0-14.0	Alpha	9.1 ^b		8.0-10.0	Alpha	20.2 ^b
		Beta	2830			Beta	18.0 ^b
						Tritium	1.50
SB41	0.0-2.0	Alpha	12.4 ^b		10.0-12.0	Alpha	19.8 ^b
		Beta	14.9 ^b			Beta	49.5
						Tritium	1.27
SB110	0.0-1.5	Tritium	0.49	SB147	0.0-2.0	Beta	157
						Tritium	0.67
SB129	6.0-8.0	Alpha	13.6 ^b		2.0-4.0	Alpha	16.3 ^b
		Beta	28.5 ^b			Beta	28.0 ^b
						Tritium	0.36
	8.0-8.4	Alpha	17.5 ^b		4.0-4.6	Alpha	14.1 ^b
		Beta	44.7			Beta	33.2 ^b
						Tritium	0.17 ^b
SB144	0.0-2.0	Alpha	30.0 ^b	SB148	6.0-8.0	Alpha	18.0 ^b
		Beta	41.4			Beta	39.3
		Tritium	0.77		8.0-10.0	Alpha	24.0 ^b
	4.0-6.0	Alpha	12.8 ^b			Beta	31.6 ^b
		Beta	12.0 ^b		10.0-11.5	Alpha	26.1 ^b
	8.0-10.0	Tritium	1.29			Beta	998
		Alpha	37.1 ^b		2.0-4.0	Alpha	26.0 ^b
		Beta	21.6 ^b			Beta	37.0
		Tritium	1.61				
	10.0-12.0	Alpha	22.3 ^b	SB149	4.0-6.0	Alpha	20.0 ^b
		Beta	25.9 ^b			Beta	97.0
		Tritium	2.06		6.0-8.0	Alpha	19.4 ^b
SB145	2.0-4.0	Alpha	25.3 ^b			Beta	178
		Beta	26.8 ^b	SB150	2.0-4.0	Beta	9.4 ^b
SB146	0.0-2.0	Alpha	26.1 ^b				
		Beta	45.1		4.0-4.4	Alpha	10.9 ^b
		Tritium	1.19			Beta	358
	2.0-4.0	Alpha	25.4 ^b				
		Beta	65.0				
		Tritium	1.07				
	4.0-6.0	Alpha	20.2 ^b				
		Beta	65.2				
		Tritium	1.32				

Table 6.7 (continued)

Boring	Depth (ft BGS) ^a	Analyte	Activity (pCi/g)	Boring	Depth (ft BGS) ^a	Analyte	Activity (pCi/g)
SB 150 (continued)	4.0-6.0	Alpha Beta	19.0 ^b 17.1 ^b	SB160	0.0-2.0	Alpha Beta Tritium	29.9 ^b 60.5 0.45
SB152	0.0-2.0	Alpha Beta	15.3 ^b 122		2.0-4.0	Alpha Beta Tritium	386 550 0.13 ^b
	2.0-4.0	Alpha Beta	25.3 ^b 456		4.0-6.0	Alpha Beta	1890 3218
	4.0-6.0	Alpha Beta	14.8 ^b 641	SB162	4.0-6.0	Alpha Beta	39.8 ^b 49.6
	6.0-8.0	Alpha Beta	29.4 ^b 336		6.0-6.8	Alpha Beta	41.3 ^b 48.0
	8.0-9.5	Alpha Beta	43.4 ^b 596	SB163	0.0-2.0	Alpha Beta Tritium	8.2 ^b 12.9 ^b 0.15 ^b
SB153	1.0-3.0	Alpha Beta	18.7 ^b 13.6 ^b		2.0-3.5	Alpha Beta Tritium	3.6 ^b 20.0 0.12 ^b
	3.0-5.0	Alpha Beta	7.8 ^b 23.8 ^b	SB164	0.0-2.0	Alpha Beta Tritium	24.6 ^b 156 0.18 ^b
	5.0-7.0	Alpha Beta	51.2 ^b 1230		2.0-4.0	Alpha Beta Tritium	22.8 ^b 84.4 1.17
	7.0-8.9	Alpha Beta	29.1 ^b 329	SB165	2.0-4.0	Alpha Beta Tritium	33.3 ^b 43.2 0.41
SB154	1.0-3.0	Alpha Beta	11.5 ^b 22.9 ^b		4.0-6.0	Alpha Beta Tritium	43.7 ^b 48.2 0.93
	3.0-5.0	Alpha Beta	19.8 ^b 22.0 ^b		6.0-8.1	Alpha Beta Tritium	29.0 ^b 98.4 4.0
SB156	2.0-4.0	Alpha Beta	29.7 ^b 42.2	SB166	0.0-2.0	Alpha Beta	28.9 ^b 49.2
SB157	0.0-2.0	Beta	25.0 ^b		2.0-4.0	Alpha Beta Tritium	27.3 ^b 40.9 0.53
	2.0-3.7	Alpha Beta	24.5 ^b 18.8 ^b				

Table 6.7 (continued)

Boring	Depth (ft BGS) ^a	Analyte	Activity (pCi/g)	Boring	Depth (ft BGS) ^a	Analyte	Activity (pCi/g)
SB166 (continued)	4.0-5.7	Alpha	27.6 ^b	SB 214 (continued)	4.0-4.3	Alpha	16.3 ^b
		Beta	51.1			Beta	27.4 ^b
		Tritium	0.44			Tritium	0.47
SB171	2.0-3.6	Alpha	26.8 ^b	SB241	0.0-2.0	Alpha	27.0 ^b
		Beta	43.1			Beta	130
SB214	0.0-2.0	Alpha	25.9 ^b		4.0-5.5	Alpha	16.6 ^b
		Beta	68.2			Beta	1084
		Tritium	0.28			Tritium	1.73
	2.0-4.0	Alpha	27.7 ^b				
		Beta	25.8 ^b				
		Tritium	0.33				

^aBGS = below ground surface.^bBelow maximum reference level.

**Table 6.8. Nonradiological contamination detected in
Isotopes Area groundwater**

Well (type) ^a	Date	Sample type	Analyte	Concentration ($\mu\text{g/L}$)
597 (I)	10/90	Low base	Cadmium	2.1 ^b
			Chromium	22.6 ^b
			Lead	14.0 ^b
	11/90	Low base	Beryllium	2.7
			Cadmium	6.5
			Chromium	59.7
			Lead	53.6
	3/91	High base	Beryllium	1.2
			Chromium	22.8 ^b
			Lead	16.5 ^b
598 (R)	10/90	Low base	1,2-dichloroethene	67.0
			Trichloroethene	210
			Chromium	15.5 ^b
			Lead	13.0 ^b
	3/91	High base	1,2-dichloroethene	32.0
			Trichloroethene	140
			Beryllium	1.4
			Chromium	27.2
			Lead	33.9
	4/91	High base	1,2-dichloroethene	28.0
			Trichloroethene	160
			Beryllium	2.2
			Chromium	36.5
			Lead	37.4
608 (R)	12/91	Low base	Beryllium	6.1
			Chromium	71.2
			Lead	75.6
613 (I)	5/86	High base	Beryllium	2.4
615 (I)	8/86	Low base	Beryllium	1.1
			Cadmium	3.8 ^b

^aI = interface, R = bedrock.

^bBelow maximum reference level.

Table 6.9. Radiological sampling results from core hole CH-8

Interval	Depth (ft BGS) ^a	Head (ft MSL) ^b	Gross alpha (pCi/L)	Gross beta (pCi/L)	Tritium (pCi/L)
7	11.05-12.2	804.8	697	32,080	450
6	16.2-21.2	804.3	1,295	118,960	660
5	24.2-26.2	806.52	2,516	113,545	3,170
4	29.2-33.2	806.12	4,263.3	156,799	2,670
3	36.2-38.2	806.12	3,775	487,093	3,580
2	41.2-43.2	806.12	5,093	585,497	3,780
1	46.2-53.9	806.02	950.8	205,124	NA ^c
			1,461.4 ^d	215,495 ^d	3,410 ^d

^aBGS = below ground surface.^bMSL = mean sea level.^cNA = not applicable.^dDuplicate sample.

Table 6.10. Historical radiological analytical results (in pCi/L) for storm drain outfalls 341 and 342, Well 812, and piezometer 539

	Date	Gross alpha	Gross beta	Tritium	Total rad Sr
Well 812	12/12/88	232.2	17,820	7,560	7,560
	1/24/89	148.5	11,340	5,400	6,210
	6/20/89	129.5	9,990	5,670	3,240
	10/19/89	180.9	11,340	12,420	5,670
	10/4/90	297	16,200	11,340	8,100
	3/26/91	259.2	14,310	10,800	7,560
	11/1/91	170	7,800	18,000	
	2/24/92	297	12,690	9,450	7,830
Piezometer 539	10/16/86	98.4	3,390.2	6,814.5	
	9/29/90	1,150	12,100	13,500	5,880 ^a
	3/18/91	210	10,729	11,990	3,783 ^a
	11/1/91	180	7,200	17,000	
Storm drain 341	9/18/86	20	3,240		
	10/1/86	108	2,565		
	10/13/86	216	6,210		
	10/27/86	270	7,560		
	4/14/87	130	7,020		
	4/28/87	62	5,400		
	5/27/87	116	8,100		
	5/8/89	42	4,860		
	6/28/89	111	8,100		
	4/1/91		3,510		
	11/1/91	43	1,800	1,800	
	4/15/92	102.6	2,700	972	
Storm drain 342	9/18/86	73	13,230		
	10/1/86	454	11,340		
	10/13/86	270	8,370		
	10/27/86	262	6,480		
	4/14/87	259	19,170		
	4/28/87	248	15,660		
	5/27/87	132	11,610		
	5/8/89	42	4,185		
	6/28/89	51	2,835		
	4/1/91		324		
	11/1/91	180	10,000	12,000	
	4/15/92	186.3	7,020	5,400	

^aOnly ⁹⁰Sr measured.

**Table 6.11. Radiological contamination detected
in 3042 area groundwater**

Well (Type) ^a	Date	Sample type	Analyte	Activity (pCi/L)
588 (O)	12/91	Low base	Alpha Beta	48.9 335
589 (R)	1/91	High base storm	Alpha Beta Tritium	36.7 520 35,600
	5/91	High base	Alpha Beta Tritium	76.9 552 17,600
596 (I)	4/86	High base	Alpha Beta Tritium	1.7 ^b 6.0 4.2 ^b
	11/91	Low base	Alpha Tritium	125 1,140 ^b
603 (R)	11/91	Low base	Alpha Beta Tritium	54.5 203 61,750
607 (R)	12/91	Low base	Alpha Beta Tritium	2.3 ^b 18.9 3,550
612 (I)	6/86	High base	Alpha Beta Tritium	5.1 66.4 14,354
30421 (Sump)	8/93	Low base	Alpha Beta	23.2 4,590

^aO = overburden, R = bedrock, I = interface.

^bBelow maximum reference level.

**Table 6.12. Radiological contamination detected
in 3042 area soil**

Boring	Depth (ft BGS) ^a	Analyte	Activity (pCi/g)
SB142	2.0–4.0	Tritium	0.42
		Alpha	12.6 ^b
		Beta	21.8 ^b
	4.0–6.0	Tritium	0.45
		Alpha	19.0 ^b
		Beta	38.5
	8.0–10.0	Tritium	0.79
		Alpha	21.4 ^b
		Beta	49.7
	10.0–12.0	Tritium	0.48
		Alpha	20.1 ^b
		Beta	42.3
SB257	4.0–5.9	Tritium	1.17
		Alpha	22.0 ^b
		Beta	30.0 ^b

^aBGS = below ground surface.

^bBelow maximum reference level.

Table 6.13. Nonradiological contamination detected in 3042 area groundwater

Well (type) ^a	Date	Sample type	Analyte	Concentration (µg/L)
588 (O)	10/91	Low base	Trichloroethene	16.0
			Beryllium	1.8
			Chromium	112
			Lead	41.2
589 (R)	10/90	Low base	Trichloroethene	2.0
			Beryllium	3.4
			Cadmium	4.4 ^b
			Chromium	85.9
	11/90	Low base	Beryllium	3.5
			Cadmium	6.9
			Chromium	168
			Lead	72.2
	6/91	High base	Beryllium	4.4
			Chromium	128
			Lead	77.1
596 (I)	5/86	High base	Beryllium	4.1
	10/91	Low base	Trichloroethene	20.0
	11/91	Low base	Beryllium	1.1
			Chromium	26.7
603 (R)	11/91	Low base	Lead	101
			Beryllium	10.7
			Chromium	82.9
607 (R)	11/91	Low base	Lead	415
			Chromium	17.2 ^b
30421 (Sump)	2/90	High base	Lead	173
			Chromium	202
	3/90	High base	Lead	2,230

^aO = overburden, R = bedrock, I = interface.^bBelow maximum reference level.

**Table 6.14. Radiological contamination detected in
detention basin (3513) area groundwater**

Well (type) ^a	Date	Sample type	Analyte	Activity (pCi/L)
877 (I)	2/91	High base storm	Alpha	12
			Beta	33
			Tritium	2560
	5/91	High base	Alpha	58
			Beta	61
			Tritium	2340
884 (I)	2/91	High base storm	Beta	4 ^b
			Tritium	1630 ^b
	5/91	High base	Tritium	1710 ^b
1102 (I)	2/91	High base storm	Alpha	120
			Beta	2040
			Tritium	24,900
	4/91	High base	Tritium	42,370
	6/91	High base	Alpha	9
1103 (I)	2/91	High base storm	Beta	2200
			Alpha	7
			Tritium	78
	5/91	High base	Tritium	19,900
			Beta	67
			Tritium	16,140
1104 (I)	2/91	High base storm	Alpha	19
			Beta	205
			Tritium	79,500
	4/91	High base	Tritium	50,950
	6/91	High base	Beta	155

^aI = Interface.

^bBelow maximum reference level.

**Table 6.15. Radiological contamination detected in
equalization basin (3524) area groundwater**

Well (type) ^a	Date	Sample type	Analyte	Activity (pCi/L)
579 (I)	4/86	High base	Alpha	1 ^b
			Beta	5 ^b
			Tritium	8 ^b
	1-2/91	High base storm	Beta	79
			Tritium	7280
	4/91	High base	Beta	114
			Tritium	3330
874 (I)	2/91	High base storm	Alpha	74
			Beta	2710
			Tritium	404,000
	5/91	High base	Beta	1083
			Tritium	275,100
875 (I)	2/91	High base storm	Alpha	287
			Beta	5710
			Tritium	185,000
	4/91	High base	Tritium	827,670
	5/91	High base	Alpha	4 ^b
			Beta	48
876 (I)	5/91	High base	Beta	8
			Tritium	338,800
885 (R)	2/91	High base storm	Alpha	9
			Beta	94
			Tritium	912,000
	4/91	High base	Beta	77
			Tritium	838,200
1100 (O)	2/91	High base storm	Alpha	12
			Beta	215
			Tritium	104,000
	5/91	High base	Alpha	3 ^b
			Beta	118
			Tritium	2540
1101 (R)	2/91	High base storm	Alpha	17
			Beta	191
	5/91	High base	Beta	188
			Tritium	168,530

^aI = interface, R = bedrock, O = overburden.

^bBelow maximum reference level.

**Table 6.16. Radiological contamination detected in
3539/3540 area groundwater**

Well (type) ^a	Date	Sample type	Analyte	Activity (pCi/L)
877 (I)	2/91	High base storm	Alpha	12
			Beta	33
			Tritium	2560
	5/91	High base	Alpha	58
			Beta	61
			Tritium	2340
878 (I)	4/91	High base	Tritium	2660
879 (I)	2/91	High base storm	Tritium	3020
	4-5/91	High base	Alpha	5.0
			Tritium	2830
880 (I)	2/91	High base storm	Beta	8
			Tritium	2760
	5/91	High base	Tritium	2860
881 (I)	2/91	High base storm	Alpha	6
	3/91	High base	Tritium	2560
	5/91	High base	Tritium	2240
882 (I)	2/91	High base storm	Beta	56
			Tritium	2180
	4/91	High base	Beta	43
			Tritium	10,400
884 (I)	2/91	High base storm	Beta	4 ^b
			Tritium	1680 ^b
	5/91	High base	Tritium	1710 ^b

^aI = interface.

^bBelow maximum reference level.

Table 6.17. Radiological contamination detected in detention basin (3513) area soil

Boring	Depth (ft BGS) ^a	Analyte	Activity (pCi/g)
SB102	4.0-6.0	Alpha	35 ^b
		Beta	44
		Tritium	0.06 ^b
	6.0-7.5	Alpha	296
		Beta	264
		Tritium	0.74
SB103	0.0-2.0	Alpha	28 ^b
		Beta	338
	4.0-6.0	Alpha	16 ^b
		Beta	36
	8.0-9.9	Alpha	20 ^b
		Beta	29 ^b

^aBGS = below ground surface.

^bBelow maximum reference level.

Table 6.18. Radiological contamination detected in equalization basin (3524) area soil

Boring	Depth (ft BGS) ^a	Analyte	Activity (pCi/g)
SB104	2.0-4.0	Alpha	35 ^b
		Beta	505
		Tritium	0.27
	6.0-7.0	Alpha	36 ^b
		Beta	43
		Tritium	8.2
SB105	4.0-4.6	Alpha	39 ^b
		Beta	68
		Tritium	0.14 ^b
SB113	2.0-4.0	Alpha	24 ^b
		Beta	152
		Tritium	0.28
SB189	2.0-4.0	Alpha	216
		Beta	9,871
		Tritium	0.17 ^b
	4.0-4.3	Alpha	74
		Beta	21,382
		Tritium	0.11 ^b

^aBGS = below ground surface.

^bBelow maximum reference level.

Table 6.19. Radiological contamination detected in 3539/3540 area soil

Boring	Depth (ft BGS) ^a	Analyte	Activity (pCi/g)
SB102	0.0-2.0	Alpha	5 ^b
		Beta	51
	10.0-12.0	Alpha	27 ^b
		Beta	28 ^b
	12.0-13.3	Alpha	16 ^b
		Beta	24 ^b

^aBGS = below ground surface.

^bBelow maximum reference level.

**Table 6.20. Nonradiological contamination detected in
equalization basin (3524) area groundwater**

Well (type) ^a	Date	Sample type	Analyte	Concentration (μg/L)
579 (I)	10/90	Low base	Chromium	40.6
	11/90	Low base	Cadmium	6.2
			Chromium	35.7
	3/91	High base	Lead	23.5 ^b
	4/91	High base	Chromium	37.8
Lead			6.8 ^b	
874 (I)	10/90	Low base	Lead	2.7 ^b
	5/91	High base	Chromium	5.6 ^b
875 (I)	11/90	Low base	Lead	5.3 ^b
			Chromium	11.3 ^b
	4/91	High base	1,2-dichloroethene	5.0
			Lead	3.6 ^b
876 (I)	10/90	Low base	1,2-dichloroethene	17.0
			Trichloroethene	24.0
	4/91	High base	1,2-dichloroethene	14.0
	5/91	High base	Lead	7.1 ^b
885 (R)	10/90	Low base	1,2-dichloroethene	18.0
			Vinyl chloride	5.0
			Cadmium	4.5 ^b
			Chromium	17.6 ^b
	4/91	High base	1,2-dichloroethene	9.0
	5/91	High base	Chromium	7.1 ^b
1100 (O)	10/90	Low base	1,2-dichloroethene	46.0
			Vinyl chloride	11.0
			Lead	4.0 ^b
	4/91	High base	1,2-dichloroethene	2.0 ^b
5/91	High base	Chromium	6.4 ^b	
1101 (R)	11/90	Low base	Chromium	46.7
			Lead	15.1 ^b
	4/91	High base	1,2-dichloroethene	35.0
5/91	High base	Lead	18.3 ^b	

^aI = interface, R = bedrock, O = overburden.

^bBelow maximum reference level.

**Table 6.21. Nonradiological contamination detected in
detention basin (3513) area groundwater**

Well (type) ^a	Date	Sample type	Analyte	Concentration ($\mu\text{g/L}$)
877 (I)	10/90	Low base	Lead	5.8 ^b
884 (I)	10/90	Low base	Lead	6.0 ^b
	5/91	High base	Lead	17.7 ^b
1102 (I)	10/90	Low base	1,2-dichloroethene	410
			Vinyl chloride	6.0
			Cadmium	2.6 ^b
			Chromium	11.5 ^b
	4/91	High base	1,2-dichloroethene	280
			Vinyl chloride	8.0
1103 (I)	10/90	Low base	Trichloroethene	6.0
			1,2-dichloroethene	8.0
			Vinyl chloride	19.0
			Cadmium	2.5 ^b
			Chromium	71.1
	1/91	High base storm	Lead	10.2 ^b
1104 (I)	5/91	High base	Lead	22.2 ^b
	10/90	Low base	Chromium	19.3

^aI = interface.

^bBelow maximum reference level.

**Table 6.22. Nonradiological contamination detected in
3539/3540 area groundwater**

Well (type) ^a	Date	Sample Type	Analyte	Concentration (μg/L)
877 (I)	10/90	Low base	Lead	5.8 ^b
878 (I)	10/90	Low base	Cadmium	2.9 ^b
			Chromium	21.8 ^b
879 (I)	5/91	High base	Lead	2.6 ^b
	10/90	Low base	Cadmium	9.5
			Chromium	27.5
880 (I)	5/91	High base	Lead	41.0
	10/90	Low base	Cadmium	4.1 ^b
			Chromium	17.7 ^b
			Lead	4.9 ^b
881 (I)	10/90	Low base	Cadmium	4.3 ^b
			Chromium	25.1 ^b
			Lead	5.4 ^b
	12/90	Low base	Trichloroethene	5.0
			1,2-dichloroethene	14.0
			Vinyl chloride	10.0
	4/91	High base	Vinyl chloride	12.0
882 (I)	5/91	High base	Lead	7.3 ^b
	10/90	Low base	Cadmium	3.7 ^b
			Chromium	23.0 ^b
884 (I)	10/90	Low base	Lead	6.0 ^b
	5/91	High base	Lead	17.7 ^b

^aI = interface.

