MARTIN MARIETTA

ORNL/ER-299

**Site Characterization Summary Report
for Waste Area Grouping 10 Wells
at the Old Hydrofracture Facility
Oak Ridge National Laboratory
Oak Ridge, Tennessee**

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Energy Systems Environmental Restoration Program
ORNL Environmental Restoration Program

Site Characterization Summary Report for Waste Area Grouping 10
Wells at the Old Hydrofracture Facility
Oak Ridge National Laboratory
Oak Ridge, Tennessee

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Environmental Restoration and Waste Management Programs
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6285
managed by

MARTIN MARIETTA ENERGY SYSTEMS, INC.

for the
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PREFACE

This *Site Characterization Summary Report for WAG 10 Wells at the Old Hydrofracture Facility at Oak Ridge National Laboratory, Oak Ridge, Tennessee* (ORNL/ER-299) was prepared in accordance with requirements under the Comprehensive Environmental Response, Compensation, and Liability Act for reporting the results of a site characterization for public review. This work was performed under Work Breakdown Structure 1.4.12.6.1.10.42 (Activity Data Sheet 3310, "WAG 10"). Publication of this document meets a Fiscal Year Work Agreement milestone of March 23, 1995. This document provides the Environmental Restoration Program with information about the results of investigations performed at WAG 10. Information provided in this document forms the basis for decisions regarding the need for subsequent action at WAG 10.

EXECUTIVE SUMMARY

Four hydrofracture sites at the Oak Ridge National Laboratory in Oak Ridge, Tennessee, were used for development, demonstration, and full-scale disposal operations from 1959 to 1984. The first two sites (HF-1 and HF-2) were used for demonstration of the hydrofracture concept. The third site, the Old Hydrofracture Facility (OHF) (HF-3), was used first for pilot-scale testing followed by waste disposal. The fourth site, the New Hydrofracture Facility (NHF) (HF-4), was designed and operated as a full-scale disposal system for low-level liquid waste. In all, more than 5 million gal of waste grout mix containing approximately 1.4 million Ci of radioactivity was disposed of via hydrofracture through a series of 46 injections at HF-3 and HF-4. Several wells were installed to monitor the performance of hydrofracture operations. These wells compose Waste Area Grouping (WAG) 10 Operable Unit (OU) 3: Wells and Boreholes. Disposal activities were discontinued at the OHF in 1979 and at the NHF in 1984.

The primary goal of this investigation was to gain sufficient data about the wells near the OHF to determine the type and best method of final disposition for the well. Borehole geophysical logs were obtained from the wells to determine the well casing bond and casing integrity, to extract well construction details for each well, to assist in future plugging and abandonment (P&A) activities, and to determine the suitability of the wells for future site monitoring. The secondary goals were to determine the stratigraphic position of the rock cover and observation wells, subsurface geology at the OHF site, and possible artificially induced or natural pathways for the spread of contaminants from hydrofracture activities. The OHF investigation is necessary to support well P&A on a series of abandoned wells that if left open may interfere with potential remedial actions at WAG 5. As such, the effort does not directly support a regulatory mandate. Screening-level geochemical characterization of the wellbore water was performed to support the primary and secondary goals and the management of wastes generated during P&A.

Twenty-three OHF wells were originally scheduled for evaluation in this study. Of those 23 wells, 2 wells (1954 and 1966) were not accessible and, therefore, were not evaluated. Two additional non-OHF wells (1920 and 1943) near the HF-2 site were added to the investigation to provide supplemental data on the injection zone. Investigation of the injection well (1944) was not within the scope of this investigation. Standing water was grab sampled from the 23 wells (21 OHF and 2 HF-2 wells) evaluated in this study, but only 19 of the wells could be geophysically logged. The narrow diameter of the remaining 4 wells (1948, 1958, 1962, and 1964) was smaller than the diameter of the logging tools.

The 19 wells that were geophysically logged were ranked to establish a priority for P&A; they were compared with each other, not evaluated relative to quantitative human health or ecological criteria. Four of the wells (1946, 1953, 1965, and 1967) received high ranks (7 to 9) and, with qualification, should be plugged and abandoned as soon as possible. Well 1953, however, provides an excellent opportunity for future monitoring/sampling at the OHF because it provides a long openhole interval covering the middle Rogersville Shale through the lower Pumpkin Valley Shale section (injection horizon). Temporary recompletion as a multiport well should be considered with permanent abandonment at a later date.

Three other OHF wells (1947, 1950, and 1956) provide an opportunity for retrofitting and sampling/monitoring at OHF; these wells have open hole intervals that cover the Rogersville Shale and Rutledge Limestone. The two wells located east of OHF (1920 and 1943) should be considered for retrofitting and future sampling/monitoring at HF-2.

Geologic cross sections were constructed for the OHF area. Interpretations of these and other acquired data reveal that several mechanisms have been active in the spread of radioactive contaminants associated with OHF operations and brine. They are as follows:

- Several of the wells that penetrate the injection interval are contaminated with grout and grout filtrate. These observation wells provide a potential pathway for upsection migration of contaminants.
- Evidence of upsection migration of contaminated grout filtrate was discovered (well 1967) in the Rutledge Limestone. It is unknown whether the contaminants migrated through an open natural fracture/joint system, a reactivated system, or a system created by hydrofracture operations.
- Some wellbores (e.g., well 1963) have provided a pathway for the upsection migration of what appears to be natural brine. It is unknown whether the brine migrated through an open natural fracture/joint system or a reactivated system.

Pressurized conditions were encountered in three observation wells that intersect the grout sheets. The pressures were not considered to result from biological activity. The existence of pressures in the injection formations provides the gradient necessary to drive vertical migration, thereby potentially creating a dynamic groundwater flow system. However, data collected in this effort indicate only the potential for contaminant transport within the wells. The OU3 OHF effort was not designed to determine whether transport is actively occurring within the rock matrix, but the increasing trend in radioactivity with depth and the presence of nitrate in some rock cover wells supports the concept that contaminated groundwater has migrated upward approximately 200 ft within the rock from the plane of injection. Furthermore, the presence of nitrate and radionuclides in the NHF rock cover wells also supports the concept of vertical movement induced by fracturing.

Contamination of the rock cover wells from HF injections does not necessarily mean that the groundwater flow system is dynamic. Vertical transport could have occurred only during the injections when injection pressures opened existing planes of weakness in the rock and provided the gradient to move contaminants upward through rock with a temporarily increased permeability. Dissipation of the pressure may have reduced permeability, thereby trapping contamination within a static flow system.

Based on the likely condition of an upward pressure gradient from the injection zone to the near-surface environment, a re-evaluation of the priorities of Melton Valley remedial activities with respect to the remaining OU3 wells (especially those near the NHF and DM-series wells) and the OU2 investigation would seem prudent. Because of the high volume and short time span in which injections were done at the NHF, the potential for NHF wells requiring P&A is significant.

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ACRONYMS

BOC	bottom of casing
BNI	Bechtel National, Inc.
BTOC	below top of casing
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLP	Contract Laboratory Program
CSL	Close Support Laboratory
DOE	Department of Energy
EPA	Environmental Protection Agency
FFA	Federal Facilities Agreement
FSP	field sampling plan
ID	inside diameter
msl	mean sea level
NHF	New Hydrofracture Facility
OHF	Old Hydrofracture Facility
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
OU	operable unit
P&A	plugging and abandonment
RCRA	Resource Conservation and Recovery Act
RFA	RCRA facilities assessment
RFI	RCRA facilities investigation
RI/FS	remedial investigation/feasibility study
RIIP	remedial investigation implementation plan
SCSR	site characterization summary report
SP	spontaneous potential
SPR	single-point resistivity
SWMU	solid waste management unit
TAL	Target Analyte List
TCL	Target Compound List
TCLP	toxicity characteristic leaching procedure
TDEC	Tennessee Department of Environment and Conservation
TDS	total dissolved solids
VDL	variable density log
VOC	volatile organic compound
WAG	Waste Area Grouping

1. INTRODUCTION

The Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee, is operated for the Department of Energy (DOE) by Martin Marietta Energy Systems (Energy Systems). As part of its DOE mission, ORNL has pioneered waste disposal technologies throughout the years of site operations since World War II. In the late 1950s, efforts were made to develop a permanent disposal alternative to the surface impoundments at ORNL at the request of the National Academy of Sciences. One such technology, the hydrofracture process, involved forming fractures in an underlying geologic host formation (a low-permeability shale) at depths of up to 1000 ft and subsequently injecting a grout slurry containing low-level liquid waste, cement, and other additives at an injection pressure of about 2000 psi. The objective of the effort was to develop a grout slurry that could be injected as a liquid but would solidify after injection, thereby immobilizing the radioisotopes contained in the low-level liquid waste.

The scope of this site characterization was the access, sampling, logging, and evaluation of observation wells near the Old Hydrofracture Facility (OHF) in preparation for plugging, recompletion, or other final disposition of the wells.

1.1 REMEDIAL INVESTIGATION/FEASIBILITY STUDY STRATEGY FOR WAG 10

In the remedial investigation/feasibility study (RI/FS) process and in response to Environmental Protection Agency (EPA) comments on the Waste Area Grouping (WAG) 10 remedial investigation implementation plan (BNI 1990), ORNL developed a strategy for expediting actions at WAG 10. The strategy focuses available resources on achieving an early action for plugging and abandoning the many existing wells and boreholes associated with WAG 10. Meanwhile, the strategy calls for more investigations to evaluate the nature and extent of groundwater contamination; this information will support design of a long-term monitoring network for WAG 10 and, if required, remedial design for groundwater remediation. The strategy acknowledges the impetus for early actions while recognizing that WAG 10 presents long-term monitoring needs. This strategy for the WAG 10 RI/FS was presented to EPA and the Tennessee Department of Environmental Conservation (TDEC) on February 13, 1992, at a working group meeting in Oak Ridge, Tennessee. Integral to the strategy is the proposed division of WAG 10 into three operable units (OUs), as defined below.

Operable unit	Description
OU1: Grout sheets	Solidified grout and contaminated rock layered between or surrounding the grout sheets.
OU2: Groundwater	Groundwater, including free liquids resulting from hydrofracture injections and contaminated groundwater that may be migrating toward the surface.
OU3: Wells and boreholes	Injection wells, deep observation and monitoring wells, and deep boreholes associated with WAG 10.

Note: These OUs were initially proposed in the ORNL Environmental Restoration Division Life Cycle Costing Workshop conducted in October 1991.

The investigation reported in this site characterization summary report (SCSR) is the initial step leading to recommendation for early action for plugging and abandonment (P&A) of wells and boreholes near the OHF in WAG 10. These wells were examined first to facilitate a potential capping option for nearby WAG 5 trenches. A similar investigation examining the wells and boreholes near the New Hydrofracture Facility (NHF) is under way.

The purpose of these site characterization investigations is to achieve an early action to inhibit contaminant transport through wells and boreholes. To facilitate a rapid, cost-effective early action, determination of the nature and extent of contamination, evaluation of contaminant fate and transport, and hydrogeological characterization, which generally are components of a remedial investigation, were not included in the site characterization.

After the wells and boreholes at WAG 10 are plugged and abandoned, the potential for transport of contaminants from WAG 10 exists primarily as part of WAG 10 OU2: Groundwater. DOE, in conjunction with EPA and TDEC, is currently developing a strategy for addressing groundwater at ORNL, including the creation of the ORNL area-wide groundwater program encompassing groundwater associated with all WAGs in Bechtel Valley and Melton Valley. The strategy for the investigation of OU2, including groundwater characterization and determination of the nature, extent, transport, and fate of WAG 10 contaminants, will be integrated into the ORNL area-wide groundwater program.

1.2 REGULATORY BACKGROUND AND STATUS

Along with the WAG 10 hydrofracture injection sites, ORNL contains a large number of sites used for storage, treatment, and/or disposal of liquid and solid wastes, including underground storage tanks, surface impoundments, pits/trenches, landfills, and waste treatment facilities. Many of these facilities are associated with environmental releases of radioactive and nonradioactive contaminants. In addition, spills and leaks have occurred as a result of routine waste management practices, resulting in contaminant releases to the environment. ORNL identified a list of solid waste management units (SWMUs) as a first step in complying with Resource Conservation and Recovery Act (RCRA) corrective action requirements specified in ORNL's RCRA permit for its Hazardous Waste Storage Facility (Building 7652). These requirements address releases of hazardous waste and hazardous waste constituents from all SWMUs, regardless of whether the units were used to manage hazardous waste.

To simplify planning and implementation of the corrective action program, ORNL grouped its waste management sites into 20 WAGs. Each WAG contains one or more SWMUs within geographically contiguous and/or hydrologically defined areas. Evaluation of the ORNL WAGs was begun as part of a RCRA facility assessment (RFA) completed in 1987. The RFA identified WAGs (and SWMUs) requiring further characterization through a RCRA facility investigation (RFI) to determine the source and magnitude of contaminant releases. WAG 10 was included in the list of sites for which an RFI was required.

The Environmental Protection Agency (EPA) included the ORNL Oak Ridge Reservation (ORR) on the Federal Agency Hazardous Waste Compliance Docket established under Section 120 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and placed the ORR on the National Priorities List in November 1989. The Federal Facilities Agreement (FFA), involving DOE, EPA Region IV, and TDEC, became effective on January 1, 1992. One of the primary goals of the FFA was to integrate the ongoing RCRA corrective action program with the CERCLA requirements for National Priorities List sites as established by the National Oil and Hazardous Substances Contingency Plan.

As detailed in the FFA, DOE agreed to coordinate the RCRA and CERCLA response actions at ORNL to minimize duplication of investigative and analytical work associated with identification, assessment, and cleanup of the ORNL WAGs. The FFA also specified that CERCLA terminology be used for the investigation, evaluation of alternatives, and design and cleanup work (i.e., RI/FS and remedial design/remedial action). For WAG 10, ORNL planned to combine the RFI and remedial investigation into a single investigation designed to meet the requirements of the RCRA corrective action program and CERCLA for closure of the WAG 10 hydrofracture sites.

In January 1988, the Energy Systems contractor, Bechtel National, Inc. (BNI), under supervision of the Remedial Action Program for Energy Systems, developed a remedial investigation implementation plan for WAG 10 (BNI 1988). Revision 2 of the plan was issued in March 1990 (BNI 1990). A revised implementation strategy was developed in a February 13, 1992, working group meeting by DOE, TDEC, Energy Systems, and its subcontractors. WAG 10 was segregated into three OUs: OU1 - grout sheets (and any contaminated rock in or around the grout sheets); OU2 - groundwater; and OU3 - wells and boreholes (including injection wells, deep observation wells, monitoring wells, and deep boreholes associated with WAG 10). A general strategy for the WAG 10 RI/FS was presented in Volume 2 of the implementation plan (BNI 1992), which also contains a field sampling plan (FSP) and a quality assurance project plan. This site characterization is part of the investigation of OU3 wells and boreholes.

1.3 OPERATIONAL BACKGROUND

Four hydrofracture sites at ORNL were used for development, demonstration, and full-scale disposal operations (Fig. 1.1). The first two sites (HF-1 and HF-2) were used only for demonstration of the hydrofracture concept. The third site, the OHF (HF-3), was used first for pilot-scale testing followed by a series of waste disposal injections. The fourth site, the NHF (HF-4), was designed and operated as a full-scale disposal system for low-level liquid waste. In all, more than 5 million gallons of waste grout mix containing approximately 1.4 million Ci of radioactivity was disposed of via hydrofracture through a series of 46 injections at HF-3 and HF-4. Radioactivity (360,000 Ci) and 2.2 million gal of grout were injected at the OHF in 7 test and 15 production injections. Disposal activities using the hydrofracture process were discontinued at the OHF in 1979 and at the NHF in 1984. DOE was directed by EPA Region IV and the Tennessee Department of Health and Environment (currently the TDEC) to develop remedial action plans for

permanent closure of all four sites, under authorization of RCRA and the Underground Injection Control regulations of the Safe Drinking Water Act.

OU3 wells and boreholes received the highest priority for study and remediation because of the high potential for exposure to humans and the near-surface environment and the feasibility of the potential technical approaches to remediation of the OU. OU1 and OU2 were deemed a lesser priority because of the lack of an immediate exposure pathway (although groundwater may have a relatively high potential for migration under the proper circumstances, as discussed in Sect. 8 of this report). Extraction or in situ remediation of the OU2 groundwater (or liquid wastes) within the briny, low-permeability hydrogeologic horizon in which it resides is not technically feasible at this time. While it is technically feasible to mine or remove the solid OU3 grout from a nominal depth of 1000 ft using current technology, the activity would pose a greater risk to human health and the environment than is currently posed by leaving the grout in place. Because OU3 has the greatest risk-reduction potential and is the most technically feasible to remediate, it was scheduled for remediation, based on a phased "observational" approach.

Concurrent with this site characterization has been a remedial investigation of the entire WAG 5 and a decontamination and decommissioning study of the OHF buildings. A potential early action or remedial action for the portion of WAG 5 near the OHF would be to install a cap to reduce infiltration of precipitation, which would thereby reduce the migration of any contaminants in the soil. Any construction-type actions, such as building demolition, well plugging, or well removal, need to be accomplished before a cap is installed. This was the time-critical driver for this characterization. The 23 wells near the OHF may interfere with a capping or decontamination and decommissioning of the OHF building and are the WAG 10 OU3 wells addressed in this characterization. Two additional wells near the HF-2 site (1920 and 1943) were added to provide additional information in the same strata as the OHF injection zone and to support additional field studies done at WAG 10. Figures 1.2 and 1.3 show an aerial photograph and map of the WAG 10 OU3 OHF wells.

Fig. 1.1. WAG 10 hydrofracture sites in Melton Valley.

Fig. 1.2. WAG 10 Operable Unit 3, Phase 1 Well Locations

Fig. 1.3. WAG 10 OHF Basemap

2. OVERVIEW OF SITE CHARACTERIZATION FIELD WORK

The objectives defined in Sect. 3 were met through a field effort involving tapping potentially pressurized wells, sampling and analyzing wellbore water, and obtaining geophysical logs from each well to evaluate well construction and integrity. The field effort began in November 1993 and concluded in August 1994. A detailed discussion of these activities is provided in BNI (1995).

In January 1986, a sampling team at nearby deep groundwater monitoring well DM1-PV was splattered with contaminated material during sampling of the well. DM1-PV is completed in the same geologic strata as the hydrofracture injections at OHF and NHF (Energy Systems 1986a). It is unclear whether the pressure in the well causing the artesian effect is a function of the injections or a natural result of an aquifer confined by low hydraulic conductivity beds dipping south from Haw Ridge to the injection site. The potential for pressure in the wells during the investigation required that a pressure-conservative drilling apparatus [described in BNI (1995)] be used to gain initial access to the wells.

Because of the uncertain construction of the WAG 10 observation and rock cover wells (e.g., materials used, casing deterioration), obtaining defensible data of sufficient quality to support RCRA or CERCLA groundwater compliance monitoring requirements was not a goal of this preliminary sampling event. The water data were used to characterize contamination in the standing water column within the well casing and openhole section and thereby support waste management and health and safety concerns regarding geophysical logging and potential P&A efforts.

Water was sampled near the top, in the middle, and near the bottom of the standing water column in each well. Samples were obtained using a downhole sampling device that obtained grab samples at depth but was not designed to maintain hydrostatic pressure during withdrawal of the sampler or transfer of the samples. Lack of pressure integrity affects alkalinity and pH measurements but should not have significant impact on screening quality level radiochemical, inorganic, and organic samples. Four small-diameter observation wells were constructed of 1.25-in.-inside-diameter tubing, which precluded use of the downhole sampling device or insertion of geophysical logging equipment. Small-diameter observation well samples were obtained with a bailer, which, as discussed in Sect. 8.3, did not prove to be representative of deep wellbore water. Wellbore water was analyzed at ORNL's Environmental Restoration Close Support Laboratory (CSL) for the parameters identified in Table 2.1. An offsite laboratory was used for Target Analyte List (TAL) analytes (metals) and Target Compound List (TCL) organic compounds using EPA Contract Laboratory Program (CLP) methods.

To minimize waste generation, the wells were not purged before sampling. The integrity of the casing is uncertain. Therefore, the wellbore water data are not representative of formation water. Deep water samples were not collected using a pressure-conservative sampler; therefore, off-gassing and precipitation reactions may have altered ionic chemistry. Data from this initial characterization effort will not be used to support quantitative human health or ecological risk assessment.

The radiochemistry data are sufficient to support characterization of the overall level of activity (e.g., gross alpha, beta, and gamma activity). Evaluation of the ionic chemistry and total dissolved solids (TDS) data indicates that they are sufficient to characterize basic water types, such as calcium bicarbonate surface water or sodium chloride brines, and to identify anomalously low ionic concentrations, which are probably the result of dilution from low-TDS injection solutions.

The data were collected in accordance with quality assurance requirements, quality control oversight, and corrective action, which are discussed in the WAG 10 quality assurance project plan (BNI 1992). Procedures were followed that address determination of precision, completeness, and accuracy requirements; field and CSL equipment calibration; verification of analytical data; recording of field data and calibration results; quality control surveillance and monitoring of field and laboratory activities; and management of corrective actions. Analysis of field and laboratory quality assurance data is presented in BNI (1995).

Three types of wells were sampled and logged during the WAG 10 OHF investigation. Deep observation wells were completed within the injection horizon and consist entirely of casing cemented in place without a designed open interval. Historically, gamma-ray logging tools were run through the casing to identify the position of the grout sheets after each injection. Two types of casing materials were used in construction of the deep observation wells: small-diameter casing of only 1.25 in. inside diameter and large-diameter casing exceeding 2 in. inside diameter (typically 2 $\frac{7}{8}$ in.). The small-diameter casing is significant because the restricted size prevented use of reliable sampling probes or geophysical logging sondes. The observation well casings were typically installed from the surface into the upper Pumpkin Valley Shale.

The rock cover wells were used to monitor formation pressures in the "rock cover" formations, the Rutledge Limestone and/or Rogersville Shale, during the injections and thereby identify increased hydrostatic pressures in the overlying formations that could be indicative of vertical fracturing. Construction of the rock cover wells was variable; some were pilot wells cased to total depth, whereas others have openhole intervals in the Rogersville Shale and/or Rutledge Limestone. As necessary, the wells were topped off with potable water between injections to allow monitoring of wellbore pressures.

Table 2.1. Analytes and parameters for well water samples

Close Support Laboratory	Offsite Laboratory
Alkalinity	TAL analytes (metals)
Ammonium	TCL organic compounds using EPA CLP methods
Bromide	
Chloride	
Fluoride	
Nitrate	
Phosphate	
Sulfate	
Naphthalene	
Calcium	
Lithium	
Magnesium	
Potassium	
Sodium	
pH	
Total dissolved solids	
Total suspended solids	
1,1-Dichloroethene	
Benzene	
Carbon tetrachloride	
Chloroform	
Ethylbenzene	
Methylene chloride	
Tetrachloroethene	
Toluene	
trans-1,2-Dichloroethene	
Trichloroethene	
Xylene (total)	
Alpha	
Beta	
C-14	
Co-60	
Cs-137	
Gamma	
Total radioactive strontium	
Tritium	

Source: BNI 1995.

3. OBJECTIVES

The objectives of the site characterization are taken from the screening-level risk assessment and the strategy/technical approach for OU3 wells and boreholes in the FSP for WAG 10 (BNI 1992). The investigation of WAG 10 OU3 is designed to

- facilitate an early action by determining the applicability and necessity of the response actions/technologies identified in the FSP,
- collect sufficient data to design and implement the selected action/technology, and
- gather opportunistic hydrogeologic characterization data for consideration in a subsequent OU2 (groundwater, or Melton Valley groundwater) investigation.

According to the FSP, the remedial action objectives for all WAG 10 OU3 wells and boreholes are to mitigate leaching of contaminants from the wellbores or boreholes, stop potential transport of contaminants along wellbores or boreholes, and prevent unacceptable exposure to human health and the environment from contaminated materials within the wellbores or boreholes. These objectives were developed to control, mitigate, or remove various risk elements identified in the screening-level risk assessment in the FSP. The risk elements identified were

- a source risk from the leaching of contaminants from wells, some of which were contaminated during the injection process,
- a transport pathway risk from the potential passage of contaminants from one formation to another across open intervals of the wells and in areas where the well casing and cement do not provide an adequate barrier to flow, and
- an exposure risk to an intruder attempting to drink well water.

The general response actions or technologies identified in the FSP to mitigate or remove the above risks were institutional controls and P&A (or recompletion) of the wells and boreholes. Institutional controls address only the exposure risk. P&A would remove the source, transport, and exposure risk from wells and boreholes, although the potential for worker exposure would temporarily increase during P&A field activities. Recompletion to collect additional data would be done in wells as a temporary measure before P&A or in wells where none of the aforementioned risks exist. The representative alternatives were no action (a CERCLA requirement) and institutional controls plus a combination of well recompletion and P&A. The focus of this investigation is to acquire information to support future P&A or recompletion of OHF wells.

As stated in the FSP, the objectives for an OU3 investigation are to

- determine which wells are potential candidates for recompletion and which are candidates for P&A,

- provide data to support the preliminary design of well recompletion and P&A, and
- refine the conceptual model to support OU2 planning.

Fulfilling these objectives was the scope of this investigation of 23 WAG 10 wells near the OHF. Two additional wells near the HF-2 site were also examined and used to gain additional data. To achieve these objectives, the following elements were included in this investigation:

- accessing the wells using a pressure-conservative drilling apparatus to tap into the wellbore, controlling any flow of contaminants from the well, and reducing risk to workers, human health in general, and the environment;
- sampling the water in the wellbore to determine the potential characteristics of wastewater during recompletion or plugging of the well, the probable near-well groundwater composition, the salinity/density to help determine the short-term origin of the well water, and appropriate protection to workers at the well;
- recording any pressure in the wells and analyzing any wellhead gases to determine the origin of wellhead pressures;
- analyzing samples of the well water for the analytes listed in Table 2.1;
- geophysically logging the well to help determine the construction characteristics of the wells, current integrity of any barriers to flow, evidence of flow within the wellbore (i.e., temperature or salinity anomalies), and verification of lithologic horizons;
- developing a conceptual model of potential transport pathways for each well from the existing and investigation data to support design of well P&A; and
- analyzing the well condition to determine necessary procedures for abandonment and to rank the wells for early attention based on the contamination, migration potential (artesian condition), and well integrity.

Work is currently under way pursuing similar objectives for WAG 10 wells near the NHF.

4. DOCUMENT ORGANIZATION

This SCSR is the second in a series of three documents reporting the first phase of the WAG 10 OU3 investigation. The first document, the WAG 10 Well Evaluation Technical Bulletin (BNI 1995), summarizes field activities for this effort, including modification and tapping of enclosed wells, sampling of wells, and borehole geophysical logging. It presents the methodology for tapping and sampling wells; discusses problems encountered during tapping, sampling, and downhole logging; presents organic, inorganic, and radiochemical well water data; discusses field quality assurance results; and presents the geophysical logs.

This document reviews the objectives of the investigation, presents the hydrogeological setting, briefly reviews the site and operational history, develops a conceptual model for wellbore transport, analyzes current well-specific conditions, and makes recommendations for further work. This document provides the necessary analysis to develop a decision for recompletion or P&A of the wells addressed in this investigation.

A subsequent document to this SCSR is the *Plugging and Abandonment Options Analysis Report for OHF Wells in WAG 10*, which uses information from this SCSR to develop an approach for the final disposition of these wells. The P&A report defines well P&A objectives, identifies the regulatory setting, investigates remedial action options and technologies, identifies alternatives, and provides a cost analysis of P&A options. For wells posing an immediate risk to human health or the environment, the report may recommend a fast action to create a time-critical barrier to flow in the wellbore of high-risk wells.

5. SITE AND OPERATIONAL HISTORY

A chronology of the site operational history is presented in Table 5.1. Contaminated grout was injected at the OHF in HF-3 well 1944 (completed by February 1964). A total of 25 injections were conducted between February 1964 and May 1979. The 7 experimental or pilot injections were followed by 18 production-type injections. All OHF injections took place within the upper Pumpkin Valley Shale in well 1944. As indicated in Table 5.1, up to four injections took place within a single slot cut into the casing of well 1944. Table 5.2 lists the content of the injections, including radioisotope activities in Ci, total activity in Ci, waste volume in gallons, and grout volume in gallons.