^bBelow maximum reference level.

**Table 6.23. Nonradiological contamination detected in
impoundments area soil**

Boring	Depth (ft BGS) ^a	Analyte	Concentration ($\mu\text{g/kg}$)
SB100	0.0–2.0	Chromium	14,800 ^b
		Lead	31,600 ^b
	10.0–12.0	Chromium	14,800 ^b
		Lead	24,200 ^b
	12.0–13.3	Chromium	15,000 ^b
		Lead	13,400 ^b
SB102	6.0–7.5	Chromium	19,500 ^b
		Lead	30,200 ^b
SB103	0.0–2.0	Chromium	17,000 ^b
		Lead	19,300 ^b
	4.0–6.0	Chromium	10,500 ^b
		Lead	25,300 ^b
	8.0–9.9	Chromium	20,900 ^b
		Lead	15,600 ^b
SB104	2.0–4.0	Chromium	11,900 ^b
		Lead	38,800 ^b
	6.0–7.0	Chromium	27,600 ^b
		Lead	52,500
SB105	4.0–4.6	Chromium	12,300 ^b
		Lead	22,900 ^b
SB113	2.0–4.0	Chromium	22,800 ^b
		Lead	34,200 ^b
SB189	4.0–4.3	Chromium	20,300 ^b
		Lead	18,100 ^b

^aBGS = below ground surface.

^bBelow maximum reference level.

**Table 6.24. Radiological contamination detected in
SWSA 1 groundwater**

Well (type) ^a	Date	Sample type	Analyte	Activity (pCi/L)
571(I)	4/86	High base	Alpha	3 ^b
			Beta	120
			Tritium	6 ^b
	2-4/91	High base	Alpha	48
			Beta	227
			Tritium	1,810 ^b
580 (R)	7/86	Low base	Alpha	13
			Beta	404
			Tritium	1,558 ^b
827 (I)	12/88	High base	Tritium	1,242 ^b
	2/89	High base	Alpha	1 ^b
			Beta	8
			Tritium	1,971
	6/89	Low base	Beta	8
			Tritium	2,025
	1/89	High base	Beta	1 ^b
			Tritium	1,674
	9/90	Low base	Alpha	4
			Beta	8
			Tritium	1,134 ^b
	3/91	High base	Alpha	2 ^b
			Beta	5 ^b
			Tritium	1,500 ^b
	2/92	High base	Alpha	2 ^b
			Beta	8
			Tritium	1,026 ^b
828 (R)	12/88	High base	Alpha	3 ^b
			Beta	2 ^b
			Tritium	1,053 ^b
	2/89	High base	Beta	3 ^b
			Tritium	2,511
	6/89	Low base	Beta	4 ^b
			Tritium	2,430
	10/89	Low base	Tritium	2,349
	10/90	Low base	Alpha	2 ^b
			Beta	2 ^b
			Tritium	1,215 ^b

Table 6.24 (continued)

Well (type) ^a	Date	Sample type	Analyte	Activity (pCi/L)
828 (R) (continued)	3/91	High base	Alpha	13
			Beta	10
			Tritium	2,090
	2/92	High base	Alpha	3 ^b
			Beta	5 ^b
			Tritium	2,025
829 (I)	12/88	High base	Alpha	6
			Beta	35
			Tritium	1,377 ^b
	2/89	High base	Alpha	1 ^b
			Beta	41
			Tritium	2,673
	6/89	Low base	Alpha	3 ^b
			Beta	41
			Tritium	1,998
	10/89	Low base	Alpha	20
			Beta	46
			Tritium	1,485 ^b
	9/90	Low base	Alpha	5
			Beta	46
			Tritium	810 ^b
	3/91	High base	Alpha	3 ^b
			Beta	32
			Tritium	837 ^b
	2/92	High base	Alpha	4
			Beta	43
			Tritium	1,377
946 (I)	10/90	Low base	Alpha	3 ^b
			Beta	43
			Tritium	999 ^b
	3/91	High base	Alpha	11
			Beta	35
			Tritium	1,790 ^b
	4-5/91		Alpha	5
			Beta	29
			Tritium	1,680 ^b
	2/92	High base	Alpha	2 ^b
			Beta	43
			Tritium	1,377 ^b

Table 6.24 (continued)

Well (type) ^a	Date	Sample type	Analyte	Activity (pCi/L)
947 (R)	10/90	Low base	Alpha	1 ^b
			Beta	10
			Tritium	10,530
	3/91	High base	Beta	3 ^b
			Tritium	5,670
	2/92	High base	Alpha	6
			Beta	9
			Tritium	13,230

^aI = interface, R = bedrock.^bBelow maximum reference level.

Table 6.25. Radiological contamination detected in SWSA 2 groundwater

Well (type) ^a	Date	Sample type	Analyte	Activity (pCi/L)
615 (I)	7/86	Low base	Alpha	1 ^b
			Beta	254
			Tritium	13,255
621 (R)	4/86	High base	Alpha	4
			Beta	8
			Tritium	8 ^b
	2-5/91	High base	Alpha	7
			Beta	7
			Tritium	5,050
622 (I)	5/86	Low base	Alpha	4
			Beta	17
			Tritium	9 ^b
	3-5/91	High base	Alpha	29
			Beta	31
			Tritium	6,360
630 (R)	7/86	Low base	Alpha	3 ^b
			Beta	30
			Tritium	4,935
633 (R)	8/86	Low base	Alpha	13
			Beta	31
			Tritium	2,079
634 (R)	3-5/91	High base	Alpha	10
			Beta	13
			Tritium	2,920

Table 6.25 (continued)

Well (type) ^a	Date	Sample type	Analyte	Activity (pCi/L)
818 (R)	12/88	High base	Beta Tritium	2 ^b 2,187
	1/89	High base	Beta Tritium	1 ^b 2,970
	5/89	Low base	Beta Tritium	2 ^b 1,377
	10/89	Low base	Alpha Beta Tritium	1 ^b 2 ^b 7,020
	9/90	Low base	Alpha Beta Tritium	1 ^b 5 ^b 3,780
	3/91	High base	Alpha Beta Tritium	1 ^b 4 ^b 3,240
	1/92	High base	Alpha Beta Tritium	1 ^b 7 4,860
819 (R)	12/88	High base	Alpha Beta	5 2 ^b
	2/89	High base	Alpha Beta Tritium	1 ^b 2 ^b 702 ^b
	5/89	Low base	Beta Tritium	6 1377 ^b
	10/89	Low base	Beta Tritium	4 ^b 2,214
	9/90	Low base	Alpha Beta Tritium	1 ^b 9 2,268
	2-3/91	High base	Alpha Beta Tritium	2 ^b 2 ^b 1,269
	11/92	High base	Alpha Beta	3 ^b 12
820 (R)	12/88	High base	Beta Tritium	2 ^b 5,400
	2/89	High base	Beta Tritium	1 ^b 5,400

Table 6.25 (continued)

Well (type) ^a	Date	Sample type	Analyte	Activity (pCi/L)
821 (R)	6/89	Low base	Beta Tritium	3 ^b 1728 ^b
	10/89	Low base	Alpha Beta Tritium	3 ^b 13 10,800
	9/90	Low base	Alpha Beta Tritium	3 ^b 9 5,940
	3/91	High base	Alpha Beta Tritium	2 ^b 5 ^b 5,610
	1/92	High base	Alpha Beta Tritium	2 ^b 2 ^b 14,040
	12/88	High base	Alpha Tritium	5 ^b 675 ^b
	2/89	High base	Beta Tritium	1 ^b 1,512 ^b
	6/89	Low base	Beta Tritium	3 ^b 459 ^b
	10/89	Low base	Beta Tritium	3 ^b 2,133
	9/90	Low base	Alpha Beta Tritium	2 ^b 14 2,970
	3/91	High base	Alpha Beta Tritium	1 ^b 2 ^b 1917 ^b
	1/92	High base	Beta Tritium	4 ^b 2,700
	12/88-1/89	High base	Alpha Beta Tritium	1 ^b 6 7,830
	6/89	Low base	Alpha Beta Tritium	1 ^b 3 ^b 2,052
822 (I)	10/89	Low base	Alpha Beta Tritium	1 ^b 4 ^b 5,940

Table 6.25 (continued)

Well (type) ^a	Date	Sample type	Analyte	Activity (pCi/L)
	9/90	Low base	Alpha	4
			Beta	6
			Tritium	6,480

^aI = interface, R = bedrock.^bBelow maximum reference level.

Table 6.26. Radiological contamination detected in piezometer 536 and well 810 area groundwater

Well (type) ^a	Water elevation (ft MSL) ^b	Sample date	Sample type	Analyte	Activity (pCi/L)
533 (R)	794.78	3/91-5/91	High base	Alpha	32
				Beta	675
				Tritium	2190
	790.29	9/90-10/90	Low base	Alpha	33
				Beta	84
				Tritium	2300
536 (R)	788.00	3/91-5/91	High base	Alpha	15
				Beta	21
				Tritium	2100
	786.93	9/90-10/90	Low base	Alpha	<12
				Beta	26
				Tritium	1800 ^c
540 (R)	785.34	3/91-5/91	High base	Tritium	1310 ^c
	785.99	9/90-10/90	Low base	Beta	71
				Tritium	1960
541 (I)	785.21	3/91-5/91	High base	Alpha	48
				Beta	42
				Tritium	1660 ^c
	784.47	9/90-10/90	Low base	Alpha	18
				Beta	21
				Tritium	1030 ^c
810 (I)	787.07	3/91-5/91	High base	Alpha	1 ^c
				Beta	7
				Tritium	2970
	786.35	9/90-10/90	Low base	Alpha	<11
				Beta	<25
				Tritium	1800 ^c
811 (R)	789.40	9/90-10/90	Low base	Alpha	<11
				Beta	<25
				Tritium	<490
First Creek at Unit F	800±1				

^aR = bedrock, I = interface.^bMSL = mean sea level.^cBelow maximum reference level.

**Table 6.27. Radiological contamination detected in
2533 sump area groundwater**

Well (type) ^a	Date	Sample type	Analyte	Activity (pCi/L)
563 (I)	7/86	Low base	Alpha	9
			Beta	78
			Tritium	3376
	4/91	High base	Alpha	32
			Beta	195
			Tritium	4260
564 (R)	3-4/91	High base	Alpha	28
			Beta	805
	1/91	High base	Tritium	108,000
	4/91	High base	Alpha	63,070
565 (I)	5/86	Low base	Alpha	2 ^b
			Beta	10
			Tritium	5 ^b
566 (I)	1-2/91	High base	Alpha	165
			Beta	439
			Tritium	233,000
	3-5/91	High base	Alpha	212
			Beta	154
			Tritium	145,870
567 (I)	7/86	Low base	Alpha	4
			Beta	28
			Tritium	1558 ^b
2531 Sump	3/90	High base	Alpha	21
			Beta	1650
			Tritium	2460
2533 Sump	3/90	High base	Alpha	2860
			Beta	385,000
			Tritium	935,000

^aR = bedrock, I = interface.

^bBelow maximum reference level.

**Table 6.28. Radiological contamination
detected in 2533 sump area soils**

Boring	Depth (ft BGS) ^a	Analyte	Activity (pCi/g)
SB78	0-2	Alpha	21 ^b
		Beta	38
		Tritium	0.27
SB181	0-2	Alpha	68
		Beta	37
	6-7.2	Alpha	20 ^b
		Beta	245
		Tritium	0.54

^aBGS = below ground surface.

^bBelow maximum reference level.

**Table 6.29. Radiological and nonradiological contamination
detected in CH-9 area groundwater**

Well or core hole (depth) (Unit)	Analyte	Value	Head MSL ^a	Head measurement date
CH-9-2 (126-138)(G)	Alpha, pCi/L	4	785.69	8/7/91
	Beta, pCi/L	12		
	Tritium, pCi/L	29,980		
CH-9-4 (314-327) (F)	Alpha, pCi/L	5	795.47	8/12/91
	Beta, pCi/L	18		
	Tritium, pCi/L	18,220		
CH-9-2 (126-138) (G)	1,2-dichloroethene, µg/L	17		
	Toluene, µg/L	5		
	Vinyl chloride, µg/L	18		
CH-9-4 (314-327) (F)	1,2-dichloroethene, µg/L	21		
	Acetone, µg/L	180		
	Toluene, µg/L	120		
565			783.86	9/30/91
886	Beta, pCi/L	14	781.67	9/30/91
	Tritium, pCi/L	11,620		
	1,2-dichloroethene, µg/L	18 ^b		
	Trichloroethene, µg/L	15 ^b		
874	Alpha, pCi/L	74 ^c	779.61	9/30/91
	Beta, pCi/L	1049 ^b		
	Tritium, pCi/L	275,100 ^b		

^aMSL = mean sea level.

^bHigh base sample.

^cLow base sample.

**Table 6.30. Radiological contamination detected
in the well 830 area**

Groundwater			
Date	Sample type	Analyte	Activity (pCi/g)
12/14/88	High base	Gross beta	54
		Tritium	54,000
1/16/89	High base	Gross beta	84
		Tritium	35,100
2/14/89	High base	Gross beta	70
		Tritium	37,800
6/07/89	Low base	Gross beta	73
		Tritium	37,800
10/01/90	Low base	Gross beta	149
		Tritium	29,700
Soil			
Boring	Depth (ft BGS)^a	Analyte	Activity (pCi/g)
SB95	0-1	Gross alpha	52 ^b
		Gross beta	912
		Tritium	3
SB96	0-1	Gross alpha	127
		Gross beta	4,045
		Tritium	3
SB97	0-1.8	Gross alpha	41 ^b
		Gross beta	596
		Tritium	0.3
SB211	8-9.8	Gross alpha	25 ^b
		Gross beta	85
		Tritium	0.15 ^b

^aBGS = below ground surface.

^bBelow maximum reference level.

Table 6.31. Radiological contamination detected in piezometer 584

Date	Analyte	Activity (pCi/L)
12/10/91	Alpha	6,611
	Beta	1,346,395
	Tritium	1,618 ^a

^aBelow maximum reference level.

Table 6.32. Radiological contamination detected in the piezometer 590 area

Groundwater			
Date	Sample type	Analyte	Activity (pCi/L)
11/91	Low base	Alpha	87.9
		Beta	5,278
		Tritium	22,530
Soil			
Boring	Depth (ft BGS) ^a	Analyte	Activity (pCi/g)
SB165	2.0–4.0	Alpha	33.3 ^b
		Beta	43.2
		Tritium	0.41
	4.0–6.0	Alpha	43.7 ^b
		Beta	48.2
		Tritium	0.93
	6.0–8.1	Alpha	29 ^b
		Beta	98.4
		Tritium	4.0
SB241	0.0–2.0	Alpha	27 ^b
		Beta	130
	4.0–5.5	Alpha	16.6 ^b
		Beta	1084
		Tritium	1.73

^aBGS = below ground surface.

^bBelow maximum reference level.

Table 6.33. Radiological contamination detected in the piezometer 593 area

Groundwater			
Date	Sample type	Analyte	Activity (pCi/L)
2/91	High base storm	Alpha	114
		Beta	128
		Tritium	730 ^a
Soil			
Boring	Depth (ft BGS) ^b	Analyte	Activity (pCi/g)
SB184	0.0–2.0	Alpha	26 ^a
		Beta	27 ^a
		Tritium	0.2 ^a
	6.0–8.0	Alpha	22.6 ^a
		Beta	18.7 ^a
		Tritium	0.3
SB247	8.0–10.0	Alpha	24.8 ^a
		Beta	32.7 ^a
		Tritium	0.2 ^a
	10.0–11.7	Alpha	23.2 ^a
		Beta	30.2 ^a
		Tritium	0.16 ^a
SB248	4.0–6.0	Alpha	7.9 ^a
		Beta	15 ^a
		Tritium	0.13 ^a
	9.0–10.0	Alpha	9.3 ^a
		Beta	27 ^a
		Tritium	0.08 ^a
SB260	6.0–8.0	Alpha	10.3 ^a
		Beta	14.4 ^a
		Tritium	0.05 ^a
	8.0–10.0	Alpha	6.3 ^a
		Beta	14 ^a
		Tritium	0.06 ^a

^aBelow maximum reference level.

^bBGS = below ground surface.

Table 6.34. Piezometric heads and hydraulic conductivities in CH-7A packer test intervals

Interval (ft BGS) ^a	Head (ft MSL) ^b	Hydraulic conductivity (cm/s)
61.13–68.43	805.66	2×10^{-6}
70.13–77.43	804.09	8×10^{-6}
84.08–91.38	802.25	6×10^{-5}
116.63–123.93	804.40	1×10^{-3}
123.93–131.23	806.00	1×10^{-2}
158.13–165.43	813.76	1×10^{-7}

^aBGS = below ground surface.^bMSL = mean sea level.**Table 6.35. Contamination detected in CH-7A groundwater samples**

Radiological contamination			
Interval (depth) (Unit)	Analyte	Activity (pCi/L)	Head (ft MSL) ^a
1 (84-91)(D)	Alpha	1.1 ^b	802.25
	Beta	6.3	
	Tritium	3180	
2 (70-77)(D)	Alpha	4.1	804.09
	Beta	23.4	
	Tritium	2370	
Nonradiological contamination			
Interval (Depth)(Unit)	Analyte	Concentration (μg/L)	
1 (84-91)(D)	Tetrachloroethene	2	
	Trichloroethene	180	
2 (70-77)(D)	Tetrachloroethene	6	
	Trichloroethene	87	
	Chloroform	2	
	Toluene	2	

^aMSL = mean sea level.^bDetected below maximum background.

Table 6.36. Contamination detected in Building 3592 area soil

Mercury contamination			Radiological contamination			
Boring	Depth (ft BGS) ^a	Concentration ($\mu\text{g/kg}$)	Boring	Depth (ft BGS)	Analyte	Activity (pCi/g)
SB175	1.0-2.0	548,000	SB175	1.0-2.0	Alpha	44 ^b
					Beta	34.5 ^b
					Tritium	0.05 ^b
	2.0-4.0	89,800			Alpha	86.3
					Beta	87.8
					Tritium	0.07 ^b
	4.0-6.0	5,000		4.0-6.0	Alpha	21.6 ^b
					Beta	30.2 ^b
					Tritium	0.11 ^b
	6.0-8.0	13,900		6.0-8.0	Alpha	191
					Beta	212
					Tritium	0.10 ^b
	8.0-8.9	1,000	SB176	0.0-2.0	Alpha	107
					Beta	111
					Tritium	0.04 ^b
SB176	0.0-2.0	16,400			Alpha	43.2 ^b
					Beta	40.9
					Tritium	0.01 ^b
	2.0-4.0	1,000		4.0-6.0	Alpha	122
					Beta	69.5
					Tritium	0.03 ^b
	4.0-6.0	4,200		6.0-7.2	Alpha	30.4 ^b
					Beta	40.5
					Tritium	0.31

^aBGS = below ground surface.^bBelow maximum reference level.

Table 6.37. Contamination detected in piezometer 553 groundwater

Radiological contamination				Nonradiological contamination			
Date	Sample type	Analyte	Activity (pCi/L)	Date	Sample type	Analyte ^a	Concentration (µg/L)
9/90-10/90	Low base	Alpha	18.4	9/90-10/90	Low base	Beryllium	21.3
		Beta	23.2			Cadmium	26.9
		Tritium	2160			Chromium	268
3/91-5/91	High base	Beta	4.9			Cobalt	267
		Tritium	2240			Copper	224
						Lead	312
						Mercury	1.2
						Nickel	304
						Silver	30.7
						Vanadium	379
						1,1-DCA	42
						1,2-DCA	2
						1,1,1-TCA	28
						1,1-DCE	4
						Acetone	14
						Benzene	160
						Toluene	41
						Ethylbenzene	120
						Xylenes	190
				3/91-5/91	High base	Chromium	5.3 ^b
						Cobalt	4.2
						Lead	11.7 ^b
						Mercury	0.24
						Nickel	9.7 ^b
						Vanadium	10.6
						1,1-DCA	18
						1,1,1-TCA	9
						Benzene	51
						Toluene	10
						Ethylbenzene	25
						Xylenes	51

^a1,1-DCA = 1,1-dichloroethane; 1,2-DCA = 1,2-dichloroethane; 1,1,1-TCA = 1,1,1-trichloroethane; 1,1-DCE = 1,1-dichloroethene.

^bBelow maximum reference level.

Table 6.38. Radiological contamination detected in groundwater northwest of WAG 1 boundary

Well (type) ^a	Date	Sample type	Analyte	Activity (pCi/L)
538 (R)	9/90-10/90	Low base	Alpha	136
			Beta	162
			Tritium	1400 ^b
	3/91-5/91	High base	Alpha	247
			Beta	118
			Tritium	1780 ^b
545 (R)	9/90-10/90	Low base	Alpha	37.7
			Beta	40.8
			Tritium	3700
	3/91-5/91	High base	Alpha	56.3
			Beta	48.6
			Tritium	3200
546 (R)	3/91-5/91	High base	Alpha	19.0
			Beta	12.9
			Tritium	2500
549 (R)	9/90-10/90	Low base	Alpha	118
			Beta	155
			Tritium	3600
	3/91-5/91	High base	Alpha	38.2
			Beta	132
			Tritium	3640
572 (R)	9/90-10/90	Low base	Alpha	113
			Beta	114
			Tritium	2760
	3/91-5/91	High base	Alpha	5.6
			Beta	2.7 ^b
			Tritium	2150
587 (R)	9/90-10/90	Low base	Alpha	10.7
			Beta	9.3
			Tritium	1360 ^b
	3/91-5/91	High base	Alpha	2.8 ^b
			Beta	7.4
			Tritium	1570 ^b

^aR = bedrock.

^bBelow maximum reference level.

**Table 6.39. Nonradiological contamination detected in
groundwater northwest of WAG 1 boundary**

Well (type) ^a	Date	Sample type	Analyte	Concentration ($\mu\text{g/L}$)
538 (R)	9/90-10/90	Low base	Beryllium	8.9
			Chromium	62.1
			Cobalt	79.1
			Copper	51.9
			Lead	93.7
			Mercury	0.48
			Nickel	82.6
			Silver	20.1
			Vanadium	54.5
			Trichloroethene	3
	3/91-5/91	High base	Beryllium	14.3
			Chromium	143
			Cobalt	138
			Copper	90.4
			Lead	103
			Nickel	137
			Vanadium	180
545 (R)	9/90-10/90	Low base	Chromium	20.7 ^b
			Lead	20.5 ^b
			Vanadium	23.8
	3/91-5/91	High base	Chromium	21.7 ^b
			Cobalt	10.7
			Lead	19.1 ^b
			Vanadium	25.2
546 (R)	3/91-5/91	High base	Beryllium	2
			Chromium	23.3 ^b
			Cobalt	13
			Copper	6.1 ^b
			Lead	14.8 ^b
			Nickel	17.2 ^b
			Vanadium	16.8
			Trichloroethene	27
549 (R)	9/90-10/90	Low base	Beryllium	4.2
			Chromium	106
			Cobalt	62.2
			Lead	32.4
			Nickel	139
			Vanadium	95.2
	3/91-5/91	High base	Beryllium	3.1
			Chromium	110
			Cobalt	51.2
			Copper	39.7

Table 6.39 (continued)

Well (type) ^a	Date	Sample type	Analyte	Concentration (µg/L)
549 (R) (continued)			Lead	21.8 ^b
			Nickel	115
			Silver	11.6
			Vanadium	110
572 (R)	9/90-10/90	Low base	Beryllium	1.0
			Chromium	20.9 ^b
			Cobalt	5.1
			Copper	14.1
			Lead	15.6 ^b
			Nickel	28.5 ^b
			Silver	11.8
			Vanadium	15.7
	3/91-5/91	High base	Beryllium	1.6
			Chromium	36.1
			Cobalt	17.8
			Lead	30.7
			Nickel	42.3
			Vanadium	40.6
587 (R)	9/90-10/90	Low base	Chromium	42.2
			Copper	56.1
			Lead	628
			Nickel	45.1
			Silver	19.2
			Vanadium	39.6
			Toluene	6
	3/91-5/91	High base	Chromium	4.2 ^b
			Lead	52
			Nickel	6.7 ^b
			Vanadium	6.0

^aR = bedrock.^bBelow maximum reference level.

Table 6.40. Radiological contamination detected in piezometer 601 groundwater

Date	Sample type	Analyte	Activity (pCi/L)
9/90-10/90	Low base	Alpha	117
		Beta	1040
		Tritium	3520
3/91-5/91	High base	Alpha	32.2
		Beta	2999
		Tritium	1620 ^a

^aBelow maximum reference level.

Table 6.41. Criteria for choosing water quality and water level monitoring locations

Well and type ^a	Area ^b	Historic water level	RI sample ^c	Upgraded ^d	Well pair	Contaminated	Monitor water quality	Monitor water level ^e
535 (I)	CH-8	Yes	Yes(CSL)			Yes	Yes	
537 (R)	Misc	Yes						Yes
538 (R)	NW	Yes	Yes	Yes		Yes	Yes	
539 (R)	CH-8	Yes	Yes	Yes		Yes	Yes	Yes
540 (R)	First Cr.	Yes	Yes	Yes	Yes(811)	Yes		Yes
542 (R)	2500	Yes						Yes
543 (I)	2500	Yes	Yes	Yes		Yes		Yes
544 (R)	2500	Yes						Yes
545 (R)	NW	Yes	Yes	Yes		Yes		Yes
546 (R)	NW	Yes	Yes	Yes		Yes		Yes
547 (I)	NW	Yes		Yes			Yes	Yes
548 (I)	2500	Yes	Yes	Yes		Yes		Yes
549 (R)	NW	Yes	Yes	Yes		Yes	Yes	Yes
553 (I)	2519	Yes	Yes	Yes		Yes	Yes	Yes
554 (I)	2500	Yes	Yes	Yes		Yes		Yes
555 (O)	2000	Yes						Yes
557 (R)	N	Yes						Yes
560 (R)	CH-8	Yes		Yes			Yes	Yes
561 (I)	CH-8	Yes	Yes(CSL)	Yes		Yes		Yes
563 (I)	2533 sump	Yes	Yes	Yes		Yes		Yes
564 (R)	2533 sump	Yes	Yes	Yes		Yes	Yes	
566 (R)	2533 sump	Yes	Yes	Yes		Yes	Yes	
567 (I)	2533 sump	Yes					Yes	
571 (I)	SWSA 1	Yes	Yes	Yes		Yes	Yes	
573 (I)	3001/3019	Yes					Yes	Yes

Table 6.41 (continued)

Well and type ^a	Area ^b	Historic water level	RI sample ^c	Upgraded ^d	Well pair	Contaminated	Monitor water quality	Monitor water level ^e
577 (I)	2500	Yes	Yes(CSL)			Yes		Yes
579 (I)	IMP	Yes	Yes	Yes		Yes		Yes
581 (I)	3000	Yes						Yes
582 (I)	3001/3019	Yes					Yes	Yes
583 (R)	3001/3019	Yes		Yes			Yes	Yes
584 (I)	3026	Yes	Yes(CSL)			Yes	Yes	Yes
588 (O)	ORR	Yes	Yes			Yes	Yes	Yes
589 (R)	ORR	Yes	Yes	Yes		Yes	Yes	Yes
590 (I)	3026	Yes	Yes			Yes	Yes	Yes
591 (I)	3026	Yes						Yes
592 (I)	3500	Yes						Yes
593 (I)	3500	Yes	Yes			Yes	Yes	
598 (R)	ISO	Yes	Yes	Yes		Yes	Yes	Yes
599 (R)	3500	Yes	Yes	Yes		Yes	Yes	Yes
600 (R)	3500	Yes						
601 (I)	3500	Yes	Yes	Yes		Yes	Yes	Yes
603 (R)	ORR	Yes	Yes			Yes	Yes	Yes
604 (I)	3500	Yes	Yes	Yes		Yes	Yes	Yes
607 (R)	ORR	Yes	Yes			Yes	Yes	Yes
608 (R)	ISO	Yes	Yes			Yes	Yes	Yes
611 (I)	3000	Yes	Yes	Yes		Yes		Yes
616 (I)	ISO	Yes		Yes				Yes
622 (I)	SWSA 2	Yes	Yes	Yes		Yes	Yes	Yes
626 (R)	4500	Yes		Yes				Yes
627 (I)	4500	Yes		Yes				Yes

Table 6.41 (continued)

Well and type ^a	Area ^b	Historic water level	RI sample ^c	Upgraded ^d	Well pair	Contaminated	Monitor water quality	Monitor water level ^e
631 (R)	SWSA 2	Yes						Yes
634 (R)	SWSA 2	Yes	Yes	Yes		Yes		Yes
721 (O)	SW							Yes
806 (I)	SW			C			Yes	
807 (I)	SW			C	Yes(808)		Yes	
808 (R)	SW			C	Yes(807)		Yes	
809 (I)	SW			C			Yes	
810 (I)	Unit F			C			Yes	Yes
811 (R)	2500			C	Yes(540)		Yes	
812 (R)	CH-8		Yes(CSL)	C		Yes	Yes	Yes
813 (R)	NW			C			Yes	
814 (R)	NW		Yes	C		Yes	Yes	Yes
815 (R)	N			C	Yes(816)		Yes	Yes
816 (R)	N			C	Yes(815)		Yes	
817 (I)	3000			C			Yes	
818 (R)	SWSA 2		Yes	C		Yes	Yes	
819 (R)	SWSA 2		Yes	C		Yes	Yes	
820 (R)	SWSA 2		Yes	C	Yes(821)	Yes	Yes	Yes
821 (R)	SWSA 2			C	Yes(820)		Yes	
822 (I)	SWSA 2			C			Yes	
823 (I)	4500			C			Yes	
824 (I)	4500		Yes	C		Yes	Yes	
825 (R)	3500			C	Yes(826,610)		Yes	
826 (I)	3500		Yes	C	Yes(825)	Yes	Yes	
827 (I)	SWSA 1		Yes	C		Yes	Yes	Yes

Table 6.41 (continued)

Well and type ^a	Area ^b	Historic water level	RI sample ^c	Upgraded ^d	Well pair	Contaminated	Monitor water quality	Monitor water level ^e
828 (R)	SWSA 1		Yes	C		Yes	Yes	Yes
829 (I)	SWSA 1			C			Yes	Yes
830 (I)	2500			C			Yes	
874 (I)	IMP		Yes	C		Yes	Yes	Yes
875 (I)	IMP		Yes	C	Yes(885)	Yes	Yes	
876 (I)	IMP		Yes	C		Yes	Yes	Yes
882 (I)	IMP		Yes	C		Yes		Yes
885 (R)	IMP		Yes	C	Yes(875)	Yes	Yes	
946 (O)	SWSA 1		Yes	C		Yes	Yes	
947 (R)	SWSA 1			C			Yes	
1102 (I)	IMP	Yes	Yes			Yes		Yes
1103 (I)	IMP	Yes	Yes			Yes	Yes	Yes
1104 (I)	IMP	Yes	Yes			Yes	Yes	
SB132 (O)	3001/3019		Yes			Yes	Yes	
SB189 (O)	IMP		Yes			Yes	Yes	

^aI = interface, R = bedrock, O = overburden.

^bMisc = miscellaneous, NW = area northwest of WAG 1 boundary, N = area north of WAG 1 boundary, ISO = Isotopes Area, IMP = Impoundments Area, SWSA = Solid Waste Storage Area, SW = southwestern part of WAG 1, ORR = Oak Ridge Research Reactor (3042).

^cRI = remedial investigation, CSL = Close Support Laboratory.

^dC = compliance quality construction.

^eContinuous water level monitoring occurs at wells 540, 546, 549, 599, 604, and 634.

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Table 6.42. Water quality and water level monitoring locations

Well	Monitor water quality	Monitor water level	Well	Monitor water quality	Monitor water level	Well	Monitor water quality	Monitor water level
535	Yes		587		Yes	815	Yes	Yes
537		Yes	588	Yes	Yes	816	Yes	
538	Yes		589		Yes	817	Yes	
539	Yes	Yes	590	Yes	Yes	818	Yes	Yes
540		Yes	591		Yes	819	Yes	
542		Yes	592		Yes	820	Yes	Yes
543		Yes	593	Yes		821	Yes	
544		Yes	598	Yes		822	Yes	
545		Yes	599	Yes	Yes	823	Yes	
546		Yes	600		Yes	824	Yes	
547	Yes	Yes	601	Yes	Yes	825	Yes	
548		Yes	603		Yes	826	Yes	
549	Yes	Yes	604		Yes	827	Yes	Yes
553	Yes	Yes	607		Yes	828	Yes	Yes
554		Yes	608		Yes	829	Yes	Yes
555		Yes	611		Yes	830	Yes	
557		Yes	616		Yes	873		Yes
560	Yes	Yes	622	Yes	Yes	874	Yes	Yes
561		Yes	626		Yes	875	Yes	
563		Yes	627		Yes	876	Yes	Yes
564	Yes		631		Yes	878		Yes
566	Yes	Yes	634		Yes	882		Yes
567	Yes		721		Yes	883		Yes
571	Yes		806	Yes		885	Yes	
573	Yes	Yes	807	Yes		886		Yes
577		Yes	808	Yes		946	Yes	
578		Yes	809	Yes		947	Yes	
579		Yes	810	Yes	Yes	1102		Yes
581		Yes	811	Yes		1103	Yes	Yes
582	Yes	Yes	812	Yes	Yes	1104	Yes	
583	Yes		813	Yes		SB132	Yes	
584	Yes	Yes	814	Yes	Yes	SB189	Yes	

7. FIELD SAMPLING PLAN

7.1 INTRODUCTION AND PURPOSE

Groundwater discharge to surface water bodies (WOC, First Creek, and Fifth Creek) may constitute a significant pathway for migration of contaminants from WAG 1 to potential off-site receptors. Investigations of groundwater flow and quality at WAG 1 conducted during Phase I of the RI have shown that the flow regime is complex and that there are contaminants in the groundwater. An investigation of WAG 1 hydrogeology will be conducted during Phase II of the RI to further define groundwater flow and quality.

The groundwater investigation will focus on collecting sufficient supplemental characterization data to support assessment of risk and remedial alternatives. The general objectives of the WAG 1 RI groundwater investigation are to

- characterize movement of groundwater through and away from WAG 1,
- characterize groundwater quality in WAG 1,
- investigate the interaction between surface water and groundwater and the degree of interaction among water-bearing zones, and
- identify sources of WAG 1 groundwater contamination.

7.2 PROJECT ORGANIZATION AND RESPONSIBILITIES

This project is being conducted under the direction of the ER Program that was established by the DOE "to manage the assessment, investigations, analysis, and specific closure activities to reduce adverse risk to health and environment and achieve regulatory compliance." The DOE-ORO established an ER Division to achieve that mission.

A subcontractor for implementation of field activities to be conducted for this project has not yet been identified. After this has been done, those positions that are to be filled with the subcontractor's employees will be included in a letter amendment to this report.

The ORNL ER Program is responsible for remedial investigation efforts at ORNL including scheduling, budgeting, project management oversight, and reporting. The ORNL ER Program Manager is responsible for overall management of ORNL ER Program personnel and activities and for providing budget and programmatic information to the Central ER Division. The WAG 1 ER Program Manager manages projects that are directly involved with remedial investigations at WAG 1, including remedial investigations and remedial design activities. Responsibilities include coordination, budget forecasting, and resource commitments.

The WAG 1 ER Project Manager is responsible for designing, managing, and coordinating field activities associated with the remedial investigation. Responsibilities include notification and coordination of field activity plans and schedules, obtaining all required permits and documentation, assuring that all applicable procedures are adhered to, and analyzing and interpreting the data. The WAG 1 ER QA Specialist, Industrial Hygienist, Health Physicist, Waste Management Coordinator, and Health and Safety Officer ensure that all applicable procedures and requirements are in place. Individuals currently identified on the project team include the following:

ORNL ER Program Manager	H. L. Boston
WAG 1 ER Program Manager	L. L. Kaiser
WAG 1 Groundwater OU Project Manager	R. R. Lee
ORNL Facility Manager	J. H. Hooyman
ORNL ER QA Specialist	P. A. Schrandt
Waste Management Officer	T. F. Scanlan
Waste Generator Certification Officer	S. E. Childs
ORNL Groundwater Coordinator	F. P. Baxter
Environmental Compliance Officer	N. S. Dailey
ES&H Oversight Officer	C. Clark
Radiation Protection Oversight	J. L. Gray
Industrial Hygiene Oversight	A. W. Saulsbury
Industrial Safety Oversight	J. D. Miller
Laboratory Protection Officer	J. S. Abercrombie

7.3 PROJECT DESCRIPTION

7.3.1 History and Current Conditions

The original objective of the ORNL site was to produce gram quantities of plutonium. The site initially included a nuclear reactor, a chemical separations plant, a number of underground storage tanks, and a variety of support facilities. Over the past 50 years, the site has undergone many changes in facilities and operations performed. An overview of historical operations and facilities at ORNL is given in Sect. 2.2.

Historically, numerous contaminant releases have occurred in WAG 1. Because of the complex and variable nature of the operations conducted at ORNL and the secrecy surrounding many of these operations, complete documentation of all releases is not available. A catalog of SWMUs in WAG 1 can be found in the ORNL "Contaminated Sites Summary Sheets" (ORNL 1990). These SWMUs were identified by ORNL to be potential sources of contamination that might pose a threat to human health or the environment. A detailed discussion of the characteristics of the SWMUs is presented in the "Site Characterization Summary Report" for WAG 1 (BNI 1992) prepared as part of Phase I of the RI.

7.3.2 Conceptual Site Model

The WAG 1 groundwater flow conceptual model is that the WAG is the groundwater discharge area for the Knox Group aquifer underlying the adjacent Chestnut Ridge recharge area. Local recharge within WAG 1 occurs on the hilltop area in the northern portion of the WAG, with discharge taking place through the overlying geologic units to surface water. Seasonal water table rise is a system-wide, piston-like response to precipitation. Throughout much of the WAG, significant amounts of discharging groundwater are intercepted by the extensive underground process waste pipeline system and liquid waste storage tank network. This groundwater is subsequently sent to the PWTP for treatment.

The greatest flux of contaminants through groundwater to this network occurs during periods of elevated water table in response to precipitation. It is partly because of this network that contamination found in WAG 1 groundwater is generally not detected in adjacent surface water bodies. The extent of surface water contamination would be anticipated to be much greater in the absence of this network.

The occurrence of stratabound groundwater flow at WAG 1 has been described by Ketelle and Lee (1992). In stratabound flow, the bulk of groundwater movement is envisioned to be essentially confined within discrete geologic strata. The direction of movement is determined by the hydraulic gradient within a stratum from the point of observation to the nearest surface water drainage. Comparatively minor stratum leakage occurs along the local or site-wide hydraulic head profile. Vertical leakage continues until another stratum is encountered through which stratabound flow can occur. Groundwater flow and contaminant migration is thus envisioned to occur in a trellis-like pattern.

Stratabound flow would not be expected to occur in thin-bedded rocks with a mixed carbonate and clastic composition which do not contain laterally extensive fractures. Because the bulk of ORNL facilities are underlain by such thin-bedded rocks, stratabound flow is not considered to be the only flow and transport mechanism at WAG 1. However, strata do occur in these units which have the potential for stratabound flow development, and that mechanism must be considered to occur at least locally.

For a more complete discussion of the conceptual site model for WAG 1, see Sect. 3.5.

7.3.3 Identification of Investigation Requirements

Section 5.1 lists chemical-specific and radionuclide-specific ARARs for groundwater for contaminants of concern in WAG 1. Contaminants of concern were identified from site characterization activities conducted under Phase I of the WAG 1 Groundwater RI. Results of these activities were reported in the Site Characterization Summary Report for WAG 1 (BNI 1992) and are summarized for contaminated areas in WAG 1 in Chap. 6.

This report applies to site characterization and remedial activities which are proposed for Phase II of the WAG 1 Groundwater RI. Phase II of the RI is one phase of a long-term multi-phase RI which is anticipated for WAG 1.

The primary remedial action goal for Phase II of the RI is to prevent off-site migration of contaminants found in groundwater, either by movement of contaminated groundwater off-WAG or by discharge of contaminated groundwater to surface water which subsequently moves off-WAG. A secondary goal of Phase II of the RI is to eliminate or control sources of groundwater contamination. Future phases of the RI will address cleanup of contaminated groundwater in WAG 1.

Phase I of the RI identified areas of radiologically contaminated groundwater and limited areas of nonradiological contamination of groundwater with volatile organic compounds and metals in WAG 1. Contaminated soil, which may serve as a secondary source of groundwater contamination, was also identified. Chapter 6 of this report contains a discussion of the groundwater and soil contamination found in contaminated areas of WAG 1.

As stated previously, the primary goal of Phase II of the WAG 1 Groundwater RI is to prevent off-site migration of contaminants in groundwater. Remedial technologies which may be used to accomplish this goal include trenches and subsurface drains to intercept contaminated groundwater; installation and operation of pumping wells to contain contaminant plumes; and lining of storm sewers to prevent infiltration of contaminated groundwater into the sewers and subsequent discharge to surface waters.

A secondary goal of the RI is to identify and control of sources of groundwater contamination. Technologies that may be used to accomplish this goal are exploratory drilling, pumping of contaminated groundwater in source areas, excavation of contaminated soils that may be serving as secondary sources of groundwater contamination, and/or in-situ immobilization of contaminants.

7.4 SITE ACTION PLAN/DATA QUALITY OBJECTIVES

Data needs based on the apparent nature and extent of contamination and WAG 1 groundwater conceptual model were described in Chap. 6. The site action plan was developed to obtain additional site data consistent with the observational approach.

The observational approach provides a conceptual framework for integrating site characterization and remediation. The approach recognizes the inherent uncertainties in site data and focuses on sufficient data to support decision making for potential response actions and the baseline risk assessment rather than on simple data completeness.

Focusing the RI investigation on collecting data sufficient for evaluation and selection of remedial alternatives provides a logical structure to both the definition of data needs and the analysis and interpretation of analytical results. Planned sampling activities allocate and

prioritize samples based on the level of data confidence and availability for the identified areas of concern described in Chap. 6. The sampling effort focuses on the projected data needs sufficient for informed decision making for the evaluation of potential remedial alternatives.

Based on these assumptions, the program objectives for the Phase II Groundwater WAG 1 RI are as follows:

- The available groundwater data are currently insufficient to adequately describe the nature and extent of groundwater contamination such that informed decisions can be made regarding potential remediation alternatives. Consequently, the sampling objectives focus on the identification and quantification of groundwater contaminants to make such decisions.
- Contamination has been identified in shallow groundwater. Therefore, the investigation will concentrate on the areal extent of contamination in shallow groundwater and also make recommendations regarding additional investigations in deeper groundwater.
- Contamination is interpreted to be migrating off-WAG to First Creek. Therefore, the investigation will seek to identify potential source areas.
- The temporal distribution of groundwater contamination is poorly documented. Therefore, long-term groundwater monitoring and sampling will be performed over a wide area in WAG 1.