Three types of wells were installed between July 1961 and June 1985 to monitor the OHF injections. The rock cover wells installed were wells 1945, 1947, 1950, 1951, 1952, 1955, 1956, 1957, 1959, 1960, 1961, 1963, and 1967. Construction of the rock cover wells was variable. Some were pilot wells cased to total depth, whereas others have openhole intervals in the Rogersville Shale and/or Rutledge Limestone. If necessary, the wells were topped off with fresh water between injections so that a pressure gauge in the wellhead could monitor the impact of the injection pressure on the pressure in the rock cover well, as determined by the pressure measured in the continuous water column. Pressures observed at the rock cover wells were compiled based on Weeren (1974, 1976, and 1980) and are presented in Table 5.3. The possible effects of this freshwater infusion (overprinting) on the analysis and evaluation of current salinity patterns in the wells are discussed in general terms in Sect. 7.3 and specifically for each well in Sects. 8.2.1 through 8.2.19. Because the total volume of water injected into each well was not recorded, it is difficult to determine the magnitude of change in rock cover wellbore water chemistry in response to the addition of presumably near-neutral pH, low-TDS, potable water to the formation water. The total volume of water added between injections was approximately 4 gal (Weeren 1976). TDS values in the upper portion of the rock cover wells are generally low and increase significantly at the bottom. Although the volume of the wellbore water affected by dilution with potable water is not known, it is reasonable to assume that the density differences restricted the mixing to the upper portion of the well.

The two other types of wells are large- and small-diameter observation wells. The large-diameter wells (1946, 1949, 1954, 1965, and 1966) are completely cased wells with diameters greater than 2 in., have no planned open intervals, and are completed in the Pumpkin Valley Shale within or through the injection horizon. Observation wells 1954 and 1966 are plugged. Well 1953 is cased to approximately 500 ft, with an openhole interval from the lower Rogersville Shale into the lower Pumpkin Valley Shale. Except for wells 1946, 1949, and 1964, cement grout was used to cement observation and rock cover casings. The bottom 150 ft of wells 1946 and 1949 and the bottom 350 ft of well 1949 were cemented using a low-strength Latex-based grout to provide elasticity, thereby preventing cracking at the casing bond in response to injection-induced tensile stresses on the well casing.

The two wells near the HF-2 site included in this investigation, 1920 and 1943, were grouped with the large-diameter HF-3 observation wells. These wells, located generally along strike from HF-3, have long openhole intervals from the Nolichucky Shale into the lower Pumpkin Valley Shale.

The small-diameter observation wells (1948, 1958, 1962, and 1964) are cased, have no planned open interval, and are completed in the Pumpkin Valley Shale. These wells have an inner tubing with an internal diameter of only 1.25 in. The small-diameter wells were drilled with a nominal 3- to 4-in. bit and completed with a small galvanized riser cemented in place.

Both large- and small-diameter observation wells were designed to allow borehole gamma logs (small-diameter logging sonde, calibrated in mrem/h) to be run to identify the grout sheets without providing a conduit to the surface for the contaminated grout. Some observation wells were installed with low-strength grout in the bottom 150 ft of the borehole to prevent cracking of the grout in response to tensile stress induced during the injection.

In addition to the radionuclides listed in Table 5.2, information on the types and concentrations of other inorganic constituents of the bulk stored waste [taken from Autrey et al. (1989)] is presented in Table 5.4. Table 5.5 summarizes inorganic waste constituents available for some injections, as presented in Weeren (1974, 1976, and 1980). Comparison of the lists indicates that the concentrations of major anions and TDS are significantly lower in the bulk tanked waste than in the waste associated with specific injections. Characterization of the inorganic composition of injected waste discussed in this document is based on the injection-specific data presented in Weeren (1974, 1976, and 1980). These data indicate that the highest anion concentrations are from nitrate (15,000 to 85,000 mg/L), sodium (23,000 to 60,349 mg/L), carbonate (8000 to 23,000 mg/L), and sulfate (10,000 to 18,000 mg/L). TDS values are also high, ranging from 80,000 to 140,000 mg/L.

The grout component of the injected grout/waste mix typically consisted of approximately 2.5 parts cement, 2.5 parts fly ash, 1 part attapulgite clay, 0.5 part grundite, and 0.003 part delta gluconolactone retarder (Weeren 1974; de Laguna et al. 1968). The grout and waste constituents present an anthropogenic source term of radiological or other ionic constituents that may affect groundwater surrounding the monitoring and observation wells via leaching. Wellbore water may also be affected by a contaminated grout filtrate that is generated as the grout hardens. The specific chemical makeup of the grout filtrate is unknown; however, it can be assumed that the constituents are similar to those of the waste/grout mix, but the concentrations would likely differ because of preferential containment of constituents in the hardened grout. Bleedback solutions were forced back into the injection well after injection pressure ceased because of high hydrostatic and lithostatic pressures in the formation; analysis of these solutions could provide the best data on the filtrate composition. Unfortunately, few chemical analytical data for bleedback solutions are available. Weeren (1974) presents some limited bleedback data from injections ILW-8 through ILW-11 that indicate sodium concentrations ranging from 24,000 to 35,000 mg/L; pH ranging from 10.0 to 12.3; and ^{90}Sr , ^{137}Cs , ^{106}Ru , ^{134}Cs , and ^{60}Co activities ranging from 2.5×10^{-5} to 2.5×10^{-3} Ci/gal. How much the bleedback solutions were diluted by clean water flushing of the injection well to remove remaining grout is unknown.

The chemistry of formation water may also be affected by the use of water to begin the fracturing process. After the casing was slotted, fresh water (relative to the injection formation brines) was injected under high pressure. Complete records on the volume of injected water are not

available; however, Weeren (1974) indicates that 2000 to 3000 gal of water could have been initially injected at each waste/grout injection event.

The regulatory and planning history of the WAG 10 characterization activities is summarized in Sect. 2. The field portion of the WAG 10 investigation began in November 1993 and concluded with the end of geophysical logging by the ORNL Geology and Geophysics Group in August 1994.

Table 5.1. Summary of site operational history

Alias/ Injection	ORNL Well ID	Start Date	Finish Date	Event	Comments / Unusual Conditions
Large-Diameter Monitoring Wells					
N-150	1949	May-63	May-63	Well Installation	Bottom 350 ft of tubing was butt welded. Drilled to 350 ft depth.
E-320	1946	Jul-72	Jul-72	Well Installation	No grout sheets intersected. Bottom 150 ft of cement was low strength. Drilled to 840 ft depth.
S-220W	1965	Jul-72	Jul-72	Well Installation	Grout sheet intersected during drilling at 798 ft. Drilled to 820 ft depth.
NE-100	1953	Jun-85	Jun-85	Well Installation	Open corehole
Pilot Wells (Cemented)					
E-320P	1947			Well Installation	Casing set, not drilled out. Drilled to 500 ft depth.
N-375P	1952	Dec-67	Dec-67	Well Installation	Casing set, not drilled out. Drilled to 500 ft depth.
NE-300P	1957			Well Installation	Casing set, not drilled out. Drilled to 500 ft depth.
NW-290P	1961			Well Installation	Casing set, not drilled out. Drilled to 500 ft depth.
Rock Cover Wells					
N-200R	1950	Dec-63	Dec-63	Well Installation	Prototype rock cover well. Drilled to 650 ft depth.
NE-125R	1955	Dec-65	Dec-65	Well Installation	Ruptured at some time during or before ILW-12-14, but still usable. Drilled to 600 ft depth.
NW-175R	1959	Dec-65	Dec-65	Well Installation	Drilled to 570 ft depth.
E-300R	1945	Jun-69	Jun-69	Well Installation	Drilled to 600 ft depth.
N-275R	1951	Jun-69	Jun-69	Well Installation	Drilled to 600 ft depth.
NE-200R	1956	Jun-69	Jun-69	Well Installation	Drilled to 600 ft depth.
NW-250R	1960	Jun-69	Jun-69	Well Installation	Drilled to 600 ft depth.
S-200R	1963	Dec-69	Dec-69	Well Installation	Drilled to 600 ft depth.
W-300R	1967	Dec-69	Dec-69	Well Installation	Drilled to 650 ft depth.
Small-Diameter Monitoring Wells					
W-300	1966	Jul-61	Jul-61	Well Installation	Core analysis in ORNL-4259. Plugged during 1975 injection series. Plugged at surface 5/82. Drilled to 3,263 ft depth.
N-100	1948	Aug-64	Aug-64	Well Installation	Flowed salt water (2 gal/day). Drilled to 1,000 ft depth.
NW-100	1958	Aug-64	Aug-64	Well Installation	Ruptured at some time during or before ILW-12-14, but still usable. Drilled to 1,000 ft depth.

Table 5.1. Summary of site operational history (continued)

Alias/ Injection	ORNL Well ID	Start Date	Finish Date	Event	Comments / Unusual Conditions
NE-125	1954	Sep-64	Sep-64	Well Installation	Intercepted by grout sheet during injection ILW-13, 900 psi noted at wellhead. After ILW-16 cap was broken during cold weather, a small amount of contaminated water leaked up the well, leaving it too contaminated to log. Drilled to 1,030 ft depth.
S-100	1962	Nov-64	Nov-64	Well Installation	Tubing ruptured, well plugged at 700 ft during injections ILW-12 through ILW-14. Drilled to 1,032 ft depth.
S-220	1964	Dec-68	Dec-68	Well Installation	Tubing pulled apart by ILW-5. The pilot hole for this well was drilled and cased to a depth of 600 ft in the spring of 1967. The first radioactive grout sheet was penetrated on June 13 at the depth of 864.1 ft. Drilled to 1,050 ft depth.
Pilot or Test Injections					
Injection 1	1944	Feb-64	Feb-64	Injection	Injected at 945 ft depth.
Injection 2	1944	Feb-64	Feb-64	Injection	Injected at 924 ft depth.
Injection 3	1944	Apr-64	Apr-64	Injection	Injected at 912 ft depth.
Injection 4	1944	Apr-64	Apr-64	Injection	Injected at 900 ft depth.
Injection 5	1944	May-64	May-64	Injection	Injected at 890 ft depth.
Injection 6A	1944	May-65	May-65	Injection	Injected at 880 ft depth.
Injection 6B	1944	May-65	May-65	Injection	Injected at 872 ft depth.
Injection 7	1944	Aug-65	Aug-65	Injection	Injected at 872 ft depth.
Production-Type Injections					
ILW-1A	1944	Dec-65	Dec-66	Injection	NA
ILW-1B	1944	Dec-66	Dec-66	Injection	NA
ILW-2A	1944	Apr-67	Apr-67	Injection	
ILW-2B	1944	Apr-67	Apr-67	Injection	Injected at 862 ft depth.
ILW-8	1944	Sep-72	Sep-72	Injection	Injected at 832 ft depth.
ILW-9	1944	Oct-72	Oct-72	Injection	Injected at 832 ft depth.
ILW-10	1944	Nov-72	Nov-72	Injection	Vertical movement of grout sheets in ILW-10 and 11 was greater than had been previously observed, probably due to abnormalities in the shale bedding. Injected at 832 ft depth.
ILW-11	1944	Dec-72	Dec-72	Injection	Injected at 832 ft depth.

Table 5.1. Summary of site operational history (continued)

Alias/ Injection	ORNL Well ID	Start Date	Finish Date	Event	Comments / Unusual Conditions
ILW-12	1944	Jan-75	Jan-75	Injection	Injected at 822 ft depth.
ILW-13	1944	Apr-75	Apr-75	Injection	Injected at 822 ft depth.
ILW-14	1944	Jun-75	Jun-75	Injection	W-300, S-100, plugged during injection. Injected at 822 ft depth.
ILW-15	1944	Jun-77	Jun-77	Injection	Injection ILW-15 shutdown due to leak of grout to the waste pit. Eroded drain valves. Completed injection 2 days later. Injected at 822 ft depth.
ILW-16	1944	Nov-77	Nov-77	Injection	A bleedback operation was attempted, but no water was recovered. Injected at 812 ft depth.
ILW-17	1944	Sep-78	Sep-78	Injection	NE-125 casing was pulled apart and no longer usable. Injected at 802 ft depth.
ILW-18	1944	May-79	May-79	Injection	Injected at 784 ft depth.

Table 5.2. Radioisotopic content of injections at the OHF

Isotope / Parameter	Gross Alpha	Gross Gamma	Au-198 (Ci)	Ce-144 (Ci)	Cm-244 (Ci)	Co-60 (Ci)	Cs-134 (Ci)	Cs-137 (Ci)	Pu-238 (Ci)	Pu-239 (Ci)	Ru-106 (Ci)	Sr-90 (Ci)	Total Activity	Waste Volume (gal)	Volume (gal)
Injection-1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	37,300	40,383
Injection-2	NA	NA	30	NA	NA	NA	NA	NA	NA	NA	NA	NA	30	28,300	37,791
Injection-3	NA	NA	NA	NA	NA	NA	NA	75	NA	NA	NA	5	80	33,500	65,314
Injection-4	NA	NA	NA	NA	NA	NA	NA	50	NA	NA	1	1	52	35,900	57,467
Injection-5	NA	NA	NA	4,099	NA	4	NA	143	NA	NA	44	610	4,900	147,600	211,275
Injection-6	NA	NA	NA	NA	NA	1	NA	1,562	NA	NA	2	330	1,895	68,400	98,470
Injection-7	NA	NA	NA	NA	NA	14	NA	3,358	NA	NA	2	492	3,866	85,000	123,411
ILW-1A	NA	NA	NA	20	NA	16	NA	11,500	NA	NA	1	41	11,578	37,440	55,000
ILW-1B	NA	NA	NA	13	NA	3	NA	7,600	NA	NA	8	38	7,662	26,000	40,197
ILW-2A	NA	NA	NA	NA	NA	236	NA	31,329	NA	NA	99	564	32,228	81,400	121,805
ILW-2B	NA	NA	NA	NA	NA	199	NA	26,350	NA	NA	83	474	27,106	64,345	108,600
ILW-3	NA	NA	NA	NA	NA	NA	NA	17,000	NA	NA	NA	9,000	26,000	83,000	146,751
ILW-4	NA	NA	NA	NA	NA	NA	NA	51,900	NA	1.10	NA	4,300	56,201	86,190	130,675
ILW-5	NA	NA	NA	NA	NA	NA	NA	69,400	NA	1.15	NA	500	69,901	87,110	115,174
ILW-6	NA	NA	NA	NA	NA	NA	NA	89,000	NA	0.24	NA	8,900	97,900	79,350	126,331
ILW-7	NA	NA	NA	NA	19.2	NA	NA	44,833	NA	1.77	NA	2,747	47,601	83,000	145,670
ILW-8	NA	NA	NA	NA	NA	NA	NA	27,917	NA	NA	2,523	45	30,485	72,700	108,600
ILW-9	NA	NA	NA	NA	6.0	NA	NA	23,359	NA	NA	376	231	23,972	68,300	114,000
ILW-10	NA	NA	NA	NA	29.0	NA	NA	18,817	NA	NA	593	1,331	20,770	84,760	132,960
ILW-11	NA	NA	NA	NA	148.0	NA	NA	23,297	NA	NA	365	1,090	24,900	75,760	125,490
ILW-12	NA	NA	NA	NA	15.0	NA	104	11,976	NA	NA	342	1,639	14,076	25,710	42,100
ILW-13	NA	NA	NA	NA	NA	81	NA	35,254	NA	NA	475	3,305	39,115	81,000	126,100
ILW-14	NA	NA	NA	NA	NA	NA	NA	30,671	NA	NA	NA	2,795	33,466	82,970	138,700
ILW-15	NA	NA	NA	NA	NA	3,077	NA	22,907	2	1.00	390	151	26,528	91,000	145,037
ILW-16	NA	NA	NA	NA	NA	204	81	14,151	NA	NA	17	1,530	15,983	55,000	79,500
ILW-17	NA	NA	NA	NA	2.0	199	138	21,078	NA	NA	343	602	22,362	82,300	137,500
ILW-18	1	2,670	NA	NA	NA	143	353	13,713	NA	NA	NA	28	16,908	86,014	139,000

NA = Not Available

Table 5.3 Summary of injection-related pressures observed in rock cover wells

[illegible]

Table 5.3 Summary of injection-related pressures observed in rock cover wells (continued)

INJECTION #	DATE	ELAPSED TIME (hrs)	E300 Pressure (psi)	N200 Pressure (psi)	N275 Pressure (psi)	NE125 Pressure (psi)	NE200 Pressure (psi)	NW175 Pressure (psi)	NW250 Pressure (psi)	S200 Pressure (psi)	W300 Pressure (psi)
ILW-13	4/29/75	0	0	0	15	-7	13	-14	1	25	3
ILW-13	4/29/75	0.75	2	0	15.5	7.5	-7	-16	0	27	3
ILW-13	4/29/75	3.58	2	0	15	10	-6	-18	0	35	3.5
ILW-13	4/29/75	4.91	2	0	14	24	17.5	-12	0	36	3.5
ILW-13	4/29/75	7.41	0	0	11.5	21	6	-6	0	60	3.5
ILW-13	4/29/75	10.41	0	0	10	60	39	16	3.5	60	2
ILW-13	4/29/75	208.3	3	0	10	18	10	1	9	50	0
ILW-14	6/18/75	0	0	0	11.5	25.5	0	-7	4	41	0
ILW-14	6/18/75	0.78	4	0	11	19	5	-8	4	41	0
ILW-14	6/18/75	2.36	4	0	11	24	10	-27	3	40	0
ILW-14	6/18/75	5.02	2	0	11	25	8	0	3.5	41	3
ILW-14	6/18/75	6.27	0	0	11	35	14	1	3.5	42	3
ILW-15	6/30/77	0	11	-7.9	3	-7.4	-12	-7.4	2	7	-1
ILW-15	6/30/77	1.43	12	-7.9	3	-7.4	12	-7.4	2	8	-1
ILW-15	6/30/77	2.93	10.5	-7.9	4	10	25	-8.4	0	9	-1
ILW-15	6/30/77	4.59	7.5	-7.9	3	12.5	32	-9.8	-2	9	-1
ILW-15	6/30/77	6	6	-7.9	2	14	29.5	-8.4	-2	9	-1
ILW-15	7/2/77	47.17	10	-7.4	-1	15	10	-5.4	1	15	0
ILW-15	7/2/77	48.33	9.5	-7.9	-0.5	25.5	11	-2.5	1	14	0
ILW-15	7/2/77	51.41	3.5	-1	0	50	22	19	10	12	0
ILW-15	7/2/77	53.74	0	0	0	52	26.5	19	15	18	0
ILW-16	11/1/77	0	12	6	2	0	3	-2.5	6	19	0
ILW-16	11/1/77	0.96	11	3.5	20.5	6	1.5	4	19	0	0
ILW-16	11/1/77	2.79	10	-0.5	0.5	19	43	40	29	17.5	0
ILW-16	11/1/77	4.2	7	-0.5	0	21.5	3	51.5	55	18.5	0
ILW-16	11/1/77	5.61	7	-4.9	-0.5	27	1	44	57	43.5	0
ILW-16	11/1/77	7.19	15	-6.9	0.5	32	3.5	39	52.5	42.5	0
ILW-17	9/1/78	0.8	21.5	-5.9	4.5	0	-5.4	-2.9	5	20	-0.5
ILW-17	9/1/78	4.13	30.5	-9.8	3	0	-9.3	-6.9	3	20.5	-0.5
ILW-17	9/1/78	6.13	34.5	-10.3	0.5	-2.5	-10.6	-8.3	0.5	20	0
ILW-17	9/1/78	7.13	35	-10.8	0	-3.5	-11.3	-8.8	0	19.5	-0.5
ILW-17	9/1/78	8.79	36.5	-12.3	-0.7	-4.7	-11.8	-10.1	-1	19	0
ILW-18	5/18/79	0	0.5	0	0	-0.5	3.7	0	0	23.5	0
ILW-18	5/18/79	0.66	0.5	0	0	0.5	3.7	0.5	0	29	0
ILW-18	5/18/79	3.32	1.2	0	0.5	0	5.5	0.5	0	37.5	0
ILW-18	5/18/79	4.48	2	0.5	0.3	45.5	21	0.3	0	37.5	0
ILW-18	5/18/79	5.81	2	0	0	43	39	1.5	0	35	0
ILW-18	5/18/79	7.06	10	0	0	37	40	2	0	34	0
ILW-18	5/18/79	9.72	10	0	2.5	44	44	2.5	0	30	0
ILW-18	5/18/79	10.8	0	0	3.5	56.5	0	0	0	27	0

* Reading Offscale

Table 5.4. Waste characterization data^a for OHF waste storage tanks

Analytes	Tank liquids					Tank sludges				
	T1	T2	T3	T4	T9	T1	T2	T3	T4	T9
<i>Anions (liquid: mg/L; sludge: mg/Kg)</i>										
Chloride (Cl ⁻)	7.8	12	7	3.1	290	---	4.90%	29%	<0.83%	3%
Fluoride (F ⁻)	1	1	1.8	1.1	1	---	<0.8%	<12.7%	<0.83%	<0.7
Nitrate (NO ₃ ⁻)	16	8	53	26	110	---	---	---	---	---
Phosphate (PO ₄ ⁻³)	<5	<5	160	51	<5	---	---	<62.5%	<42%	---
Sulfate (SO ₄ ⁻²)	7.5	21	15	6.3	37	---	14%	<62.5%	<42%	6.80
Carbonate (CO ₃ ⁻²)	600	2400	4800	3000	<600	---	---	---	---	---
Bicarbonate (HCO ₃ ⁻)	0.04	0.09	---	---	0.03	---	---	---	---	---
<i>Metals (liquid: mg/L; sludge: mg/Kg)</i>										
Barium (Ba)	<0.04	<0.04	<0.02	<0.04	0.12	88	33	74	<53	115
Cadmium (Cd)	<0.02	<0.02	<0.01	<0.02	<0.02	8.7	6.6	5.7	10	7.8
Chromium (Cr)	0.29	<0.13	14	9.4	0.4	134	184	69	162	<10
Mercury (Hg)	0.06	0.1	---	1.1	3.4	74	70	40	585	39
Nickel (Ni)	<0.2	<0.2	<0.1	<0.2	<0.02	192	72	57	160	380
Lead (Pb)	<1	<1	<0.5	<1	<1	863	354	295	512	543
Thallium (Tl)	<0.2	<0.1	<0.45	<0.09	<0.1	1.7	<1.2	<0.6	0.7	<1.7
<i>Miscellaneous</i>										
pH	9.3	9.4	12.7	11.7	8.8	N/A	N/A	N/A	N/A	N/A
TDS (mg/L)	6,400	11,500	51,900	23,600	41,500	N/A	N/A	N/A	N/A	N/A

Source: Autrey et al. 1989.

^aBased on total metals analysis

Injections ILW-8, ILW-9, ILW-10, ILW-11 ^a			Injection ILW-12 ^b			Injection ILW-13 ^b		
Constituent	Average Concentration (Mole/Liter)	Concentration (mg/L)	Constituent	Average Concentration (Mole/Liter)	Concentration (mg/L)	Constituent	Average Concentration (Mole/Liter)	Concentration (mg/L)
Na ⁺	1.015	23,335	Na ⁺	1.935	44,486	Na ⁺	1.263	29,036
Al ⁺³	0.012	318	Al ⁺³	0.020	540	Al ⁺³	0.028	755
NH ₄ ⁺	0.032	572	NH ₄ ⁺	0.032	567	NH ₄ ⁺	0.032	567
OH ⁻	0.193	3,273	OH ⁻	0.105	1,785	OH ⁻	0.373	6,341
NO ₃ ⁻	0.618	38,285	NO ₃ ⁻	1.370	84,940	NO ₃ ⁻	0.253	15,686
Cl ⁻	0.101	3,572	Cl ⁻	0.210	7,445	Cl ⁻	0.046	1,631
SO ₄ ⁻²	0.128	12,320	SO ₄ ⁻²	0.120	11,479	SO ₄ ⁻²	0.184	17,675
CO ₃ ⁻²	0.148	8,850	CO ₃ ⁻²	0.278	16,642	CO ₃ ⁻²	0.160	9,595
Waste TDS (mg/L) =		90,523	Waste TDS (mg/L) =		167,883	Waste TDS (mg/L) =		81,287
Injection ILW-14 ^b			Injection ILW-15 ^c			Injection ILW-16 ^c		
Na ⁺	1.588	36,508	Na ⁺	1.839	42,279	Na ⁺	2.572	59,130
Al ⁺³	0.019	518	Al ⁺³	0.015	391	Al ⁺³	0.029	782
NH ₄ ⁺	0.003	50	NH ₄ ⁺	0.021	369	NH ₄ ⁺	1.50E-05	0
OH ⁻	0.435	7,395	OH ⁻	0.540	9,180	OH ⁻	0.340	5,780
NO ₃ ⁻	0.405	25,135	NO ₃ ⁻	0.740	45,880	NO ₃ ⁻	0.635	39,370
Cl ⁻	0.130	4,609	Cl ⁻	0.167	5,921	Cl ⁻	0.039	1,383
SO ₄ ⁻²	0.189	18,155	SO ₄ ⁻²	0.108	10,326	SO ₄ ⁻²	0.119	11,431
CO ₃ ⁻²	0.150	8,996	CO ₃ ⁻²	0.390	23,388	CO ₃ ⁻²	0.340	20,390
Waste TDS (mg/L) =		101,366	Waste TDS (mg/L) =		137,734	Waste TDS (mg/L) =		138,267
Injection ILW-18 ^c			<p style="text-align: center;">Notes</p> <p>^a Average waste concentration from Weeren (1974).</p> <p>^b Average waste concentration from Weeren (1976).</p> <p>^c Average waste concentration from Weeren (1980).</p>					
Na ⁺	2.625	60,349						
Al ⁺³	0.036	958						
NH ₄ ⁺	NA							
OH ⁻	0.465	7,905						
NO ₃ ⁻	1.284	79,608						
Cl ⁻	NA							
SO ₄ ⁻²	NA							
CO ₃ ⁻²	0.385	23,088						
Waste TDS (mg/L) =		171,908						

^a Average waste concentration from Weeren (1974).
^b Average waste concentration from Weeren (1976).
^c Average waste concentration from Weeren (1980).

^b Average waste concentration from Weeren (1976).

^c Average waste concentration from Weeren (1980).

6. HYDROGEOLOGIC SETTING

6.1 REGIONAL GEOLOGY

The rocks that underlie the Valley and Ridge Province in the ORR vicinity are Lower Paleozoic sediments. From oldest to youngest, the stratigraphic units are the clastic Early Cambrian Rome Formation, the mixed clastic and carbonate Middle and Late Cambrian Conasauga Group, the carbonate Late Cambrian and Early Ordovician Knox Group, and the mixed carbonate and clastic Middle Ordovician Chickamauga Group (Stockdale 1951; McMaster 1963).

The stratigraphic units crop out in a series of northeast to southwest trending linear belts that are the result of fault motion along the Copper Creek and White Oak Mountain thrust faults (Fig. 6.1). Imbricate thrust faulting is part of a major decollement of the Southern Appalachian, thin-skinned, orogenic thrust belt (Roeder, Gilbert, and Witherspoon 1978). In the general vicinity of the ORR, such thrust faulting has resulted in the Lower Cambrian Rome Formation being juxtaposed on the Middle Ordovician Chickamauga Group.

The regional strike of strata in this portion of the Valley and Ridge Province is N50W, and the dip of rocks at the surface is 25° to 55° to the southeast. At depth, the dip decreases to nearly horizontal, and the thrust faults become nearly horizontal in the subsurface to form essentially bedding-parallel faults. Horizontal displacement along a major thrust fault can be as great as 45 to 95 km (Roeder, Gilbert, and Witherspoon 1978). Local fault displacements are estimated to be somewhat less, on the order of 10 to 15 km. Within the sediments of the imbricate thrust sheets, a large number of small-scale folds and fractures have formed. This has resulted in a complex structural fabric.

6.2 SITE GEOLOGY

The site geology is discussed in Haase (1983, 1985) and Haase, Switek, and Stow (1985). While much of the recent published geologic information on the stratigraphy and structure of Melton Valley has focused on the NHF (HF-4), these observations can be generally applied to the other hydrofracture sites (HF-1, HF-2, and HF-3). In the following discussion, emphasis is placed on the disposal (injection) formation, the upper Pumpkin Valley Shale.

Figure 6.2 shows the locations of all wells discussed in this report. Representative geologic features of the OHF and NHF hydrofracture sites are shown in Figs. 6.1 and 6.3. Figure 6.1 illustrates the generalized geology for the four site locations. Figure 6.3 is a generalized geologic map and cross section showing the locations of the OHF and NHF and formations penetrated by specific types of wells. Observation wells such as well 1965 penetrate the injection horizon into the lower Pumpkin Valley Shale. Rock cover wells such as well 1957 are completed in the Rogersville Shale or Rutledge Limestone and were used to monitor injection pressures in the overlying rock cover formations.

At the HF-3 and HF-4 hydrofracture sites, the stratigraphic sequence in the basal portion of the Copper Creek thrust fault block consists of, from bottom to top, the Rome Formation, the Conasauga Group, and the Knox Group (Fig. 6.4):

- The Rome Formation is 90 to 150 m thick and consists of massive sandstones, thinly bedded siltstones, and laminated shales and mudstones.
- The Conasauga Group, which includes the disposal (injection) formation (upper and lower Pumpkin Valley Shale), is 550 to 610 m thick and consists of six formations. They are, in ascending order, the Pumpkin Valley Shale, Rutledge Limestone, Rogersville Shale, Maryville Limestone (upper and lower), Nolichucky Shale, and Maynardville Limestone. The clastic-rich formations, including the Pumpkin Valley Shale, consist of thinly bedded siltstones and laminated shales and mudstones. The carbonate-rich formations consist of coarse- to fine-grained limestones, conglomerates, and calcareous siltstones and shales.
- The Knox Group consists of chert-rich carbonates, principally massive dolostone with subordinate amounts of limestone, and locally abundant sandstones. The Knox Group has been divided into five formations (Mascot Dolomite, Kingsport Formation, Longview Dolomite, Chepultepec Dolomite, and Copper Ridge Dolomite) near the ORNL site, that range from 610 to 670 m in thickness (Milici 1973).

The structural fabric of strata at the base of the Copper Creek thrust sheet is characterized by multiple fracture/joint sets and several generations of small-scale folds and faults. These features are controlling factors for deep groundwater flow (Ossi 1979, Sledz and Huff 1981) and are associated with the major orogenic event of faulting that deformed the entire Valley and Ridge Province.

Several tear faults have been postulated, cutting across the leading edge of the Copper Creek thrust sheet, in the immediate vicinity of the hydrofracture sites (Haase 1985). The net effect of these faults is to divide the leading edge of the thrust sheet into a series of discrete units that have rotated with respect to each other. Fault strike is generally oblique to that of the Copper Creek thrust fault, and fault dip is steep. Motion along tear faults is complex but is typically a combination of lateral and dip-slip movement. Based on mapping, total displacement along the tear fault appears to be on the order of several tens of meters. Most of the tear faults, associated with thrusting, are 0.8 to 3 km long and are expected to attenuate within strata of the Knox Group that crop out to the southeast.

The natural lateral and vertical distribution of rock types within the Pumpkin Valley Shale explains local variations in physical, mechanical, mineralogical, and geochemical properties within this formation (Haase 1985). In Melton Valley, the Pumpkin Valley Shale is approximately 105 m thick and can be divided into a siltstone-rich, 45-m-thick lower member and a shale-rich, 60-m-thick upper member. The lower contact of the formation is gradational over a 2- to 3-m-thick interval into massive to thick-bedded sandstones of the upper Rome Formation. The upper contact of the formation is also gradational over a 3-m-thick interval into limestones and calcareous shales of the

Rutledge Limestone. The carbonate interval, near the base of the Rutledge, has been informally referred to as the "three finger limestone" and was used as a marker during hydrofracturing at the OHF.

The Pumpkin Valley Shale is composed of several distinct mudstones, shales, and siltstones, which are common to both members. The two members differ primarily in the relative proportions of the different lithologies, in the character of the interstratified sequences of the different lithologies throughout the member, and in the nature of the primary bedding structures within the constituent lithologies.

Deformation features associated with major, regional tectonic events are ubiquitous in the shale. Joints, fractures, folds, and faults occur throughout the section. At least two, and locally as many as four, joint sets have been identified; these joints are important in controlling groundwater flow (Sledz and Huff 1981).

The joint patterns can be related to major structures (i.e., the Copper Creek thrust fault and specific folding events related to thrust motion). Within a particular interval, joint spacing, length, and density are a complex function of lithology and bed thickness. Furthermore, although joint sets show fairly constant orientations with respect to major structures, specific joint sets exhibit significant variation within lateral distances as much as several hundred meters. The vertical and lateral continuity of joints is limited by the complex interstratification patterns. Individual joints do not commonly extend more than several tens of meters.

Small-scale fractures are abundant within the siltstone-rich intervals of the Pumpkin Valley Shale. At least two generations of cross-cutting fractures are identified in drill core. As with the joints, fractures are most numerous within siltstones, although locally, mudstones and shales contain significant numbers of fractures. At depth, most fractures are filled with secondary carbonate. In some cases, the fractures are totally healed (cemented) with carbonate. In others, however, visual evidence suggests openings that allow groundwater flow.

Joints and fractures, when open, provide the most efficient natural flow path within the clastic and carbonate section underlying the hydrofracture facilities. Healed joints and fractures, while basically impermeable under undisturbed subsurface conditions, provide planes of weakness within the clastic rock section. When disturbed, such as by hydrofracturing activities, these planes of weakness could be reactivated and could contribute to movement within the deep flow system.

As the leading edge of an artificially created fracture moves out from the point source into the formation, a network of microfractures is also created in association with the major fracture. The induced microfracture systems would contribute to the total effective fracture porosity and permeability of the rock section.

The three types of fractures that could contribute to migration of contaminants, therefore, are

- the open fracture network,
- the reactivated fracture network, and
- an artificially induced network of microfractures.

6.3 GROUNDWATER

6.3.1 Regional Characteristics

There are limited data describing regional groundwater flow within Melton Valley. Mechanisms and rates of flow appear to be controlled by topography, lithology, and structure. No wells are developed in the Rome Formation near the OHF site. Because of the highly variable lithology of the Conasauga Group, groundwater conditions also vary. In the carbonate-rich formations, groundwater may move along small solution cavities and fractures; in the more shale-rich lithologies, movement is almost solely along fractures.

6.3.2 Site Characteristics

Data describing deep groundwater at the hydrofracture sites are limited. Although many wells and coreholes have been drilled over the last three decades, only recently have groundwater wells been constructed for hydrologic data acquisition.

Permeability data for the strata at depths similar to the injection zone are sparse. De Laguna et al. (1968 and unpublished data) reported low laboratory permeability measurements on the order of 10^{-5} md for drill core of the Pumpkin Valley Shale. Observed recovery rates of wells recently drilled to the injection interval also indicate low permeability. The impact of the hydrofracture injection activities on the hydraulic characteristics of the strata is presently unknown.

6.4 GROUNDWATER HYDROLOGY

6.4.1 Groundwater Circulation Patterns and Specific Discharges

Water levels were measured at each WAG 10 well during wet seasonal conditions (April 14, 1994). Wells 1946, 1953, and 1965 were under pressure at the time of initial well tapping activities. After sampling, wells 1946 and 1953 recharged and are once again pressurized. Pressure time series data are presented in BNI (1995). Artesian conditions are summarized in Table 6.1, and water level data for all WAG 10 wells are shown in Fig. 6.5, which presents total heads that have been corrected for wellhead pressure.

A time series of wellhead pressures was obtained for wells 1946, 1953, and 1965 between January 12 and May 2, 1994. Wellhead pressures in wells 1946 and 1953 vary between 25 to 36 psi and 24 to 29 psi, respectively (Fig. 6.6). Well 1965 shows inconsistent pressurization to about 1 psi.

Two explanations identify conditions conducive for flowing artesian wells: outcrop-related, geologically controlled and/or topographically controlled groundwater systems. An aquifer that is recharged in an upland area can develop a hydraulic head distribution whereby the hydraulic head in the aquifer downdip from the recharge area is higher than the surface elevation. A well open to the aquifer at such a location and open at the surface will flow. This type of geologic control is present at the site where the Pumpkin Valley Shale outcrops to the north on Haw Ridge and dips to the south to an approximate depth of 850 ft beneath the OHF (Fig. 6.7). Unpublished hydraulic head data for deep wells HHMS-12, HHMS-13, and HHMS-14 (Energy Systems 1995) indicate that pressurized conditions exist within the Rome Formation. Therefore, another potential mechanism for naturally pressurizing the Pumpkin Valley Shale is transmission of hydrostatic pressure from the Rome upward into the Pumpkin Valley Shale (see Fig. 6.7).

The second and more dominant control on artesian wells is topography. Deep aquifers beneath Melton Valley are topographically controlled by the marked relief of Haw Ridge to the north and Copper Ridge to the south. WAG 10 wells that intersect a head value above the land surface produce flowing artesian conditions. Artesian conditions existed before injection activities at the OHF. Injection well 1944 (3-INJECT) was artesian when it was initially drilled (personal communication H. O. Weeren, former OHF Manager, to G. L. Underberg; December 1993). Hydrofracturing did, however, increase fracture porosity and permeability, which created variability of artesian conditions.

Four WAG 5 wells (0461, 0462, 0463, and 1877) ranging in depth from 100 to 200 ft were also found to be flowing artesian, with approximately 12 ft of head above ground surface. These artesian wells are completed in the Maryville Limestone Formation parallel to strike at the base of Copper Ridge. Therefore, artesian conditions observed in deep wells 1946, 1953, and 1965 could also result from pressure being transmitted through the shallow flow system, probably in discrete fracture sets, pressurizing the wellbore water through breaches in the shallow well casing. More extensive hydrologic characterization will need to be conducted within the OHF area, or pressure/flow profiles will need to be developed for the pressurized wells, to conclude that the wellbore pressures originate in the deep flow system.

6.4.2 Hydraulic Parameters

The relationship between shallow groundwater at WAG 5 and the deeper groundwater at WAG 10 is schematically depicted in Fig. 6.8. The shallow groundwater system above WAG 10 is a heterogeneous, anisotropic aquifer dominated by fracture flow. Soil samples collected from below the shallow water table indicate that some intergranular flow may also be significant because of weathering and dissolution/leaching of bedrock materials. In addition, some saprolitic horizons have dense fracture networks that may approximate a porous medium for flow considerations.

Effective porosity in the regolith ranges from 0.10 to 0.15 (granular regolith) and 0.001 to 0.1 (saprolite) (Moore 1989); however, much higher porosities are possible (e.g., 0.3 to 0.5) depending on the degree of weathering and lithology of parent bedrock material. A tracer test at another burial ground in Melton Valley yielded a regolith porosity of 0.03 (Webster and Bradley 1988). Specific yields for the regolith, an indication of the storage capacity of the medium, average 0.0025 near the water table (Moore 1989). Bedrock porosity is predominantly controlled by the aperture and spacing of fractures and is highly variable; Solomon et al. (1992) reported effective porosity (i.e., that fraction of the rock volume that permits fluid flow) of about 0.00035.

As part of work performed by Moore and Toran (1992), hydraulic conductivity values for the groundwater intervals of 0 to 30 ft, 30 to 100 ft, and 100 to 200 ft were obtained from 90 single-well slug tests. Test results show higher conductivity in the shallow zones (usually in saprolitic regolith) and much lower conductivity in the deeper bedrock. Mean conductivity results decrease from 1.6×10^{-1} ft/day in the 0- to 30-ft interval, to 3.3×10^{-2} ft/day in the 30- to 100-ft interval, and finally to 5.0×10^{-4} ft/day in the 100- to 200-ft interval. Shallow groundwater has an average hydraulic conductivity (based on the geometric mean of 71 tests) of approximately 0.16 ft/day. These values correlate relatively well with slug-test-derived average conductivity values of 0.15 ft/day (Moore 1989) and 0.26 ft/day (Moore and Toran 1992).

Hydraulic conductivities in boreholes exceeding 200 ft were measured throughout the ORR, typically in the Conasauga Group. The hydraulic conductivities of WAG 10 wells are unknown; however, deep wells neighboring the site and completed in the same interval have estimated values ranging from 2.8×10^{-2} ft/day to 2.8×10^{-6} ft/day, with mean values of 10^{-4} to 10^{-5} ft/day for most areas (Solomon et al. 1992). Porosity values of 0.2 to 0.4 percent were measured using core samples from borings penetrating the Conasauga Group (Solomon et al. 1992). Low permeability at depth appears to be common for formations with unfractured matrices.

Based on visual inspection of core samples collected from the three 500-ft wells (4167, 4169, and 4170) installed as part of the WAG 5 remedial investigation and core descriptions from other nearby deep wells, the number of open (permeable) fractures appears to decrease with depth; however, fractures in significant density would increase permeability, enhance flow, and affect temperature, pressure, and geochemical properties. Structure-related deformations such as localized folds and faults are also potential enhancers of flow and are instrumental in creating the potential for upward movement of contaminants. Such deformation was observed at depth in all three WAG 5 cores and to a greater extent in well 4170 near the OHF.

During flow meter testing of well 4170, located approximately 300 ft northwest of the injection well (1944), groundwater was purged at a constant rate to induce flow into the borehole. Well 0466, approximately 70 ft east of well 4170, was fitted with a continuous water level indicator and data logger to monitor fluctuations in the deeper water table. Well 4170 is cased to a depth of 100 ft, with an open interval through the Maryville Limestone-Rutledge Limestone section, and well 0466 has an open interval from 142 to 152 ft through the Maryville Limestone. During the test, a drop in water level was recorded at well 0466, indicating significant communication in the Maryville Limestone between the wells in the area at depth. The flow meter test results for each of the three

500-ft-deep WAG 5 wells were similar in that below approximately 200 ft, little to no flow was identified to an instrument resolution of 0.01 gpm.

6.4.3 Geochemical Data

Groundwater salinity

A geochemical evaluation of WAG 10 groundwater was completed to provide screening level data to support evaluation of wellbore integrity and to determine the types of waste expected to be generated during potential P&A operations. The evaluation was based on total ion concentration data for major anions and cations and radiochemical constituents. Complete geochemical evaluation of a groundwater system requires a large number of chemical analyses carried out on high-quality water samples taken from a representative set of wells in an area. It should be noted that groundwater collected from WAG 10 wells were grab samples that were analyzed at a CSL. The wells were not purged before sampling. The data are useful in evaluating the degree of contamination in the wells and the integrity of the well seals.

As groundwater moves through a flow system, it typically undergoes a geochemical evolution. Generally, salinity (as reflected by increased TDS) will increase along the flow path (i.e., water from a recharge area is usually relatively fresh, and water from discharge areas is often relatively saline). The analytical results from well sampling around the OHF show significant variation in TDS concentrations compared with concentrations in neighboring wells of similar formation and depth. TDS was measured in 21 WAG 10 wells at sampling intervals at variable depths from the top, middle, and bottom of each well. These results are summarized in Table 6.2. Although TDS values generally increase with depth, as shown in the mean TDS values, the values vary significantly with elevation and among wells, as discussed in Sect. 7.3.

Several wells that were sampled showed little to no variation in TDS throughout the wellbore. For example, the TDS results for the top, middle, and bottom sampling intervals of well 1962 were 249, 303, and 227 mg/L, respectively (fresh water). This suggests that the well casing is possibly not open to the surrounding groundwater and that the water present in the borehole is a remnant of well installation activities. Other wells showed elevated salinity throughout the standing water, indicating possible circulation of deeper groundwater up and down the water column or a possible breach of the casing integrity. Results for well 1963 showed brine TDS concentrations of 157,258 mg/L (top), 166,968 mg/L (middle), and 174,220 mg/L (bottom). This rock cover well has an open interval in the lower Rutledge Limestone.

During the WAG 5 remedial investigation, 3 wells were cored to a depth of approximately 500 ft (4167, 4169, and 4170). Well 4170 is located approximately 300 ft northwest of the injection well (1944) and is near several of the WAG 10 deep monitoring wells. During drilling operations a conductivity probe was used at the beginning of each day in an attempt to determine the fresh water/saline water contact. Saline water was not encountered in any of the three WAG 5 wells, suggesting that the low saline water interface (greater than 500 ft deep) observed in some rock cover wells (Sect. 7.3) may be the result of the natural, undisturbed TDS distribution.

Groundwater chemistry

Significant variations in the chemical characteristics of groundwater with depth have been observed in Melton Valley. At depths ranging from less than 60 to less than 150 ft, calcium is the dominant cation and bicarbonate is the dominant anion (Bailey and Lee 1991, Webster and Bradley 1988, Dreier and Toran 1989). At depths between approximately 60 and 150 ft, the composition shifts to sodium as the dominant cation with bicarbonate remaining as the dominant anion. Between depths of about 450 to 1200 ft, the sodium bicarbonate water grades to a sodium chloride brine, typical of the deep flow zone (Solomon et al. 1992).

Extensive geochemical data for the deep flow system are not available. Table 6.3 presents major ion data for three classes of background wells: (1) deep oil wells off the ORR (exact locations are not available), (2) other monitoring and rock cover wells associated with operations of HF-2 and HF-4 that are considered to be affected by HF wastes, and (3) wells associated with operations of HF-2 and HF-4 that are not necessarily affected by HF wastes. The presence of nitrate, a mobile constituent of the injected waste, was used as the criterion for determining whether wells associated with operations of HF-2 and HF-4 were chemically affected by HF injections. Unfortunately, there is a dearth of natural background data for the deep flow system that do not have the potential for being tainted by injection activities because most deep wells were constructed for monitoring hydrofracture activities. Inorganic OHF wellbore data will be compared with available background data to help identify OHF wells that have been affected by injected grout and fluids. This analysis will be done in conjunction with radiological analyses of OHF wellbore water and geophysical logging, so the uncertain quality of the background data should not have a serious impact on the interpretations presented in Sect. 8.

It should be noted that the deep sample from WOL-1, located approximately 4500 ft west of the NHF injection well, had a nitrate concentration of 3000 mg/L. The quality of this result is not known, and it is uncertain without additional sampling and hydrogeologic investigations that the source was the HF operations.

Figure 6.9 presents Na:Cl, Ca:Cl, and Br:Cl ionic ratios for the three types of background wells. There does not appear to be a difference between the Br:Cl and Ca:Cl ratios for the three types of wells. Br:Cl and Ca:Cl background ratios were 0.011 and 0.135, respectively, based on all wells. The Na:Cl ratio for HF-affected wells is significantly higher (0.387) than that for wells potentially not affected by HF operations (0.060), possibly because of the introduction of solutions with a Cl concentration lower than that of the natural brine (see Table 5.5) into the HF-affected wellbores.

Table 6.4 presents the basic statistics of inorganic parameters for both rock cover and large-diameter observation wells. Sections 8.1 through 8.19 present the well-specific radiological and inorganic parameters, which are discussed in Sect. 8.2. Ionic balance calculations (Fig. 6.10) indicate a range of inorganic data quality. Fifty-two percent of the samples are within a 10 percent relative difference in ionic balance. However, ionic balances of 26 percent of the ionic data exceed

25 percent relative difference. Inorganic data for samples that exceeded an ionic balance of 25 percent relative difference were not used in any analyses.

Figure 6.11 is a series of trilinear diagrams for the top, middle, and bottom sampling intervals. The samples were taken at the top, middle, and bottom of the wellbore and are not meant to be linked to a distinct stratigraphic or geochemical component of the groundwater system. Because of varying well depth, there is some overlap in the intervals: top sample elevations range from 801 to 698 ft msl, middle sample elevations range from 566 to 251 ft msl, and bottom sample elevations range from 341 to -214 ft msl. The inorganic chemistry of the top sampling interval shows a fairly wide distribution of calcium, chloride, sulfate, sodium, and magnesium. The overall chemistry becomes increasingly dominated by sodium and chloride at depth, as evident by the clustering in the middle and bottom sample intervals. Such a distribution is expected as the deep samples become dominated by the sodium chloride brine.

Figures 6.12 and 6.13 present major ionic ratios for large-diameter observation and rock cover wells for each sampling interval. The average Br:Cl ratio for the large-diameter observation wells is about an order of magnitude (0.00025) below the background value (0.011). The average Ca:Cl ratio of 0.137 is equal to the background value of 0.135. Similarly, the Na:Cl ratio (0.397) is the same as the background value for wells potentially affected by HF operations (0.382). There does not appear to be a difference among ionic ratios among the sampling intervals in the observation wells, although the small size of the data set limits the ability to distinguish differences among the intervals. The bromine content of the wastes is not known, so it is unclear whether the lower Br:Cl ratios in the OHF observation wells are influenced by waste-related fluids.

Na:Cl ratios for top rock cover well samples (Fig. 6.13) are similar to background Na:Cl ratios for deeper wells potentially affected by HF operations. Bottom rock cover sample Na:Cl ratios (0.170) are close to background (0.471), but the middle sample Na:Cl ratios are significantly lower. The Ca:Cl ratios for bottom samples (0.031) and Br:Cl ratios for all samples (0.0003) are also lower than background values (0.135 and 0.011, respectively). It is difficult at this time to determine the significance of these differences without adequate characterization of the natural chemistry of the deep flow system. It is not clear if these ionic ratios are the result of an infusion of injection fluids into the observation and rock cover wells, are the result of an introduction of potable water into the wells during OHF operations, or represent natural variability of the intermediate and deep groundwater flow system.

Figure 6.14 presents data from the background well pH data set. The data show a uniform distribution of pH values from 4 to 8. There does not appear to be a distinct trend with depth or between classes of background wells. Figure 6.15 presents the distribution of TDS data with elevation and indicates a wide scattering of TDS values in the shallower wells; TDS increases as depth increases for the wells both affected and potentially unaffected by HF operations. TDS data are not available for the background deep oil wells.

Stable field pH measurements were not always obtained from the intermediate and deep flow system based on observations that noted sample "offgassing" and precipitation. However, Fig. 6.16

indicates that the percent relative difference between field pH and pH measured in the CSL, after the sample gas pressures equilibrated with the atmosphere, is generally not that great. Eighty-six percent of the field and laboratory pH measurement pairs are within a 10 percent difference relative to each other. Section 7.4 presents the well-specific distribution of pH values.

Inorganic data are used in Sect. 8.2 to identify deviations in wellbore chemistry from expected ambient conditions that might indicate impact from injection-related fluids. This analysis is inconclusive in some cases because of potential overprinting of chemical impacts from the injected waste material, relict pH impacts from poorly set well construction grout, and the natural spatial geochemical variability in a fractured environment. Furthermore, data are not available to adequately characterize the concentrations of chemical constituents within fluids associated with the injection, such as the fresh water used to initiate the well fracture and the filtrate generated during curing of the grout. As discussed in Sect. 1, data were collected for the primary purposes of evaluating potential risks associated with radionuclide concentrations within the wellbore and identifying waste management issues that may be encountered during well P&A.

Water quality data such as major ion concentrations, pH, and TDS will be used to support both the conceptual model of potential wellbore transport (see Sect. 7) and the evaluation of well-specific conditions. However, the analyses do not completely rely on the inorganic geochemical data, but rather use the data in conjunction with geophysical evidence of well casing integrity. The geochemical data will be used in the following ways to identify injection-related impacts on the observation and rock cover wells:

- Well-specific ionic ratios will be used to identify anomalies relative to the background ionic ratios previously discussed in this section. Anomalous ionic ratios may result from injection-related fluids mixed with ambient deep groundwater in the wellbore. For example, higher Na:Cl or Ca:Cl ratios could result from waste fluids with lower chloride content mixed with the high chloride brines.
- Anomalously low TDS values may result from infusion of fresh water or filtrate into the wellbore. The range of waste TDS values presented in Table 6.4 is generally about the same concentration as the deep brine, so a significant increase in TDS is not expected to be observed in the wellbore. Filtrate could be of lower TDS than the waste material if ions adsorbed within the set grout.
- Nitrate was a significant ionic component of the waste, and because it generally behaves as a conservative tracer in groundwater, it will be used to identify any impact from injection-related fluids.

The major ion proportions determined for WAG 10 groundwater were compared with those reported in Nativ and Hunley (1993) in an attempt to recognize uncontaminated saline groundwater. The WAG 10 data are presented in Figs. 6.11 and 6.12. The three ionic ratios used for comparison are sodium chloride (Na:Cl), calcium chloride (Ca:Cl), and bromium chloride (Br:Cl).

The estimated ionic ratios from Nativ and Hunley are: Na:Cl $\approx$ 0.58 (by equivalency), Ca:Cl $\approx$ 0.28 (by equivalency), and Br:Cl $\approx 14 \times 10^{-3}$ (by molecular weight). The estimated proportions of those ions for the WAG 10 groundwater samples are: Na:Cl $\approx$ 0.85 (rock cover wells) and 0.67 (observation wells), Ca:Cl $\approx$ 0.29 (rock cover wells) and 0.40 (observation wells), and Br:Cl $\approx 7 \times 10^{-3}$ (all wells). These ionic proportions were used in Sect. 8 of this report in an attempt to qualify uncontaminated versus contaminated groundwater.

Fig. 6.3. WAG 10 generalized geologic map.

		Lithology	Thickness, m	Formation		Structural Characteristics	Hydrologic Unit
ORDOVICIAN	LOWER MISSISSIPPIAN		31-46	Mfp	Fort Payne Formation	Strong unit	Aquitard
	MISSISSIPPIAN-DEVONIAN		6-10	MDc	Chattanooga Shale	Weak unit	
	LOWER SILURIAN		190-200	Sr	Rockwood Formation	Strong unit	
	UPPER		60-75	Os	Sequatchie Formation	Weak units	
			60-70	Or	Reedsville Shale		
			98-138	Ocy/l	Catheys / Leipers Formation	Strong units Ramp zone	
			25-30	Ocn	Cannon Limestone		
			20-25	Oh	Hermitage Formation		
			128-137	Oca	Carters Limestone		
			60-69	Olb	Lebanon Limestone		
			88-95	Ord	Ridley Limestone		
			58-76	Omp	Murfreesboro / Pierce Limestone		
			100-160	Ops	Pond Springs Formation		
			75-150	Oma	Mascot Dolomite		
			90-150	Ok	Kingsport Formation		
			40-60	Olv	Longview Dolomite		
			152-213	Oc	Chepultepec Dolomite		
CAMBRIAN		244-335	Ccr	Copper Ridge Dolomite	Weak units Basal décollement	Aquitard	
		100-110	Cmn	Maynardville Limestone			
		MIDDLE		150-180	Cn		Nolichucky Shale
				98-125	Cmr		Maryville Limestone
				25-34	Crg		Rogersville Shale
		LOWER		31-37	Crt		Rutledge Limestone
				56-70	Cpv		Pumpkin Valley Shale
		450 +	Cr	Rome Formation			

Fig. 6.4. Stratigraphic section in East Fork Valley, East Fork Ridge and Pilot Knob, Pine Ridge, Bear Creek Valley, and Chestnut Ridge. Source: Hatcher et al. 1992.

Fig. 6.5. Total head measurements in WAG 10 OHF wells on April 14, 1994.

Fig. 6.6. WAG 10 wellhead pressure time series.

Fig. 6.7. Geologic and topographic controls for artesian flow at WAG 10.

a) North/south section through WAG 5 and WAG 10

b) East/west section through WAG 5 and WAG 10

Fig. 6.8. Schematic description of the relationship between WAG 5 and WAG 10 contamination sources.

Fig. 6.9. Background major ion ratios.

Fig. 6.10. Distribution of WAG 10 OHF ionic balances.

Top Sampling Interval
(816 to 698 ft msl)

Middle Sampling
(566 to 251)

NOTE: Includes only data with ionic balances < 25% relative difference.

● - Observati

○ - Rock Cov

Figure 6.11 Piper diagram of major ion ch

g Interval
t msl)

Bottom Sampling Interval
(232 to 214 ft msl)

n Wells

r Wells

chemistry from WAG 10 OHF wellbores.

Fig. 6.12. Large-diameter observation well ionic ratios.

Fig. 6.13. Rock cover well ionic ratios.

Fig. 6.14. Distribution of pH in all background wells.

Fig. 6.15. Distribution of TDS in background wells.

Fig. 6.16. Comparison of field and laboratory pH values.

Table 6.1. Artesian pressures at time of tapping

Artesian well ^a	Under pressure (psi)	Lowest penetrating formation	Water elev. above ground surface (ft)	Total depth (ft)
1946	25	Pv ^b	59.3	840
1953	27	Pv	63.3	1040
1965	1	Pv	5.05	840

^aPressure at time of tapping.

^bPv = Pumpkin Valley Shale.