These objectives have been established to provide a foundation for data collection activities described in this document such that sufficient data will be collected to characterize the site, assess human health risk, evaluate remedial alternatives, determine design criteria, or monitor site conditions and/or remedial action effectiveness. Adherence to these objectives is essential for ensuring that characterization, decision making, and remedial alternatives are adequate and that cost/schedule overruns do not occur.

DQOs are the endpoints in the formulation of a set of constraints designed to meet the project objectives and to design a study. The process sequentially develops the consideration of relevant issues such as the definition of the problem, decision points, participants, and uncertainties. Chapter 1 describes the DQOs developed for this report.

Because of the complex nature of groundwater flow and contaminant transport in WAG 1, this document provides preliminary DQOs that can be established at this stage of investigation. DQOs for subsequent RI phases will be contingent on the results of activities to be conducted in earlier RI phases; thus, establishing DQOs will be an evolving process.

At present, DQO decision rules for source investigations are as follows: (1) if a source is identified, develop preliminary remedial actions and data needs to evaluate these remedial actions; (2) if contamination is found, but at levels below what may be considered a source, then develop further exploration plans to identify the source; if contamination is not found, then no further action will be taken in the area. For contamination migration pathways, decision rules are as follows: (1) if contamination is found, then perform further exploration

and sampling to characterize the pathway and identify the source; (2) if a pathway is found, then develop preliminary remedial actions and determine data needs to evaluate these remedial actions; (3) if contamination is not found, then no further action will be taken. For groundwater monitoring, decision rules are as follows: (1) if contamination levels increase, then continue monitoring and develop plans to identify the source of contamination and potential remedial actions or removal actions; (2) if contamination levels decrease, then attempt to identify the reason for the change and continue monitoring until levels fall below background.

Chapter 6 provides the rationale used in establishing sampling objectives and selecting sampling locations and techniques. The following subsections summarize the DQOs for each of the areas of concern described in Chap. 6.

Analysis of existing groundwater elevation and quality data indicates a certain seasonality to many of the data. While sufficient data are not yet available to perform a more rigorous analysis, it can be expected that apparently heterogeneous data will be obtained. Comparison of results among sampling events must therefore be interpreted with caution.

7.4.1 Building 3001/3019 Area

Based on the history of operations, reported pipeline leaks in the area, and analytical results from a temporary piezometer located near a pipeline trench in the area, groundwater in the Building 3001/3019 area has a high likelihood of being contaminated and is the principal candidate source area for the CH-8 plume. Underlying Unit D cavtose bedrock significantly complicates analysis of flow pathways.

The bulk of the existing piezometers in the area contain only perched water, and essentially no information is available to describe the configuration of the water table surface or the quality of the groundwater. The additional wells described in Chap. 6 will provide those data which will then provide the necessary basis for informed decision making about selecting from a range of possible remediation alternatives. The wells located to the south and southwest of Building 3019 will also be used in evaluating possible CH-8 plume source areas.

Because no groundwater analytical data exist for the area, there is considerable uncertainty about the extent of possible contamination that might be encountered in exploration. The approach adopted in this report is to use the levels of contamination found in CH-8 (nominally 5×10^5 pCi/L gross beta, principally ^{90}Sr) as a basis for defining "significant" contamination and a CH-8 "source." The approach also assumes that Unit D groundwater migrates upward into overlying Unit E for discharge to pipeline trenches and/or surface water (e.g., the CH-8 plume).

Unit D groundwater encountered in exploration which contains about 1×10^5 pCi/L gross beta activity will be defined as "significant" contamination. For those wells located to identify a CH-8 source, less than 5×10^5 pCi/L gross beta activity will not be considered a source, from 5×10^5 to 1×10^6 pCi/L gross beta activity will be considered to be near a source, and

greater than 1×10^6 pCi/L gross beta activity will be considered a source. Subjective judgement, considering nominally 10% analytical error, will be used in evaluating results near boundary values, and definition values may change as results are obtained. In addition, the gross beta activity must consist predominantly of ^{90}Sr . Because ^{90}Sr is more mobile than ^{137}Cs in groundwater and assuming that both ^{90}Sr and ^{137}Cs are present in the source area, it may be reasonable to anticipate that the concentration of ^{137}Cs may also increase in close proximity to the source.

The Building 3001/3019 exploration program is designed to provide wide areal distribution, investigate specific areas with known historic leaks, and bracket or eliminate specific areas which might be reasonably considered to be sources for the CH-8 plume. Isotopic comparisons among groundwater analytical results both between new well locations and between those and CH-8 will also provide information about the possibility of multiple contaminated areas.

While considering all possible exploration result combinations is not feasible, several scenarios are considered in the exploration program which will lead to relatively definitive data interpretations and decision rules. For example, if only those wells located near known pipeline leak sites (near soil borings SB130 and SB132) meet the criteria for source definition, a local, and possible sole, source area will be interpreted. If the new core hole near piezometer 583 encounters significant contamination in Unit D at depth, a down dip migration interpretation will be made; the converse would also be made.

If significant contamination is encountered in all wells, an areally disperse contamination distribution interpretation will be made. Numerous interpretations are possible if such contamination is encountered in only a limited number of wells, depending on the levels of contamination and the distribution of wells. In both cases, however, the apparent contaminant distribution can be described to aid decision making about the need for additional data or possible remediation alternatives.

If significant contamination is not encountered in any well, two interpretations are possible. First, extensive contamination does not exist in Unit D in the area and CH-8 contamination is from another area, or the contaminant-containing cavities were not encountered by the comparatively small boring and the area will remain as a candidate for significant contamination. At this time, it is likely that the former interpretation will be made.

7.4.2 Underground Tanks

As described in Chap. 6, data associated with underground tanks are limited to monthly dry well sampling and tank level data. These data are used to determine tank inleakage/outleakage and the radiological content of dry well data to identify tank excursions. Groundwater data are limited to areas outside the near vicinity of the tanks in undisturbed material. Essentially no groundwater data are available from the excavations in the immediate vicinity of the tanks. Inferences from saturated soil borings suggest that NTF groundwater is

contaminated, and STF groundwater is not. Similarly, soil contamination is at depth in the NTF and in shallower soils in the STF.

The principal objective of data acquisition in the near vicinity of underground tanks is to obtain groundwater elevation data to describe the configuration of the water table in the immediate vicinity of the tanks, and in the case of the NTF and STF, within the excavations surrounding the tanks. A secondary objective is to compare water quality data at those locations with similar data from tank dry wells on the opposite sides of the tanks to describe the distribution of contaminants in the near vicinity of the tanks.

Isotopic comparisons among samples will determine the source of contamination currently identified in tank dry well monthly sampling. For example, if contaminant levels and compositions in an upgradient drive point are similar to a tank dry well, it can be concluded that a contaminant source exists outside the tank excavation. Isotopic and contaminant level dissimilarities would lead to different conclusions depending on the locations and extent of the dissimilarities.

7.4.3 Isotopes Area

Data acquisition and monitoring in the Isotopes Area are designed to serve several purposes. Monitoring of the Building 3033 sump, PWT system manholes MH 114 and MH 233, and the new corehole west of Building 3038 seek to identify sources of contamination. Contaminant level and composition comparisons among samples and with locations in the Hillside area are intended to help determine whether the contamination is from a local or remote source. The new core hole will investigate the possibility of a CH-8 "mirror image" contaminant plume migrating to the east. Analyses from MH 114 and MH 233 will also be used to evaluate contaminant flux through those areas of groundwater collection and possible collection of UST contaminants.

Monitoring Stockdale core hole 33 and comparison of the results with surrounding sampling locations will assess the possibility of underflow of Fifth Creek. A definitive positive result will likely only occur with the presence of similar isotopes as those found in the Isotopes Area and an absence of those isotopes in piezometer 622 further to the east. If the analytical results indicate an absence of contamination, the core hole will likely be recommended for plugging and abandonment. Monitoring piezometer 598 will look for excursions from previous analytical results. An excursion will be considered to be a factor of 2 or 3 higher than previous results and will initiate an immediate resampling. Confirmation of the elevated values and continued rising values in subsequent sampling events would likely be interpreted as changing conditions (e.g., a broken pipeline in the area) and would initiate more aggressive investigations. The nature of those investigations cannot yet be determined.

7.4.4 CH-8 Plume

CH-8 plume investigations seek to (1) identify a contaminant source(s), (2) further characterize the areal and vertical distribution of the plume, and (3) initiate a contaminant plume interception early action. Criteria to describe the presence of a contaminant are discussed in Sect. 7.3.1 above. Plume characterization will be a simple presence/absence determination from sampling with the bulk of the gross beta activity composed of ^{90}Sr . The precise locations for plume interceptor trenches will be determined after the results from characterization are obtained. At present, however, it is envisioned that a trench location very near the western WAG boundary, one nominally 300 to 400 ft west of CH-8, and an interception gallery adjacent to the storm sewer manhole north of Building 2013 will be installed. The use of CH-8 as a contaminant removal location is also considered likely. Exploratory wells which encounter significant contamination may also be considered as removal locations.

7.4.5 Oak Ridge Research Reactor

Explorations and monitoring associated with the ORR are primarily related to migration pathway investigations from the Building 3001/3019 area. Contaminant levels and compositions will be compared with results from the locations in the Building 3001/3019 area. The comparison will reveal the areal distribution of contaminants.

7.4.6 Pipelines

Pipeline studies are intended to determine if contaminants are migrating through trench backfill material for discharge to surface water. Identification of contaminants in a pipeline trench sample will initiate an immediate confirmatory resampling. Remedial measures to halt contaminant discharge through the backfill material will depend on the level of contamination and specifics of the problem. The overall objective will be to identify the source of the contamination, stop seepage into the trench, and stop the discharge to surface water.

7.4.7 Well 830

Nonintrusive spring and seep sampling adjacent to WOC south of well 830 will seek to determine if contaminants identified in the well are discharging to the creek. Remedial measures to halt the discharge(s) will depend on the specific conditions encountered.

7.4.8 Monitoring at Other Locations

The objective of monitoring at other locations which exhibit contamination is to maintain continuous record and to watch for temporal changes. Excursions from historic results will initiate confirmatory resampling. Potential remedial measures will consider the extent of contamination, its areal distribution, and possible source(s).

7.5 SAMPLE TRACKING AND RECORDS MANAGEMENT

In order to meet the regulatory requirements for the acquisition of legally defensible data, analytical results and accompanying QA reports must be collected, managed, and analyzed in a well-documented and efficient manner. To meet this requirement, staff supporting the ER Program must follow an environmental information management process throughout the collection, management, storage, and analysis of their site characterization data. The overall goal of this process is to minimize the impact of uncertainties associated with data management activities on the execution of the project and the interpretation and application of its results. This section describes the specific activities that must be conducted during the environmental information management process associated with site characterization studies.

7.5.1 Sample and Analysis Planning

Data needs based on project objectives have been defined prior to the initiation of the field and analytical activities. During the development of the DQOs, specific concentration levels of concern for each analyte to be collected are determined, and specific analytical methods and detection limits are set. Plans for the collection of field and laboratory QC samples (including field blanks, trip blanks, equipment rinsates, laboratory blanks, surrogates, calibrations, matrix spikes, etc.) are finalized and summarized. All applicable Sampling and Analysis Plan data (including sample identification, sampling locations, depths, media, equipment, analysis types, bottles, preservatives, etc.) are entered into a WAG 1 Site ER data base. Tables 7.1 and 7.2 show the WAG 1 water level and water quality monitoring plans.

The locations listed in Table 7.1 will provide a reasonable areal distribution of wells and piezometers that will describe the overall configuration of the water table surface for baseline water monitoring. More importantly, however, the information about area-specific data can be put into the context of the overall WAG to address issues such as flow and transport mechanisms and contaminant flux out of WAG 1. Sampling locations listed in Table 7.2 are selected to monitor areas of concern described in Chap. 6 and to evaluate and monitor contaminant transport pathways. The sampling frequency is selected to monitor temporal variations in contaminant concentrations at different stages of the precipitation year. From these data, estimates can be made regarding contaminant flux during both dry and wet periods.

7.5.2 Field Sampling Preparation

Standardized reporting forms for field and analytical results and QA/QC information will be created. All field personnel will be trained in filling out field data sheets, use of proper reporting units, characterization codes, chain-of-custody procedures, and documenting deviations from the Sampling and Analysis Plan. Preprinted field log sheets, groundwater collection forms, labels, and tags will be generated based on the Sampling and Analysis Plan.

Table 7.1. WAG 1 water level monitoring plan^a

Location	Area	Frequency	Location	Area	Frequency
539	CH-8	Continuous	543	2500	Monthly
561	CH-8	Continuous	544	2500	Monthly
812	CH-8	Monthly	577	2500	Monthly
560	CH-8	Monthly	554	2500	Monthly
555	2000	Monthly	542	2500	Monthly
582	3001/3019	Monthly	548	2500	Monthly
573	3001/3019	Monthly	553	2519	Monthly
581	3001/3019	Monthly	563	2533 sump	Monthly
603	ORR	Monthly	566	2533 sump	Continuous
607	ORR	Monthly	592	3500	Monthly
588	ORR	Monthly	601	3500	Monthly
589	ORR	Continuous	604	3500	Monthly
611	Fifth Cr.	Monthly	599	3500	Monthly
616	ISO	Monthly	600	3500	Monthly
608	ISO	Monthly	873	3500	Continuous
591	3026	Monthly	886	3500	Continuous
584	3026	Monthly	627	4500	Monthly
590	3026	Monthly	626	4500	Monthly
818	SWSA 2	Continuous	537	1500	Monthly
820	SWSA 2	Monthly	1102	IMP	Monthly
622	SWSA 2	Monthly	883	IMP	Continuous
631	SWSA 2	Monthly	882	IMP	Monthly
634	SWSA 2	Monthly	878	IMP	Continuous
814	NW	Monthly	876	IMP	Monthly
546	NW	Continuous	1103	IMP	Monthly
547	NW	Monthly	579	IMP	Monthly
549	NW	Continuous	874	IMP	Monthly
545	NW	Monthly	578	STF	Monthly
587	NW	Continuous	827	SWSA 1	Monthly
815	N	Monthly	828	SWSA 1	Continuous
557	N	Monthly	829	SWSA 1	Monthly
540	First. Cr.	Monthly	721	SW	Monthly
810	Unit F	Monthly			

^aAbbreviations used in the table: IMP = Impoundments Area, ISO = Isotopes Area, N = area north of WAG 1 boundary, NW = area northwest of WAG 1 boundary, ORR = Oak Ridge Research Reactor (3042), STF = South Tank Farm, SW = area southwest of WAG 1 boundary, SWSA = solid waste storage area.

Table 7.2. WAG 1 water quality monitoring plan^a

Location	Area	Parameters	Frequency (per year)	Notes
830	2500	Tritium	2	ILW leak
553	2519	Metals, BTEX, TPH	2	Diesel UST, high metal concentrations
2531 sump	2533 sump	Alpha, beta, tritium	2	2533 sump plume monitoring
2533 sump	2533 sump	Alpha, beta, tritium	2	2533 sump plume; LLW leak
567	2533 sump	Alpha, beta, tritium	1	2533 sump plume monitoring
564	2533 sump	Alpha, beta, tritium	2	2533 sump plume monitoring
566	2533 sump	Alpha, beta, tritium	2	2533 sump plume monitoring
SB132	3001/3019	Alpha, beta, tritium, isotopics	2	LLW leak; CH-8 source investigation
584	3026	Alpha, beta, tritium	2	LLW leaks; high alpha and beta
590	3026	Alpha, beta, tritium	2	Leaks/spills from 3024, 3026, WC-4
601	3500	Alpha, beta, tritium, mercury	2	Elevated rad; mercury from 3503
599	3500	VOCs	2	Elevated VOCs
593	3525	Alpha, beta	1	Monitor elevated alpha and beta
824	WOC	Mercury	2	Mercury from 4501 and/or 4508
CH-8: 2 and 3 ^b	CH-8	Alpha, beta, tritium, isotopics	2	CH-8 plume investigation
812	CH-8	Alpha, beta, tritium, isotopics	2	CH-8 plume monitoring
535	CH-8	Alpha, beta, tritium, isotopics	2	CH-8 plume underflow of First Creek
539	CH-8	Alpha, beta, tritium, isotopics	2	CH-8 plume monitoring
874	IMP	Alpha, beta, tritium	2	Rad monitoring downgradient of impoundments
875	IMP	Alpha, beta, tritium	2	Rad monitoring downgradient of impoundments

Table 7.2 (continued)

Location	Area	Parameters	Frequency (per year)	Notes
885	IMP	Alpha, beta, tritium	2	Rad monitoring downgradient of impoundments
876	IMP	Alpha, beta, tritium	2	Rad monitoring downgradient of impoundments
1102	IMP	Alpha, beta, tritium	2	Rad monitoring downgradient of impoundments
1103	IMP	Alpha, beta, tritium	2	Rad monitoring downgradient of impoundments
1104	IMP	Alpha, beta, tritium	2	Rad monitoring downgradient of impoundments
SB189	IMP	Alpha, beta, tritium, isotopics	1	Confirm high beta and ⁶³ Ni
598	ISO	Alpha, beta, tritium, isotopics, VOCs	2	Monitor elevated rad and VOCs; confirm ⁶³ Ni
3033 sump	ISO	Alpha, beta, tritium, isotopics	2	Source investigation
MH114	ISO	Alpha, beta, tritium, isotopics, BTEX, TPH	2	Source investigation
MH233	ISO	Alpha, beta, tritium, isotopics, BTEX, TPH	2	Source investigation
Stockdale CH33	ISO	Alpha, beta, tritium, isotopics	2	Source investigation; underflow of Fifth Cr
549	NW	Alpha, beta, tritium, isotopics, metals, VOCs	1	Monitor elevated rad, metals, and VOCs
538	NW	Alpha, beta, tritium, metals, VOCs	1	Monitor elevated rad, metals, and VOCs
547	NW	Alpha, beta, tritium, metals, VOCs	1	Monitor elevated rad, metals, and VOCs
3042 sump	ORR	Alpha, beta, tritium, isotopics, BTEX, TPH	2	Confirm groundwater rad contam; source investigation
571	SWSA 1	Alpha, beta, tritium, isotopics	2	Monitor poss contam migration
622	SWSA 2	Alpha, beta, tritium	2	Monitor poss contam migration
4501 sumps (4)	4501	Mercury	2	Monitor mercury contamination
559	3108	BTEX, TPH, alpha, beta, tritium	2	Petroleum UST; monitor rad

Table 7.2 (continued)

Location	Area	Parameters	Frequency (per year)	Notes
555	2026	BTEX, TPH, alpha, beta, tritium	2	Petroleum UST; monitor rad
581	3002	BTEX, TPH, alpha, beta, tritium	2	Petroleum UST; monitor rad
583	NTF	BTEX, TPH, alpha, beta, tritium	2	Petroleum UST; monitor rad
600	3598	BTEX, TPH, alpha, beta, tritium	2	Petroleum UST; monitor rad
614	3027	BTEX, TPH, alpha, beta, tritium	2	Petroleum UST; monitor rad

^aAbbreviations used in the table: BTEX = benzene, toluene, ethylbenzene, xylenes; ILW = intermediate-level waste; IMP = Impoundments Area; ISO = Isotopes Area; LLW = low-level waste; NTF = North Tank Farm; NW = area northwest of WAG 1 boundary; ORR = Oak Ridge Research Reactor; (3042); SWSA = solid waste storage area; TPH = total petroleum hydrocarbons; UST = underground storage tank; VOC = volatile organic compound; WOC = White Oak Creek.

^bCH-8 will be monitored in intervals 2 and 3.

7.5.3 Field Sample Collection and Measurement

The preprinted field log sheets will be bound into logbooks and carried into the field. As samples are collected in the field, the logbooks will be used to record required measurements (including temperature, conductivity, pH, purge volumes, radiation and organic vapor analyzer measurements, etc.) by the field team personnel. All deviations from the Sampling and Analysis Plan will be noted, and the logbooks will be signed and verified. All sample measurement data from the field logbooks plus well construction forms, lithologic logs, and other field characterization information will be entered manually (using double data entry and comparison protocols) into appropriate data tables.

7.5.4 Chain-of-Custody Reporting

Sample bottles will be tracked from the field collection activities to the analytical laboratory following proper chain-of-custody protocols and using standardized chain-of-custody forms. The analytical laboratory will return a copy of the chain-of-custody form to the data generator immediately upon receipt of the sample containers. The sample receiving report supplied by the analytical laboratory will be reviewed and compared to the Sampling and Analysis Plan to ensure that the proper chemical and radiological analyses are carried out. Sections 8.2.4 and 8.3.5 contain more detailed information about sample preservation and chain of custody.

7.5.5 Analytical Laboratory Interaction and Communication

Standardized formats for manual and electronic transfer of results and associated QA/QC information from the analytical laboratory to the data generator will be established before submission of analytical results. The analytical laboratory will undergo pre-award audits, and subsequent surveillances will be conducted to ensure compliance with sample handling and analytical result reporting requirements. Any problems encountered will be handled through nonconformance reporting.

7.5.6 Data Verification and Validation

Data packages received from the analytical laboratory will be reviewed and verified using EPA's Contract Laboratory Program Contract Compliance Screening software (or equivalent checklists for non-Contract Laboratory Program methods). All data packages received from the analytical laboratory will then be validated using Computer Assisted Validation and Evaluation Analysis Tool software (which follows EPA's *Laboratory Data Validation Functional Guidelines for Evaluating Organics Analyses*). Radiochemical data validation will meet the criteria specified in EPA/540/G-93/071. The output (checklist or exception reports) from both the data verification and data validation steps will be reviewed and evaluated by the data validators. Final data usability flags based on the data validation process will be appended to each analytical result and stored in the WAG 1 data base. Data validation will

be performed by a subcontractor, and detailed data validation procedures prepared by the subcontractor will be included as an addendum to this report when completed.

7.5.7 Data Centralization and Storage

All Sampling and Analysis Plan data, field collection and measurement data, chain-of-custody data, analytical results, applicable QA/QC information, and validation flags will be linked and stored in appropriate data tables. A standardized set of data tables, relations, and characterization codes will be used for storing site characterization data.

7.5.8 Historical Data Loading

An evaluation of existing (historical) data sources, including an analysis of data types, content, sources, formats, and current methods of handling and storage, will be conducted. The historical data files will then be transferred to the appropriate data tables, renamed, and reformatted, and the characterization codes will be standardized.

7.5.9 Data Evaluation

Field and analytical result measurements that are at or below the detection limits will be clearly identified in the data base with a data qualifier flag. The number of significant figures reported for raw data will reflect the precision of the measurement technique. The distribution of the site characterization data will be tested for normality. Data values determined to be potential outliers will be corrected only if the cause of the deviation can be documented. Data precision will be determined by examining field duplicate and analytical duplicate (or split) results. Data accuracy will be determined by examining matrix spike, surrogate, and interval standard results. Data representativeness will be determined by evaluating field blank, trip blank, equipment rinsate blank, and analytical laboratory blank results. Data completeness will be determined by comparing the final number of validated sample results obtained in the investigation to the number of samples required by DQOs and stated in the Sampling and Analysis Plan. Data comparability will be determined by comparing newly collected site characterization information to data previously attained using similar sample collection and laboratory analysis methods.

7.5.10 Graphical Display

Site characterization data will be arranged and presented in a clear and logical format using standardized graphical and geographical methodologies. Plots of individual analyte data (and statistical summary information) showing the changes in contaminant concentrations over time will be produced.

7.5.11 Geographical Display and Spatial Analysis

The following geographical displays and spatial analyses will be generated from the data:

- maps displaying raw data values and summary statistics (mean, minimum, and maximum) of chemical and radiological concentrations at each sampling location;
- maps of groundwater elevations, surface and subsurface water flows, and other hydrogeological parameters;
- maps displaying those analytes that exceed regulatory limits or background levels; and
- maps of the geographical (lateral) extent of contamination and the vertical distribution of contaminants.

7.5.12 Data Summarization and Reporting

Standardized data reports will be developed that present results clearly and with standardized annotation and clearly referenced data sources. A sorted tabular listing of raw chemical and radionuclide concentrations will be created. Reports will be produced containing the following information:

- a summary of chemical and radionuclide concentrations at each sampling and/or measurement location for each sampling and/or measurement period,
- comparisons of the estimated chemical and radionuclide concentration at each sampling and/or measurement point to previous concentration estimates at that point,
- comparisons of the estimated chemical and radiological concentrations at each sampling and/or measurement point to established regulatory standards, and
- comparisons of the estimated chemical and radionuclide concentrations at various sampling and/or measurement locations to those at background or control locations.

7.5.13 Document Control and Records Management

Paper copies of all original field and analytical results, data reduction and summarization programs, data packages and associated QA/QC information, and chain-of-custody forms will be indexed, cataloged into appropriate file groups and series, stored on optical disk, and archived. All electronic versions of environmental data (including computer programs used to manipulate or report the data) will be backed up and archived periodically. These requirements are intended to address the requirements of ES/ER/TM-4/R1.

Samples will be tracked by chain-of-custody forms until the samples are received in the laboratory and by the laboratory tracking system thereafter. Analytical results will be stored in the WAG 1 Site ER data base after the analytical results are obtained.

8. FIELD QUALITY ASSURANCE PROJECT PLAN

8.1 INTRODUCTION

This Field QAPjP addresses field activities only. A separate Laboratory QAPjP will be prepared in accordance with the Laboratory Quality Assurance Plan approved by the ORNL APO and will address QA issues related to laboratory analyses. Sections describing the project objectives and organization, data quality objectives, and the sampling and analysis plan are found in the Field Sampling Plan (Chap. 7). This document implements the requirements of ES/ER/TM-4/R3, *Environmental Restoration Quality Program Plan*.

8.2 SAMPLE COLLECTION PROCEDURES

8.2.1 Groundwater Monitoring Well Installation and Development

Shallow groundwater quality wells will be Type 304 stainless steel, screened across the water table, and will meet the following well construction specifications:

1. Construction of shallow groundwater wells will be in accordance with specifications illustrated in Fig. 8.1.
2. Water quality wells will be constructed of Type 304 stainless steel. Scoping wells or wells/piezometers used only for measuring water levels may be constructed of other approved materials.
3. Wells will be screened across the water table. A 1- to 2-ft long casing/sediment trap will be installed below the screen.
4. The height of the sandpack will extend at least 2 ft above the top of the screen. However, some shallow wells (i.e., those less than about 15 ft deep) may require less sandpack thickness to accommodate the 2-ft-thick bentonite pellet seal. The shallow depth will allow visual confirmation that the sandpack has been placed without bridging, thus preventing subsequent consolidation of the sand and potential exposure of the screen.
5. The length of the screen will vary with stratigraphy, but will be 10 ft or less.
6. A bentonite pellet seal will extend approximately 2 ft above the top of the sandpack. If the hole is dry, the pellets will be wetted with potable water to initiate expansion of the bentonite seal. A cement-bentonite grout will be tremied in place above the top of the bentonite seal to ground surface.
7. A structurally sound concrete pad with either an upright protective casing or roadbox (if flush-mounted) will be placed at the surface. Where upright protective casing is used, four guardposts will be installed around the casing and pad.
8. For flush-mount installations, the well will be secured with a locking sanitary seal at the top of the riser pipe. For above-ground installations, the well will be secured with an inner cap on the riser pipe and a locking protective steel outer casing.

Fig. 8.1. Construction standards for shallow groundwater quality wells.

9. Wells will be developed using a combination of surging and pumping as described in this supplement and in accordance with ESP-600 (Energy Systems 1990b).

Deep groundwater quality wells will be Type 304 stainless steel, screened in deeper water-bearing fractures at selected depths below the top of competent rock, and will meet the following well construction specifications:

1. Construction of deep groundwater wells will be in accordance with specifications illustrated in Fig. 8.2.
2. Water quality wells will be constructed of Type 304 stainless steel. Scoping wells or wells used only for measuring water levels may be constructed of other approved materials.
3. A steel casing, permanently grouted in place, will be installed from ground surface to at least 2 ft below the top of competent rock. This will limit the potential for cross-contamination between upper and lower portions of the aquifer. Isolation casing will be installed as needed to prevent potential cross-contamination below surface casing.
4. Deep wells will be screened below the top of competent rock in a lower prominent fracture zone ("Fracture," as used in this criterion, includes solution channels, voids, etc.).
5. The length of the screen will be 15 ft maximum and will vary with the nature and extent of the fracture(s) encountered. A 1- to 2-ft long casing/sediment trap will be installed below the screen.
6. A bentonite pellet seal will extend at least 2 ft above the top of the sandpack. It will be installed below the top of competent rock. A cement-bentonite grout will be tremied in place above the top of the bentonite seal.
7. A structurally sound concrete pad with either an upright protective casing or roadbox (if flush-mounted) will be placed at the surface. Where upright protective casing is used, four guardposts will be installed around the casing and pad.
8. For flush-mount installations, the well will be secured with a locking sanitary seal at the top of the riser pipe. For aboveground installations, the well will be secured with an inner cap on the riser pipe and a locking protective steel outer casing.
9. Wells will be developed using a combination of surging and pumping as described in this supplement and in accordance with ESP-600.

A detailed drilling log will be kept by a field geologist and will include (at a minimum) description of soil and rock materials and their characteristics, drilling procedures/bit type and sizes used, air/water circulation loss, and drilling progress. Selection of the screened interval will be made by the WAG 1 RI Project Manager and will be supported by examination of drill logs, bedrock core, and/or saturated conditions encountered during drilling. As a minimum, the drilling log will also list the personnel present, drilling equipment used, weather conditions, well designation, location, type and size of casing and well screen, depth of well screen, and total drilled depth. This information will also be presented in well construction diagrams similar to Figs. 8.1 and 8.2 as appropriate.

The piezometer risers and screens will be nominal 2-4-in.-diam stainless steel for providing water quality data and schedule-40 PVC for water level data. If geologic conditions

NOT TO SCALE

Fig. 8.2. Construction standards for deep groundwater quality wells.

are favorable, stainless steel piezometer materials may be driven. Water levels will be monitored to assess groundwater occurrence, fluctuation, and gradient (Sect. 8.2.2).

Wells will be installed in boreholes drilled through both soil and bedrock. At locations where borings will be progressed through rock, a permanent steel casing will be grouted in place at least 2 ft below the top of competent bedrock. Augers used to drill through the overburden will be removed and a divertor casing will be installed (i.e., grouted in place) to facilitate containment of drill cuttings during installation of permanent casing. The borehole will then be advanced at least 2 ft into competent rock with a roller bit using air rotary techniques. A permanent steel casing with centralizer will be lowered in place below the top of competent rock to the total depth of the borehole, displacing grout up the annular space between the borehole and the casing. Alternatively, pressure grouting through the casing may be performed until the annulus is completely filled. A setup period of not less than 24 h will be allowed before the borehole is advanced below the permanent surface casing. A roller bit will be used to drill out grout and/or the PVC end cap at the base of the permanent casing. During air rotary operations, a divertor will be used to capture drill cuttings and collect them in a containment box.

Air rotary techniques will be used to progress the borehole below the permanent casing. At deep well locations, the boring will be progressed to a selected depth below the top of competent rock. The depth selection will be based on the compilation and assessment of existing water quality data, evaluation of existing wells and hydrologic data, Close Support Laboratory screening analyses, and water level data developed during Phase I of the RI. Final consideration will include all of these background data categories and all of the data generated from drilling and testing the boring.

Upon completion of drilling and data assessment, the screened interval will be chosen. If the chosen screened interval is shallower than the total depth of the boring, the lower portion of the borehole to be abandoned will be plugged back to the bottom of the proposed screened interval. Plugging materials will include cement-bentonite grout with a maximum 2-ft-thick bentonite pellet plug at the top. Grouting will be performed using the tremie method.

Wells will be fabricated of sections of flush-coupled 2- or 4-in. inside diameter pipe; the diameter selected will be based on reported well recoveries of similarly installed existing wells. All couplings between sections of pipe will be threaded and wrapped with Teflon tape before joining. The bottom of each well screen will be fitted with a sediment sump and plug. All well screens will be 0.01-in. factory-slotted or wire-wound. Well construction materials will be decontaminated at the factory and transported to the site wrapped in an inert substance.

The annulus between the well and the wall of the borehole will be a minimum of 2 in. The annulus between the well screen and the borehole wall will be packed with clean sand compatible with the selected screen size and formation materials. Sand will extend about 2 ft above the top of the screened interval; sandpack height may be increased slightly to accommodate a seasonal high groundwater table or borehole conditions. A minimum 2-ft-thick

bentonite seal will be placed above the sandpack. The annular space not filled with sand or bentonite will be filled with cement-bentonite grout using the tremie method. Well installation will be performed in accordance with ESP-600, "Groundwater Sampling Procedures: Well Installation, Development and Abandonment" (Energy Systems 1990b).

Finished wells will be completed at the surface in one of two ways. The Project Manager will decide which surface finish configuration will be used for each well. One method is to install a 5-ft length of protective steel casing cemented approximately 2.5 ft into the ground. The protective casing remaining above the ground will have a locking cap and an identification tag, and guardposts will be cemented in place around the well. The second method is to install a flush-mount roadbox assembly completed at ground surface. The riser pipe within the roadbox will be fitted with a locking sanitary seal. All locks for new RI installations will be keyed alike.

Well development will be performed on all new wells constructed during the RI. Each well will be developed as soon as practicable but not before 24 h from the time the well was constructed. Development will remove fluids that were introduced during drilling and aquifer testing and sediments that entered the sandpack and screened interval during well installation. Encouraging the movement of formation waters through the well will ultimately decrease the time required for groundwater equilibration.

Well development will be accomplished by a combination of surging and pumping. Slow recharging or less-productive wells may be developed using a bailer. The well will initially be surged throughout the screened interval with a surge block. This will be followed by pumping throughout the screened interval with a purging apparatus constructed such that air is not directly forced into the formation. Wells will be developed until water clarity is significantly improved and a sufficient number of well volumes have been removed. The number of well volumes removed will depend on aquifer characteristics across the screened interval of the well, such as recovery, but will generally be at least three. Procedure ESP-600 (Energy Systems 1990b) guidance will be followed for performing and terminating well development at a given well.

Temporary piezometers will be installed in pipeline trenches to an estimated maximum depth of 10 ft. If geologic conditions are not favorable for driving, an alternative means of penetration may be required (e.g., small-diameter power auger or hand auger). A stainless steel piezometer will be installed to the bottom of the augered hole and backfilled with sand to about 1 ft above the screened interval. A PVC piezometer may be used at augered locations where water levels are the primary concern. A bentonite seal will be installed from the top of the sand pack to the ground surface.

Some development efforts may be performed at piezometer locations to encourage the movement of formation water. Purging will be accomplished using either small-diameter tubing and foot valve (i.e., inertial system) or peristaltic pumps.

Disposal of soil, water, and sediments removed during development will be in accordance with the Waste Management Plan for the WAG 1 RI/FS study. All equipment used during well installation and development will be decontaminated in accordance with ESP-900, "Cleaning and Decontaminating Sample Containers and Sampling Devices," and/or ESP-901, "Equipment Decontamination."

8.2.2 Well Abandonment

If the well must be abandoned during installation, the grouting will be accomplished progressively as the casing (or hollow stem auger) is withdrawn. The casing(s) and screen of any well to be abandoned will be removed, if required by the Plugging and Abandonment Plan. The borehole will be grouted from the bottom up by the tremie method. The grout will be pumped until it reaches the ground surface. The site will be checked for grout settlement after 24 h and any depressions will be refilled with grout and rechecked until hardened grout is flush with the ground surface.

If not previously surveyed, the abandoned well site will be surveyed and located on a suitable map. All casings, screen or other material removed from an abandoned well will be characterized for contamination and disposed of accordingly or decontaminated.

8.2.3 Groundwater Level Measurements

Groundwater level measurements are needed to assess seasonal fluctuations of the water table surface during dry and wet conditions. The objective of this task is to obtain information to assess groundwater flow direction, hydraulic gradients, seasonal high and low water table conditions, groundwater and pipeline trench interactions, and the relationship between groundwater and surface water flow regimes.

Water level data will be obtained from newly installed and developed wells and piezometers, existing piezometers and wells, and selected stream locations. Actual locations will be chosen based on evaluation of existing wells.

Collection of any single round of discrete water level measurements will occur on the same day. Water levels will be measured to the nearest 0.01 ft, in accordance with ESP-302-1, "Groundwater Sampling Procedures: Water Level Measurements Using Water Level Indicator" (Energy Systems 1990b). All measuring devices will be calibrated with an approved standard. Calibration documentation is required as a quality assurance record.

Continuous water levels will be collected from selected wells using a data logger and transducers with appropriate PSI ratings. Water level and barometric measurements will be gaged and electronically recorded at 8-h intervals. Data will be transferred daily from the data logger memory to a hard disk.

All water level measuring instruments that contact groundwater will be decontaminated in accordance with ESP-901 "Equipment Decontamination" (Energy Systems 1990b). As they

are removed from the well, all cables and probes will be wiped down using a cloth saturated with isopropyl alcohol.

8.2.4 Groundwater Sampling

The objective of this task is to investigate the types and range of concentrations of contaminants in the groundwater. Contaminant concentrations, groundwater chemistry, estimated flow directions and rates, and contaminant mobility and toxicity will be used to locate sources of contaminants, assess the potential impact of contaminants from WAG 1 sources on potential receptors, and evaluate remedial alternatives.

Groundwater samples will be analyzed for the parameters listed in Table 8.1. For each sampling event at each location, both field-filtered and nonfiltered methods will be performed for metals and radiological constituents to support development of remediation alternatives by identifying dissolved, colloidal, and settleable solid contaminants in groundwater. Sample cooler temperature and pH checks will be recorded with date and time both when the coolers are shipped and received by the analytical laboratory to ensure temperature and pH maintenance during transit. Field QC samples will be collected at the frequencies stated in Sect. 8.9 to assess the quality of the field sampling effort.

RCRA compliance quality wells will be sampled using dedicated bladder pumps. Non-dedicated samplers such as bailers, peristaltic pumps, and inertial lift systems (i.e., tubing and foot valve) and all purging devices that will be used at other locations will be decontaminated after each sampling. All hoisting lines will be dedicated, used once and then disposed of in accordance with procedures described in the Waste Management Plan, or constructed of Teflon/stainless steel and will be decontaminated after each use. A general sequence for purging and sampling is as follows:

- Measure the water level in accordance with ESP-302-1.
- In productive wells (i.e., sufficient water inflow to allow continuous purging), purge by pumping and simultaneously measure the pH, Eh, specific conductivity, and temperature of each well volume.
- In less-productive wells (i.e., wells that can be purged to “dryness”), purge by bailing or pumping and make one measurement of pH, Eh, specific conductivity, and temperature.
- Collect the samples and handle as described in Sect. 8.3. Sampling of wells that are purged to “dryness” will be performed after sufficient recharge, but not more than 24 h after purging is completed.

Productive monitoring wells will be purged and sampled using a piston pump or positive displacement bladder pump. Alternatively, wells may be purged with a 2-in. stainless steel electric submersible pump or an air-displacement pump and sampled with a bottom-loading stainless steel or Teflon bailer. All sampling equipment in contact with the sample will be constructed of either stainless steel or Teflon. For purging, the intake of nondedicated pumps will be placed below the top of the water column and lowered as the water level is drawn down by pumping. Lowering will continue during drawdown in order to completely remove

Table 8.1. Requirements for groundwater samples collected in WAG 1

Parameter	Holding time ^a	Container	Preservative	Minimum sample size (mL)
Volatile organics (BTEX) ^b	14 d	Two 40-mL glass vials with Teflon-lined caps	4 drops concentrated HCl, 4° C	40
Chlorinated hydrocarbons	7 d ^c 40 d ^d	Two 40-mL glass vials with Teflon-lined caps	4 drops of 10% sodium thiosulfate, 4 drops concentrated HCl, 4° C	40
Total petroleum hydrocarbons	28 d	Glass jar with Teflon-lined cap	4° C	1000
Metals	6 months	Polyethylene bottle	HNO ₃ to pH <2.0, 4° C	100
Mercury	28 d	Polyethylene bottle	HNO ₃ to pH <2.0, 4° C	100
Gross alpha/beta	6 months	Polyethylene bottle	HNO ₃ to pH <2.0	1000
Tritium	45 d	Glass bottle	None	250
Isotopics ^e	6 months	Polyethylene bottle	HNO ₃ to pH <2.0	1000

^aFrom time of collection.^bBTEX = benzene, toluene, ethylbenzene, xylenes.^cFor extraction.^dFor analysis.^eFission products comprising alpha- and beta-emitting radionuclides at ORNL.

the water column, and purged water will be passed directly from the pump discharge tubing into a chamber. Field parameters (pH, Eh, specific conductivity, and temperature) will be measured in the chamber before the water contacts the atmosphere.

Radiological scans will be performed at the discharge of the chamber. Samples will be collected from the discharge tubing when the field parameters remain stable (within 10 percent of consecutive well volume measurements) or at least three well volumes of water have been purged from the well. A well volume is defined as the volume of water contained

in the well at the onset of pumping. Less-productive wells may be purged and sampled using bottom-loading stainless steel bailers. The well will be bailed dry and allowed to recharge sufficiently before sample collection.

Before preservation, both field-filtered and nonfiltered aliquots will be obtained for metal and radiological constituent sampling. The remaining aliquots will not be filtered in the field before preservation. Requirements for sample containers and methods of preservation will be in accordance with EPA/540/G-93/071.

Specific guidance and field procedures for well purging and sampling are included in ESP-302-2, ESP-302-3, ESP-302-4, and ESP-302-5 (Energy Systems 1990b). Requirements for sample labeling and chain of custody are described in Sect. 8.3. All sampling equipment that contacts groundwater will be decontaminated in accordance with ESP-901. "Equipment Decontamination," or ESP-900, "Cleaning and Decontaminating Sample Containers and Sampling Devices" (Energy Systems 1990b).

8.2.5 Groundwater Aquifer Testing

Aquifer testing may be performed on all new wells to aid the understanding of aquifer hydraulics and groundwater flow paths. Aquifer testing of existing wells will not be performed. Combining water level data (Sect. 8.2.2) with both new and existing well aquifer test values for hydraulic conductivity will allow calculation of transmissivity, groundwater velocity, and flow direction. Analytical methods will be determined by the Project Manager on the basis of aquifer geometry and hydraulic characteristics. The resulting data will be used to quantify the hydraulic conductivity of the groundwater system and assess the interaction of shallow and deeper zones of potential contamination.

Slug tests may be conducted using two different slug displacement methods (rising head and falling head). Initially, a weighted, stainless steel "pig," sized appropriately for the well being tested, will be inserted. The falling head recovery of the well will be recorded using either an electronic tape or transducer and data logger. After the well recovers to static conditions, the pig will be removed. The same recording method will be used to monitor the resulting rising head recovery. The rising head method is suited to most aquifer and well characteristics. The falling head method is best suited to fully submerged zones and will be used as appropriate for comparison with rising head test values.

Disposal of water generated during aquifer tests will be in accordance with the Waste Management Plan for the WAG 1 RI/FS. All equipment used will be decontaminated in accordance with ESP-901 (Energy Systems 1990b).