Table 6.2. Groundwater salinity and pH in WAG 10 OHF wells

Statistical results	Sampling elevations (ft msl)					
	Top interval (816 to 698)		Middle interval (566 to 251)		Bottom interval (232 to -214)	
	TDS (mg/L)	pH	TDS (mg/L)	pH	TDS (mg/L)	pH
Maximum	157,258	11.56	166,968	12.39	174,220	11.64
Minimum	130	5.04	111	5.68	227	5.64
Median	363	9.74	1,126	9.98	75,713	8.94
No. of samples	22	22	23	24	14	13

Table 6.3. Chemical analyses of groundwater samples obtained from deep wells

Well	Depth (ft)	Elevation (ft msl)	Ca	Mg	Na	K	Sr	Li	Cl	Br	NO3	SO4	HCO3	TDS	ph
Oil Wells Located off the Oak Ridge Reservation (Morgan County)^a															
ARM #4	500	300	4,940	2,150	44,400	324	NA	NA	77,900	651	258	638	7.36	NA	5.51
B&Wmorg	3,975	-3175	3,120	1,830	24,200	593	NA	NA	46,200	198	208	283	10.9	NA	4.92
B&W	1,672	-872	44,100	3,240	24,100	309	NA	NA	122,400	271	197	969	0.96	NA	4.16
BobyMor	1,730	-930	4,000	2,580	31,200	276	NA	NA	60,700	384	200	607	2.62	NA	7.35
Samples Potentially Affected by Hydrofracture Operations^b															
WOL-1	1,250	-493	34,000	5,300	67,000	290	3,500	ND	190,000	1,600	3,000	16	2	302,537	4.6
HF-4SW400RC	600	200	23,000	3,600	48,000	ND	2,300	ND	120,000	1,100	31	ND	ND	198,650	4.8
HF-4SW400RC	600	200	25,200	5,300	60,500	180	3,020	42	155,000	1,300	7	ND	1	251,090	4.4
HF-4SE400RC	685	115	14,100	1,740	44,100	180	1,740	30	100,000	900	5	ND	2	164,177	6.3
HF-4S200RC	597	203	13,000	2,200	27,000	ND	1,300	ND	71,000	580	20	ND	ND	115,490	4.9
HF-4NE400RC	580	185	16,000	3,000	44,000	ND	1,600	ND	95,000	790	34	ND	ND	160,920	5.9
HF-4NE400RC	580	185	12,200	2,770	41,600	130	1,530	25.7	100,000	800	4	ND	4	159,363	4.7
HF-4N200RC	400	370	16,000	2,900	44,000	ND	1,600	ND	97,000	770	28	ND	ND	162,770	5.2
HF-4E200RC	640	145	12,200	2,880	44,500	160	1,540	59.8	120,000	830	5	ND	6	182,549	4.7
HF-2S400	340	440	20	9	1,230	8	2.2	ND	1,600	10	82	150	684	3,741	7.3
HF-2S400	120	660	85	14	90	8	1.6	1	1,200	7	14	100	603	2,933	7
HF-2E200	645	140	19,000	3,300	48,000	ND	2,000	ND	120,000	880	32	ND	ND	193,840	4.1
DM1-PV	1,050	-282	22,000	4,100	59,000	240	2,300	55	150,000	1,400	1,991	ND	0	237,640	4.4
DM-3RT	550	220	11,000	2,900	35,000	140	1,300	33	93,000	950	442	ND	0	143,340	4.6
DM-3PV	875	-105	2,800	260	12,000	77	210	11	24,000	210	66	522	60	39,347	6.9
DM-1RT	700	68	13,000	2,700	30,000	740	1,300	28	98,000	840	18	ND	3	145,740	6.8
DM-1RM	1,085	-317	11,000	1,300	37,000	330	870	55	91,000	750	9	330	20	141,500	8.4
Samples Potentially Not Affected by Hydrofracture Operations															
WOL-1	0	757	31,000	4,900	81,000	ND	3,400	ND	163,000	ND	ND	ND	ND	292,389	NA
HF-4W200RC	640	143	7,410	1,110	21,200	8,830	890	37.4	68,200	499	ND	ND	19.2	99,611	7.5
HF-4SE400RC	690	110	12,400	3,320	33,700	8,460	1,490	51	113,000	839	ND	ND	0.3	165,265	4.3
HF-4S200RC	690	110	4,810	736	11,400	5,190	551	18.7	33,700	238	ND	ND	14.3	51,597	6.7
HF-4S200RC	590	210	2,370	331	8,630	50	266	ND	20,000	220	ND	ND	0	31,876	5.3
HF-4NW400RC	570	200	2,820	297	8,890	1,430	297	13.4	23,400	190	ND	ND	16.3	37,646	7.4
HF-4NE400RC	570	195	15,500	3,120	27,700	17,300	1,880	53.2	117,000	1,101	ND	ND	0.2	166,779	4.4
HF-4E200RC	640	145	13,400	3,040	26,600	11,400	1,620	40.6	101,000	933	ND	ND	0	147,091	3.5
HF-2W60	800	-12	4,900	990	20,000	80	440	14	48,000	520	ND	ND	ND	74,850	5.3
HF-2S400	960	-180	10,000	2,070	36,400	137	952	25.2	10,000	550	ND	ND	ND	150,354	5.1
HF-2E600	665	129	35	12	2,100	7	3.5	1.5	1,800	14	ND	1,900	ND	3,965	6.7
HF-2E500	665	133	280	90	5,700	23	21	4.4	9,000	70	ND	1,800	ND	16,995	6.7
HF-2E400	665	129	46	13	2,400	8	3.8	1.7	2,000	15	ND	2,400	ND	6,895	6.8
HF-2E200	495	294	210	63	5,100	21	16	3.9	9,100	60	ND	1,700	ND	16,280	6.1
HF-2E100	650	138	110	14	3,800	82	9.1	2.8	5,200	36	ND	2,200	ND	11,459	7.8
DM-2RM	1,250	-491	15,000	2,300	57,000	890	1,400	88	130,000	1,500	ND	ND	366	206,590	10.3
DM-2PV	1,050	-291	26,000	4,400	57,000	230	2,600	51	150,000	2,100	ND	ND	0	240,230	4.3

^a Wellhead elevations not available. Sample elevations based on assumed wellhead elevation of 800 ft msl.

^b Presence of nitrate assumed to be an indicator of chemical impact from IIF injected fluids.

NA = Not Available.

ND = Not Detected.

Table 6.4. WAG 10 OHF well inorganic parameter statistics

Observation Wells: Top Samples								
Analyte	Count	Minimum	25% Quartile	Median	75% Quartile	Maximum	Average	Geometric Mean
Na	6	6.7	12.2	27.1	115.9	631.7	140.9	39.6
K	6	1.6	2.6	4.5	5.3	8.1	4.4	3.8
Ca	6	6.8	8.5	10.8	76.5	806.9	156.9	28.0
Mg	6	0.8	3.2	5.8	8.7	216.6	40.2	7.2
Cl	6	9.9	15.2	20.3	54.4	558.8	114.8	35.7
HCO3	4	0.0	9.3	25.4	57.5	114.7	41.4	5.2
CO3	4	0.4	4.7	8.8	11.7	12.0	7.5	4.4
SO4	6	0.2	0.3	11.7	48.4	79.9	26.8	3.9
NO3	0							
TDS	4	260.0	280.3	290.5	316.0	382.0	305.8	302.6
TSS	4	2.0	2.8	10.5	27.3	55.0	19.5	8.8
PH	4	8.8	9.3	9.8	10.4	11.6	10.0	9.9
Alkalinity	4	29.0	46.3	86.5	136.3	182.0	96.0	75.9
Observation Wells: Middle Samples								
Analyte	Count	Minimum	25% Quartile	Median	75% Quartile	Maximum	Average	Geometric Mean
Na	6	12.3	13.3	1,638.4	5,361.7	11,837.3	3,533.4	287.8
K	6	2.3	3.1	7.4	17.2	36.9	12.7	7.6
Ca	6	9.5	37.7	108.5	669.1	1,869.3	494.3	123.1
Mg	6	0.8	5.4	8.3	168.2	231.5	79.1	15.4
Cl	6	15.5	24.5	2,009.9	9,482.2	16,821.0	5,365.3	454.4
HCO3	2	60.0	65.8	71.6	77.4	83.2	71.6	70.6
CO3	2	1.0	1.4	1.8	2.2	2.6	1.8	1.6
SO4	6	1.0	31.1	298.6	705.5	1,665.1	507.7	97.7
NO3	0							
TDS	4	228.0	426.8	3,676.0	14,450.5	37,225.0	11,201.3	2,314.6
TSS	4	10.0	13.0	132.0	270.3	331.0	151.3	58.3
PH	3	7.1	7.8	8.5	10.1	11.8	9.1	8.9
Alkalinity	3	60.0	73.0	86.0	175.0	264.0	136.7	110.9
Observation Wells: Bottom Samples								
Analyte	Count	Minimum	25% Quartile	Median	75% Quartile	Maximum	Average	Geometric Mean
Na	6	15.2	5,611.9	17,693.6	35,741.6	66,501.7	24,207.7	5,862.2
K	6	4.5	24.2	52.9	480.1	1,000.0	291.2	72.1
Ca	6	88.1	549.4	5,079.6	19,366.5	23,735.4	9,525.1	2,125.6
Mg	6	2.6	28.9	125.7	1,561.4	4,000.0	1,048.4	129.3
Cl	6	35.1	7,386.2	35,495.5	67,419.5	115,360.4	43,744.0	10,218.0
HCO3	3	43.0	65.3	87.6	209.5	331.4	154.0	107.7
CO3	3	0.2	13.6	27.1	1,810.2	3,593.2	1,206.8	24.8
SO4	6	8.7	47.5	158.4	474.3	2,124.6	506.7	138.3
NO3	1	12,975.9	12,975.9	12,975.9	12,975.9	12,975.9	12,975.9	12,975.9
TDS	4	975.0	7,700.3	23,055.0	41,310.0	56,736.0	25,955.3	11,875.9
TSS	4	40.0	50.5	79.5	153.0	297.0	124.0	90.6
PH	3	7.6	8.3	8.9	10.3	11.6	9.4	9.2
Alkalinity	3	43.0	201.0	359.0	2,129.0	3,899.0	1,433.7	391.9

Table 6.4. WAG 10 OHF inorganic parameter statistics (continued)

Rock Cover Wells: Top Samples								
Analyte	Count	Minimum	25% Quartile	Median	75% Quartile	Maximum	Average	Geometric Mean
Na	13	5.5	9.8	35.9	60.4	41,317.9	3,214.3	47.1
K	13	2.4	5.9	7.5	16.4	94.1	16.2	9.1
Ca	13	3.1	4.3	7.7	56.4	13,178.4	1,074.3	23.1
Mg	13	0.2	0.8	2.8	5.1	3,310.7	258.2	3.5
Cl	13	7.3	37.0	60.6	175.8	74,431.6	5,869.9	109.2
HCO3	12	5.4	9.0	10.0	19.2	44.9	17.3	13.6
CO3	12	0.0	2.8	6.9	14.4	40.3	10.9	1.3
SO4	13	0.2	0.5	2.0	14.2	55.5	9.4	2.6
NO3	0							
TDS	13	133.0	344.0	508.0	795.0	157,258.0	12,858.8	854.0
TSS	13	3.0	8.0	21.0	54.0	956.0	116.3	24.9
PH	13	5.0	9.4	9.7	10.0	10.8	9.2	8.9
Alkalinity	13	10.0	14.0	27.0	47.0	90.0	31.6	24.6
Rock Cover Wells: Middle Samples								
Analyte	Count	Minimum	25% Quartile	Median	75% Quartile	Maximum	Arithmetic Mean	Geometric Mean
Na	12	12.9	55.0	26,028.6	31,642.0	63,108.5	20,982.9	1,797.5
K	12	5.7	8.0	81.3	94.6	2,000.0	216.0	41.0
Ca	12	32.4	233.8	9,072.0	13,051.2	24,912.8	7,841.5	1,967.9
Mg	12	0.3	0.6	353.3	1,576.6	5,951.4	1,238.9	42.9
Cl	12	12.1	328.5	54,574.7	71,796.4	147,303.9	48,229.3	6,180.9
HCO3	11	0.5	8.7	11.5	21.5	43.3	16.1	9.9
CO3	11	0.0	0.5	2.6	8.4	887.6	85.7	1.1
SO4	12	2.0	10.0	20.4	38.3	202.2	37.0	20.7
NO3	0							
TDS	13	111.0	238.0	1,126.0	87,765.0	166,968.0	47,351.7	3,733.8
TSS	13	2.0	7.0	15.0	71.0	484.0	79.0	23.0
PH	13	5.7	8.6	9.6	10.7	11.7	9.5	9.2
Alkalinity	13	10.0	21.0	37.0	52.0	1,157.0	123.1	38.9
Rock Cover Wells: Bottom Samples								
Analyte	Count	Minimum	25% Quartile	Median	75% Quartile	Maximum	Average	Geometric Mean
Na	26	40.4	399.8	26,968.8	32,430.6	43,666.4	20,180.4	5,162.4
K	26	5.1	66.3	85.9	102.8	400.0	104.4	75.7
Ca	26	161.1	6,047.9	9,245.5	11,743.2	13,953.0	8,275.3	4,593.7
Mg	26	2.0	19.3	638.3	2,043.5	3,600.6	1,153.9	145.2
Cl	26	937.9	10,359.2	60,793.9	72,294.3	117,963.3	51,385.8	23,394.8
HCO3	26	2.3	10.0	15.0	23.3	60.7	18.2	12.9
CO3	26	0.0	0.1	4.9	139.2	697.6	108.8	4.1
SO4	13	5.0	10.0	20.0	28.9	200.0	32.4	18.7
NO3	13							
TDS	26	2,138.0	16,740.0	94,691.0	114,799.0	174,220.0	78,286.7	40,512.4
TSS	26	9.0	79.0	162.0	677.0	1,561.0	378.4	152.2
PH	26	5.6	8.1	9.2	11.5	12.4	9.5	9.3
Alkalinity	13	10.0	17.0	36.0	304.0	1,928.0	270.2	69.4

7. CONCEPTUAL MODEL AND CONTAMINANT DISTRIBUTION

WAG 10 consists of the subsurface facilities and grout sheets related to hydrofracture operations at four sites located in Melton Valley at ORNL. Two of the facilities were experimental sites (HF-1 and HF-2), at which a total of less than 100 Ci of short half-life radionuclides were introduced into the Pumpkin Valley Shale in three test injections. The other two—OHF, HF-3 and NHF, H-4—were operational facilities that were used over a 20-year period to inject radioactive mixtures of liquid and sludge waste and grout into the Pumpkin Valley Shale. A schematic representation of the injection activity is shown in Fig. 7.1. WAG 10 addresses only the subsurface facilities, including wells and grout sheets. Surface facilities are considered part of the other WAGs.

7.1 POTENTIAL EXPOSURE AND TRANSPORT MECHANISMS AND PATHWAYS

This section discusses the mechanisms by which injected contamination can be transported along potential exposure pathways. Because data were not collected to directly address contaminant migration within the rock matrix, the discussion of hydrogeologic transport outside the wellbores is somewhat speculative. However, the discussion is included to provide some insight into possible mechanisms that might account for the variability observed in the wellbore data.

Aqueous radioactive contaminants may have been introduced into the subsurface as

- part of the hydrofracture process,
- leaching from contaminated grout,
- through incomplete mixing of the grout, and/or
- as phase separation water (grout filtrate) released during grout setup.

During the initial stages of injection and shortly after the total slug of contaminated grout has been injected, the driving mechanism for migration of contaminants would be primarily artificially induced pressure. This pressure regime would dominate the ambient head distribution and alter the normal flow system. Contaminated grout would be expected to primarily remain within the induced fracture. Some of the grout, before setup, might also escape to cased and uncased boreholes that were in-place before injection.

As the contaminated grout is injected and cures, grout filtrate separation (phase separation) occurs. The volume of grout filtrate separating primarily depends on the initial mixture of the contaminated grout. Compositionally, the contaminated filtrate mimics the injected grout. The dominant ions present will consist of deep brine cations (calcium, sodium, magnesium, and potassium) and anions (bicarbonate, chloride, and chloride). The filtrate would also contain constituents of the grout; however, direct samples of the filtrate were not obtained, so it can only be assumed that the constituents identified in Tables 5.4 and 5.5 are contained in the filtrate. The specific proportion of these constituents in the filtrate has not been determined but is likely different than in the waste because of differential sorption within the grout matrix. Bleedback filtrate was analyzed for a limited number of radionuclides (see Sect. 5); however, the samples are probably not

representative of the filtrate in the formation because the injection well was flushed with water after the injection and before bleedback solutions were sampled.

As the grout filtrate migrates into and through the microfracture and fracture system, some of the ions will diffuse into the rock matrix. The rate at which contaminants transfer from the face of the fracture into the matrix depends on the concentration gradient, the diffusive cross-sectional area, and the molecular diffusion coefficient. The net effect of matrix diffusion is to reduce contaminant mobility by movement into immobile water within the matrix and increase the amount of time that is necessary for contamination to move through the system as the constituents move slowly out of the matrix back into the fracture when concentrations within the fracture are reduced (Solomon et al. 1992).

The contaminated liquids could, under pressure, migrate along bedding planes and through open fractures/joints into formations overlying or underlying the targeted injection horizon (Pumpkin Valley Shale). After dissipation of the induced pressure, the regional hydrogeologic flow regime would once again dominate. This flow regime near the OHF, however, would have been altered by the opening of fresh pathways (induced fractures, microfractures, and boreholes). Radioactive contaminants would be transported with groundwater through and along these migration pathways. In some areas, where the fracture system is enhanced by folds and faults, contaminants could be expected to migrate upsection and possibly to surface discharge points.

High levels of salinity, with characteristic natural brine concentrations, were measured in the standing water column of several wells (e.g., TDS in well 1963 at a depth of 50 ft below the ground surface is 157,258 mg/L). High TDS concentrations are present in wells completed in the Rogersville Shale and Rutledge Limestone and in deeper observation wells that penetrate the Pumpkin Valley Shale.

One plausible explanation for the anomalous distribution of high TDS concentrations is that the hydrofracturing activities uplifted the immediate area, opened existing planes of weakness, and caused an increase in the fracture/joint network permeability. An alternative hypothesis is that discrete, artificially induced, new, preferential pathways were created in the overlying rock cover, thus allowing deep natural brine solutions to migrate upsection.

Contaminants could also move vertically in wellbores through annular or intrawell flow. Results from the borehole geophysical logging program identified numerous anomalies and poor casing integrity in the majority of the wells. Many wells were also interpreted to have substandard grout bonding between the casing and the borehole wall. The combined effect of local hydrogeology, hydrofracturing operations, and poor well quality could be significant and may play a major role in transport of contaminants in the wellbore. The migration pathways discussed are shown in Fig. 7.2.

7.2 DISTRIBUTION OF WELLBORE CONTAMINATION

Eighteen separate low-level radioactive grout injections were performed at the OHF (HF-3) over the course of approximately 14 years of operations (1966-79). The injection well (well 1944) casing was slotted at 9 discrete depths approximately 10 ft apart. The initial injection (1A) was initiated at a depth of 872 ft below the ground surface, and the final injection (18) was at 790 ft below the ground surface. All 18 injections were within the upper Pumpkin Valley Shale.

The grout sheets and phase separation liquids (grout filtrate) extend radially from the injection point. The radial extent, however, is slightly biased up the regional dip towards the north-northwest. Several WAG 10 wells were monitored during injection operations to identify grout sheet migration pathways. These monitoring data and borehole geophysical logs were used to construct three cross sections (A-A', B-B', and C-C') through the OHF area that show the spatial distribution of grout sheets with respect to well type and sampling results (Figs. 7.3, 7.4, and 7.5, respectively). The estimated spatial extent of three grout sheets calculated by Weeren (1976) is presented in Fig. 7.6. The extent of the ILW-12, ILW-13, and ILW-14 grout sheets is based on intersection with observation wells and wellhead pressure changes observed in overlying rock cover wells.

Groundwater sampling of WAG 10 wells surrounding the OHF revealed large horizontal and vertical variations in chemical compositions among wells and within the stagnant water column of wells completed at similar elevations and formations. An example of this variation in groundwater chemistry is seen by comparing bottom interval samples from three neighboring rock cover wells: 1955, 1956, and 1957 (See Fig. 7.3). These wells were drilled to elevations of 194, 206, and 314.8 ft msl, respectively. Well 1955 has an openhole interval over the middle Rogersville Shale into the upper Rutledge Limestone. Well 1956 has an openhole interval in the lower Rogersville Shale. Well 1957 is cased to the bottom within the lower Rogersville Shale; however, based on geophysical evidence, this well has low integrity, and water from the Rogersville is thought to have flowed into the wellbore. The three wells are approximately 120 ft apart, along a northwest transect from the OHF injection well.

Well 1955 is approximately 80 ft from the injection well. TDS values from bottom interval groundwater samples from wells 1955 and 1956 differ by nearly 117,000 mg/L [well 1955 $\approx$ 2,100 mg/L (brackish), and well 1956 $\approx$ 119,000 mg/L (high saline/brine)]. The bottom interval TDS value from the low-integrity cased well 1957 is approximately 24,000 mg/L (saline). These variations in TDS are not typical of a natural hydrogeochemical evolution along a probable flow path, indicating either separate flow paths for each well or impact by the injections.

The difference in the groundwater salinity in these wells may be partially attributed to the low chloride (Cl) concentration of the injection fluids (Table 5.5). The injection fluid could produce a dilution effect on the natural brine along the variable migratory pathways of the grout sheets. If this hypothesis is correct, well 1955 would be expected to have been greatly affected by the injection activities and, thus, the well should be highly contaminated.

However, well 1955 is one of the least contaminated OHF wells, with an absence of injection waste indicator parameters such as nitrate. Order-of-magnitude salinity variations over short distances suggest low groundwater circulation and limited hydraulic connection. In a natural environment this would be indicative of fractured formations with a limited interconnected fracture/joint network, such as the Pumpkin Valley Shale. However, within minor, individual, open fracture networks, active groundwater circulation could be significant. The total volume of water moving through these fractures would be low. Figure 7.7 summarizes the TDS distribution within and among OHF rock cover and large-diameter observation wells. Small-diameter observation wells are excluded from discussions of water chemistry and contamination because, as discussed in Sect. 8.3, middle and bottom samples from these wells are not considered representative of wellbore water at depth. Figure 7.7 shows relatively low TDS, indicating fresh or saline wellbore water near the injection horizon with brine existing in the bottom of many rock cover wells. The high degree of variability in TDS among the wells is evident, with brine to the surface of well 1963 and with fresh water in adjacent observation well 1965 and rock cover well 1955. It is not clear whether TDS is lower in the observation wells as a result of the entirely cased wellbore or dilution of natural brines with lower TDS injection solutions. The low degree of contamination in well 1949 relative to other observation wells (see Sect. 8.2.8) does not support the latter concept. Additional discussion of the TDS distribution is provided in Sect. 7.3. TDS values are uniformly low in small-diameter observation wells, which, as discussed in Sect. 8.3 and BNI (1995), is a function of poor sample integrity resulting from the use of small-diameter bailers.

The spatial distribution of radionuclides is more a function of proximity to the grout sheets than is the case for other chemical constituents. The variability of radioactive contaminants (total alpha, beta, and gamma, and tritium) among WAG 10 wells is illustrated in Figs. 7.8 through 7.11, respectively.

Figure 7.8 shows that total alpha activity is generally elevated in the bottom of the rock cover and observation wells, indicating a relationship with injected solutions. Elevated alpha activity in the middle sample of well 1963 is correlated with the anomalous, shallow, high TDS in this well. Beta contamination in wells appears to gradationally increase with depth (Fig. 7.9). Groundwater samples collected from observation wells that intersect and penetrate the grout sheet varied from being only slightly contaminated (well 1949 ≈ 4900 pCi/L beta) to highly contaminated [well 1953 (openhole 497.5 to 1039.8 ft) ≈ 75 million pCi/L beta, and well 1965 (cased to total depth) ≈ 16 million pCi/L beta]. The high beta in well 1965 probably indicates a breach in the well casing and/or vertical migration of injection grout along the well annulus; this well is obstructed at approximately 815 ft.

The distribution of total gamma is more limited to grout sheet contacts with observation wells (Fig. 7.10). In general, concentrations of alpha, beta, and gamma contaminants appear to increase with depth. Figure 7.11 shows that in many wells tritium concentrations decrease with depth. This is not surprising because WAG 5 provides an available uphole source. The relationship between tritium and WAG 5 sources is further discussed in Sect. 7.5.

Because the wellbore and/or well annulus are the preferential vertical pathways for contaminants, it is difficult to separate vertical transport associated with the well from potential vertical transport within the rock. Contamination of the rock cover wells with OHF injected waste constituents would indicate that there has been at least approximately 200 ft of vertical transport from the injection horizon in the Pumpkin Valley Shale to the upper Rutledge Limestone or lower Rogersville Shale. Figure 7.12 presents the distribution of radioactivity with depth and shows significant increases in alpha, beta, and gamma activity from top to bottom, suggesting an influx of radionuclides in the bottom of the well rather than through leaky near-surface well casings. Switek, Haase, and Stow 1987 identified nitrate concentrations ranging from 20 to 54 mg/L in the bottom of NHF rock cover wells, suggesting upward migration of NHF injected wastes. Similarly, nitrate was found above detection limits in the bottom of OHF rock cover wells 1967 (442 mg/L) and 1955 (4.7 mg/L).

7.3 VARIABILITY OF TDS DISTRIBUTION

Figure 7.13 shows the distribution of TDS in individual wells as a function of depth and well type. The variability of saline water in WAG 10 wells may be used to infer potential wellbore migration. Natural brine at the OHF appears to be about 400 to 500 ft below ground surface. Wells such as 1963 that have high saline/brine concentrations (exceeding 100,000 mg/L) at shallow depths suggest the presence of hydrofracture-enhanced deep groundwater circulation. Shallow saline groundwater may also be indicative of poor well integrity and, thus, may identify potential conduits for vertical migration of contaminants. Wells with high salinity concentrations at shallow depths should be considered for P&A because they provide a vertical pathway for the migration of aqueous contaminants and high saline waters to overlying intervals. Salinity generally increases with depth; however, as indicated in Table 6.4, the median TDS value is lower in observation wells than in rock cover wells.

Mapping the aerial extent of the injections identified a greater thickness of grout sheets north-northwest of injection well 1944 (de Laguna 1968 and Figs 7.3, 7.4, and 7.5). The spatial distribution of TDS concentrations relative to the extent of grout sheet overlap is significant because it shows that wells located over this area (wells 1950, 1951, and 1960) have salinity concentrations equivalent to high saline/brine water at 200 to 300 ft below the ground surface ($\approx 100,000$ mg/L) (see Fig. 7.4). This suggests that the thickening (artificial uplift) increased the effective vertical permeability of the fracture/joint network of the rock cover formations and provided a migratory pathway for high saline/brine and other contaminants. Well 1955, which is only 80 ft from the injection well, however, demonstrates the variability of this mounding effect in that this well has a low TDS concentration (2138 mg/L) at a depth of 550 ft in the middle Rogersville to upper Rutledge Limestone.

As discussed in Sect. 5.0, rock cover wells were topped off with potable water before each injection, and wellhead pressures were monitored during the injection to determine whether there was pressure breakthrough in the Rutledge Limestone and Rogersville Shale rock cover formations. Rock cover pressure data provided in Weeren (1974, 1976, and 1980) were evaluated to determine whether there was a correlation between rock cover wellhead pressure and the elevation of the saline surface.

Such a correlation would indicate that the variability of the rock cover TDS values is a function of injection pressures driving deep brines to the surface in preferential fracture pathways intersecting rock cover wellbores. Figure 7.14 presents the maximum recorded rock cover pressure plotted against the saline water elevation, which does not indicate that any relationship exists. Therefore, the pressure distribution from the wells does not support the interpretation that saline water was driven upward.

Variability in TDS distribution can be expected in a heterogeneous-fractured flow system. Therefore, whether the overall variability of TDS presented in Fig. 7.13 results from the injected wastes or natural variation is unclear. However, wells such as 1963 and 1949 with high and low TDS, respectively, throughout the wellbore are anomalous because brine is not expected near the surface nor is nearly fresh water expected in the deeper flow zone. An injection-related mechanism for driving brine upward into the wellbore or diluting wellbore water with fresh water could be responsible.

7.4 VARIABILITY OF pH

The vertical and horizontal distribution of pH within the OHF wellbores could be controlled by the natural distribution of pH within the shallow, intermediate, and deep flow zones; influx of injection fluids into the wells; degradation of the grout sheets resulting in a basic pH; or degradation of the well grout, which can be responsible for pH above 10 (Dreier and Toran 1989). Figure 7.15 shows the vertical profile for observation and rock cover well pH relative to the range of background pHs. The majority of background wells deeper than 500 ft have a pH below 7. In general, pH values in the observation and rock cover wells tend to be basic, particularly in the top samples of the rock cover wells. The distribution of pH in the rock cover wells does not support the concept of grout sheet or injected fluids causing basic pH because the observed pH increases rather than decreases from the open interval of the well. The higher pH values could result from degradation of the well grout over time.

Figure 7.15 plots field pH as a function of distance from the injection well and does not indicate any trends that might suggest a systematic change in pH related to distance from the injection source.

7.5 INTERSECTION WITH WAG 5 CONTAMINATION

OHF wells are clustered around the OHF facility in the southwest corner of WAG 5 near the confluence of White Oak Creek and Melton Branch. These wells are situated downgradient of the SWSA 5 trenches and auger hole burial ground. Seasonally, these trench and auger holes become inundated by shallow groundwater (less than 50 ft), and leachable contaminants are transported through pore space and preferential pathways to the receiving streams (White Oak Creek and Melton Branch). WAG 10 wells with leaky casings, breached casings, and/or poor grout bonding of the annular spacing become a potential pathway for downward migration from shallow WAG 5 contaminant sources. Evidence of this active source is provided in the gamma ray logs run in wells

1955 and 1956. Elevated gamma ray responses in the shallow section are measured in both of these wells (see Figs. 8.5 and 8.16).

WAG 5 tritium concentrations in shallow groundwater within the overlying regolith range from 500,000 to 2 million pCi/L, with contaminated sources to the east exceeding 800 million pCi/L. Tritium concentrations in WAG 10 wells generally decrease with depth and typically range from approximately 1000 to 10,000 pCi/L. Well 1967 is an exception in that the middle sampling interval (depth of 328 ft), yielded a tritium concentration in excess of 3 million pCi/L, which would imply an influence from a shallow source. Figure 7.16 maps the tritium plume from shallow groundwater sources at WAG 5 with an overlay of WAG 10 well concentrations with depth. Wells 1948, 1951, 1952, 1955, 1956, 1957, 1959, 1960, and 1967 have vertical tritium distributions that decrease from top to bottom. With the exception of wells 1951 and 1952, the concentrations of the WAG 5 tritium plume are high enough to be responsible for the tritium concentrations observed in these wells. It is quite possible that wells 1951 and 1952 intersect tritium-contaminated fracture systems that were not identified in the WAG 5 investigation.

Figures 7.17 and 7.18 present the total beta and alpha activities in groundwater from wells and drivepoints completed near the water table near the OHF and the western portion of WAG 5. The 1966/1967 and 1963/1964/1965 well clusters do not appear to be contributing contamination to the shallow groundwater system. Beta contamination in the top samples of the 1963/1964/1965 well cluster is high enough, ranging from 1140 to 15,500 pCi/L; however, contamination in the shallow system increases to the west of the cluster and is considerably higher to the east (near drivepoints 4290 through 4295), suggesting other sources of contamination. The eastern source is the shallow WAG 5 burial trenches. Similarly, beta activity increases away from the 1966/1967 well cluster. A similar pattern is evident in the distribution of the alpha activity. The presence of contamination from the WAG 5 trenches is evidently masking any contribution of radioactivity to the shallow flow system from the OHF wells. Moreover, not enough shallow groundwater data are available for north of the 1966/1967 and 1963/1964/1965 well clusters to evaluate any potential WAG 10 impacts in this area.

7.6 POTENTIAL BOREHOLE CONTRIBUTION TO SEEP SP00D

Seep SP00D is located in an area of relatively flat, drained floodplain near the confluence of Melton Branch and White Oak Creek (see Fig. 7.16). No known contaminant sources are in the immediate vicinity; the area was not used for disposal of wastes and was not part of the solid waste storage area 5 south burial ground. Melton Branch is incised approximately 4 ft below the general floodplain elevation on the northeast bank and about 4 to 15 ft below the west/south bank.

The seep SP00D area has been characterized as a significant source of the ^{90}Sr flux in Melton Branch. Newsom et al. (1993) estimated that discharge from this area contributes approximately 10 to 15 percent of the total ^{90}Sr flux in the White Oak Creek watershed. DOE has initiated a non-time-critical removal action for seep SP00D involving a collect and treat system for removal of ^{90}Sr . Construction activities for the system were completed and were brought on-line in November 1994.

During construction activities for the removal action, a hole of approximately 6 ft² was excavated 2 to 3 ft into the bedrock (weathered shale) under the streambed and into the bank area containing seep SP00D. Two bedrock seeps discharging upwards through partially calcite-filled fractures and into the streambed were identified. This observation confirmed interpretations based on drive-point sampling results that the discharge is from the vertically upward movement of intermediate or deep groundwater rather than the lateral migration of shallow groundwater from the floodplain or upgradient area. The combined flow rate for these seeps was approximately 0.8 gal/min. Filtered water samples collected from these seeps contained an average gross beta activity of approximately 160,000 pCi/L.

It is important to note that no known waste burials occurred in the area, and there is no evidence of surface soil contamination. These factors negate the importance of percolation, surface runoff, interflow, and shallow groundwater as transport or release mechanisms and/or migration pathways. Although shallow groundwater accounts for almost two-thirds of the water budget leaving the area, contaminant flux via this pathway is most likely limited to the flux of contaminants entering from deeper groundwater. Local structural deformation (folds and faults) combined with an artificially enhanced fracture/joint network may be responsible for significant upward movement and possible contaminant discharge at seep SP00D. Analytical results for surface water sampling are summarized in Table 7.1.

Surface water ion and radiological results for seep SP00D do not appear to be indicative of WAG 10 well results obtained for the bottom or middle groundwater sampling intervals. Chloride, magnesium, and calcium concentrations in the seep sample are several orders of magnitude less than in deeper groundwater. The geochemistry of the top groundwater sampling interval, which was generally sampled at a depth of less than 75 ft, is more representative of concentrations obtained from the seep. However, because groundwater typically undergoes a geochemical evolution as it moves through a flow system, it would be difficult to predict the final composition of deep, radioactively contaminated, brine groundwater after it vertically migrates through 800 ft of calcareous shales and limestones and ultimately discharges in a creek bed. Some contribution from WAG 10 to seep SP00D cannot be entirely ruled out.

Vertical migration of contaminants through a well borehole pathway is one way that high concentrations of contaminants (radioactive and high saline/brine) can reach the near surface without being diluted. Well 1963 shows consistently high radionuclide and brine concentrations at all three sampling intervals. The brine concentration (TDS $\approx$ 158,000 mg/L) at a depth of 32 ft suggests flowing conditions within the well. A tritium concentration of 11 million pCi/L (observed at seep D) is not found at such magnitude within the WAG 10 wells (typically less than 10,000 pCi/L). The exception is well 1967, which has a concentration exceeding 3 million pCi/L at a depth of approximately 330 ft and is near seep SP00D. The data do not support the hypothesis that well 1967 functions as a vertical conduit supplying tritium to seep SP00D because the tritium concentration is about one-third the concentration observed at seep SP00D. Well 1966, a deep well that penetrates the Rome Formation, could be a possible conduit for a deeper source that produces the elevated tritium concentrations found both in well 1967 and at seep SP00D. Unfortunately, 1966 is currently plugged; no chemical data are available.

NOT TO SCALE

Fig. 7.1. Schematic representation of hydrofracture injection process.

Fig. 7.2. Schematic representation of migration pathways for hydrofracture contaminants.

Neutron (cps)

Gamma (cps)

A

Elevation (FT., MSL)

Well 1956
(Projected 30')

Well 1953
(Projected 80')

Well 1955
(Projected 65')

Neutron (cps)

Neutron (cps)

Neutron (cps)

0 250 500

0 250 500

0 250 500

Gamma (cps)

Gamma (cps)

Gamma (cps)

0 50 100

0 125 250

0 50 100

801	
TDS	294 mg/L
Nitrate	ND
Alpha	21 pCi/L
Beta	1,874,317 pCi/L
Gamma	426 pCi/L
Tritium	ND

746	
TDS	
Nitrate	
Alpha	
Beta	2.
Gamma	
Tritium	2.

1400
Gamma (cps)

483	
TDS	
Nitrate	
Alpha	
Beta	2.
Gamma	
Tritium	

16000
Gamma (cps)

Well 1944
(OHF Injection Well)
(Projected 80')

46
263 mg/L
ND
15 pCi/L
2,343 pCi/L
21 pCi/L
2,381 pCi/L

483
111 mg/L
ND
ND
2,187 pCi/L
22 pCi/L
578 pCi/L

€n

u€mr

733	
TDS	508 mg/L
Nitrate	ND
Alpha	40 pCi/L
Beta	4,412 pCi/L
Gamma	77 pCi/L
Tritium	1,894,820 pCi/L

l€mr

433	
TDS	611 mg/L
Nitrate	1 mg/L
Alpha	56 pCi/L
Beta	6,284 pCi/L
Gamma	117 pCi/L
Tritium	3,079,559 pCi/L

€rg

Well 1967

Neutron (cps)

Gamma (cps)

A'

Well 1967

Neutron (cps)

Gamma (cps)

A'

733	
TDS	508 mg/L
Nitrate	ND
Alpha	40 pCi/L
Beta	4,412 pCi/L
Gamma	77 pCi/L
Tritium	1,894,820 pCi/L

433	
TDS	611 mg/L
Nitrate	1 mg/L
Alpha	56 pCi/L
Beta	6,284 pCi/L
Gamma	117 pCi/L
Tritium	3,079,559 pCi/L

l mr

u mr

u

Well 1953
(Projected 80')

Well 1955
(Projected 65')

801
294 mg/L
ND
21 pc/L
1,874,317 pc/L
426 pc/L
ND

746	TDS	263 mg/L
	Nitrate	ND
	Alpha	15 pc/L
	Beta	2,343 pc/L
	Gamma	21 pc/L
	Tritium	2,381 pc/L

483	TDS	111 mg/L
	Nitrate	ND
	Alpha	ND
	Beta	2,187 pc/L
	Gamma	22 pc/L
	Tritium	578 pc/L

Gamma (cps)
1400

Well 1944
(OHF Injection Well
(Projected 80'))

Well 1957

Neutron (cps)
0 250 500

Gamma (cps)

A

820

720

620

520

420

TDS	1,887 mg/L
Nitrate	ND
Alpha	ND
Beta	88 pc/L
Gamma	1,310 pc/L
Tritium	21,546 pc/L

791

TDS	133 mg/L
Nitrate	ND
Alpha	25 pc/L
Beta	3,071 pc/L
Tritium	7,431 pc/L

754

TDS	2,033 mg/L
Nitrate	ND
Alpha	11 pc/L
Beta	80 pc/L
Gamma	117 pc/L
Tritium	6,075 pc/L

566

TDS	183 mg/L
Nitrate	ND
Alpha	28 pc/L
Beta	2,923 pc/L
Gamma	67 pc/L
Tritium	6,548 pc/L

521

Well 1956 (Projected 30')

Neutron (cps)
0 250 500

Gamma (cps)

100 50 0

TDS	
Nitrate	
Alpha	
Beta	
Gamma	
Tritium	

Well 1957

Neutron (cps)

Gamma (cps)

A

820

720

620

520

420

n (FT., MSL)

791	
TDS	1,887 mg/L
Nitrate	ND
Alpha	ND
Beta	88 pCi/L
Gamma	1,310 pCi/L
Tritium	21,546 pCi/L

7	
TDS	
Nitrate	
Alpha	
Beta	
Tritium	

566	
TDS	2,033 mg/L
Nitrate	ND
Alpha	11 pCi/L
Beta	80 pCi/L
Gamma	117 pCi/L
Tritium	6,075 pCi/L

TDS	
Nitrate	
Alpha	
Beta	
Gamma	
Tritium	

E

320

TDS	24,412 mg/L
Nitrate	ND
Alpha	ND
Beta	694 pCi/L
Gamma	384 pCi/L
Tritium	3,868 pCi/L

232	
TDS	11
Nitrate	
Alpha	
Beta	
Gamma	
Tritium	

220

120

20

0

-20

-120

-220

-320

0

0.1-1.0

1.1-10

11-100

281	
Gamma	664 pCi/L
TDS	37,225 mg/L
Nitrate	5,366 mg/L
Alpha	633 pCi/L
Beta	77,387,500 pCi/L
Tritium	ND

TDS
Nitrate
Alpha
Beta
Gamma
Tritium

-214	
TDS	36,168 mg/L
Nitrate	4,981 mg/L
Alpha	801 pCi/L
Beta	75,627,453 pCi/L
Gamma	101,000 pCi/L
Tritium	ND

220
2,138 mg/L
5 mg/L
ND
9,594 pCi/L
103 pCi/L
813 pCi/L

300

400

Distance (FT)

erg

ϵ_{rt}

137	
TDS	110.5
Nitrate	4
Alpha	7
Beta	13.1
Gamma	2
Tritium	32.1

ϵ_{pv}

ϵ_{pv}

400

500

Plan View
(Section A-A')

137	
TDS	110,545 mg/L
Nitrate	442 mg/L
Alpha	724 pCi/L
Beta	13,113 pCi/L
Gamma	264 pCi/L
Tritium	32,118 pCi/L

Plan View
(Section A-A')

-220

-320

0

- Notes:
- 1) Grout sheet intersects with Well 1967 from Well 1966 located approximately
 - 2) Grout sheet intersects with Well 1953 from Well 1954 located approximately

7

?

-214	
TDS	36,168 mg/L
Nitrate	4,981 mg/L
Alpha	801 pCi/L
Beta	75,627,453 pCi/L
Gamma	101,000 pCi/L
Tritium	ND

→

100

200

1967 are based on well data
approximately 12 ft to the north west.
1953 are based on well data
approximately 25 ft to the north west.

Fig. 7.3. OHF WAG 10 wells (Section A-A').

.00

500

-320

600

The map shows the study area with various sampling locations marked by circles and rectangles. The locations are labeled with years: 1945, 1946, 1947, 1948, 1949, 1950, 1951, 1952, 1953, 1954, 1955, 1956, 1957, 1958, 1959, 1960, 1961, 1962, 1963, 1964, 1965, 1966, and 1967. The map also shows the OHF Pond, OHF Gate, and Old Hydrofracture Facility. A dashed line indicates a boundary, and a solid line indicates a road. A north arrow is present in the top right corner.

Well 1952

Well 1951

(Projected 30')

Well 1949

Well 1944
(OHF Injection Well)

0

0

€n

u€mr

l€mr

738	
TDS	260 mg/L
Nitrate	ND
Alpha	ND
Beta	10,940 pCi/L
Gamma	990 pCi/L
Tritium	6,162 pCi/L

344	
TDS	493 mg/L
Nitrate	ND
Alpha	ND
Beta	4,150 pCi/L
Gamma	720 pCi/L
Tritium	3,085 pCi/L

Neutron (cps)

0 250 500

Gamma (cps)

0 500 1000

B'

820

720

620

520

420

320

738

TDS	260 mg/L
Nitrate	ND
Alpha	ND
Beta	10,940 pCi/L
Gamma	990 pCi/L
Tritium	6,162 pCi/L

344

TDS	493 mg/L
Nitrate	ND
Alpha	ND
Beta	4,150 pCi/L
Gamma	720 pCi/L

Elevation (FT., MS)

320

220

120

20

0

-100

-200

319	
TDS	3,875 mg/L
Nitrate	ND
Alpha	ND
Beta	ND
Gamma	0 pCi/L
Tritium	6,523 pCi/L

215	
TDS	94,691 mg/L
Nitrate	ND
Alpha	ND
Beta	56,196 pCi/L
Gamma	0 pCi/L
Tritium	2,357 pCi/L

304	
TDS	88,958 mg/L
Nitrate	ND
Alpha	ND
Beta	ND
Gamma	0 pCi/L
Tritium	ND

16000
Gamma (cps)

-200	
TDS	975 mg/L
Nitrate	ND
Alpha	9 pCi
Beta	4,890 pCi
Gamma	753 pCi
Tritium	255 pCi

16000

~~Gamma (cps)~~

Injections

-200	
DS	975 mg/L
iltrate	ND
lpha	9 pCi/L
eta	4,890 pCi/L
gamma	753 pCi/L
tritium	255 pCi/L

€rt

€pv

-36	
TDS	56,73€
Nitrate	4,91€
Alpha	1,49€
Beta	16,455,54€
Gamma	1,650,00€
Tritium	726,68€

€pv

Notes: 1) Grout sheet intersects with Well 1965 are based on well data from Well 1964 located approximately 22 ft to the east.

data

Fig. 7.4.

Fig. 7.4. OHF WAG 10 wells (Section B-B').

Plan View
(Section B-B')

Well 1961

Well 1960

Neutron (cps)

Neutron (cps)

0 250 500

0 250 500

C

Gamma (cps)

Gamma (cps)

0 50 100 0 50 100

820

720

620

520

420

727	
TDS	705 mg/L
Nitrate	ND
Alpha	8 pCi/L
Beta	84 pCi/L
Gamma	0 pCi/L
Tritium	3,797 pCi/L

716	
TDS	4
Nitrate	N
Alpha	:
Beta	1.4
Gamma	:
Tritium	1 05

502	
TDS	1,126 mg/L
Nitrate	1 mg/L
Alpha	ND
Beta	32 pCi/L
Tritium	7,567 pCi/L

450	
TDS	116
Nitrate	:
Alpha	:
Beta	1.4
Gamma	:
Tritium	4

Well 1960

Well 1959
(Projected 10')

Neutron (cps)

Neutron (cps)

Gamma (cps)

Gamma (cps)

Well 1958
(Projected 30')

Well 1955
(Projected 50')

Neutron (cps)

Gamma (cps)

Well 1944
Injection Well
(Projected 45')

58
30')

725	
TDS	269 mg/L
Nitrate	ND
Alpha	14 pCi/L
Beta	74,897 pCi/L
Gamma	12,100 pCi/L
Tritium	ND

TDS
Nitrate
Alpha
Beta
Gamma
Tritium

TDS
Nitrate
Alpha
Beta
Gamma
Tritium

II 1955

ected 50')

tron (cps)

ma (cps)

746	
TDS	263 mg/L
Nitrate	ND
Alpha	15 pCi/L
Beta	2,343 pCi/L
Gamma	21 pCi/L
Tritium	2,381 pCi/L

483	
TDS	111 mg/L
Nitrate	ND
Alpha	ND
Beta	2,187 pCi/L
Gamma	22 pCi/L
Tritium	578 pCi/L

Well 1946

Neutron (cps)

Gamma (cps)

C'

Elevation (FT.,MS)

252	
TDS	278 mg/L
Nitrate	ND
Alpha	17 pCi/L
Beta	129,376 pCi/L
Gamma	22,000 pCi/L
Tritium	ND

227	
TDS	114,799 mg/L
Nitrate	ND
Alpha	688 pCi/L
Beta	1,014 pCi/L
Gamma	0 pCi/L
Tritium	2,399 pCi/L

180	
TDS	531 mg/L
Nitrate	ND
Alpha	28 pCi/L
Beta	128,782 pCi/L
Gamma	20,800 pCi/L
Tritium	ND

220	
TDS	2,138 mg/L
Nitrate	5 mg/L
Alpha	ND
Beta	9,594 pCi/L
Gamma	103 pCi/L
Tritium	813 pCi/L

Beta
Gamm
Tritiu

€rg

€rt

€pv

TDS
Nitrate
Alpha
Beta
Gamm
Tritium

400

500

Beta	1,385 pCi/L
Gamma	340 pCi/L
Tritium	1,147 pCi/L

Fig. 7.5. OHF WAG 10 wells (Section C-C').

400

500

Plan View
(Section C-C')

500

600

-100

-200

-300

Plan View
(Section C-C')

Fig. 7.6. Approximate extent of injections ILW-12, ILW-13, AND ILW-14.

LEGEND

TOTAL DISSOLVED SOLIDS (mg/L)

- 0 - 1,000
- 1,000 - 10,000
- 10,000 - 100,000
- >100,000

Fig. 7.7. Total Dissolved Solids (TDS) in WAG 10 OHF wells

LEGEND

TOTAL ALPHA CONCENTRATION (pCi/L)

- UNDETECTED
- 0 - 100
- 101 - 500
- ⊗ 501 - 1,000
- ⊗ 1,001 - 2,000

Fig. 7.8. Total Alpha in WAG 10 OHF wells

LEGEND

TOTAL BETA CONCENTRATION (pCi/L)

- UNDETECTED
- 0 - 100
- 101 - 1,000
- ◐ 1,001 - 10,000
- ◑ 10,001 - 100,000
- ◒ 100,001 - 1,000,000
- ◓ > 1,000,000

Fig. 7.9. Total Beta in WAG 10
OHF wells

LEGEND

TOTAL GAMMA CONCENTRATION (pCi/L)

- 0 - 100
- 101 - 1,000
- 1,001 - 25,000
- 25,001 - 100,000
- 100,001 - 1,000,000
- > 1,000,000

Fig. 7.10. Total Gamma in WAG 10 OHF wells

Fig. 7.11. Total Tritium in WAG 10
OHF wells

Fig. 7.12. Vertical distribution of activity in rock cover wells

Top			
Statistics	Alpha	Beta	Gamma
Minimum	8.2	33.0	21.1
25th Percentile	14.0	86.8	29.1
Median	21.1	847.5	29.5
75th Percentile	28.3	2,524.6	65.4
Maximum	52.2	4,411.6	1,310.0
Geometric Mean	20.2	497.5	61.5

Middle			
Statistics	Alpha	Beta	Gamma
Minimum	10.7	31.5	22.0
25th Percentile	10.8	262.3	44.3
Median	27.7	1,192.4	75.5
75th Percentile	56.3	2,370.9	117.0
Maximum	1,730.5	13,605.9	273.0
Geometric Mean	50.0	830.9	71.6

Bottom			
Statistics	Alpha	Beta	Gamma
Minimum	688.1	325.9	57.3
25th Percentile	715.3	1,217.9	103.5
Median	832.4	4,458.4	118.5
75th Percentile	943.2	12,233.3	231.0
Maximum	951.3	56,196.1	384.0
Geometric Mean	817.2	3,863.3	142.3

Fig. 7.13. Vertical TDS distribution in rock cover and observation wells.

^a Saline water elevation determined based on the minimum detectable fluid resistivity log corresponding to approximately 10,000 mg/L TDS.

^b Maximum pressure is the maximum pressure at the rock cover well head observed during any of the OHF injections. Pressure data was taken from Weeren (1974, 1976, and 1980).

Fig. 7.14. Saline water elevation vs. maximum observed rock cover pressure during OHF operations.

Fig. 7.15. Distribution of background, rock cover, and observation well pH.

Areal Extent of Tritium Contamination in WAG 5 Shallow Groundwater

Tritium Activity in
Shallow Groundwater (< 30')
(pCi/L)

LEGEND

- Rock cover well
- Observation well w/ small riser diameter
- Observation well w/ large riser diameter
- △ Surface seep

Vertical Extent of Tritium Contamination in WAG 10 Wells

Fig. 7.16. Extent of tritium contamination in WAG 5 and WAG 10 groundwater.

19118 WAG10 10F053.DGN
3/21/95

Fig. 7.17. Total beta distribution in WAG 10 OHF shallow groundwater.

WAG 10 10F052.DGN
3/21/95

Fig. 7.18. Total alpha distribution in WAG 10 OHF shallow groundwater.

Table 7.1. Summary of analytical results for surface water at seep SP00D

Analyte	Results		Units
	Unfiltered	Filtered	
Chloride	18.3		mg/L
Sulfate	28.68		mg/L
Calcium	120.4		mg/L
Magnesium	15.19		mg/L
Potassium	1.77		mg/L
Sodium	17.06		mg/L
Alpha particle	480.8	499.4	pCi/L
Beta particle	203,177	157,350	pCi/L
C-14	52,628	51,571	pCi/L
Total radioactive strontium	96,955	32,144	pCi/L
Tritium	10,992,072	10,967,838	pCi/L

8. ANALYSIS OF WELL CONDITIONS

This section presents an interpretation of the condition of each OHF well based on historical and investigation data. An examination and interpretation of the geophysical logging, geochemical data, radiochemical data, and historical records of construction and operations will be used to develop conclusions on the current state of the wells and potential future actions for the wells.

Section 8.1 of this SCSR describes the characteristics and capabilities of the various borehole logs run for this investigation. Section 8.2 provides interpretation, analysis, and evaluation of the well-specific geophysical logging results and the geochemical and radiochemical data. Table 8.1 summarizes the well construction information derived from interpretation of the geophysical logs, wellbore standing water chemistry and radionuclide contamination, interpretation of well conditions, and conclusions regarding the final proposed disposition of the wells.

A qualitative ranking of the wells is provided in Table 8.1 by deriving a numerical ranking of 1 to 3 for contamination, migration potential, and well integrity. Contamination is defined as the concentration of hazardous constituents, primarily radiological, observed in the wellbore water based on grab sampling the top, middle, and bottom of the standing water column. The sampling methodology and analytical methods are presented in Sect. 2 and further discussed in BNI (1995). A contamination score of 1 indicates low contamination, primarily from influx of natural brine groundwater. A contamination score of 3 was assigned to the most contaminated WAG 10 OHF wells due to high concentrations of radionuclides.

The migration potential score is based on observed migration of contaminants up the wellbore or inferred migration within the well annulus. Wellbore migration was typically determined by evaluating the degree of stratification of TDS, radionuclides, or nitrate within the standing water column or postulated flux of water in and/or out of the wellbore, based on the geophysical logs. The contamination and migration potential scores are independent. For example, a well may have been highly contaminated at the bottom but not have exhibited migration of contamination to the middle and top sample locations (e.g., Table 8.1, well 1946). A migration potential score of 1 indicates that the well does not show evidence of significant transport within the wellbore, whereas a score of 3 indicates the highest degree of transport within the wellbore. Transport is generally, but not necessarily, from bottom to top. Higher contaminant concentrations were observed in the top or middle of some wells rather than the bottom (e.g., Table 8.1, tritium within well 1967), although wells with this characteristic generally had a smaller range of contaminant concentrations than wells where the highest concentrations were at the bottom of the well.

The well integrity score, derived from interpretation of the borehole geophysical logs, is based on the

- Interpreted physical condition of the well casing,
- Physical and chemical characteristics of the water in the borehole,
- Physical and chemical characteristics of the geologic formations logged,

- Physical and chemical characteristics of the injected contaminated grout, and
- The interpreted casing-to-grout-to-formation bond.

The integrity score for the well casing and grout quantifies the efficiency of the well completion in preventing the flux of formation water into the wellbore and/or potential migration of grout up the well annulus. A score of 1 indicates a low degree of flux of formation water through the well casing, whereas a score of 3 indicates poor isolation of the wellbore from the formation. Well integrity was evaluated independent of the contamination or migration potential scores. For example, well 1956 (Table 8.1) has medium contamination and low migration potential, but poor casing integrity.

Figures 8.1 through 8.19 present well-specific summaries of the geophysical logs (caliper, residual temperature, fluid resistivity, velocity, gamma ray, interpreted cement bond, and far receiver variable density log) together with histograms of radionuclide activity, TDS, nitrate, and anion/cation distributions at each of the three sampling levels. The complete suites of logs and well construction details are in Appendix A.

Modern geophysical logs and well construction details were not available for the following wells constructed with small-diameter (1.25-in.) tubing: wells 1948, 1958, 1962, and 1964; or for the injection well (1944). Commercial geophysical logs for well 1944 and old gamma logs for the other wells were located and are included along with a well construction sketch for each of the wells in Appendix A. Wells 1966 and 1954 are plugged at the surface and, therefore, were not tapped or sampled.

The approximate well construction detail, provided in Figs. 8.1 through 8.19, is based on historical records, field observations, and geophysical log interpretation. These sketches are invaluable for planning future P&A activities and/or site monitoring using existing wells.

The suite of logs that were run in the WAG 10 wells are discussed in BNI (1995). The hard copies of the logs are presented as Appendix 24 of that report. The logs, which provide data for cased holes and are useful for evaluating well integrity and construction detail, are discussed briefly in the following sections.

8.1 BOREHOLE LOG CHARACTERISTICS AND CAPABILITIES

The discussion and interpretation of the geophysical logs run at WAG 10 are based on comparison with other logs and reference documents (Hilchie 1982; Keys 1989; Nielson and Aller 1984; Thornhill and Benefield 1990).

8.1.1 Mechanical

A caliper log was run in all OHF wells logged. The caliper log provides a continuous record of borehole diameter (shape). The tool can be run in any borehole condition (open or cased hole).

In openholes, the caliper provides useful information on lithology, fractures, vugs, solution cavities, obstructions, and washouts. The caliper is also used to correct other logs before interpretation to compensate for borehole conditions.

The caliper log is a valuable tool for evaluating the integrity and construction details of cased holes. Casing collars in wells can usually be located with this tool. Other casing conditions, such as excessive corrosion, pitting, casing openings, and scaling, may also be indicated by the caliper response.

8.1.2 Electrical

Spontaneous potential (SP) and single-point resistivity (SPR) logs were run in OHF wells. The SP log provides a record with depth of the direct current potential of a moving electrode within an open borehole and a reference surface electrode. Differences in spontaneous (current) potential are caused by the borehole fluid, in situ formation fluid, type and amount of clay and/or shale present, porosity/permeability, and lithology.

The SP log is used to estimate "shaliness," locate contacts between permeable and less-permeable beds, correlate beds from well to well, identify permeable beds, and determine formation water resistivity. According to literature, the SP log is useful only in open boreholes containing conductive fluid.