8.2.6 Corehole Installation, Development, and Testing

Drilling of the borehole through the overburden will be accomplished using a continuous flight hollow-stem auger. Soil samples will be taken at 2-ft intervals using a split spoon sampler in accordance with procedures established with the subcontractor performing the work. Upon auger refusal at the top of bedrock, 8-in. surface casing will be set from the ground surface to the top of bedrock and grouted in place. Six-inch inner casing will be set into competent bedrock to accommodate casing advancing equipment. A coring rig will then be mobilized to begin rock-coring activities.

Core will be obtained using a size HQ triple-tube wire-line core barrel with a diamond-impregnated coring bit using recirculated water as the drilling fluid. The water will be contained on site by a mud pan with baffles. The outer core barrel will remain at the bottom of the hole upon completion of a coring run (generally 10 ft) while the inner barrel will be retrieved. The core will be extruded out of the inner core barrel and then pushed or pulled out of the innermost barrel, which will be composed of Lexan tubing.

A detailed field log will be kept by the site geologist in accordance with ESP-303-6 for each corehole. As a minimum, log entries will include descriptions of lithology, discontinuities, fractures per foot, penetration rates, the length of the run, recovery in feet and percent, the core run number, and the associated box number. There will also be a column for comments, including any pertinent drilling information such as water loss or gain, rig chatter, and drillers' comments.

After each core section is described, it will be handled according to procedures described in ESP-303-6 (Energy Systems 1990b), including marking the core to avoid confusion concerning orientation (top versus bottom); placing the core in a sturdy wooden box with spacers at the bottom of each core run and in intervals of missing core; labeling the core box with the run number, associated depth, recovery in length and percent, WAG number, and corehole number; and photographing the core after it has been placed in the box.

Westbay multiport monitoring systems may be installed in selected coreholes. The use of multiport systems will be dependent on the presence of contamination, identification of discrete fracture zones, and on assessment of hydrogeologic conditions for the explored depths. The purpose of multilevel monitoring is to characterize the vertical distribution of contaminants and hydraulic heads by sampling and pressure testing discrete zones.

Sampling of discrete intervals in coreholes equipped with Westbay multiport systems will be performed by connecting a peristaltic pump to the appropriate sampling port with Teflon tubing. Before the sample is collected, each interval will be purged a total of three times its volume. Samples will be decanted directly into sample containers. Field blank, equipment rinsate, and duplicate samples will be collected as described in Sect. 8.9.

8.3 SAMPLE AND DOCUMENT CUSTODY PROCEDURES

In order to meet the regulatory requirements for the acquisition of legally defensible data, results and accompanying QA reports must be collected, managed, and analyzed in a well-documented and efficient manner. To meet this requirement, staff supporting the ER Program must follow an environmental information management process throughout the collection, management, storage, and analysis of site characterization data. The overall goal of this process is to minimize the impact of uncertainties associated with data management activities on the execution of the project and the interpretation and application of its results.

An integral part of field QA/QC measures will be maintenance of accurate and complete field records, including logbooks and appropriate field data forms. Field records will be recorded legibly in permanent ink and will be sufficiently complete for reconstruction of data-gathering activities by a qualified individual (other than the originator) when data are reduced. Field notebook entries should be factual, detailed, and objective. The field records will be the basis for later written reports, and all entries must be free of terminology that might prove inappropriate. The method of data reduction will be identified and recorded. Field-generated data will be collected and reviewed daily for accuracy and completeness by the Site Project Manager. The Site Project Manager will forward field notebooks to the WAG 1 ER Project Manager at the conclusion of field activities. The WAG ER Project Manager will be responsible for entering these data into the records management system.

8.3.1 Field Logbook

The field logbook will consist of preprinted and bound forms that have been devised based on the Sampling and Analysis Plan. The forms include the analytical requirements and QA/QC sample requirements. Information in these records will be obtained from the site exploration and sampling activities and will be reviewed by the sampling team leader. All information pertinent to field activities will be recorded. The preprinted forms call for the following information:

- project name or identification;
- names and affiliations of sample collector(s) and all individuals involved in the project, including visitors;
- general description of the day's field activities;
- documentation of weather conditions;
- samples collected and numbers assigned to them;
- date and time of sampling;
- source/location of the sample;
- method of sample collection;
- analyses required; and
- serial number(s) on seal(s) and transportation case(s), if any.

When samples are delivered to the laboratory for analysis, the chain of custody record number, date of shipment, number of shipping containers, samples sent, and delivery person's name will be recorded in the project notebook.

8.3.2 Site Logbook

The site logbook provides a centralized, easily available, and current source of field information. It is permanently bound, with serially numbered pages, and has a hard cover. The site logbook is a master record of all site investigation activities, and entries are usually made at the end of the day.

The site logbook chronicles all field investigation activities but does not have the same level of detail as the field logbook. It delineates conditions and activities occurring on a given day and references the appropriate field logbook forms for specific information. For example, to find specific information relative to the conditions under which a groundwater sample was taken, one would look in the site logbook for the appropriate day and find the reference to the field logbook for detailed information regarding the sampling event. The site logbook is also used to record *all* field changes with the supporting rationale. Sampling logs, dedicated instrument logs for calibration and maintenance information, and other specialized logs will often be needed in addition to the site and field logbooks.

The senior person on site responsible for the field effort is also responsible for completing the site logbook. This individual must sign and date the logbook at the end of each page. Pages should not be removed. All partially used pages must be "lined out" to prevent data entry at a later date. The front of the site logbook must list, as applicable, the project name and number, name of the subcontractor, and dates of use. The following items are to be included in the site logbook:

- Daily weather conditions and a brief outline of personnel present.
- Name, title, organization, and purpose of each visitor entering the investigation site during the day.
- A brief outline of scheduled or undertaken activities for each day and references to the appropriate field logbooks, forms, computer files, and records for details.
- Specific comments on problems that occurred during daily activities, their final resolution, and anticipated impact on the field investigation.
- Field changes or variances with references to the appropriate documentation of these changes.
- A record of telephone calls (incoming or outgoing) pertaining directly to the decision-making process of the field investigation and a summary of the content of these conversations.
- A list of all chain of custody details, including traffic reports, air bill numbers, analytical request forms, chain of custody forms, sample label or tag numbers, and laboratories to which samples were sent, or a reference to the field logbook where specific information

can be found. *(Note: This information, because of its importance, is the only detailed information placed in a site logbook.)* (See ESP-500 for the chain of custody procedure.)

- A record of instrument calibrations, including the names of personnel performing the calibrations, with reference to any specific calibration logs or field logbooks.
- A record of major equipment decontamination, with reference to the field logbook which contains specific documentation.

8.3.3 Specialized Logs

Specialized logs that may be required in addition to the field and site logbooks may include, but may not be limited to, the following:

- Instrument log: documents routine maintenance, repairs, or any other information relevant to instrument performance.
- Sample log: lists all samples submitted by the field crew.
- Analyses log: records analyses, including calibration samples, methods, blanks, matrix spikes, equipment rinsates, routine samples, and any other analyses.
- Standards log: records all standards for traceability. Must include standard manufacturer, lot number, and expiration date.

8.3.4 Sample Labels

At the time of sample collection, each sample should be identified by affixing a preprinted pressure-sensitive gummed label on the container. Any additional notations required on the label should be made in indelible ink. Information on the sample label includes:

- unique sample number,
- project number or identification,
- analysis required,
- name of collector(s), and
- date and time of collection.

8.3.5 Chain of Custody

Chain of custody will meet the requirements of ESP-500. After labeling, sample containers are placed in a transportation case (i.e., insulated cooler), which will be accompanied by a chain of custody record form. A minimum of two signed and dated paper security/custody seals are attached to two of the four ends of the cooler, so that the transportation case cannot be opened without breaking the seal. The seal should be placed where it will not be broken under normal handling conditions.

The chain of custody procedure creates an accurate written record that can be used to trace the handling and possession of a sample, from collection through analysis.

A sample is in one's custody if it is (1) in one's actual possession, (2) in one's view, after being in one's possession, (3) in one's physical possession and then locked up so that no one can tamper with it, or (4) kept in a secured area, restricted to authorized personnel only.

When transferring possession of samples, the person relinquishing custody will sign and record the date and time on the chain of custody record. Each sample will be accounted for by a custody transfer, although samples may be transferred as a group. Every person who takes custody should fill in the appropriate section of a chain of custody record; however, to prevent undue proliferation of custody records, the number of persons involved in the chain of possession should be minimized.

The sampling technician is responsible for seeing that samples are properly preserved, labelled, packaged, and dispatched to the laboratory for analyses. The responsibility includes completing and verifying data accuracy and then dating and signing the appropriate section of the chain of custody record.

8.4 FIELD MONITORING PROGRAM

Continuous real-time assessment of potentially hazardous chemical concentrations and surficial radiological levels will be performed while conducting operations during the WAG 1 RI. The deployment of monitoring equipment will depend upon the site-specific activities being conducted. This monitoring program, described in the Health and Safety Plan, is designed to protect all on-site investigative personnel from potential chemical and radiological contaminants. Additional specific procedures and details for the Health and Safety Plan will be prepared by a subcontractor and will be included as an addendum to this report when completed.

8.4.1 Instrument Calibration

All instruments will be calibrated according to established procedures or in accordance with applicable manufacturers' recommendations and specifications described in the manufacturer's operation manual. Readings will be recorded on the Daily Instrument Calibration Check Sheet, located in the field logbook in a section dedicated to calibration and vital information about the instruments. Such information includes instrument identification number, calibration procedure number, PM procedure number, and frequency of calibration. This information will be documented either in the field logbook or another readily available field log. Calibration acceptance criteria are included in each of the procedures included in this section. All instruments will have a calibration expiration date sticker or tag attached unless the instrument requires calibration by the user at the time of use.

8.4.2 Background Readings

Before any field activities commence, background concentrations and levels near the site will be monitored and recorded. Before each day of sampling activities, a designated sampler

will take each of the field monitoring instruments at least 20 ft upwind of the sampling area or 20 ft into the support zone and record the readings of those instruments. At a minimum, the background readings should be taken from the organic vapor monitor (OVM), the combustible gas indicator, the NaI scintillation detector, the Geiger-Müller (GM) pancake meter, and the ZnS alpha scintillation detector. To obtain accurate results, daily background readings will be taken away from areas of potential contamination. Background readings will be taken into account before an action level is established.

8.4.3 Chemical Monitoring

8.4.3.1 Chemical monitoring equipment

Equipment necessary for on-site environmental monitoring consists of an OVM or photoionization detector (equipped with an 11.8- or 11.7-eV lamp), and a four-sensor combustible gas indicator, such as a GasTech model GX-86. Chemical monitoring will be conducted according to ESP-307-6, Organic Vapor Detection (Energy Systems 1990b).

8.4.3.2 Chemical monitoring frequency and action limits

Volatile organic and combustible gas monitoring utilizing the OVM or GX-86, or equivalents, will be performed upon entering potentially hazardous investigation sites. Continuous monitoring using all chemical monitoring equipment required will be performed to ensure, within the levels of detection of the instrumentation employed, that the site is free of hazardous gas and radiation levels at the breathing zone. Soil samples suspected of having hazardous gas or vapor concentrations will be monitored with the OVM. The surrounding air, borehole at the surface, and soil sample cuttings will be monitored upon each split-barrel sampler or auger being brought to the surface. All data for each monitoring occurrence will be recorded.

The OVM has an alarm preset to 1.00 ppm. The GX-86 is equipped with a micro-processing unit that enables continuous monitoring of four parameters simultaneously. In addition, the unit has alarms preset for the parameters shown in Table 8.2.

**Table 8.2. OVM preset
alarm parameters**

Parameter	Low	High
LEL	10%	50%
O ₂	19.5%	22%
H ₂ S	10 ppm	30 ppm
CO	35 ppm	100 ppm

The action level for the OVM is 1.0 ppm. Table 8.3 lists action levels for the GX-86.

Table 8.3. Action levels for the GX-86

Parameter	Action level
LEL	10%
O ₂	<19.5% or >22%
H ₂ S	10 ppm
CO	35 ppm

Because of potential health hazards and unknown characteristics, if concentrations of volatile organics measured on the OVM exceed 1.0 ppm above background concentrations at the breathing zone for more than 30 s, all personnel, at the direction of the site health and safety officer (SHSO) should evacuate the work site upwind and to the border of the contamination reduction zone and the support zone. The same requirements for work site evacuation will be employed if any of the action limits developed for the GX-86 are met or exceeded for more than 30 s in the breathing zone. An industrial hygienist representing the WAG 1 site will be summoned to assess the potential hazard of the conditions and to determine whether work should continue.

8.4.4 Radiological Monitoring

8.4.4.1 Radiological monitoring equipment

All radiological monitoring equipment used in the field is required to have up-to-date calibration stickers. No instrument that is out of calibration will be used. It is also necessary to note that instrument and probe combinations are calibrated as a set; therefore, rate meters and probes will not be interchanged. If interchange becomes necessary, the rate meter and probe combination will be returned to a trained and qualified instrument technician, who will be responsible for calibrating the unit. Instrument response check measures performed in the field are *not* a substitute for calibration. Radiological equipment necessary to conduct on-site monitoring will consist of the detector systems (or equivalents) shown in Table 8.4. Radiological monitoring will be conducted according to ESP-307-7, Operation of Radiation Survey Instruments (Energy Systems 1990b).

8.4.4.2 Radiological scanning frequency and action limits

Radiological scanning for surface beta and gamma radiation will be performed at each borehole location before sampling begins. Evacuation will be required when the following action levels have been reached: (1) a count rate of 2000 counts per minute (cpm) above background at 1 ft above the ground surface, measured with the GM pancake instrument or

Table 8.4. Portable detector systems used in on-site monitoring

Meter	Probe	Purpose
Bicron Analyst	Eberline HP-260 GM pancake with fine mesh screen	Monitoring beta- gamma surface contamination levels
Victoreen 490	Victoreen 489-55	Gross gamma monitoring/scanning
Bicron Analyst	ORNL Q2101, "beer mug," ZnS scintillator	Monitoring alpha surface contamination levels

(2) a rate of 800,000 cpm at 1 ft above the ground surface, measured with the NaI scintillator. Should such action levels be indicated, all personnel will move from the work site to the contamination reduction zone. A health physicist from the ORNL Health Physics Department will visit the site to assess the potential hazard and determine whether work should continue. ORNL Health Physics will be responsible for any necessary posting of contaminated areas identified during the site investigation and field work.

Soil retrieved from sampling devices, bedrock cores, and drill cuttings will be screened for each sampled interval to determine whether elevated radioactivity levels are present. The GM pancake instrument will be used to monitor the soil as close to the surface as possible and to monitor potential radiation levels around the workers. It should not be assumed that this arrangement monitors the breathing zone of the site investigative personnel. All data collected for each monitoring occurrence will be recorded by the SHSO or his or her designee for maintaining radiological monitoring information.

Each worker's hands and footwear will be frisked and scanned, and release limits must be met for an individual to leave the exclusion zone. The radioactive contamination release limits for equipment, clothing, and skin for WAG 1 are given in Table 8.5.

The alpha and beta-gamma instruments read in counts per minute, so a conversion is required to compare field readings to contamination release limits, which are given in disintegrations per minute (dpm) per 100 cm². A conversion factor is posted on each alpha instrument for converting from counts per minute to dpm/100 cm² (alpha). This conversion factor will normally range from 7 to 12 dpm/100 cm² per cpm. Conversion factors are not posted on GM pancake instruments because factors vary depending upon the nuclide of interest; the surface material (e.g., concrete, steel, clothing); and the probe efficiency. A conservative conversion factor of 40 dpm/100 cm² per cpm should be used for estimating beta surface contamination levels with an Eberline HP-260 pancake probe.

Table 8.5. Radioactive contamination release limits for equipment, clothing, and skin for WAG 1
 [Values are in disintegrations per minute per 100 cm²]

	Alpha		Beta-gamma	
	Direct ^a	Removable ^b	Direct ^a	Removable ^b
Skin	1000	None detectable	5000	None detectable
Clothing	1000	None detectable	5000	None detectable
Equipment	5000	1000	5000	1000

^aFixed plus removable.

^bTransferable.

8.5 PREVENTIVE MAINTENANCE

To ensure compliance of all field sampling instruments and to minimize and prevent instrument malfunctions and/or failure, a preventive maintenance program that includes annual factory maintenance and a factory recalibration check must be established by the sampling group. The dates of scheduled maintenance and factory calibration and settings must be recorded and available for inspection by WAG 1 ER Program personnel or any designated auditor from DOE or a regulatory agency.

A current factory calibration check will be performed on the instruments used in the field. A daily calibration or instrument response check will be performed on each instrument before it is used in the field, as described in Sect. 8.4. All instruments that do not meet factory standards will be removed from service, documented in the field logbook, and returned to the maintenance shop of the field sampling crew for further maintenance.

Any instruments used in the field activities for this investigation that belong to the ORNL Industrial Hygiene Department will be maintained and calibrated by Industrial Hygiene. The Industrial Hygiene Department has implemented its own preventive maintenance program to ensure reliability and compliance of its equipment.

All radiological instruments must be maintained and calibrated by the sampling group. It is the responsibility of the sampling group to ensure calibration for each instrument before it is taken into the field. All instruments are maintained in accordance with the standards of National Institute of Standards and Technology.

8.6 FIELD ANALYSES

Field analyses that will be performed during this investigation include those for screening of soil cores before samples are collected. The screenings will follow procedures outlined in

previous sections. Laboratory analyses will follow the procedures included in the laboratory QAPjP and directions per the Statement of Work.

8.7 DATA REDUCTION AND REPORTING

Data validation is a systematic process for reviewing a body of data against a set of criteria to ensure that the data are adequate for their intended use. Data validation consists of data screening, checking, auditing, verification, certification, and review. All data for this investigation will be evaluated by QA/QC methods and internal peer review. Data will be entered into common, standardized formats. A Data Management Plan is required and will be developed in accordance with procedures established by the subcontractor doing the work and the Project Manager. The QA/QC Coordinator and Site Project Manager will be responsible for checking field QC sample results to ensure that field measurement and sampling protocols have been observed. Trained, qualified, and approved reviewers are responsible for ensuring that data reduction calculations are documented and checked by qualified personnel. These reviews will check

- date and time sampled,
- preservation,
- standard operating procedures (SOPs),
- calibration method and frequency, and
- chain of custody documentation.

The data reduction, validation, and reporting requirements are different for each type of data. The types of data include

- descriptions of soil cores, bedrock drill cuttings, and sediment samples;
- monitoring and background data taken with screening instruments during sample collection activities;
- surveyed locations of data collection points;
- maps of the areas under investigation; and
- laboratory analyses of environmental, duplicate, and QA samples.

Each type of data is discussed in this section, along with any associated reduction, validation, and reporting requirements.

8.7.1 Descriptions of Soil Cores, Bedrock Drill Cuttings, and Bedrock Cores

Sample collectors will use a Munsel Soil Chart to describe the types of material excavated during the subsurface soil drilling, bedrock coring, and groundwater monitoring well installation as these activities are accomplished. The subsurface soil and bedrock cores will be described and used to help further define the geology of the area. The characteristics of these soil cores, drill cuttings, and bedrock cores that are to be recorded are defined in the sections that follow.

8.7.1.1 Soil core descriptions

The following information about soil cores retrieved during subsurface soil sampling will be noted in the lithologic log:

- length of sample core retrieved;
- soil color;
- soil texture (i.e., grain size, silt sand gravel, etc.);
- proportions of sand, silt, clay, or gravel; and
- any gradational changes along the length of the core and any distinct soil characteristic boundaries.

Soil cores will be photographed with color print film.

8.7.1.2 Air rotary drill cuttings

The following information will be included in descriptions of air rotary drill cuttings ejected during drilling operations for bedrock monitoring well installations:

- color,
- results of any field lithologic tests such as acid reactions,
- notes of any voids or caverns through which the bit passes, and
- grain size, if apparent.

8.7.1.3 Bedrock core descriptions

The following characteristics will be recorded for bedrock cores retrieved during the installation of coreholes in WAG 1 and noted on the core log:

- top and bottom of cored interval;
- percentage of core recovery;
- core breakage due to discontinuities (natural fractures vs. coring induced breaks);
- rock classification and lithology; and
- lithologic changes and boundaries

Bedrock cores will be photographed with color print film.

8.7.2 Monitoring and Background Data from Field Screening Instruments

Field screening instrument readings of air immediately above the sample collection point or at the surface of a borehole are reported on an Air Quality Monitoring Record. The instruments used to take these readings will be calibrated and maintained according to the procedures outlined in Sect. 8.5. Each soil and bedrock core will be scanned for organic and radiological contamination. The results of the scans will be reported on the lithologic log. These records will be retained by the Site Project Manager until the completion of field

activities, after which they will be permanently stored by the WAG 1 ER Records Manager. Copies of these records will be included in reports required for this remedial investigation and will be made available to members of the multidisciplinary team that evaluates data and draws conclusions on the nature and extent of contamination at the site under investigation.

8.7.3 Analyses of Environmental Samples

Analytical results of environmental, duplicate, and QA samples will be reported according to the specifications included in the Laboratory QAPjP that will be prepared by the analytical laboratory according to specifications in the Laboratory Quality Assurance Plan approved by the ORNL APO. The results of these analyses will be used to perform a baseline risk assessment, remedial investigation report, feasibility study, and other reports outlined in Chap. 1 of this report, in accordance with FFA requirements.

8.8 FIELD QA/QC SAMPLES

Field QC samples are used to monitor sample-handling techniques, equipment and container decontamination procedures, and chain of custody. The types of QC samples to be used in this program are duplicate samples, preservation blanks, trip blanks, equipment rinsates, and field blanks.

8.8.1 Field Duplicates

Field duplicate samples will be collected to detect variability in sampling technique or method. Duplicate samples will be collected simultaneously with original water samples. Samples for volatile organics analysis are not to be split. Field duplicates will be collected at a frequency of 10% of the samples collected per sampling event. ("Per sampling event" means distance between sampling locations for field activities.)