SPR logging is based on Ohm's Law:

$$E = Ir$$

E = voltage (in volts)

I = current (in amperes)

r = resistance (in ohms)

SPR measures the resistance ($r = E/I$) of the rock unit(s), formation fluid(s), and borehole fluid. The principle of SPR logging is straightforward. The current (I) is held constant while the voltage (E) is measured between the movable lead electrode and a surface electrode. Voltage is then converted to resistance and plotted. SPR logs are valuable for obtaining information on lithology, unit contacts, porosity/permeability, fractures, and solution cavities. The logs are run in open boreholes containing conductive fluid.

The SP and SPR logs were run in the cased intervals of the OHF wells. The resulting logs provided useful information to aid in interpretation of well integrity. In many cases, the responses of these logs confirmed an interpretation of low casing integrity. The response observed consisted of a blocky pattern, with the top and bottom of the block correlating to casing joints.

8.1.3 Nuclear

Natural gamma, 4-Pi density, and neutron nuclear logs were run in WAG 10 wells.

The natural gamma log (also referred to as a gamma log or gamma ray log), in borehole environments that have not been affected by man, measures total (passive) gamma radiation within a selected energy range in the borehole. The most significant naturally occurring radionuclides that account for gamma response are potassium-40 and the daughter products of the uranium and thorium decay series.

Where manmade radionuclides may be encountered in the groundwater, formation, or well annulus and/or adsorbed on shale intervals, they contribute cumulatively to the total gamma response (i.e., they are additive). The specific radionuclides, however, cannot be identified on the routine gamma log unless spectral-logging equipment is used. Some of the possible contributors to the total gamma ray response could include illite, smectites, potassium feldspar, glauconite, mica, muscovite, organic material, organic colloids, uranyl ion precipitates, aqueous radionuclides, contaminated grout, and contaminated grout filtrate.

Gamma ray logs, which can be run in open or cased boreholes, are commonly used to estimate clay and/or shale content. The same application can be made in aquifers if suitable laboratory data are available to support a relationship. Gamma logs are also used for lithologic determination, correlation, and estimation of effective porosity/permeability.

In a cased borehole, the gamma ray formation signature is suppressed by any hole conditions that modify the travel path of the photons. Casing, multiple casing, cement, and large-diameter boreholes will, in general, reduce the gamma response. Care should be taken when interpreting a gamma log run in a cased well if construction details are unknown.

The 4-Pi density log (also referred to as a gamma-gamma log) uses an activated source (cesium-137) and measures the effect of induced radiation and its degradation. The log, if calibrated, can be used to determine bulk density. In lithologies where both the matrix and fluid densities are known, total porosity can be determined by using the calibrated log measured bulk density. Because the ORNL 4-Pi density tool is uncalibrated, it cannot be used to determine porosity other than in a relative sense. The 4-Pi density tool can be run in open and cased boreholes.

The 4-Pi density log is affected by borehole conditions, casing, cement, and gravel pack. Quantitative log interpretation of formation characteristics would be suspect unless well construction details and conventional core are available for calibration. This tool, however, can provide some information on well construction details. Top(s) of cemented zones, gravel packs, and bottom(s) of multiple casing string can, in some cases, be recognized based on 4-Pi density response.

The neutron log response reflects the hydrogen content within the borehole environment and the formation. A detector on the tool measures attenuation by hydrogen of neutrons emitted from an americium and beryllium (Am/Be) source within the tool. Neutrons have no electrical charge and

have approximately the same mass as hydrogen. Therefore, hydrogen is responsible for most of the energy loss. Neutron logs can be run in open or cased boreholes.

The neutron log response can be used to determine total porosity (below water table), moisture content (above water table), specific yield of unconfined aquifers, perched water, and lithology. Log response can also be used for well-to-well correlation. Well casing will not cause a major effect on the neutron log response. Changes in thickness and/or the lack of fill in the annular space will affect the neutron response because of water filling the voids.

8.1.4 Acoustic

Acoustic velocity logs and variable density logs (VDLs) were run in all OHF wells.

The acoustic log records the shortest time (interval transit time) required for a compressional (P) wave to travel vertically through a known distance of formation next to the wellbore. Normally, the log records the interval travel time. A velocity log is computed and plotted by using the reciprocal of interval transit time.

Log velocity, when recorded in an open fluid-filled borehole that is in good condition, is directly related to degree of rock consolidation, lithology, porosity, rock elasticity, and strength. In common applications, it is used primarily to determine lithology and porosity. The velocity log response is also useful for well-to-well correlation.

The VDL (also referred to as a three-dimensional velocity log) tool transmits an acoustic signal and records all returning waveforms. The hard-copy log record displays changes in amplitude of cycles as dark (troughs) and light (peaks) bands. Changes in amplitude can also be displayed in color to highlight waveform arrivals (Figs. 8.20 and 8.21).

Interpretation of the VDL (open borehole) can provide information on lithology, fracturing, and structure. A digital VDL, as run by the ORNL Geophysics Group, can be most useful because the data can be quantitatively analyzed to obtain elastic rock properties (e.g., bulk modulus, shear modulus, Poisson's ratio, and Young's modulus).

Run in a cased borehole, the VDL provides valuable information that can be used to evaluate well integrity. The acoustic signal produced by a transmitter within the VDL tool passes through each medium (fluid within the borehole, casing, cement, and formation), is refracted, and then is received (known spacing) by the tool (Fig. 8.21). Because the velocity (transit time) of each medium is different, waveform arrival times to the receiver vary; the idealized order of waveform arrivals, based on the velocity of each medium, would be casing, formation, and borehole fluid.

When a velocity log is run in combination with the VDL in cased boreholes, it can provide useful information on the condition of bonding between casing/cement and cement/formation. The response of the velocity log in cased boreholes would be similar to a cement bond log. In cased boreholes, however, the velocity log cannot be used for quantitative log interpretation.

Well integrity designations (below), from the standpoint of casing/cement and cement/formation bonding, can be evaluated by interpretation of the velocity log, in combination with the VDL. The most common log responses are outlined below.

- Good casing/cement and cement/formation bond
 - weak casing arrivals on the VDL
 - strong formation arrivals on the VDL
 - no chevron "W" patterns at casing collars on the VDL
 - velocity log response similar to open borehole (strong formation arrivals)
- Good casing bond but poor formation bond
 - weak casing arrivals on the VDL
 - weak or nonexistent formation arrivals on the VDL
 - consistent velocity on the velocity log
- Poor casing/cement bond
 - strong casing (casing ringing) arrivals on the VDL
 - very weak or nonexistent formation arrivals on the VDL
 - clear chevron ("W") patterns at casing collars on the VDL
 - slight decrease in velocity at collars on the velocity log
 - consistent velocity on the velocity log

8.2 WELL-SPECIFIC DESCRIPTION, INTERPRETATION, AND CONCLUSIONS

Sections 8.2.1 through 8.2.19 describe the results of geophysical logging and chemical analysis of wellbore water, interpretation of the data, and conclusions regarding well integrity and sources and degree of contamination. The wells are presented in rank order determined by the methodology discussed in Sect. 8 and presented in Table 8.1. Table 8.2 summarizes the radiochemical contamination in each well in terms of the maximum alpha, gamma, beta, and tritium activity observed in the wellbore, regardless of where in the well the maximum activity was observed. Minor ion concentrations are presented in Table 8.3.

8.2.1 Observation Well 1953 (3NE-100)

Well 1953 is located up dip, approximately 100 ft northeast (ORNL grid north) of the injection well. This well is the only well at the OHF site that is open through the grout sheet injection horizon. The openhole interval (497.5 to 1039.8 ft) is over the lower Rogersville Shale, Rutledge Limestone, and upper Pumpkin Valley Shale, and into the lower Pumpkin Valley Shale. Well 1953 was installed in a cored hole drilled in 1987, 8 years after the last OHF grout injection (ILW-18) was done in May 1979. The artesian nature of the well was noted at the time of wellhead tapping and during geophysical borehole logging. Artesian conditions have persisted at about 26 psi (BNI 1995). The flow rate from the well is typically very low (less than 1 gal/h).

Well 1953 is cased to approximately 500 ft. Selected logs are presented in Fig. 8.1, and the complete suite of logs is included in Appendix A. Interpretation of the geophysical logs indicates

that the casing is poorly bonded from 5 to 147 ft and well bonded from 147 ft to the bottom of the casing. The casing appears to be in relatively good condition, with only scattered intervals of corrosion and/or scaling. Minor openings at joints are apparent on the caliper log. The fluid resistivity log measures fresh water at the top of the well and a gradual transition to brackish to saline water at the bottom of the well. Laboratory-measured TDS confirms this interpretation.

The caliper log, over the openhole interval (497.5 to 1039.8 ft), indicates that the borehole wall is generally smooth. Three borehole enlargements were measured (590, 826, and 994 ft) in the upper Rutledge Limestone and upper and lower Pumpkin Valley Shale, respectively. The enlargement at 826 ft seems to correlate with the center of the contaminated grout sheet interval.

The residual temperature log displays a gradual increase in temperature from the bottom of the casing to the center of the grout sheets. This increase in temperature ($\approx 1.5^\circ\text{F}$), while slight, is significant and would indicate heat generation due to radioactive decay, or residual heat from injected materials on grout setup. The temperature gradually decreases below this depth to the total depth of the well.

The passive gamma ray and neutron log response are uncharacteristically high throughout the logged interval (cased and uncased section). These two tools are both influenced by the penetrated grout sheets. The neutron source in the sonde is overwhelmed by the influence of the grout sheets. This is especially apparent at the center of the grout interval (≈ 815 ft).

Observation well 1953 (3NE-100) wellbore water characterization

Total beta activity in the standing water in well 1953 exceeds 75,000,000 pCi/L in the middle and bottom samples (Fig. 8.1). Total beta activity is the highest radioactivity in OHF wells (see Table 8.2). Beta activity is significantly lower (1,874,000 pCi/L) in the surface sample but is still elevated. Total gamma and alpha activities are relatively low but increase from the top sample downward to activities of 101,000 and 800 pCi/L, respectively, at the bottom. C-14 concentrations increase from 118,000 pCi/L at that surface to over 35,000,000 pCi/L in the middle and bottom samples. Total radioactive strontium concentrations increase from 7370 pCi/L to over 30,000,000 pCi/L in the middle and bottom samples. Co-60 was also identified in the bottom sample at 6,110 pCi/L. Tritium concentrations are anomalously low relative to concentrations in other observation wells, as discussed in Sect. 7.4. The middle and bottom samples were collected approximately 200 ft above and 215 ft below the grout sheet injection interval.

TDS data indicate fresh water near the surface (less than 300 mg/L, within the cased interval) with nearly equivalent saline water concentrations in the middle and bottom samples (37,000 and 36,000 mg/L, respectively, within the openhole interval). These saline water concentrations are significantly lower than the nearby DM series wells also completed in the Pumpkin Valley Shale: DM1 and DM2 at 91,000 and 130,000 ppm, respectively (Nativ and Hunley 1993). This suggests dilution of standing water by the introduction of relatively lower-TDS injection fluids that are typically less than 5000 ppm (Switek, Haase, and Stow 1987) or mixing with lower-TDS natural formation waters. The stratification evident by the order of magnitude increase in radionuclide

concentrations between the top and middle/bottom samples, however, does not support the concept of significant mixing and dilution of relatively near-surface waters with deep brines.

The major ion distributions of the middle and bottom samples are nearly identical. Sodium and chloride are the dominant ions at depth. Calcium, carbonate, and bicarbonate concentrations are reduced, whereas the sulfate concentration increases in the middle and bottom samples relative to the surface sample. Nitrate is also present in significant concentrations in the middle (5366 mg/L) and bottom (4980 mg/L) samples, indicating influence from grout-related waste solutions. Na:Cl ratios of about 7.0 at the middle and bottom are elevated relative to the background ratios of both HF-affected (0.387) and non-HF-affected background wells. Bromide was not detected.

Observation well 1953 (3NE-100) interpretation and conclusions

Although well 1953 is under artesian conditions, an order-of-magnitude difference in radionuclide and major ion concentrations has been maintained between the top and middle/bottom samples, indicating stratification of wellbore water. Low TDS and below-detection-limit nitrate in the top sample indicates that either (1) the contaminated water column is being diluted by freshwater influx into the upper portion of the wellbore or (2) the wellbore water is stratified by other mechanisms, and the reduced concentrations of radionuclides at the surface are due to transport by diffusion or a small degree of advective flow. The chemical and radiochemical concentrations of the bottom and middle samples are nearly identical, suggesting mixing in the open interval.

Flowing artesian conditions in wells located northeast (generally along strike) are known in the area of this well. These particular artesian wells are completed in the Maryville Limestone. The artesian condition noted for well 1953 could be the result of poor bonding and integrity of the upper portion of the well. An influx of fresh water under pressure, probably from the Maryville Limestone, could explain this situation.

Well 1953 is highly contaminated with radionuclides and should be considered a prime candidate for P&A (well score of 9). This well, however, also provides an excellent opportunity for future monitoring/sampling at the OHF for the following reasons:

- The well is in-place and provides a long, openhole, potential monitoring interval covering the middle Rogersville Shale through lower Pumpkin Valley Shale section.
- The borehole wall of the openhole is smooth and could be easily equipped with packers and samplers for obtaining pressure measurements and representative groundwater samples.
- Liquid waste generation, while a concern, would be minimized.
- The original conventional core collected from this well still exists for possible future study.
- Approval for drilling a new monitoring well through the grout sheets is highly unlikely.

8.2.2 Observation Well 1965 (3S-220W)

Well 1965 is located down dip, approximately 220 ft west (ORNL grid north) of the injection well. This well penetrates the grout sheets within the upper Pumpkin Valley Shale and is cased to total depth (Fig. 7.3). The geophysical logs were run to a depth of 813 ft in well 1965 but could not be run to the reported total depth (840 ft). The grout sheets were encountered at approximately 725 ft in the upper Pumpkin Valley Shale.

Selected logs are presented in Fig. 8.2, and the complete suite of logs is included in Appendix A. Interpretation of the geophysical logs indicates that the casing is poorly bonded from 34 ft to the bottom of the logged interval (813+ ft). Scattered intervals of corrosion and/or scaling are noted in the casing. The fluid resistivity increases with depth to approximately 605 ft, indicating a slight freshening of the standing water. The resistivity shows a gradual increase from this depth to 725 ft. Laboratory-measured TDS confirms the interpretation that fresh water is present at the top and middle of the water column, and saline in the bottom sample ($\approx 57,000$ mg/L).

The passive gamma ray and neutron log response, as expected, are uncharacteristically high throughout the logged cased interval. These two tools are both influenced by the penetrated grout sheets in the upper Pumpkin Valley Shale from approximately 725 to 805 ft.

The gamma ray and neutron responses in this well are very different when compared with well 1953. In well 1953, the two log responses display a "feathering out" (decreasing response) going uphole away from the grout sheets. In well 1965, the high gamma response correlates with a low neutron response and occurs over shaley portions of the section. This relationship is noted from the top to the bottom of the well. The response seems to imply that either contaminated grout has migrated up the well annulus and preferentially adsorbed on the shales with relatively higher cation exchange capacity (compared with carbonate intervals) or that contaminated grout filtrate has migrated upsection through a series permeable microfractures.

Observation well 1965 (3S-220W) wellbore water characterization

Radionuclide concentrations are high in the bottom sample collected from well 1965. Total beta concentrations increase from less than 11,000 pCi/L in the top and middle samples to approximately 14,500,000 pCi/L in the bottom sample (Fig. 8.2). Primary beta-emitters in the bottom sample are C-14 and total radioactive strontium. Unlike in well 1953, gamma activity is also higher in the bottom sample (1,650,000 pCi/L), than in the middle and top samples (less than 1000 pCi/L). Gamma-emitting radionuclides are Cs-137 and Co-60. Also unlike in well 1953, high concentrations of tritium, about 725,000 pCi/L, are observed in the bottom sample. Alpha activity increases from less than 10 pCi/L in the top and middle portions of the wellbore to about 1500 pCi/L in the bottom sample. Significant radionuclide concentrations have not migrated 300 ft above the top of the grout sheet interval (730-ft depth), as evident by the relatively low activities in the middle sample (420-ft depth). The bottom sample was taken 5 ft above the bottom of the interval at a depth of 800 ft.

TDS values of less than 500 mg/L indicate fresh water in the top and middle of the wellbore. Saline water at about 57,000 mg/L was measured in the bottom sample. TDS values are again significantly lower than in the DM series wells completed in the Pumpkin Valley Shale ($\approx 250,000$ ppm) and lower than in other deep wells [DM1 and DM2, 91,000 and 130,000 ppm, respectively (Nativ and Hunley 1993)], suggesting dilution of borehole water with lower-TDS-content injection fluids (< 5000 ppm, Switek, Haase, and Stow 1987) or mixing with lower TDS waters. Nitrate was detected at about 7800 mg/L in the bottom sample, indicating mixing with grout-related waste solutions.

Calcium and sulfate are the dominant cation and anion in the top and middle portions of the borehole. Ca:Cl ratios are high in the top and middle samples at about 9 and 11 mg/L respectively. The bottom sample is dominated by sodium and chloride ions with calcium still present (121 mg/L). Na:Cl ratios are elevated at about 0.9 throughout the water column. The persistence of calcium and sulfate at the middle sample elevation suggests mixing with near surface water at this depth. Ammonium concentrations increase from less than 20 mg/L in the top and middle samples to 2225 mg/L in the bottom sample (see Table 8.3). Fluoride also increases from less than 5 mg/L at the top and middle to 165 mg/L at the bottom, which was the highest fluoride value detected. Bromide was not detected.

Observation well 1965 (3S-220W) interpretation and conclusions

The presence of calcium sulfate fresh water in the top and middle samples indicates that the fresh/saline water interface is below 420 ft. The low TDS at a depth of 420 ft also indicates the presence of near-surface groundwater at this depth in the wellbore. The order-of-magnitude increase in radionuclides and major ion concentrations has been maintained between the top and middle/bottom samples, indicating significant stratification of wellbore water. Contaminated wellbore water is confined to within at least 300 ft of the top of the injection horizon. Well 1965 has the third highest summed radioactivity. Based on the contamination in the bottom of the well, the casing appears to have been breached in the lower portion.

Well 1965 is contaminated with radionuclides. Contaminated filtrate may also have migrated uphole through the well annulus to mix with upper uncontaminated groundwater. The well is cased to total depth (840 ft). Well 1965 should be considered a prime candidate for P&A (well score of 9).

8.2.3 Observation Well 1946 (3E-320)

Well 1946 is located along regional strike, approximately 320 ft east (ORNL grid north) of the injection well. This observation well is cased to 830 ft, over the Nolichucky Shale through the upper Pumpkin Valley Shale. This well is reported to be artesian. Selected logs are presented in Fig. 8.3, and the complete suite of logs is included in Appendix A.

Interpretation of the geophysical logs indicates that the casing is generally poorly bonded to total depth; casing is essentially hanging in the hole. The caliper indicated possible precipitation or

corrosion from 397 to 490 ft and from 680 to 760 ft. SP response had a blocky pattern over several intervals, indicating possible leakage at joints. Temperature breaks at 610, 640, and 735 ft correlate with joints and could imply leakage. The fluid resistivity displayed two gradual shifts (decreasing resistivity), indicating a slight increase in conductivity (salinity). The laboratory measured fresh water from the top and middle; no bottom TDS sample was available. Grout sheets were logged over the interval from 755 ft to total depth. There is no indication that the casing was breached by the injections.

The passive gamma ray is uncharacteristically high from approximately 450 ft to well total depth. The pattern displayed by the gamma response is feathered with counts decreasing from the grout uphole. The gamma ray response in this well is similar to that observed in well 1953, cased section. The contaminated grout and/or filtrate has not preferentially adsorbed to shales as in well 1965.

Observation well 1946 (3E-320) wellbore water characterization

Radioactive contamination in well 1946 is typified by very high beta and high tritium concentrations that are stratified in the bottom portion of the well (Fig. 8.3). Beta activity increases from less than 500 pCi/L at the top to 45,100,000 pCi/L at the bottom. C-14 is present but not in sufficient activity to account for the high total beta. Total radioactive strontium is absent in the bottom sample. Tritium activity increases from near detection limits at the surface to 591,011 pCi/L at the bottom. Total alpha activity is elevated at 1900 pCi/L only in the bottom sample. Radioactivity in the middle sample is anomalously low for all radionuclides.

TDS data are not available for the middle or bottom samples because of the high activity of the samples. However, summed major ion concentrations suggest fresh water in the middle sample (70 mg/L) and brine in the bottom of the well (137,000 mg/L). The presence of fresh water in the middle portion of the well (420-ft depth) is supported by the fluid resistivity log, which shows a deep brine water interface at about 458 ft. There is a very high nitrate detection, almost 13,000 mg/L in the bottom of the wellbore, but nitrate is not detected in the top or middle samples. There is also an anomalously high bromide value at 16,100 mg/L in the bottom sample, which exceeds the next highest bromide value in well 1963 by two orders of magnitude. A high proportion of carbonate species anions exists in the top sample, but chloride becomes the dominant major ion in the middle and bottom samples. A moderate enrichment of sodium occurs between the middle and bottom samples.

Observation well 1946 (3E-320) interpretation and conclusions

Well 1946 has the second highest total radioactive contamination, almost entirely from beta-emitting radionuclides. The low total strontium activities most likely result from a matrix interference problem with the laboratory analysis or possibly the presence of an undetected beta-emitting radionuclide. The very high nitrate values indicate the presence of grout-related wastes in the bottom of the wellbore. The radionuclide and ionic data indicate that the impact of the grout sheets is restricted to the bottom portion of the well below a depth of 420 ft.

Contaminated grout has probably migrated up the well annulus and broken the casing bond. There is a possibility of inflow to the wellbore from upsection intervals. Well 1946 is cased to total depth but is reportedly artesian. Artesian conditions appear to be caused by communication with an uphole section, possibly the Maryville Limestone.

Well 1946 is contaminated with grout and grout filtrate. Casing bonding is poor and integrity is low. If left in-place, the well could contribute to migration of contaminants. Well 1946 should be plugged and abandoned (well score of 7).

8.2.4 Rock Cover Well 1967 (3W-300R)

Well 1967 is located down dip, approximately 300 ft southwest (ORNL grid north) of the injection well. This rock cover well is cased to 602 ft and has an openhole section in the lower Rutledge Limestone. Selected logs are presented in Fig. 8.3, and the complete suite of logs is included in Appendix A.

Interpretation of the geophysical logs indicates that the casing is well bonded from 2 to 602 ft. SP response through the cased interval is blocky and seems to indicate leakage at joints. The casing is interpreted to be well bonded but of low integrity. The fluid resistivity indicates fresh water confined to the cased interval and brine in the openhole section. Laboratory-measured TDS confirms the interpretation that fresh water is present at the top and middle cased section and brine is in the bottom ($\approx 111,000$ mg/L). The passive gamma ray, neutron log, and other log responses are "normal" for the rock section in this area. The caliper log indicates corroded intervals. The deviation log (Appendix A) indicates that the hole is very crooked.

Rock cover well 1967 (3W-300R) wellbore water characterization

Radiochemical contamination in well 1967 is typified by high activities of tritium at over 3,000,000 pCi/L in the middle of the wellbore, which decreases to 1,894,000 pCi/L at the top and is relatively very low (32,000 pCi/L) at the bottom (Fig. 8.4). Total beta activities increase from a low at the top of 4,400 pCi/L to a maximum at the bottom of 13,000 pCi/L, primarily from C-14 and total radioactive strontium. Total gamma activity, entirely from Cs-137, is low with a maximum activity of 264 pCi/L at the bottom. Alpha activity is low at the bottom at 724 pCi/L.

The water is fresh at the middle sample depth of 328 ft with a TDS of about 600 mg/L. However, brine conditions exist at the bottom of the rock cover well (625-ft depth, openhole interval) with a TDS of 110,000 mg/L. Nitrate was detected at the bottom of the well at a concentration of 442 mg/L.

The anion distribution is consistent for the top and middle samples with similar proportions of chloride, sulfate, and carbonate species. Chloride becomes the dominant anion in the briny bottom sample as the Na:Cl ratio is reduced from about unity in the middle to about 0.78 in the bottom. The cation distribution is also similar for the top and middle samples, with calcium and sodium/potassium dominating. Sodium becomes more dominant in the bottom sample although calcium and

magnesium are present in significant proportions. An elevated fluoride concentration of 140 mg/L was observed in the bottom sample, although Table 5.5 does not identify fluoride as a major waste constituent.

Rock cover well 1967 (3W-300R) interpretation and conclusions

The tritium concentrations in the top and middle groundwater samples are high and would imply an upsection source and possibly upward transport within the wellbore. Nitrate in the bottom sample indicates influence from the underlying grout sheets. Contaminated grout filtrate has probably migrated up to the lower Rutledge Limestone through a series of natural or induced fractures. The brine present in the openhole interval may also support this conclusion.

The high tritium in this well may be connected with WAG 5, seep D. Further investigations will be necessary to determine whether well 1967 is in communication with seep D. Whether well 1967 is serving as a source to seep D is unclear because tritium concentrations at seep D are considerably higher at approximately 11,000,000 pCi/L (BNI 1994b). The potential relationship between WAG 10 OHF wells and seep discharges along Melton Branch is discussed in Sect. 7.5.

Well 1967 is contaminated with radionuclides and nitrate. Contaminated grout filtrate may have migrated upsection into the lower Rutledge Limestone. Tritium in the uphole section is probably the result of a WAG 5 source. Casing integrity is low, and the borehole is crooked. The well is cased to 602 ft. Well 1967 is a prime candidate for P&A (well score of 7).

8.2.5 Rock Cover Well 1956 (3NE-200R)

Rock cover well 1956 is located up dip, approximately 200 ft north (ORNL grid north) of the injection well. This rock cover well is cased to 549 ft, with an open section in the lower Rogersville Shale. Selected geophysical logs are presented in Fig. 8.5, and the complete suite of logs is included in Appendix A.

Interpretation of the geophysical logs indicates that the casing is in general well bonded to 500 ft and poorly bonded from 500 ft to the bottom of the casing. The caliper measured openings at most joints and an enlargement of the cased section between 365 to 375 ft. Fluid resistivity displayed two decreasing steps. The laboratory measured fresh water in the top and middle samples, with saline/brine ($\approx 119,000$ mg/L) in the uncased section in the lower Rogersville Shale. The lower section of the borehole is crooked.

The passive gamma ray recorded two uncharacteristically high peaks from 4 to 6 ft and 15 to 25 ft. These high gamma zones are probably related to a shallow groundwater source from WAG 5. The shallow depth to saline/brine in this well is of interest; this brine appears to be formation water and not related to the contaminated grout injections.

Rock cover well 1956 (3NE-200R) wellbore water characterization

Radionuclide activities are relatively low in well 1956. Total beta activity is fairly constant from the top to the bottom of the wellbore; however, C-14 is slightly higher (1020 pCi/L) in the middle than the top (630 pCi/L) or bottom (311 pCi/L) samples. There is only a minor increase in total gamma from below detection limits at the top to 130 pCi/L at the bottom. The fifth highest alpha value, 951 pCi/L, detected at the well bottom exceeds the WAG 5 reference value of 1200 pCi/L (BNI 1994b). Tritium concentration is relatively low ($< 10,000$ pCi/L) but shows a decreasing trend from the top to the bottom.

TDS data indicate fresh water at the top and middle (286-ft) depths, which is supported by the fluid resistivity log that indicates less than saline ($< 10,000$ mg/L TDS) conditions above the 485-ft depth. Nitrate was not detected in any samples.

The major cation distribution is similar in the top and bottom samples. Anion distribution shifts from a carbonate/bicarbonate/chloride mix to predominately chloride in the middle and bottom samples. However, the total ionic concentration of 114,000 mg/L in the middle sample is not supported by the low TDS or resistivity log indicating that ionic data are probably in error. Na:Cl ratios decrease from 1.6 at the top to 0.65 at the bottom, which is more typical of the deeper brines (Nativ and Hunley 1993).

Rock cover well 1956 (3NE-200R) interpretation and conclusions

Radioactivity is generally low when compared with other OHF wells (see Table 8.2); however, total gross alpha is elevated). The absence of nitrate and the segregation of saline/brine in the open section of the well bottom indicate a lack of transport up the wellbore. There is possible influx of C-14 and tritium near the middle portion of the well, but the degree of contamination is relatively low. The observed shallow gamma peaks are likely related to shallow WAG 5 contaminated groundwater. Casing bonding of this well is generally good. Well integrity is probably low.

This well should be considered for P&A (well score of 6). The well has an openhole section in the lower Rogersville Shale, and the groundwater sampled appears to be native saline/brine formation water. This well could be retrofitted with equipment to monitor the Rogersville and gain a better understanding of the hydrogeology in the OHF area.

8.2.6 Rock Cover Well 1952 (3N-375P)

Rock cover well 1952 is located up dip, approximately 375 ft northwest (ORNL grid north) of the injection well. This rock cover well is cased to 488.6 ft and has no openhole interval. The well bottom is in the middle Rutledge Limestone. Selected geophysical logs are presented in Fig. 8.6, and the complete suite of logs is included in Appendix A.