8.8.2 Trip Blanks

Trip blanks will be used to determine if volatile organic contamination has occurred during sample collection or transport. Trip blanks are prepared before sampling and pertain only to volatile organic samples. Each trip blank will consist of two 40-mL amber septum bottles filled with deionized water. No headspace will be left in the vials. Trip blanks are not to be opened in the field. One trip blank is to accompany each cooler containing volatile organic samples. Each trip blank is to be stored at the laboratory with associated samples and analyzed with those samples.

8.8.3 Equipment Rinsates

Equipment rinsates will be collected to determine the effectiveness of decontamination procedures and to ensure that samples are not being biased in any way by the equipment used to collect them. Equipment rinsates will be taken dependent upon the number of samples

taken, sampling events, and locations. The equipment rinsate rate is 10% of the samples collected per matrix per event. If more than one type of equipment is used for a matrix, then a rinsate is collected for each piece of equipment at the same rate of 10% of the samples collected per matrix per event.

8.8.4 Field Blanks

Field blanks (samples of source water used for decontamination) will be collected to document that the rinsate water has not become contaminated in the field. One sample will be collected per day or any time the stock number of the distilled rinsate water changes.

8.9 DATA VALIDATION AND ASSESSMENT PROCEDURES

8.9.1 Field Data

The final data record for each sample will include, at a minimum, the following information:

- unique sample code,
- sampling location and sample date,
- laboratory analysis identification number,
- property or component measured,
- detection limits,
- reporting units, and
- laboratory analysis qualifiers.

In addition, specific information for each sample must also be recorded in the field logbook, as discussed in Sect. 8.4.1, and on the sample label, as described in Sect. 8.4.4. Refer to these sections for a listing of the required documentation.

Field measurement data collected during the project will be recorded or documented in the WAG 1 field logbook and on the Air Quality Monitoring Record. Field measurement data will be compiled and presented to the WAG 1 ER Project Manager as part of the remedial investigation report following the completion of characterization activities.

8.9.2 Precision, Accuracy, Representativeness, Completeness, and Comparability

Precision of monitoring instruments is determined by comparing calibration readings during to a standard. Precision in sampling is measured through the use of field duplicates. Accuracy is achieved by the use of standard criteria for container and equipment cleaning, sample collection, and personnel training and performance criteria and through uniform sample handling techniques and the use of blanks to detect contamination. Representativeness of samples collected is controlled through adherence to the detailed descriptions of sampling procedures contained in this volume.

The QA completeness objective for this project is to obtain valid analytical results for at least 95% of the samples collected during the project. This means that completeness of sample collection (the number of samples collected for which valid data are actually obtained compared to the number of valid samples planned) must be virtually 100% to allow for some laboratory waste. Accountability of samples collected, from field to final disposal, must be 100%.

Objectives for comparability between samples will be met by (1) narrowly defined sampling methodologies; (2) site surveillance and the use of standard sampling and monitoring devices; (3) personnel training; (4) documentation of sampling points; (5) stringent control limits for daily QC checks; and (6) reporting results in appropriate, comparable units.

Procedures to attain sensitivity objectives include (1) uniform training and certification for staff; (2) standard provisions for inspection, maintenance, and repair; (3) providing SOPs to technical staff; (4) reference to SOPs in the Field and Laboratory QAPjPs; and (5) field inspections by the quality assurance specialist (QAS) to determine compliance with the items specified in the support plans. Procedures regarding measurement and test equipment calibration are included in Sect. 8.5 of this Field QAPjP.

Staff responsible for particular instruments must maintain a log of calibration procedures and results, to remain with the instrument as a means of establishing a record of calibration. The Site Project Manager, the WAG 1 ER Project Manager, and the WAG 1 ER Field Coordinator will inspect the logs, which will become a part of the project records. Each operator must be trained in and familiar with the proper use of instruments and able to interpret data from the instrument properly.

Field procedures for the collection of samples are discussed in Sect. 8.3. The equipment and techniques that will be employed to obtain representative samples will be in accordance with approved Environmental Surveillance Procedures (ESP-300 series) (Energy Systems 1990b).

8.10 FIELD AUDITS AND SURVEILLANCES

Audits and surveillances of field activities will be scheduled, planned, performed, and documented by the Quality Division. The requirements set forth herein are delineated in Energy Systems quality procedures.

An audit is a planned and documented activity performed to determine, through investigation, examination, or evaluation of objective evidence, (1) the adequacy of and compliance with established procedures, instructions, drawings, and other applicable documents and (2) the effectiveness of implementation. Audits will be performed by personnel who are independent of (external to) the organization or entity being evaluated.

Surveillance is the act of monitoring or observing to verify that requirements have been specified and that items or activities conform to those specified requirements. A surveillance is an internal evaluation conducted and performed by line management personnel or their representatives to assess regularly the adequacy and effectiveness of that part of the QA program for which they are responsible.

A performance audit or surveillance evaluates the effectiveness of the project in fulfilling its objectives. A system audit or surveillance examines project activities to determine if they are comply with procedures and other applicable documents.

Audits and surveillances of field activities should consider

- permits and document approvals;
- availability and use of procedures;
- personnel training and qualifications;
- equipment calibrations;
- site control and identification;
- pre-entry briefings;
- personnel protective equipment;
- health and hazardous-material monitoring;
- sampling equipment cleanliness and decontamination;
- sample collection, preparation, and controls;
- waste controls and disposal; and
- corrective actions.

8.10.1 Audits

At least one performance audit of field activities will be performed early in the project to determine if there is objective evidence that activities are in compliance with procedures, instructions, drawings, and other documented requirements and that data quality objectives are clearly defined and implemented in plans, procedures, and other documentation. The requirement for conducting the audit of the field crew may be waived by the ER Division QA Manager if the field sampling team has been audited recently and there were no major unresolved quality problems.

Audits of field and laboratory activities will proceed as follows:

1. During the last quarter of each calendar year or at least 3 months before initiating field work, the WAG 1 ER Program Manager will notify the ER QA Manager, in writing, of the schedule of field and laboratory activities.
2. The ER Division QA Manager will prepare and send the audit schedule to the manager of the organization to be audited.
3. The ER Division QA Manager will prepare an audit plan that identifies the scope, audit requirements and objectives, lead auditor and team member(s), activities to be audited, organizations or people to be notified, applicable requirements for documentation,

schedule for the audit, documented audit procedures to be used, and any other information necessary for the successful conduct of the audit.

4. At least 2 weeks before the audit, the lead auditor will review the scope, verify the schedule, and coordinate audit activities with the manager of the affected organization to ensure that the selected activity is ready to be audited.
5. The audit team will conduct the audit in accordance with the audit plan and specific checklists.
6. Audit findings and observations will be presented to the auditee at a closeout meeting. The formal report will be issued within 30 d.
7. The auditee will respond in writing to the report within 30 d.
8. Audit findings will be validated by the responsible project management and processed in accordance with Energy Systems procedures on occurrence reporting.

8.10.2 Surveillances

Surveillance of field and laboratory activities will be performed early in the project and regularly during the life of the project to determine if personnel are adhering to procedural and documentation requirements. Surveillances will be planned, conducted, and responded to in accordance with ER Division procedure ER/C-1600, "Performance of Environmental Restoration Division Surveillance Activities." The surveillance procedure is as follows:

1. During the last quarter of each calendar year and before field work is initiated, the WAG 1 ER Project Manager will notify the QAS of the schedule of field and laboratory activities.
2. The QAS or designee will prepare a surveillance plan that identifies the scope, surveillance requirements and objectives, lead surveillant and team member(s), activities to be evaluated, organizations or people to be notified, required documentation, schedule for the surveillance, documented surveillance checklist to be used, and any other information necessary for the successful conduct of the audit.
3. Before the surveillance, the lead surveillant will review the surveillance scope, confirm the schedule, and coordinate surveillance activities with the ER Project Manager to ensure that the selected activity is ready to be evaluated.
4. The surveillance will be conducted in accordance with the surveillance plan and checklist.
5. Surveillance findings and observations will be presented to the Project Manager as they are determined. Short-term corrections may be required for problems of immediate concern. However, root causes of problems must be determined and permanent corrective action taken.
6. The formal report will be addressed to the WAG 1 ER Program Manager and will be issued within 30 d.
7. The WAG 1 ER Program Manager will respond in writing to the report within 30 d.
8. Findings will be validated by the responsible project management and processed in accordance with Energy Systems procedures on occurrence reporting.

8.11 CORRECTIVE ACTIONS

Conditions adverse to quality, which may adversely affect safety, health, the environment, or the reliability of ER activities and/or data, must be promptly identified and corrected by authorized personnel. The root cause of these significant conditions also must be properly documented and reported to management in a timely manner, in accordance with ES/ER/TM-4/R1, Sect. 2.16.

Conditions adverse to quality are defined as conditions that exceed predetermined acceptability limits, deviate from prescribed methods, fail to meet performance requirements or data quality objectives, or fail to meet customer or regulatory requirements and expectations. Typical reasons for corrective action include: nonconformances, occurrences, management reviews, appraisals, audits, problem investigations, external appraisals, reviews, and audits, etc.

The following corrective action procedure will be used by project personnel when processing conditions are adverse to quality:

1. The person who detects the adverse condition will immediately provide the field, laboratory, or other appropriate supervisor with the time, date, location, and personnel involved and a description of the adverse conditions.
2. The supervisor or SHSO will immediately determine if work should be stopped and whether a short-term correction is needed. The Energy Systems Shift Superintendent's office should be contacted to determine if the conditions should be entered into the Occurrence Reporting System, in accordance with Energy Systems procedures.
3. The supervisor or SHSO will notify the WAG 1 ER Project Manager of the conditions.
4. The WAG 1 ER Project Manager will notify the WAG 1 ER Program Manager of the conditions and assemble a team (if needed) to perform root-cause analysis and determine corrective action.
5. Before implementing the corrective action, the QAS, with technical assistance as needed, will verify that the proposed corrective action will prevent recurrence of the conditions.
6. The QAS will verify that the corrective action is properly implemented.

All identified deficiencies and nonconformances will be reported to the ORNL ER Site Program Manager and the ER QAS. Tracking and trending of such items is accomplished by the ORNL ER QAS and are reported to management monthly. The applicability of deficient items to other ER sites is performed in accordance with ER procedure ER/C-p 1606, "Review and Transmittal of Audit and/or Surveillance Findings and Observations for Potential Applicability."

8.12 QUALITY ASSURANCE REPORTS

Reports providing evidence of the quality, cost, and schedule of the project will be prepared periodically for WAG 1 ER Program management. Possible reports and their

content are listed and described below. The exact frequency of the reports will be determined when the project schedule is finalized.

8.12.1 Formal Written Reports

- Audit and surveillance reports will be prepared and submitted by the auditor or surveillant.
- Reports on significant quality problems, recommended solutions, and results of corrective actions will be prepared by the ER Project Manager.
- Remedial investigation reports and others designated by the FFA will be prepared by the appropriate project team personnel.

The ORNL ER QAS currently provides a monthly status report to the ORNL ER Site Manager on the number of surveillances and audits conducted, the findings of those surveillances and audits, and the number of nonconformance reports. Information pertaining to the status of project procedures and other project-related information is presented to the Program and Project Managers in monthly meetings. Such information includes procedures and field change reports prepared.

8.12.2 Informal Reports

Informal reports will be prepared by project personnel designated by the WAG 1 ER Program Manager. The reports will identify the status of the following:

1. permit approvals;
2. document preparation and approvals;
3. scheduled and actual completions of field sampling and laboratory analysis;
4. accuracy and precision of field and laboratory analysis;
5. amount, type, and location of field-generated wastes; and
6. actual cost and schedule compared to expected cost and schedule.

Regardless of whether reports are presented to management in writing or verbally, records of activities will be maintained by the personnel responsible for presenting the report.

8.13 TRAINING

Personnel managing or performing activities affecting quality will receive necessary indoctrination and performance-based training to ensure that suitable proficiency is achieved and maintained. Personnel to be indoctrinated or trained are identified on the basis of a "needs assessment." The extent of training will be commensurate with the (1) scope, complexity, and nature of the activity, and (2) the education, experience, and proficiency of the individual performing the task.

Performance-based training will be provided when activities are specifically detailed in procedures and the level of quality is dependent on the individual's ability to implement the procedure. Detailed standard operating procedures to perform specific activities will be prepared by a subcontractor and will be included as an addendum to this report when completed.

Records of the implementation of training may take the form of (1) attendance sheets, (2) training logs, and (3) personnel training records. These records will be maintained within the project records file as QA records.

8.14 READINESS REVIEW

An operational readiness review process will be performed in accordance with ER procedure ER/C-1610, "Conducting Project Readiness Reviews." The ORNL ER WAG 1 Program Manager is responsible for identifying the activities that require application of the readiness process and for requesting a Readiness Review Board. The readiness process must result in a documented and auditable record of measures taken to determine readiness to proceed and the decision of the review board.

9. LABORATORY QUALITY ASSURANCE PROJECT PLAN

Laboratory QA is the responsibility of the analytical laboratory as delineated in the laboratory QA plan approved by the ORNL Analytical Projects Office (APO). The laboratory QAPjP is to be prepared by a subcontractor and will be included as an addendum to this report when completed. Any analytical laboratory selected to perform work for this project must be approved by the APO, and all sample shipments must be coordinated with the APO.

10. HEALTH AND SAFETY PLAN

As part of the Environmental Restoration Program sponsored by DOE's Office of Environmental Restoration and Waste Management, the ORNL ER Site-Specific Health and Safety Plan (SSHASP) will be developed for the Phase II RI for Groundwater at WAG 1 effort throughout WAG 1. The SSHASP is developed to identify all suspected hazards attributed to the effort and to list the controls that will be in place to protect the workers and the environment from these hazards. The SSHASP is a working document that is linked to the ORNL Environmental Restoration Programmatic Health and Safety Plan (ORNL/ER-226), which elaborates on each section of the checklist.

This checklist is being written for the Energy Division of ORNL by the Measurements Applications and Development Group of the Health Science Research Division of ORNL. Both the Environmental Restoration Programmatic Health and Safety Plan and the SSHASP conform to the Occupational Safety and Health Administration standard 29 CFR 1910.120 (*Hazardous Waste Operations and Emergency Response*, as defined by the final rule of April 18, 1991) and applicable sections of 29 CFR 1926 (Construction Standards).

The major components of the SSHASP include

- assignment of key individuals to health and safety related positions and the delineation of their responsibilities,
- identification of hazards that could be encountered throughout each phase of the effort and controls for each of these hazards,
- discussion of personal protective requirements and discussion of decontamination procedures and mandatory safety requirements,
- training and medical monitoring requirements for the specific site, and
- emergency information for contingencies that may arise during field activities.

Attachment 1 to this chapter contains the table of contents from the ORNL Environmental Restoration Programmatic Health and Safety Plan and a copy of a blank SSHASP that must be completed and approved before any site activities begin.

Attachment 1

**TABLE OF CONTENTS FROM THE
ORNL ENVIRONMENTAL RESTORATION PROGRAMMATIC
HEALTH AND SAFETY PLAN**

AND

A SAMPLE SITE-SPECIFIC HEALTH AND SAFETY PLAN

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ORNL ER SITE-SPECIFIC HEALTH AND SAFETY PLAN

ORNL ER SITE-SPECIFIC HEALTH AND SAFETY PLAN APPROVAL

WORK PROJECT TITLE: _____

TASK: _____ **SSHASP No.** ☐☐☐ ☐☐☐/☐☐☐☐ ☐☐☐☐
WAG Report Year

Brief description of purpose of project and specific task(s) entailed: _____

SSHO Training Level _____ **Other** _____

 Date _____
 ORNL ER Site Project Manager*

 Date _____
 ORNL HAZWOPER Program
 Coordinator or SHEST†

 Date _____
 SSHO or ES&H technician

 Date _____
 ORNL ER Program ES&H Manager or
 designee

 Date _____
 Office of Radiation Protection
 representative

 Date _____
 DOE Project Representative

The following offices or individuals may be asked to provide review and comment, if warranted:

Facility Manager
 ORNL Hazardous Waste Operations Group
 ORNL Office of Environmental Compliance and Documentation
 ORNL Construction Engineering Manager
 ORNL Laboratory Shift Superintendent
 ORNL Fire Department
 Team Leader

*It is the responsibility of the Site Project Manager to assure that all reviewer comments are addressed.

†At HAZWOPER sites, review and approval will be required by the ORNL HAZWOPER Program Coordinator; at non-HAZWOPER sites, review and approval will be required by a member of the Safety and Health Evaluation and Support Team (SHEST).

**ORNL ER SITE-SPECIFIC HEALTH AND SAFETY PLAN
(SSHASP)**

WORK PROJECT TITLE: _____

DATE: _____ **SSHASP No.** ☐☐☐ ☐☐☐/☐☐☐☐ ☐☐☐

- This SSHASP is to be used in conjunction with to the ORNL ER Programmatic Health and Safety Plan (PHASP), which must be available on-site.
- In order to be valid, this SSHASP must undergo review and approval and have a signed approval page attached to it documenting such approval.
- This SSHASP is to be reviewed and updated (as necessary) every 6 months if the duration of the project is projected to be 6 months or greater.
- Changes in this SSHASP may require the completion of a Field Change Request/Variance Form. (Refer to Sect. 3.3 of the PHASP.)

SECTION I: Work Plan

Provide a detailed description of project objectives and how the work will be accomplished. Include all procedures or reference procedures in documents that will be available on-site. Attach additional sheets, if necessary.

SECTION II: Key Personnel:

Complete Table B.1. If site roles and/or responsibilities differ from those presented in the PHASP, attach a sheet describing the differences.

Table B.1. Key personnel

Responsibility	Name	Telephone No.	Radio No./ Beeper No.
Program Management			
DOE Project Representative			
DOE H&S Representative			
ORNL ER Program Manager			
ORNL ER Program ES&H Manager			
Project Site Organization			
ORNL ER Site Project Manager			
Facility Manager			
ORNL Construction Engineer			
Site Safety and Health Officer			
Alternate Site Safety and Health Officer			
Field Team Leader			
Decontamination Officer			
Security Officer			
Industrial Hygiene/Health Physics Technician (ES&H Technician)			
Office of Radiation Protection representative			
Industrial Hygiene representative			
Office of Industrial Safety representative			
HAZWOPER Program Coordinator			
Office of Environmental Compliance and Documentation			
Hazardous Waste Operations Group			
Laboratory Shift Superintendent			

SECTION III: Emergency Contacts and Site Map

<u>Emergency Personnel</u>	<u>Phone</u>	<u>Radio No.</u>
ORNL Emergency Response	911	
Laboratory Shift Superintendent	574-6606	Station 103
Fire Department	574-5678	
Medical Center	574-7431	
Security	574-7196	401
Industrial Hygiene	576-5064	69
Industrial Safety	576-5974	
Radiation Protection	574-6701	334
Environmental Compliance	574-8870	650
Facility Manager		
ORNL ER Site Project Manager		
ER Program ES&H Manager	574-8268	686
HAZWOPER Program Coordinator	576-5064/576-6445	69

NOTE: These phone and radio numbers are subject to change and **must be verified** before posting or including in the SSHASP.

The chain-of-command for reporting health and safety issues is shown in Fig. B.1.

ORNL-DWG 94-9245

Fig. B.1. ORNL ER chain-of command for reporting health and safety issues. The SSHO first contacts the ORNL ER ES&H Manager and the ORNL ER Site Project Manager (SPM). Then, a 3-way conference is initiated involving the SSHO, the ORNL ER ES&H Manager (or the SPM if the ER ES&H Manager is not available), and the appropriate discipline(s): HAZWOPER Program Coordinator, Office of Radiation Protection, Industrial Hygiene, Industrial Safety, Waste Management, or Environmental Compliance. In an emergency, or when neither the ORNL ER ES&H Manager (or designee) nor the SPM is available, the SSHO should contact the appropriate discipline(s) directly.

Site-Specific Health and Safety Plan

SITE MAP

Note: If there are several tasks, duplicate and complete Sects. IV through VIII for each task. Sects. VI and VIII may not need to be duplicated (see NOTE in each section).

SECTION IV: Project Hazard Evaluation

Place an X in each ☐ to indicate existing conditions or those that may be a result of site operations.

Task: (provide description of task)

Intrusive Activity? ☐ Yes ☐ No

Safety Work Permit or equivalent required? ☐ Yes ☐ No

Excavation/Penetration Permit or equivalent required? ☐ Yes ☐ No

Hot Work Permit/Burning Permit or equivalent required? ☐ Yes ☐ No

Radiation Work Permit required? ☐ Yes ☐ No

Waste Management Plan checklist required? ☐ Yes ☐ No

If no, give reason _____

Physical hazards: Industrial Safety, Industrial Hygiene, and/or the Fire Department may be contacted for assistance in completing this section.

☐ Heat stress	☐ Cold stress	☐ Noise
☐ Confined space	☐ Enclosed space	☐ Manual lifting
☐ Tripping/falling	☐ Ergonomic	☐ Vibration
☐ Oxygen deficient atmosphere	☐ Explosive/fire hazards	☐ Dusts/mists
☐ Oxygen enriched atmosphere	☐ Water	☐ Compressed gasses
- and/or cylinders

Safety/Construction Hazards: Industrial Safety, Industrial Hygiene, and/or the Fire Department may be contacted for assistance in completing this section.

☐ Trenching	☐ Drum handling	☐ Work in water/boat
☐ Demolition	☐ Elevated work heights	☐ Welding/cutting/burning
☐ Hoisting/rigging	☐ Underground hazards	☐ Overhead hazards
☐ Personnel decontamination	☐ Equipment decontamination	☐ New technology
☐ Drilling/hand augering	☐ Underground storage tanks	☐ Heavy equipment operation

Specify _____

Chemical Hazards: Industrial Hygiene may be contacted for assistance in completing this section.