Interpretation of the geophysical logs indicates that the casing is poorly bonded from 50 to 60 ft and well bonded from 60 to 488.6 ft. The temperature log displays breaks at 210, 230, and 432 ft

corresponding to joints. The well appears to have been constructed using mixed-size casing. The casing in the lower sections of the well is scaled or corroded. Fluid resistivity displayed two decreasing steps. Laboratory TDS values indicate fresh water in the top and middle samples, with brackish water (≈ 3875 mg/L) in the bottom sample. The log responses for the suite run are characteristic of the rock section in the area.

Rock cover well 1952 (3N-375P) wellbore water characterization

Beta activity is low (highest at the top at 850 pCi/L) and decreases to below detection limits in the bottom sample (Fig. 8.6). Gamma and alpha activity is very low to undetected. Tritium activities of 35,000 pCi/L exceed drinking water limits at the top and show a decreasing trend to 6500 pCi/L at the bottom.

TDS data indicate fresh water in the top and middle samples and brackish water in the bottom sample (3900 mg/L). According to the fluid resistivity log, saline water (approximately 10,000 mg/L TDS) is not encountered until about 481 ft. Nitrate was not detected in any samples.

The major ion distribution is unusual in well 1952 in that calcium becomes the more dominant cation with depth rather than sodium. Na:Cl ratios decrease from 0.49 at the top to 0.04 at the bottom, while Ca:Cl ratios increase from 0.38 at the top to 1.33 at the bottom. Chloride is the dominant anion in all samples, although carbonate/bicarbonate persists at the bottom.

Rock cover well 1952 (3N-375P) interpretation and conclusions

Tritium concentrations above drinking water standards in the upper portion of the well together with the decreasing trend in tritium and beta activity with depth indicate potential impact from shallow WAG 5 sources. Low-TDS water throughout most of the wellbore is normal for the area. The calcium-dominated waters at depth may be the result of residual dilution of the well water with potable water or influx of near-surface groundwater, as suggested by the tritium and beta data.

This well does not appear to have been affected by the hydrofracture activities. The standing water column in the well is elevated in tritium, and the well is of poor quality from a construction standpoint. The lack of a usable openhole interval and the poor quality of the well make it unsuitable for future monitoring. This well should be plugged and abandoned (well score of 6).

8.2.7 Rock Cover Well 1963 (3S-200R)

Rock cover well 1963 is located down dip, approximately 200 ft southeast (ORNL grid north) of the injection well. This rock cover well is cased to 600 ft and has an openhole interval over the lower Rutledge Limestone. Selected geophysical logs are presented in Fig. 8.7, and the complete suite of logs is included in Appendix A.

Casing bonding in well 1963 varies from bad (8 to 90 ft) to good (90 to 600 ft). Several breaks (255, 283, 477, and 508 ft) are within the cased section. The temperature breaks correlate with

joints. The caliper log measured several different inside diameter casings. It appears that mixed stock was used to construct the well. Obstructions in the wellbore were observed at 223, 258, 347, and 490 ft. Corrosion and/or scaling is common over most of the cased section. The fluid resistivity log indicates brine to the top of the water column. Laboratory-measured TDS values for the top ($\approx 157,000$ mg/L) and bottom ($\approx 174,000$ mg/L) samples indicate brine. The bottom sample was collected from the lower Rutledge Limestone openhole interval. The other log responses are fairly normal and characteristic of the rock section in the area.

Rock cover well 1963 (3S-200R) wellbore water characterization

Beta activity is an order of magnitude higher in the middle and bottom samples than in the top sample at 13,600 and 15,200 pCi/L, respectively (Fig. 8.7). Total radioactive strontium and C-14 are the identified beta-emitting radionuclides. Alpha activity is also elevated at 1700 pCi/L in the middle sample and decreases to 940 pCi/L in the bottom. Tritium concentrations are low (< 5000 pCi/L).

Well 1963 is unusual in that TDS values are uniformly high (157,000 to 174,000) from the top to bottom, indicating the presence of brine water at the surface (openhole in the lower Rutledge Limestone). Nitrate was not detected. Chloride is the predominant major anion at all levels, and the cation distribution is uniform throughout the well, with significant concentrations of calcium and magnesium at depth. Ion ratios are all representative of natural brine groundwater. Middle and bottom Ca:Cl (about 0.20), Br:Cl (0.008), and Na:Cl (about 0.62) ratios are close to the background ranges for HF-affected and non-HF-affected wells.

Rock cover well 1963 (3S-200R) interpretation and conclusions

Alpha and beta activities are moderately elevated in well 1963. This well ranks at about the midpoint of OHF wells in terms of total radioactivity. The distribution of radioactive components is about at equal levels in both the middle and bottom of the well. The available data do not identify specific flow conditions responsible for the migration of brine to the surface of this rock cover well; however, the presence of beta and alpha activity at about the same level in the bottom and middle samples indicates the potential for upward transport of contaminated brine through the wellbore or well annulus.

The casing bonding of this well varies from bad to good; however, integrity and construction quality are poor. The well provides a vertical pathway for the migration of contaminated, briny water upsection into intervals of fresh water. This well, because of the low integrity and poor construction, is unsuitable for future long-term testing/monitoring at the site. The well should be scheduled for P&A to minimize the impact of contaminated, briny water on shallower intervals (well score of 6).

8.2.8 Observation Well 1949 (3N-150)

Well 1949 is located slightly up dip and approximately 150 ft northwest (ORNL grid north) of the injection well. This observation well is cased to 1023.6 ft over the Maryville Limestone through the lower Pumpkin Valley Shale. Selected logs are presented in Fig. 8.8, and the complete suite of logs is included in Appendix A.

Interpretation of the geophysical logs indicates that the casing is in general poorly bonded to total depth. Casing is essentially hanging in the hole. The temperature log in this well was run to only 690 ft and did not cover the contaminated grout sheets. The residual temperature log displays a consistent, gradual increase to that depth. The trend noted is very similar to that observed in well 1953. It can be assumed that the temperature would show a similar peak at approximately 807 ft.

The caliper indicated possible precipitation or corrosion at numerous intervals with depth. The fluid resistivity, which was run to 690 ft, displayed a very gradual shift (decreasing resistivity), indicating a slight increase in conductivity (salinity). Laboratory-measured TDS values indicate fresh water from top to bottom in the borehole, which could indicate that the casing integrity is good. Grout sheets were logged over the interval from 740 to 930 ft. The casing bond appears to have been broken away by the injected grout. There is no indication that the casing was breached by the injections.

Above the contaminated grout sheets (< 740 ft), the passive gamma and neutron logs appear to be normal for the rock section. There is, however, one spike (110 counts per second) in the gamma at approximately 555 ft, but the cause is unknown.

The passive gamma ray and neutron log responses are high throughout the logged interval from 740 to 930 ft (over the grout sheets). These two tools are both influenced by the grout sheets penetrated by the well. The neutron source in the sonde is overwhelmed by the influence of the grout sheets. This is especially apparent at approximately 806 ft.

The log responses for well 1949 are similar to those for well 1953 and well 1946. The elevated gamma spikes measured in well 1965 are not noted in this well.

Observation well 1949 (3N-150) wellbore water characterization

Radioactivity in well 1949 is low relative to other OHF wells (see Table 8.2 and Fig. 8.7). Total beta is less than 5000 pCi/L at the bottom. Tritium and total gamma and alpha are low or near detection limits. Both gamma and beta activities are lower in the middle sample than in the top or bottom, but because of the low activities, the gradient reversal is probably not significant. The middle and bottom samples were collected 300 ft above and 120 ft below the grout sheet interval, respectively.

TDS is remarkably low for a deep observation well, and fresh water is present throughout the well. Nitrate was not detected in any sample. Chloride concentrations increase slightly with depth,

but there is a pronounced increase in calcium and carbonate/bicarbonate ions in the bottom sample. Ca:Cl ratios are higher than background (Nativ and Hunley 1993) and increase from 0.87 to 4.44 from the top to bottom.

Observation well 1949 (3N-150) interpretation and conclusions

The presence of fresh water throughout the well, lack of significant radionuclide or nitrate contamination, and the absence of chloride domination of the deep well water indicate that the casing has maintained good integrity, keeping deep brine and injection-related solutions out of the borehole. Well 1949 is in the lowest third of the OHF wells in terms of total radioactivity.

Contaminated grout has probably migrated up the well annulus and broken the casing bond. There is a possibility of minor inflow to the wellbore from upsection intervals.

Well 1949 is contaminated with grout and grout filtrate in the well annulus. Casing bonding is poor. If left open and in-place, the well annulus could provide a migration pathway for contaminants to move upsection. Well 1946 should be plugged and abandoned (well score of 5).

8.2.9 Rock Cover Well 1945 (3E-300R)

Rock cover well 1945 is located along regional strike, approximately 300 ft east (ORNL grid north) of the injection well. This rock cover well is cased to 598 ft and has an openhole interval in the lower Rutledge Limestone. Selected geophysical logs are presented in Fig. 8.9, and the complete suite of logs is included in Appendix A.

Interpretation of the geophysical logs indicates that the casing is in general well bonded to the bottom of the casing. The caliper, however, measured openings at most joints. The temperature log displays breaks within the cased section at 193 and 274 ft. Possible intervals of corrosion and/or scaling are also observed in the casing. Fluid resistivity displayed a sharp decrease beginning at approximately 193 ft. The decreasing resistivity correlates with the upper temperature break. Laboratory-measured TDS values indicate fresh water in the top, brine ($\approx 151,000$ mg/L) in the middle, and brine ($\approx 150,000$ mg/L) in the open section. The other log responses are fairly normal and characteristic of the rock section in the area.

Rock cover well 1945 (3E-300R) wellbore water characterization

Radioactivity is very low in well 1945. Beta activity is low and displays a decreasing concentration trend with depth [3100 pCi/L at the top to 1150 pCi/L at the bottom (Fig. 8.9)]. Alpha, gamma, and tritium activities are very low or not detected.

TDS and major ion data indicate that brine is present at the middle and bottom sample depths at concentrations of 151,000 and 150,000 mg/L, respectively. Nitrate was not detected. Chloride is the dominant anion at the middle and bottom elevations. Major cation ion constituents remain relatively constant with depth, with calcium and magnesium present in the bottom samples. Major

ion ratios in the middle and bottom samples are all representative of background brines: Ca:Cl between 0.30 and 0.20, Br:Cl at 0.007 in the bottom, and Na:Cl between 0.66 and 0.49.

Rock cover well 1945 (3E-300R) interpretation and conclusions

Well 1945 is one of the least radioactively contaminated of the OHF wells. The presence of brine and the absence of indicator parameters such as radionuclides or nitrate indicate influx of native briny groundwater but not the presence of injection-derived contaminants. The decreasing total beta trend with depth suggests some impact from near-surface sources, but the activities are not significant.

The integrity of this well is poor. Water of brine composition is present in the wellbore at approximately 193 ft. The well provides a vertical pathway for the migration of brine upsection into intervals of fresh water. The brine in this case is the contaminant of concern. This well is unsuitable for future testing/monitoring at the site. The well should be plugged and abandoned to minimize the impact of brine on shallower intervals (well score of 5).

8.2.10 Rock Cover Well 1950 (3N-200R)

Rock cover well 1950 is located up dip, approximately 200 ft north (ORNL grid north) of the injection well. This rock cover well is cased to 499 ft and has an openhole interval over the lower Rogersville Shale/upper Rutledge Limestone contact. Selected geophysical logs are presented in Fig. 8.10, and the complete suite of logs is included in Appendix A.

Casing bonding in well 1950 is generally bad (36 to 200 ft) and moderate (200 to 499 ft). The caliper, however, measured openings at most joints. The temperature log displays several minor breaks within the cased section (284, 358, and 435 ft). These temperature breaks correlate with openings at joints and shifts in the SP response. A possible void behind casing is noted between 65 and 70 ft. The fluid resistivity was rather low near the top of the well, indicating a higher conductivity. In most other rock cover wells, the upper portion of the wellbore contained fresh water. The conductivity continued to increase and maximized at approximately 180 ft. TDS in the top sample indicates brackish water (≈ 3500 mg/L), and highly saline water in the middle ($\approx 87,000$ mg/L) and bottom ($\approx 89,000$ mg/L) samples. The bottom sample was collected from the openhole interval. The other log responses were fairly normal and characteristic of the rock section in the area.

Rock cover well 1950 (3N-200R) wellbore water characterization

Radioactivity is very low throughout well 1950; no radionuclides were above detection limits in the bottom sample (Fig. 8.10). The highest concentration of total beta (700 pCi/L) occurred in the middle sample and decreased toward the top.

TDS data indicate brackish water at the surface (3500 mg/L) and highly saline water at the middle and bottom (nearly equal TDS concentration at approximately 88,000 mg/L). No nitrate was

detected. Major ion ratios in the middle and bottom samples are representative of natural brines; Ca:Cl is between 0.30 and 0.20, Br:Cl is at 0.007 in the bottom, and Na:Cl varies between 0.66 and 0.49.

Rock cover well 1950 (3N-200R) interpretation and conclusions

Well 1950 has not been affected by the grout injections. The highly saline water detected, high in the water column, appears to be a upwelling of native formation water. The presence of the saline water high in the wellbore presents a problem because it could migrate into shallower freshwater intervals.

The casing bonding of this well is bad to moderate and integrity is poor. Water of high saline composition is present in the wellbore at approximately 200 ft. The well provides a vertical pathway for the migration of saline water upsection into intervals of fresh water. The well does, however, provide an openhole interval that covers the lower Rogersville/upper Rutledge contact. This interval could be equipped for short-term testing and monitoring of that interval. The well should be scheduled to be plugged and abandoned to minimize the impact of high saline water on shallower intervals (well score of 5).

8.2.11 Rock Cover Well 1951 (3N-275R)

Rock cover well 1951 is located up dip, approximately 200 ft northwest (ORNL grid north) of the injection well. This rock cover well is cased to 549 ft and has an openhole interval over the lower Rutledge Limestone. Selected geophysical logs are presented in Fig. 8.11, and the complete suite of logs is included in Appendix A.

Casing bonding in well 1950 varies from bad (17 to 50 ft) to good (50 to 549 ft). The temperature log displays several breaks within the cased section (215, 302, and 427 ft). The temperature break at 215 ft correlates with an abrupt decrease in fluid resistivity marking the top of highly saline water. The upper portion of the wellbore contains fresh water. Laboratory-measured TDS in the top sample indicates fresh water (≈ 500 mg/L), and highly saline water in the middle ($\approx 88,000$ mg/L) and bottom ($\approx 95,000$ mg/L) samples. The bottom sample was collected from the openhole interval. The other log responses are fairly normal and characteristic of the rock section in the area.

Rock cover well 1951 (3N-275R) wellbore water characterization

Total beta activity was moderately high in the bottom sample at 56,000 pCi/L. C-14 and strontium concentrations were low (188 and 317 pCi/L, respectively) in the bottom sample. Gamma and alpha radioactivity was low or not detected above background. The tritium concentration was less than 5000 pCi/L in the top sample and lower in the middle and bottom samples.

TDS data indicate that saline water exists in the middle (88,000 mg/L) and bottom (95,000 mg/L) elevations. Low nitrate concentrations were found in the top sample (6.4 mg/L), but

nitrate was not detected in the lower samples. The major ion distributions of the middle and bottom samples were nearly identical. Na:Cl ratios are elevated at the top but are close to natural saline conditions in the middle and bottom at 0.75 and 0.68, respectively. Br:Cl ratios of 0.007 in the middle and bottom are also representative of natural saline conditions (Fig. 6.13). Middle and bottom Ca:Cl ratios are typical of most other OHF rock cover wells (Fig. 6.13).

Rock cover well 1951 (3N-275R) interpretation and conclusions

The bottom (lower Rutledge open interval) of well 1951 is contaminated with the seventh highest total beta activity of the OHF wells (see Table 8.2). The lack of detected nitrate and major ion ratios similar to other ORR saline waters in the middle and bottom samples indicate that the chemistry of groundwater in the lower Rutledge formation has not been significantly affected by injection-related constituents other than beta-emitting radionuclides (Fig. 8.11). A WAG 5-related uphole source may be responsible for the beta radioactivity. The well is located just west and downslope of waste trenches at WAG 5.

Well 1951 has not been significantly affected by the past grout injections. The highly saline water is distributed similar to that in well 1950 and appears to be an upwelling of native formation water. The presence of the saline water high in the wellbore presents a problem because it could migrate into shallower freshwater intervals.

The casing bonding of this well is bad to good, but integrity is poor. Water of high saline composition is present in the wellbore at approximately 215 ft. The well provides a vertical pathway for the migration of saline water upsection into intervals of fresh water. This well, because of the low integrity, is unsuitable for future long-term testing/monitoring at the site. The well should be scheduled for P&A to minimize the impact of high saline water on shallower intervals (well score of 5).

8.2.12 Rock Cover Well 1957 (3NE-300P)

Rock cover well 1957 is located updip, approximately 320 ft north (ORNL grid north) of the injection well. This rock cover well is cased to total depth at 493 ft. The well bottom is in the lower Rogersville Shale. This well was reported as artesian at the time of sampling (BNI 1995), but the source of the artesian head has not been determined. Selected geophysical logs are presented in Fig. 8.12, and the complete suite of logs is included in Appendix A.

Casing bonding in well 1957 varies from bad (2 to 42 ft) to good (90 to 600 ft). The temperature at 392 and 431 ft correlate with joints. The SP log displays a blocky pattern, possibly indicating leakage at other joints. The fluid resistivity was low to approximately 400 ft where it maximized, indicating saline water. Laboratory-measured TDS values in the top (≈ 1900 mg/L) and middle (≈ 2000 mg/L) samples indicate brackish water. The bottom sample is saline ($\approx 24,000$ mg/L). The other log responses are fairly normal and characteristic of the rock section in the area.

Rock cover well 1957 (3NE-300P) wellbore water characterization

Low undetectable levels of alpha (about 10 pCi/L), beta (less than 700 pCi/L), and gamma (1300 pCi/L) were measured in the standing water column of this well (Fig. 8.12). Tritium concentrations were elevated at 21,500 pCi/L in the top sample. The tritium is probably being contributed from a WAG 5 source. Tritium and beta activities both exhibit a decreasing trend from top to bottom in the well.

TDS values increase from about 1900 to 24,000 mg/L from top to bottom, indicating brackish to saline conditions throughout the well. Nitrate was not detected. Calcium is the predominant cation throughout the well, as evident in Ca:Cl ratios (0.9 to 1.0) that are higher and Na:Cl ratios that are lower (0.03 and 0.09) than background (Fig. 6.13).

Rock cover well 1957 (3NE-300P) interpretation and conclusions

Low beta concentrations and the lack of nitrate in the bottom of the well indicate little if any input of contamination from hydrofracture operations. The TDS and major ion constituents atypical of natural saline conditions indicate poor casing integrity and possible WAG 5 influence in this completely cased pilot rock cover well.

The casing bonding of this well is bad to good, but well integrity is poor. Water in the wellbore is brackish to saline near the bottom of casing. This well, because of the low integrity and reported artesian conditions, should be scheduled for P&A to minimize the impact of contaminated, briny water on shallower intervals (well score of 5).

8.2.13 Rock Cover Well 1959 (3NW-175R)

Rock cover well 1959 is located along regional strike, approximately 175 ft west (ORNL grid north) of the injection well. This rock cover well is cased to 492.5 ft, with an approximate 100-ft openhole interval at the lower Rogersville Shale/upper Rutledge Limestone contact. Selected geophysical logs are presented in Fig. 8.13, and the complete suite of logs is included in Appendix A.

Casing bonding in well 1959 varies from bad (29 to 40 ft) to good (40 to 492.5 ft). The temperature log displays a "ratty" pattern from approximately 300 ft to the bottom of the casing. This pattern, because of the crooked nature of the well, is not indicative of water flow into the wellbore. The fluid resistivity displayed a fairly sharp break between 70 and 100 ft. TDS values, however, reflect fresh water in the top and middle samples (≈ 800 to 200 mg/L) and high saline/brine ($\approx 115,000$ mg/L) in the bottom sample collected in the open interval. The middle sample for TDS is incorrect. High saline/brine is present in the water column at this level. The other log responses are fairly normal and characteristic of the rock section in the area.

Rock cover well 1959 (3NW-175R) wellbore water characterization

Alpha activity was moderate at 690 pCi/L at the bottom, tritium activity was low at 7500 pCi/L at the top, beta was relatively low at 1013 pCi/L at the bottom, and gamma activity was not detected above background (Fig. 8.13). Beta and alpha activities increase from the top to bottom, and tritium, which is below drinking water standards and the WAG 5 reference values, decreases from top to bottom.

TDS values indicate fresh water in the top and middle of the well with high saline/brine (115,000 mg/L) in the bottom. However, summed major ion concentrations of 111,480 mg/L in the middle sample indicate that the middle sample TDS value is in error and that brine exists in the middle portion of the well. The fluid resistivity log also indicates the presence of a saline interface (TDS > 10,000 mg/L) above the middle sample at a depth of 140 ft. Nitrate was not detected. Calcium is the major cation, with sodium becoming more dominant with depth. The carbonate/bicarbonate concentration is significant at the top, with chloride becoming the dominant anion at depth. Major ion ratios are representative of natural brine groundwater in the middle and bottom samples; Na:Cl and Ca:Cl ratios are about 0.65 and 0.26, respectively.

Rock cover well 1959 (3NW-175R) interpretation and conclusions

Well 1959 is in the lower third of OHF wells in terms of total radioactivity (see Table 8.2). Tritium is elevated in the top sample, suggesting minor influx from near-surface sources; however, the maximum tritium concentration is below the Safe Drinking Water Act maximum contaminant levels but is elevated relative to WAG 5 reference values. Ionic data and TDS indicate the presence of natural brines at a depth of at least 299 ft. The rock cover well has not been significantly affected by injections relative to other OHF wells.

The casing bonding of this well is bad to good, but well integrity is poor. The well is very crooked. Water in the wellbore is high saline/brine from the middle to the bottom of the well. This well, because of the low integrity and high saline/brine, should be scheduled for P&A to minimize the impact of influx of briny water to shallower intervals (well score of 5).

8.2.14 Rock Cover Well 1960 (3NW-250R)

Rock cover well 1960 is located along regional strike, approximately 250 ft west (ORNL grid north) of the injection well. This rock cover well is cased to 542 ft, with a short openhole interval in the lower Rutledge Limestone. Selected geophysical logs are presented in Fig. 8.14, and the complete suite of logs is included in Appendix A.

Casing bonding in well 1960 varies from bad (18 to 90 ft) to good (90 to 542 ft). The temperature log displays a break at 237 ft just below a joint. The fluid resistivity near top of hole displays a gradual decrease and pegs out at approximately 150 ft. Laboratory-measured TDS indicates fresh water (≈ 500 mg/L) and high saline/brine ($\approx 117,000$ to $112,000$ mg/L, respectively) in the middle and bottom samples. The high saline/brine TDS values are similar to those in nearby

well 1959. The bottom sample is representative of the open interval. The other log responses are fairly normal and characteristic of the rock section.

Rock cover well 1960 (3NW-250R) wellbore water characterization

Beta activity was relatively low but somewhat uniform throughout the well, increasing from 1440 pCi/L at the surface to 1830 pCi/L at the bottom (Fig. 8.14). Alpha activity was low at the surface and undetected in the middle and bottom samples. Gamma and tritium activities were also low.

TDS data indicate fresh water at the top of the well and high saline/brine at the middle (117,000 mg/L) and bottom (112,000 mg/L) portions. Nitrate was not detected. Calcium is the major cation, with sodium becoming more dominant with depth. Carbonate/bicarbonate is present at the top with chloride, becoming the dominant anion at depth. Major ion ratios are representative of natural brine groundwater in the middle and bottom samples; Na:Cl, Ca:Cl, and Br:Cl ratios are about 0.67, 0.30, and 0.0065, respectively.

Rock cover well 1960 (3NW-250R) interpretation and conclusions

Well 1959 is the third lowest OHF well in terms of total radioactivity. Ionic data and TDS indicate the presence of natural brines at a depth of at least 300 ft. The rock cover well is not significantly affected by injections relative to other OHF wells.

The casing bonding of this well is bad to good, but well integrity is poor. Water in the wellbore is high saline/brine from the middle to the bottom of the well. This well, because of the low integrity and high saline/brine, should be scheduled for P&A to minimize the impact of influx of briny water to shallower intervals (well score of 4).

8.2.15 Rock Cover Well 1961 (3NW-290P)

Rock cover well 1961 is located along regional strike, approximately 290 ft west (ORNL grid north) of the injection well. This well is cased to total depth (494 ft). The well bottom is in the upper Rutledge Limestone. Selected geophysical logs are presented in Fig. 8.15, and the complete suite of logs is included in Appendix A.

Casing bonding in well 1961 varies from bad (10 to 60 ft) to moderate (60 to 195 ft) to good (195 ft to bottom of casing). The temperature log displays a ratty pattern from approximately 125 ft to total depth. The borehole, however, is crooked and the breaks are not interpretable. The caliper log indicates that mixed stock was used to construct the well. Leakage at joints would be expected because of the poor construction. The fluid resistivity displays three steps (decreases) over the cased interval. Laboratory-measured TDS indicates a transition from fresh water (≈ 700 mg/L) to brackish (≈ 1100 mg/L) to moderately saline ($\approx 17,000$ mg/L) standing water in this well. The other log responses are fairly normal and characteristic of the rock section.

Rock cover well 1961 (3NW-290P) wellbore water characterization

Well 1961 has very low levels of alpha, beta, and gamma radioactivity, with maximum values at the bottom of the well either undetected or very low (Fig. 8.15). Tritium concentrations are also moderate relative to those in other OHF wells. The maximum beta concentration of 326 pCi/L is the lowest observed beta activity in the OHF wells.

TDS values are low, with saline water only in the bottom sample at 17,000 mg/L. A very low nitrate value, 0.93 mg/L, was estimated below detection limits in the middle sample but was not observed in the bottom of the well. Major ion data are not representative of naturally occurring brine, with calcium persisting as the major cation at depth. Chloride is the dominant anion at depth, although carbonate/bicarbonate and sulfate are also present in the bottom sample. The low Na:Cl ratio (about 0.08) and high Ca:Cl ratio (about 1.15) reflect the elevated calcium relative to natural brine.

Rock cover well 1961 (3NW-290P) interpretation and conclusions

Well 1961 is one of the least radioactive contaminated wells; alpha and tritium values are both below Safe Drinking Water Act maximum contaminant levels (see Table 8.2). Major ion constituents are atypical of natural brines, indicating either input of water from a shallower groundwater source or residual tap water input during the injection process.

The casing bonding of this well is bad to good, but well integrity is poor. The well appears to have been constructed using mixed stock and is crooked. This well, because of the low integrity and poor construction, should be scheduled for P&A (well score of 4).

8.2.16 Rock Cover Well 1955 (3NE-125R)

Rock cover well 1955 is located up dip, approximately 125 ft north (ORNL grid north) of the injection well. This well is cased to 499 ft, with an open interval from the middle Rogersville Shale into the upper Rutledge Limestone. Selected geophysical logs are presented in Fig. 8.16, and the complete suite of logs is included in Appendix A.

Casing bonding in well 1955 varies from good (23 to 450 ft) to moderate (450 ft to bottom of casing). The temperature log displays two breaks (350 and 420 ft) that correlate with steps in the fluid resistivity (decreases). Leakage at joints and corroded/scaled intervals in the casing are common. The fluid resistivity displays three steps (decreases) over the cased interval. Laboratory-measured TDS indicates fresh water (≈ 100 to 300 mg/L) to brackish (≈ 2100 mg/L) standing water in this well. The fluid resistivity also displays an increase between approximately 70 to 155 ft, which implies influx of fresher water over this interval. The source of the water is probably from the upper Maryville Limestone.

There is a high passive gamma reading from approximately 10 to 30 ft in this well. This shallow gamma response is most probably from a WAG 5 source and is not related to contaminated grout injection activities at the OHF.

Rock cover well 1955 (3NE-125R) wellbore water characterization

Alpha, beta, and gamma radioactivity was moderate to low in well 1955 and increased with depth to levels of 55, 9590, and 103 pCi/L (Fig. 8.16). Tritium contamination was very low (<2400 pCi/L) and decreased from top to bottom.