☐ Volatile organics	☐ Inorganics	☐ Carcinogen
☐ Corrosive	☐ Reproductive toxicant	☐ Metals
☐ Mutagen	☐ Flammable/explosive	☐ PCBs
☐ Mercury	☐ Asbestos	

List known primary chemicals on-site that pose a major health and safety concern. Also list exposure limits for each chemical (refer to Table 3, Sect. 6.3 of PHASP for target organs and toxic effects).

Chemical	TLV/PEL/STEL

Attach Material Safety Data Sheets (MSDSs) or have available on-site.

Ionizing Radiation Hazards: An Office of Radiation Protection representative may be contacted to assist in completion of this section.

Any known contamination present

(from prior scanning or history) ☐ Yes ☐ No

List primary contaminating isotope(s)	Range of concentration (pCi/g, pCi/L, μ Ci/mL)	Media (soil, water, air, etc.)

(DACs given in Table 4, Sect. 6.4 of PHASP.)

Ionizing Radiation Hazards (continued)**Radiography source**

Type of source _____

HP Source ID _____

Activity (Ci) _____

Radiation type☐ Alpha☐ Beta☐ Gamma☐ Neutron**Location on site**

Exposure rate measured**on-site:**

maximum

Ground surface

1 meter above ground surface

average

_____ $\mu\text{R/h}$ _____ $\mu\text{R/h}$

unknown

_____ $\mu\text{R/h}$ _____ $\mu\text{R/h}$ _____ $\mu\text{R/h}$ _____ $\mu\text{R/h}$ **Surface contamination**☐ Yes☐ No☐ Not known

fixed

_____ dpm/100 cm²

removable

_____ dpm/100 cm²**Airborne contamination**☐ Yes☐ No☐ No prior history_____ $\mu\text{Ci/mL}$ **Will operations generate a hazardous atmosphere?**☐ Yes☐ No☐ Not known

If yes, list type _____

Water contamination potential

(such as tritium)

☐ Yes☐ No☐ Not known

If yes, list type _____

Nonionizing Radiation Hazard☐ UV☐ Radiofrequency☐ Microwave☐ Laser☐ High voltage**Biological/Vector Hazards**☐ Wildlife (snakes, rodents)☐ Plants (poison ivy)☐ Medical waste☐ Bacteria☐ Parasites☐ Animal research waste☐ Insects/ticks stings/bites☐ Allergens (grasses, pollens)

Controls

Specify the hazard and list controls for each hazard identified in the previous sections (Physical Hazards, Safety/Construction Hazards, Chemical Hazards, Ionizing Radiation Hazards, Nonionizing Radiation Hazards, and Biological/Vector Hazards). Do the same for any additional hazards not previously mentioned. (Attach sheet if necessary.)

SECTION V: Monitoring Requirements: The IH and/or ORP representative may be consulted to assist in preparing this section.

ES&H Coverage

☐ Continuous

☐ Intermittent

Direct Reading Instruments	<u>Task(s)</u>	<u>Monitoring Frequency</u>	<u>Action Levels^a</u>	<u>Action^a</u>
Combustible Gas Indicator				
LEL	_____	_____	5% (confined space) >10%	_____
O ₂	_____	_____	≤19.5% or ≥22%	_____
CO	_____	_____	12.5 ppm	_____
H ₂ S	_____	_____	5 ppm	_____
Photoionization Detector (PID)	_____	_____	5 ppm for 1 min unless the chemical indicates <5 ppm	_____
Flame Ionization Detector (FID)	_____	_____	5 ppm for 1 min unless the chemical indicates <5 ppm	_____
Alpha Meter	_____	_____	>300 dpm/100 cm ²	_____
Beta/Gamma Meter	_____	_____	>1000 dpm/100 cm ²	_____
Neutron Meter	_____	_____	_____	_____
Ion Chamber	_____	_____	_____	_____
Noise Meter	_____	_____	85 dBA	_____
Other (Specify)	_____	_____	_____	_____
Personal Monitoring				
Visual pocket/Electronic dosimeter	_____	_____	_____	_____
Whole-body dosimetry	_____	_____	_____	_____
Extremity dosimetry	_____	_____	_____	_____
Whole-body count	_____	_____	_____	_____
Urinalysis/bioassay	_____	_____	_____	_____
Area Monitoring				
Chemical area monitoring	_____	_____	_____	_____
Radiation area monitoring	_____	_____	_____	_____
Personal Sampling Pumps				
Chemical	_____	_____	_____	_____
Radiological	_____	_____	_____	_____

^aSee Table 11, Site monitoring action limits, in Sect. 8.2 of the PHASP.

Instruments used by ORNL IH Section will be calibrated and maintained in accordance with IH SOP. Instruments used by the ORP are calibrated and source checked in accordance with established health physics procedures. Source-check procedures for all radiological field instruments used with this SSHASP must be attached or referenced.

Site monitoring requirements may change based upon site conditions. All changes must be reported to the SPM, the ER Program ES&H Manager (or designee), the HAZWOPER Program Coordinator, and the appropriate ORNL ES&H discipline(s).

SECTION VI: Initial Level of Personal Protective Equipment

NOTE: If all tasks require the same PPE, Sect. VI can be completed only once. If project tasks require differing combinations of PPE, Sect. VI must be completed for each different PPE ensemble.

Task(s) _____

Level of Protection: ☐ A ☐ C ☐ Modified
☐ B ☐ D Specify _____
☐ Anti-radiological contamination PPE

Respirator: ☐ SCBA ☐ Full face ☐ Half-face Resp.
☐ Escape SCBA ☐ PAPR* ☐ Other

Cartridge: _____

Protective Clothing: ☐ Tyvek ☐ Encapsulating suit
☐ Saranex ☐ Splash suit
☐ Other ☐ Energy Systems clothing
☐ Energy Systems under apparel

Head/eye/ear: ☐ Hard hat ☐ Safety glasses ☐ Goggles
☐ Splash shield ☐ Ear plugs ☐ Ear muffs
☐ Other

Gloves: ☐ Nitrile ☐ Neoprene ☐ PVC
☐ Latex ☐ Vinyl ☐ Leather
☐ Cotton ☐ Other

Footwear: ☐ Hard-toed leather ☐ Other
☐ Hard-toed rubber ☐ Rubber boots
☐ Chemical overboots

Other: Fall protection ☐ Yes ☐ No
List item(s): _____
Welding goggles/
apron/gloves ☐ Yes ☐ No
Rescue equipment ☐ Yes ☐ No
Nonsparking tools ☐ Yes ☐ No
Fire extinguisher(s) ☐ Yes ☐ No

Describe the donning/doffing steps if different from those in Sect. 7.3.5 or Attachment I of the PHASP:

* Powered air-purifying respirator.

SECTION VII: Decontamination

If decontamination is required during the course of this project:

1. List materials/equipment needed for decontamination or reference in PHASP (see Sect. 10.1).

2. Provide a description of the decontamination steps/stations or reference in the PHASP (see Sect. 10.1).

3. Describe equipment decontamination procedures (for instruments, hand tools, heavy equipment, etc.) or reference in the PHASP (see Sect. 10.2).

4. List health and safety controls to protect the workers.

SECTION VIII: Sanitation

NOTE: If the same sanitation facilities will be used for all tasks, Sect. VIII need only be completed once. If some tasks have differing or additional sanitation requirements, Sect. VIII must be completed for each task.

Task(s): _____

Potable water available? ☐ Yes ☐ No

If yes, location _____

If no, how will it be supplied? _____

Eating, drinking, chewing, use of tobacco products permitted on site?
☐ Yes ☐ No

If yes, location _____

Toilet facilities available: ☐ Yes ☐ No

If yes, location _____

If no, how will this be addressed? _____

Washing facilities available: ☐ Yes ☐ No

If yes, location _____

If no, how will this be addressed? _____

Change rooms required? ☐ Yes ☐ No

If yes, specify _____

If no, how will this be addressed? _____

SECTION IX: Training/Medical Requirements (see Sects. 7.1 and 7.4 of the PHASP).

This form should be completed by the ORNL ER Site Project Manager or designee before initiation of any field activities.

List applicable training/medical requirements for this project. Routine site workers requiring access to the work zones (contamination reduction zone and exclusion zone) must meet access requirements. Upon agreement of the ER Program ES&H Manager and the HAZWOPER Program Coordinator, the SSHO may waive specific access requirements for occasional visitors and emergency personnel.

_____ Medical examination (Note: All persons performing field activities as part of this SSHASP must have a medical examination verifying that he/she is physically capable of performing the assigned tasks.)

_____ Whole body count (in vivo)

_____ Bioassay (in vitro)

_____ List specific radionuclides assayed as part of the bioassay program

_____ 24-hour HAZWOPER (SARA/OSHA) training

_____ 40-hour HAZWOPER (SARA/OSHA) training

_____ HAZWOPER 8-hour Annual Refresher

_____ HAZWOPER 8-hour Supervisor Training

_____ ORNL General Employee Training (GET)

_____ ORNL photo ID badge required

_____ TLD badge required

_____ Respirator fit test/training

_____ Radiological Worker Training I

_____ Radiological Worker Training II

_____ HAZWOPER SSHO Training

_____ Asbestos Worker Training

_____ Defensive Driving and Nonpaved Surfaces

_____ Hazardous Waste Characterization/Waste Generator Training for Satellite

Accumulation Areas

_____ Confined Space Entrant Training

_____ Confined Space Attendant Training

_____ Specialized Equipment Training

_____ Additional site-access requirements

Specify _____

_____ First aid/CPR

_____ Additional training or medical requirements

Specify _____

HAZWOPER Medical Surveillance (see Sect. 7.4)

_____ ORNL Hazardous Waste Worker Medical Surveillance Program (only for individual meeting criteria specified in the ORNL HAZWOPER Program and Sect. 7.4.2 of the PHASP).

Note: If site conditions change, or other hazards are detected, the training and access requirements will be revised accordingly.

Site Personnel Qualifications: Copy this page and complete for each site worker.

Employee: _____ Badge No. _____		
Assigned task(s):		
	Yes	Date
Medical examination	☐	
Whole body count (in vivo)	☐	
Bioassay (in vitro)	☐	
List specific radionuclides to be assayed as part of the bioassay program (if applicable)		
OSHA 24-hour Training	☐	
OSHA 40-hour Training	☐	
OSHA Refresher 8-hour Training	☐	
HAZWOPER 8-hour Supervisor Training	☐	
ORNL General Employee Training	☐	
ORNL photo badge required	☐	
TLD badge required	☐	
Respirator fit test/training	☐	
Radiological Worker Training I	☐	
Radiological Worker Training II	☐	
HAZWOPER SSHO Training	☐	
Asbestos Worker Training	☐	
Defensive Driving and Nonpaved Surfaces Training	☐	
Hazardous Waste Characterization/Waste Generator Training for Satellite Accumulation Areas	☐	
Confined Space Entrant Training	☐	
Confined Space Attendant Training	☐	
Specialized Equipment Training	☐	
Additional site access requirement Specify:	☐	
Additional training or medical requirements Specify:	☐	

ORNL ER Documentation of HAZWOPER Field Experience: Copy this page and complete for each site worker. **NOTE:** A copy of this form should be available on-site and a copy should be sent to the ORNL ER ES&H Manager before reposit in the ORNL ER Document Management Center.

Name:	Badge:
Company:	Work Date(s): —
Completed OSHA 24-Hour Training ☐ Yes ☐ No	
Completed OSHA 40-Hour Training ☐ Yes ☐ No	
Description of hazards anticipated or encountered:	Hours
Description of duties performed:	
Tools, equipment, or instruments used:	
Level of PPE:	
Description of site briefing to personnel:	
Person appropriately performed donning/doffing of PPE:	
Person appropriately entered/exited zones and followed proper decontamination and frisking procedures:	
Total hours of field experience	
I certify that the above information accurately represents the field experience that occurred during the period noted:	
_____ Trainee Signature	_____ Date
_____ Supervisor Signature (SSHO) (person who observed the field experience)	_____ Date

ORNL ER SSHO Request Form

In order to be valid, this form must be signed by the ORNL ER Site Project Manager and the ORNL HAZWOPER Program Coordinator, with concurrence from the ORNL ER Program ES&H Manager. Qualifications for SSHOs and conditions or situations for which a waiver will be granted are listed in the ORNL ER Programmatic Health and Safety Plan (ORNL/ER-226), Sect. 4.3.2.

Requestor	Title of Requestor	Date
	<div style="display: flex; justify-content: space-around; font-size: 0.8em;"> 123 </div> <div style="display: flex; justify-content: space-around;"> <input style="width: 20px; height: 20px;" type="checkbox"/> <input style="width: 20px; height: 20px;" type="checkbox"/> <input style="width: 20px; height: 20px;" type="checkbox"/> </div>	<div style="font-size: 0.8em;">Team leader</div> <input style="width: 20px; height: 20px;" type="checkbox"/>
Name of Personnel	SSHO Level Requested	

List the educational background and experience of the above named person for whom you are requesting approval as SSHO or a waiver. List any special training (e.g., ORNL Radiological Worker Training II, ORNL SSHO Training, OSHA 40- or 24-hour Training, HAZWOPER 8-hour Supervisor Training) and experience operating Health Physics or Industrial Hygiene equipment. You may attach any additional information that will assist in the approval or waiver process.

Name of Alternate	SSHO Level Requested	Date
	<div style="display: flex; justify-content: space-around; font-size: 0.8em;"> 123 </div> <div style="display: flex; justify-content: space-around;"> <input style="width: 20px; height: 20px;" type="checkbox"/> <input style="width: 20px; height: 20px;" type="checkbox"/> <input style="width: 20px; height: 20px;" type="checkbox"/> </div>	<div style="font-size: 0.8em;">Team leader</div> <input style="width: 20px; height: 20px;" type="checkbox"/>

List the educational background and experience of the above named person for whom you are requesting approval as alternate SSHO or a waiver. List any special training (e.g., ORNL Radiological Worker Training II, ORNL SSHO Training, OSHA 40- or 24-hour Training, HAZWOPER 8-hour Supervisor Training) and experience operating Health Physics or Industrial Hygiene equipment. You may attach any additional information that will assist in the approval or waiver process.

Describe in detail the task(s) that will be performed for which approval or wavier of an SSHO is requested. Also list location and potential hazards that may be encountered.

	1 ☐	2 ☐	3 ☐	Team Leader ☐	Denied ☐
ORNL ER Site Project Manager	SSHO Level Granted				

Denied request due to the following:

	1 ☐	2 ☐	3 ☐	Team Leader ☐	Denied ☐
ORNL HAZWOPER Program Coordinator	SSHO Level Granted				

Denied request due to the following:

A signed copy of this form is to be maintained at the work site; copies should also be mailed by the ORNL ER Site Project Manager to the ORNL ER Document Management Center and the ORNL ER Program ES&H Manager (Bldg. 7078A, MS-6402).

	Yes ☐	No ☐
ORNL ER Program ES&H Manager	Concurrence	

ORNL ER INCIDENT REPORT

INCIDENT REPORT NO. ☐☐☐ - ☐☐☐☐ - ☐☐☐☐ - ☐☐
 (SSHASP#) WAG # - Report # - Year - Frequency Rate

The Incident Report Number is the number assigned to the SSHASP that the task was being performed under. The frequency rate will be assigned by the ER ES&H Manager. A copy of the signed form must be sent to the ORNL ER Document Management Center.

TO: ER PROGRAM MANAGER, ER ES&H MANAGER, ER QA MANAGER, ER SITE PROJECT MANAGER, FACILITY MANAGER, and ORNL ER DOCUMENT MANAGEMENT CENTER			
DATE OF INCIDENT _____		TIME OF INCIDENT _____ AM/PM	
I. INCIDENT (Check As Applicable) ☐ PERSONAL INJURY ☐ FATALITY ☐ UNPLANNED ENVIRONMENTAL RELEASE OR SPILL ☐ PROPERTY DAMAGE ☐ UNPLANNED PERSONNEL EXPOSURE (Rad, Chem, etc.) ☐ ZONE ACCESS INFRACTION ☐ CONTAMINATION CONTROL INFRACTION (Frisking, Using Plastic, etc.) ☐ VIOLATION IN ADHERING TO THE PHAWP OR THE SSHO INSTRUCTIONS ☐ OTHER _____			
II. NAME(S) OF INDIVIDUALS INVOLVED, BADGE NO., AND SITE LOCATION _____ _____			
III. DESCRIPTION OF INCIDENT (Attach additional information if needed) _____ _____ _____			
IV. CORRECTIVE ACTION _____ _____ _____			
V. PERSON OR DEPT. RESPONSIBLE FOR ACTION _____ DATE ACTION REQUIRED OR COMPLETED _____ ☐ CHECK IF ADDITIONAL INFORMATION IS ATTACHED. NUMBER OF PAGES _____			
INVOLVED INDIVIDUAL(S) _____ SIGNATURE		ER PROJECT MANAGER _____ SIGNATURE	
SSHO _____ SIGNATURE		ER ES&H MANAGER _____ SIGNATURE	
DATE _____		DATE _____	

SSH0:

ORP Representative:

Work Project Title:

SSHASP No:

Date:

My signature below indicates that the ORNL ER Programmatic Health and Safety Plan and the Site-Specific Health and Safety Plan have been made available for my review. I have attended a pre-entry briefing and understand the hazards at the site, the PPE requirements, the reporting chain-of-command, the emergency contacts, and the evacuation routes. I have fulfilled all training and medical requirements and agree to abide by all instructions and guidelines set forth in the PHASP and this SSHASP.

[illegible]

11. WASTE MANAGEMENT PLAN

The Waste Management Plan for the WAG 1 Groundwater RI at ORNL establishes the criteria, characterization and management methods, and operational techniques to be used for managing wastes that result from the investigation. The provisions of the plan will be implemented through project procedures and directives as necessary to ensure uniform and consistent waste management operations.

Attachment 1 to this chapter contains the table of contents from the ORNL Environmental Restoration Programmatic Waste Management Plan and a copy of the proposed Waste Management Checklist.

Attachment 1

**TABLE OF CONTENTS FROM THE
ORNL ENVIRONMENTAL RESTORATION PROGRAMMATIC
WASTE MANAGEMENT PLAN**

AND THE PROPOSED

WASTE MANAGEMENT CHECKLIST

CONTENTS

ABBREVIATIONS	v
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11-7
ER PROJECT/TASK SPECIFIC WASTE MANAGEMENT PLAN

Project Name:		Location:		Date completed:		Work Order Number:		Est. Start:		Est. Completion:	
---------------------	--	-----------------	--	-----------------------	--	--------------------------	--	-------------------	--	------------------------	--

1.0 KEY PROJECT PERSONNEL

ER Project Manager:		Address:		Phone:	
Facility Manager:		Address:		Phone:	
Construction Engineer:		Address:		Phone:	
ES&H Supervisor:		Address:		Phone:	
ER GCO:		Address:		Phone:	
Waste Generator:		Address:		Phone:	
SSHQ:		Address:		Phone:	
Packager:		Address:		Phone:	

2.0 INTRODUCTION

Project Description:

Site History:

Reference Documents:

ER PROJECT/TASK SPECIFIC WASTE MANAGEMENT PLAN

3.0 WASTE CHARACTERISTICS

Generating Activities:

☐ Coring	☐ PPE	☐ Geophysical Survey	☐ Remedial Actions
☐ Drilling	☐ Excavating	☐ D & D Activities	☐ UST Removal
☐ Deconning	☐ Renovations	☐ Well Installation/Maintenance	☐ Other
☐ Water Sampling	☐ Soil Sampling	☐ Scoping Surveys	

Explain Other:

Waste Types and Volume:

Characterization
Based Upon

Type	Category	Est. Volume*	Suspected Contaminants	Sampling & Analysis	Process Knowledge

*Note: See Appendix B Methodology for Generating Waste Volume Estimates.

4.0 HANDLING AND STORAGE REQUIREMENTS

Special Handling Procedures

Waste Storage Area Requirements

☐ Radiological Waste Storage Area:	☐ Satellite Accumulation Area:	☐ Other...
☐ 90 Day Storage Facility:	☐ AOC	

Explain Other:

Location:

Special Requirements:

ER PROJECT/TASK SPECIFIC WASTE MANAGEMENT PLAN

5.0 WASTE MINIMIZATION

Waste Minimization Plan

☐ Segregation	☐ Substitution	☐ Waste Handling (Spill Control)	☐ Equipment Selection
☐ Decontamination	☐ Dewatering	☐ Recycling	☐ Other...
☐ Compaction	☐ PPE Selection	☐ Reuse	

Explain Other:

.....

6.0 TREATMENT AND DISPOSAL

Potential Treatment/Disposal Options

Option	Capacity	Responsible Organization
.....		
.....		
.....		
.....		
.....		

WAC To Meet

.....

Applicable Waste Management Forms:

☐ UCN-2822	☐ UCN-16114	☐ UCN-13386	☐ UCN-19665	☐ TX-5352A	☐ Other...
☐ UCN-13688	☐ UCN-13698	☐ UCN-19611	☐ TX-5352	☐ UCN-2109	

7.0 WASTE CHARACTERIZATION

Waste Characterization

.....

ER PROJECT/TASK SPECIFIC WASTE MANAGEMENT PLAN

8.0 TRANSPORTATION

Transportation Requirements

Method of Transfer	Expected Route	Manifest Required		DOT Reportable Quantity
		Yes	No	

Note: For more detailed information on transportation requirements contact (at ORNL C.W. Cross, at Y-12 D.W. Foster, and at K-25 H.B. Nennstiel).

9.0 APPROVALS

Approvals

Project Manager

ER GCO

ER Program Manager

ORNL WMOG

Environmental Compliance

ORNL LCO

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