TDS data indicate fresh to slightly brackish (2100 mg/L) water at the bottom. Nitrate was found only in the bottom sample at 4.7 mg/L. Anions are dominated by bicarbonate (32 mg/L) and carbonate (22 mg/L) ions in the top and middle depths, with chloride becoming the dominant anion in the bottom. Calcium is the dominant cation in the top and middle samples, and sodium dominates at the bottom. The elevated carbonate, bicarbonate, and calcium in the top and middle samples are reflected in elevated Na:Cl (about 1.7) and Ca:Cl (about 5.5) ratios. Na:Cl (0.66), Ca:Cl (0.30), and Br:Cl (0.007) major ion ratios in the bottom sample are most representative of natural brine conditions (Fig. 6.13).

Rock cover well 1955 (3NE-125R) interpretation and conclusions

Well 1955 is ranked 15th in terms of total radioactivity, primarily from beta-emitting radionuclides in the bottom (see Table 8.2). The presence of nitrate at low concentrations in the bottom sample indicates the potential for impact from hydrofracture injections. Brackish water exists within the open interval of the well. Well 1955 should be plugged and abandoned because of poor construction and well integrity (well score of 4).

8.2.17 Monitoring Well 1920 (2E-100)

Monitoring well 1920 is located generally along regional strike, approximately a half-mile east (ORNL grid north) of the HF-3 injection well. This well is cased to 27 ft, with an open interval to 847.2 ft. The well was drilled in conjunction with operations at HF-2. The openhole section is from the Nolichucky Shale through the lower Pumpkin Valley Shale. The well is artesian. Selected geophysical logs are presented in Fig. 8.17, and the complete suite of logs is included in Appendix A.

The gamma ray and neutron responses in this well are elevated. These responses are very similar to those measured in well 1965; the high gamma response peaks are discrete and correlate with low neutron response peaks. This relationship occurs over shaley intervals within the Nolichucky Shale through the upper Pumpkin Valley Shale section.

In some cases the caliper log measures borehole enlargement correlated with the gamma and neutron response. This relationship, however, is not consistent. The elevated responses noted are also observed behind the casing in the shallow section. The responses seem to imply that either

contaminated grout has migrated up the borehole and preferentially adsorbed on the shales with relatively higher cation exchange capacities (compared with carbonate intervals), or that contaminated grout filtrate has migrated upsection through a series of permeable microfractures. To add confusion to the problem, there is an elevated gamma (exceeding 100 counts per second) behind the shallow casing. The origin of the elevated gamma log is unclear. An anomalous SP peak was also noted in the upper Maryville in this well.

Monitoring well 1920 (2E-100) wellbore water characterization

Overall radioactivity in well 1920 is low relative to that in other OHF wells (see Table 8.2). Beta and gamma activities are highest in the middle sample at 910 and 690 pCi/L, respectively (Fig. 8.17). Alpha increases to about 150 pCi/L in the bottom sample. Tritium was not detected above background.

TDS data were not available for the top sample. Brackish water is indicated at the middle and bottom elevations. Nitrate was not detected. The top major ion data are suspect because of the large charge imbalance. The middle and bottom samples indicate elevated chloride and sodium; however, the middle and bottom Na:Cl (about 1.30) and Ca:Cl (about 0.04) are high and low, respectively, relative to natural saline conditions.

Well 1920 is artesian and currently discharges to the surface at an estimated rate of less than 1 gal/h. Conductivity measurements from the top of the well of 0.63 mmhos/cm indicate that fresh water is being discharged (BNI 1995). Total gamma, beta, and alpha activities are very low (less than 30 pCi/L each) near the surface.

Monitoring well 1920 (2E-100) interpretation and conclusions

Well 1920 has the second lowest total radioactivity relative to that in OHF wells (see Table 8.2). TDS data indicate brackish conditions in the middle and bottom of the well (TDS data were not available for the top). Major ion ratios are not typical of deep brine waters.

Obviously, well 1920 is a prime candidate for P&A. The well is openhole, artesian, slightly contaminated at depth, and filled with a standing water column of brackish composition. This well, however, provides an unique opportunity to study most of the section overlying the injection horizon. The well could be easily equipped for testing/sampling and future monitoring at HF-2. Information gained would provide needed data on the hydrogeology of the site and the mechanisms that transported and concentrated "high" activity contaminated grout (well score of 4).

8.2.18 Rock Cover Well 1947 (3E-320P)

Rock cover well 1947 is along regional strike, approximately 320 ft east (ORNL grid north) of the injection well. This well is cased to 502 ft, with an open interval in the lower Rogersville Shale. Selected geophysical logs are presented in Fig. 8.18, and the complete suite of logs is included in Appendix A.

Casing bonding in well 1947 varies from bad (12 to 60 ft) to good (60 ft to bottom of casing). Intervals of corrosion/scaling are common. The fluid resistivity is consistent (indicating fresh water) through the cased section. Fluid resistivity decreases in the openhole interval (indicating brackish). Laboratory-measured TDS indicates fresh water (≈ 300 to 200 mg/L) in the top and middle samples, and brackish (≈ 6300 mg/L) in the openhole section.

Rock cover well 1947 (3E-320P) wellbore water characterization

Beta activity is moderately elevated in the bottom of well 1947 at 6300 pCi/L. Alpha and gamma activities are both low or not detected. Tritium was detected in the middle sample just above the WAG 5 reference value of 1470 pCi/L (BNI 1994b) but was not detected in the bottom sample.

TDS values indicate freshwater conditions at the top and middle and brackish water in the bottom of well 1947. Nitrate was not detected. Major ion data were not available for the middle sample. Sodium and chloride concentrations increase with depth, although carbonate concentrations are anomalously high (697 mg/L) in the bottom sample. Ca:Cl and Br:Cl ratios are indicative of natural saline conditions in the bottom interval at 0.19 and 0.004 , respectively. The Na:Cl ratio is high at 1.51 .

Rock cover well 1947 (3E-320P) interpretation and conclusions

Well 1947 is in the lower third of the OHF wells in terms of total radioactivity, primarily because of moderately elevated beta in the bottom sample. The brackish bottom sample was taken 27 ft above the open interval, indicating that natural saline or brine water has not significantly migrated up the wellbore.

The casing bonding and integrity of well 1947 is generally good. Therefore, this particular well could be equipped for testing/monitoring of the lower Rogersville in the area of the OHF. If not selected for future studies, this well should be plugged and abandoned (well score of 3).

8.2.19 Monitoring Well 1943 (2W-600)

Monitoring well 1943 is located generally along regional strike, approximately 2100 ft east (ORNL grid north) of the HF-3 injection well. This well is cased to 15 ft with an open interval to 972.9 ft. The well was drilled in conjunction with operations at HF-2. The openhole section is from the Nolichucky Shale through the lower Pumpkin Valley Shale. Selected geophysical logs are presented in Fig. 8.19, and the complete suite of logs is included in Appendix A.

The log responses are normal for the rock section in the area. However, there is an anomalous SP peak between 205 and 245 ft. The borehole is in generally good condition. Several enlargements occur primarily in the Maryville Limestone. An obstruction was also measured between 260 and 265 ft.

Monitoring well 1943 (2W-600) wellbore water characterization

Tritium and gamma activities were low throughout the well (Fig. 8.19). Alpha and beta activities were moderate, increasing to 1580 and 4226 pCi/L, respectively, in the bottom sample. An initially elevated alpha activity of 9970 pCi/L was detected at the bottom; however, analysis of subsequent samples of the well bottom indicates activities of 1580 and 188 pCi/L. The source of the alpha and beta activities is not known because only 25 Ci of gamma-emitting Cs-137 was injected in the second hydrofracture experiment (de Laguna et al. 1968).

Because of problems in obtaining adequate sample volumes with the downhole sampler, TDS data were not obtained for well 1943. However, summed major ion concentrations indicate at least brackish conditions at the top (2300 mg/L), saline conditions in the middle (19,240 mg/L), and highly saline conditions at the bottom (91,180 mg/L) of the well. Nitrate was not detected. The top major ion data are suspect because of the large charge imbalance. Na:Cl (0.68), Ca:Cl (0.27), and Br:Cl (0.008) ratios for the bottom sample are representative of natural brine conditions.

Monitoring well 1943 (2W-600) interpretation and conclusions

Well 1943 is in the lower third of the OHF wells in terms of total radioactive contamination. However, alpha and beta activities were elevated throughout the well. The source of the alpha and beta is not clear because beta- and alpha-emitting radionuclides were not reported to have been injected in the second fracturing experiment. This well would be suitable for future testing/sampling (well score of 3).

8.3 SMALL-DIAMETER OBSERVATION WELLS 1948 (3N-100), 1958 (3NW-100), 1962 (3S-100), AND 1964 (35-220)

As indicated in Fig. 7.12 and discussed in BNI (1995), analytical data from the small-diameter, 1.25-in.-inside-diameter observation wells did not exhibit an increase in TDS and major ion concentrations with depth, which was evident in most of the larger-diameter wells. As discussed in Sect. 2.2, the small-diameter observation wells were sampled with a 1-in.-inside-diameter bailer that uses ball checkvalve seals rather than the piston valves used in the larger-diameter wells. The wells were not geophysically logged, so a fluid resistivity log was not available to compare with the TDS values.

A YSI model 3000 conductivity and temperature probe was modified by the addition of 1000 ft of cable and used to develop a conductivity profile for each of the small-diameter wells; it was sufficient in identifying the approximate top of saline water, where applicable. Procedures for recalibrating the conductivity probe are discussed in BNI (1995). Figure 8.22 presents the conductivity profiles for all small-diameter wells. Off-scale conductivities correspond to TDS concentrations of approximately 10,000 mg/L.

Figure 8.22 indicates that the depths to saline water in wells 1962, 1948, 1958, and 1964 are approximately 300, 350, 490, and 690 ft below the top of casing, respectively. The fresh water bottom and middle samples from these wells most likely result from the bailer allowing fresh water to flush out the saline or brine sample during withdrawal. The varying depths to saline water in these wells reflect either natural variability in the saline water interface, varying degrees of integrity of the wall casing in preventing influx of brine groundwater, or a combination of both.

Well 1964 (3S-220) was reported to have been under artesian conditions when it was drilled following injection ILW-4 (Energy Systems 1986b). In June 1968, a "pilot hole" cased to a depth of 600 ft was deepened by core drilling. At a depth of about 815 ft, approximately 50 ft above the highest grout sheet at the time, the well began to flow at a "very slow" rate. The well was completed through the grout sheets in July 1968; afterwards flow from the well was observed at a "few gallons per hour at most" (Energy Systems 1986b). In August the well seepage was sampled and found to be more radioactive than anything seen previously. A total of between 1000 and 1500 gal of water containing about 2 Ci of ^{90}Sr was estimated to have been released.

The only borehole geophysical data available for these wells are uncalibrated gamma logs (recorded in mrem/h) obtained during injection and used to identify the position of the grout sheets. Because these logs were used only to identify grossly high levels of gamma activity, they lack the resolution to determine lithologic or well construction features. The logs, however, along with a qualitative sketch of the well details, are presented in Appendix A.

Analytical data from the small-diameter observation wells were not used for well evaluation or prioritization. Samples in these wells, whether taken from the top, middle, or bottom of the well, yield similar results. This is not consistent with the conductivity profiles done in these wells. The bailer used to collect these samples may have failed. Therefore, the analytical data for these wells were not used for well evaluation or prioritization.

8.4 ORGANIC COMPOUND DISTRIBUTION

The CSL performed analyses for the organic compounds listed in Table 2.1 on all WAG 10 OHF samples. In addition, samples from the bottom of wells 1946 and 1965 were analyzed for TCL organics using CLP protocols. Tables 8.4 and 8.5 identify all CSL volatile organic compounds (VOCs) detected above method detection limits for regular and quality control samples, respectively. Table 8.6 lists all TCL organic compounds detected.

Most wells contain a gray to gray-black oily substance, which coated the sampling wire and equipment. The oily substance was observed coating the top of the sample bailers and inside the Kemmerer sampling bottle closed at the bottom of well 1946. The substance was wiped from the wirelines and, as discussed in Sect. 5.7 of BNI (1995), did not appear to significantly contribute to cross contamination.

The oily material, however, is radioactive in wells 1946 and 1953. Field surveys of the wireline wipes from these wells indicated high levels of total beta/gamma radiation (between 750,000 and 1,000,000 counts per minute). It was impossible to adequately decontaminate the downhole sampling equipment using standard decontamination procedures because of this oily material. It was also impossible and impractical to remove the radioactive oily film from the recesses in the braided stainless steel sampler cable.

Table 8.4 indicates that all wells contain low concentrations, generally estimated to be below detection limits, of benzene, toluene, xylene, naphthalene, and methylene chloride. Benzene concentrations above detection limits were detected only in the top and bottom samples from rock cover well 1955 at 28 and 15 $\mu\text{g/L}$, respectively. Ethylbenzene was found above detection limits in the top of well 1967 (88 $\mu\text{g/L}$) and throughout well 1964 at a maximum concentration of 23 $\mu\text{g/L}$. Naphthalene was detected above detection limits in the bottom of well 1947 (153 $\mu\text{g/L}$) and middle of wells 1965 (38 $\mu\text{g/L}$), 1964 (15 $\mu\text{g/L}$), and 1961 (13 $\mu\text{g/L}$). Maximum concentrations of toluene are low in the top of well 1960 (17 $\mu\text{g/L}$) and top/middle of well 1964 (11 $\mu\text{g/L}$). Xylenes were found at the top of well 1967 at 344 $\mu\text{g/L}$ and throughout well 1964 between 72 and 94 $\mu\text{g/L}$. Lower concentrations of xylenes above detection limits were found in the top and middle of well 1965 (less than 25 $\mu\text{g/L}$).

In addition to the VOCs presented in Table 8.4, vinyl chloride, chlorobenzene, acetone, 1,2-dichloroethane, 1,1-dichloroethane, and 1,1,1-trichloroethane were tentatively identified based on a comparison of retention times of instruments used to analyze WAG 10 samples with retention times of standard solutions. The standard solutions were analyzed after the WAG 10 samples. The calculated VOC concentrations are presented in Attachment 11 of BNI (1995). Significant concentrations of vinyl chloride were observed in the bottom sample of well 1965 (4662 $\mu\text{g/L}$) and the top sample from well 1946 (90 $\mu\text{g/L}$). Vinyl chloride was also found in the field blank taken on 3/14/94 (sample 4397) after samples 4395 (3/10/94) and 4394 (3/9/94) were taken. Chlorobenzene, acetone, and 1,2-dichloroethane were tentatively identified in numerous samples at low concentration (less than 4 $\mu\text{g/L}$). 1,1-Dichloroethane was identified in samples from all three levels of well 1958 at concentrations between 13 and 16 $\mu\text{g/L}$.

Table 8.6 presents the TCL volatile and semivolatile organic data for the bottom of wells 1946 and 1965. The TCL data for 1946 confirm the presence of toluene (14 $\mu\text{g/L}$) and benzene (160 $\mu\text{g/L}$) and indicate concentrations of bis(2-ethylhexyl)phthalate, carbolic acid, di-n-butyl phthalate, and styrene that are below the detection limits to low. In addition to low concentrations of benzene, toluene, xylene, and ethylbenzene, TCL data for the bottom of well 1965 also indicate the presence of phenol compounds p-nitrophenol (570 $\mu\text{g/L}$), 2-nitro-phenol (360 $\mu\text{g/L}$), and 2,4-dinitrophenol (71 $\mu\text{g/L}$), naphthalene (25 $\mu\text{g/L}$), and 2-naphthalene (34 $\mu\text{g/L}$). Phenanthrene, bis(2-ethylhexyl)phthalate, and fluorene (2 $\mu\text{g/L}$) were also detected in trace concentrations.

The ubiquitous occurrences of benzene, toluene, xylene, and naphthalene in both observation and rock cover wells and the general absence of these compounds in trip and equipment rinse blanks (BNI 1995) indicate a source other than the injected material or field/laboratory contamination. These organic compounds are most likely from either hydrocarbon-based greases that

may have been used during well construction and/or natural hydrocarbons migrating uphole from the deeper shales. The volatile and semivolatile compounds detected in observation wells 1946 and 1965 are possibly related to the injected wastes, but because TCL analyses were not performed on the rock cover well samples, it cannot be determined that the organics are not from well installation materials.

8.5 WELLBORE WATER METAL DATA

Metals were analyzed by CLP methods to determine the type and concentrations of other metals expected in the wellbore water. Table 8.7 presents the results for unfiltered samples from the bottom of wells 1946 and 1965. Barium (4.6 to 11.8 mg/L), calcium (8450 to 9950 mg/L), iron (1.8 to 191 mg/L), lead (0.13 to 3.35 mg/L), manganese (0.34 to 2.96 mg/L), potassium (79.2 to 208 mg/L), sodium (192 to 239 mg/L), and zinc (14 to 17.8 mg/L) are present in the highest concentrations. Trace quantities of mercury (estimated at 0.46 to 1.1 $\mu\text{g/L}$) and arsenic (estimated at 8 $\mu\text{g/L}$) were also present.

8.6 SUMMARY OF ANTICIPATED WASTE CONSTITUENTS

In addition to providing a screening-level determination of the general levels of contamination in the OHF wells, wellbore chemical and radiochemical data were collected to determine the type of liquid and, by inference, solid waste types expected to be generated during P&A or redevelopment procedures. Rock cover and observation well water contamination is summarized in Tables 8.8 and 8.9, respectively.

The radiochemical data for both sets of wells indicate that most of the well water must be treated as a low-level radioactive waste generally because of high beta and gamma activity. Characterization of wellbore water as a RCRA-regulated characteristic waste is determined by comparison of aqueous concentrations to maximum permissible levels of contaminants determined by the toxicity characteristic leaching procedure (TCLP) (40 Code of Federal Regulations 261.24). Of the compounds analyzed using CSL methods, only benzene is a listed TCLP contaminant. The maximum benzene concentration is less than the maximum regulatory value of 500 $\mu\text{g/L}$. Examination of the TAL metals (see Table 8.7) and TCL organics indicates that none of these compounds exceed maximum regulatory values; however, the distribution of these metals and organics in the wells has not been completely characterized.

Contamination of well construction materials, such as wellhead materials, tubing, casing, well installation grout, and cement well pads, has not been characterized. However, it can be assumed that the well water contaminants are present on well materials via sorption. The radioactive organic material discussed in Sect. 4.4 of BNI (1995) will likely present a decontamination problem for any tools or other materials that are used to enter most OHF wells.

Fluid Resistivity
OHM-M 35
Residual Temperature
Degrees F 1.0
Gamma
CPS 15000
Caliper
Inches 5.0
Cement Bond
Bad - Good 5.5

Records 100 200 300 400 500 600 700
Microseconds Transit Time Tx to Far Receiver

Fig. 8.1.
Summary of well conditions and water chemistry:
1953 (3NE-100)

(10w1985.x00)

1965 WAG 10 OU 3 Phase 1 (Far Rec Delay=76 uS)

Records Microseconds Transit Time Tx to Far Receiver Far Point
100 200 300 400 500 600 700

Fig. 8.2.
Summary of well conditions and water chemistry:
1965 (3S-220W)

1946 WAG 10 OU 3 Phase 1 (Far Rec Delay=76 uS)

Fig. 8.3.
Summary of well conditions and water chemistry:
1946 (3E-320)

(10w1967.xa0)

1967 WAG 10 OU 3 Phase 1 (Far Rec Delay=76 uS)

Records: 100 200 300 400 500 600 700
Microseconds Transit Time Tx to Far Receiver

Fig. 8.4.
Summary of well conditions and water chemistry:
1967 (3W-300R)

(10w1956.xcd)

1956 WAG 10 OU 3 Phase 1 (Far Rec Delay=98 uS)

Records Far Point
Microseconds Transit Time Tx to Far Receiver
100 200 300 400 500 600 700

Fig. 8.5.
Summary of well conditions and water chemistry:
1956 (3NE-200R)

(10w1952.xa0)

1952 WAG 10 OU 3 Phase 1 (Far Rec Delay=98 uS)

Records 100 200 300 400 500 600 700

Microseconds Transit Time Tx to Far Receiver

Fig. 8.6.
Summary of well conditions and water chemistry:
1952 (3N-375P)

(10w1963.xa0)

1963 WAG 10 OU 3 Phase 1 (Far Rec Delay=98 uS)

Records

Microseconds Transit Time Tx to Far Receiver

100 200 300 400 500 600 700

0
100
200
300
400
500
600

Fig. 8.7.
Summary of well conditions and water chemistry:
1963 (3S-200R)

(10w1949.x00)

1949 WAG 10 OU 3 Phase 1 (Far Rec Delay=76 uS)

Records Far Point
Microseconds Transit Time Tx to Far Receiver
100 200 300 400 500 600 700

0
100
200
300
400
500
600
700
800
900
1000

Fig. 8.8.
Summary of well conditions and water chemistry:
1949 (3N-150)

(10w1945.xa0)

1945 WAG 10 OU 3 Phase 1 (Far Rec Delay=98 uS)

Records Far Point

Microseconds Transit Time Tx to Far Receiver

100 200 300 400 500 600 700

Fig. 8.9.
Summary of well conditions and water chemistry:
1945 (3E-300R)

(10w1950.x00) 1950 WAG 10 OU 3 Phase 1 (Far Rec Delay=98 uS)

Residual Temperature
Degrees F
-1.0 1.0
Fluid Resistivity
OHM-M
-5 40
Gamma
CPS
0 100
Caliper
Inches
2.0 5.0
Cement Bond
Bad Good 0.5

Records
Microseconds Transit Time Tx to Far Receiver
100 200 300 400 500 600 700

ION COLOR KEY

	Nitrate
	TDS
	Major Anions
	Cl
	CO ₃ + HCO ₃
	SO ₄
	Major Cations
	Na + K
	Ca
	Mg

Units:

Radionuclides = pCi/L

Nitrate/TDS = mg/L

Anions/Cations = meq/L

Fig. 8.10.
Summary of well conditions and water chemistry:
1950 (3N-200R)

(10w1951.xao)

1951 WAG 10 OU 3 Phase 1 (Far Rec Delay=76 uS)

records 100 200 300 400 500 600 700
Microseconds Transit Time Tx to Far Receiver

Fig. 8.11.
Summary of well conditions and water chemistry:
1951 (3N-275R)

(10w1957.x00)

1957 WAG 10 OU 3 Phase 1 (Far Rec Delay=98 uS)

Records: 547 237 237 For Pt

Microseconds Transit Time Tx to Far Receiver

100 200 300 400 500 600 700

Fig. 8.12.
Summary of well conditions and water chemistry:
1957 (3NE-300P)

(10w1959.xao)

1959 WAG 10 OU 3 Phase 1 (Far Rec Delay=76 uS)

Fluid Resistivity
OHM-M 85
Residual Temperature
Degrees F 1.0
Gamma
CPS 100
Caliper
Inches 5.0
Cement Band
Bad | Good 3.5

Records: 100 200 300 400 500 600 700
Microseconds Transit Time Tx to Far Receiver

Fig. 8.13.
Summary of well conditions and water chemistry:
1959 (3NW-175R)

(10w1960.x00)

1960 WAG 10 OU 3 Phase 1 (Far Rec Delay=98 uS)

Records Microseconds Transit Time Tx to Far Receiver

Fig. 8.14.
Summary of well conditions and water chemistry:
1960 (3NW-250R)

(10w1961.xd0)

1961 WAG 10 OU 3 Phase 1 (Far Rec Delay=98 uS)

Records: 100 200 300 400 500 600 700
Microseconds Transit Time Tx to Far Receiver

Fig. 8.15.
Summary of well conditions and water chemistry:
1961 (3NW-290P)

(10w1955,x00) 1955 WAG 10 OU 3 Phase 1 (Far Rec Delay=98 uS)

Fluid Resistivity
OHM-M 70
Residual Temperature
Degrees F 1.0
Gamma
CPS 100
Caliper
Inches 5.0
Cement Bond
Bad - Good 3.5

Records: Microseconds Transit Time Tx to Far Rec

Fig. 8.16.
Summary of well conditions and water chemistry:
1955 (3NE-125R)

(10w1920.xe3)

1920 WAG 10 OU 3 Phase 1 (Far Rec Delay=75 uS)

Records 100 200 300 400 500 600

Microseconds Transit Time Tx to Far Receiver

Fig. 8.17.
Summary of well conditions and water chemistry:
1920 (2E-100)

(10w19+7.xe0)

1947 WAG 10 OU 3 Phase 1 (Far Rec Delay=98 uS)

Records 100 200 300 400 500 600 700

Microseconds Transit Time Tx to Far Receiver

Fig. 8.18.
Summary of well conditions and water chemistry:
1947 (3E-320P)

1943 WAG 10 OU 3 Phase 1 (For Rec Delay=76 US)

Fluid Resistivity
OHM-M
0 1.5 X
Residual Temperature
Degrees F
-1.0 1.0 X
Gamma
CPS
0 1.0 X
Colliper
Inches
2.0 5.0 X
Cement Bond
Bond-I-IGood, S
0.0 1.0 X

Microseconds Transit Time Tx to For Receive
100 200 300 400 500 600 700

Fig. 8.19.
Summary of well conditions and water chemistry:
1943 (2W-600)

Fig. 8.20. Typical transit times for various media.

Fig. 8.21. Principle of operation of the Variable Density Log (VDL).

Fig. 8.22. Conductivity profiles for small-diameter wells.

Table 8.1. Summary of well log and well water chemical information

Well (Alias) [Fig.]	Well Construction	Chemistry & Contamination	Interpretation	Conclusions	Score ^a			
					C	M P	W I	Total
1953 (3NE-100) [Fig. 8.1]	<ul style="list-style-type: none"> Casing to 147 ft is poorly bonded. From 147 to 497.5 ft well bonded. Corrosion, openings and enlargements in casing. Well open below 500 ft msl to total depth (1039.8 ft). Thermal deviation (increase) near center of grout sheets. Gamma response is elevated throughout open interval. Seems to maintain lithologic character. Neutron high throughout open interval. Neutron source of sonde overwhelmed over open interval. Well under 20 - 30 psi artesian pressure. Openhole interval over lower Rogersville Shale to lower Pumpkin Valley Shale. 	<ul style="list-style-type: none"> Highest total beta; 75,000,000 pCi/L in middle and bottom, <2,000,000 pCi/L at top. Relatively low gamma; 100,000 pCi/L at bottom, 426 pCi/L at top. Nitrate about 5,000 mg/L in middle and bottom sample, not detected at top. Fresh water confined to cased interval. Saline water (TDS $\approx$ 36,500 mg/L) in openhole interval. 	<p>Despite artesian condition of well, there are order-of-magnitude differences in well water contamination between the middle/bottom samples (openhole) and the top (cased). Chemical and radiochemical concentrations of bottom and middle samples are similar, suggesting mixing in open interval or uniform distribution of groundwater contaminants between the injection horizon and the lower Rogersville Shale.</p> <p>Contaminated grout possibly present "coating" inner casing wall. Not clear if high gamma and neutron in the open interval result from buildup of "contaminated mud cake" on the borehole wall or are representative of formation contamination.</p>	<p>Although there is significant stratification of contamination between the upper sample and the middle and lower (both in the open interval), the poor casing bond (upper section) and artesian condition result in a high potential for contaminant migration upsection.</p> <p>Well is a prime candidate for P&A although consideration should be given to packing off bottom intervals for groundwater quality sampling/site monitoring.</p> <p>Original core from the well should be analyzed for radiochemistry to determine if elevated formation gamma results from migration into the openhole or is within the open formations.</p>	3	3	3	9
1965 (3S-220W) [Fig. 8.2]	<ul style="list-style-type: none"> Anomalous gamma and neutron peaks throughout the well. High gamma in bottom. Fluid resistivity break between 600-725 ft. Fresh water top and middle. Temperature break at 604 ft corresponds to fresh/saline interface. Casing bonding is poor from top of well to 813 ft. Corroded casing sections are common. Numerous high gamma peaks uphole correspond to shaley units. Intersected grout sheet at 798 ft msl during drilling. 	<ul style="list-style-type: none"> Total beta and gamma about 15,000 and 1,100,000 pCi/L, respectively, at bottom. Order-of-magnitude decrease at middle and top. Nitrate exceeds 7,000 mg/L in bottom sample. Fresh water in upper samples. Bottom sample is saline (TDS $\approx$ 57,000 mg/L). 	<p>Gamma and neutron peaks in the upper section suggest contamination via filtrate and/or grout that has migrated up the well annulus. Also possible that upwelling of contamination results from intersection of grout sheet during drilling. Contamination confined to bottom portion of well.</p>	<p>Contamination in the well annulus represents potential source to the overlying Rogersville Shale, Maryville Limestone, and regolith. Not clear if anomalous gamma and neutron in upper section of the well represent uphole contamination during drilling or upward migration of grout/filtrate.</p> <p>Well is a prime candidate for P&A.</p>	3	3	3	9
1946 (3E-320) [Fig. 8.3]	<ul style="list-style-type: none"> Temperature breaks near joints at 640 and 735 ft. Temperature changes and SP anomalies seem to indicate potential leakage between 92-152 and 368-428 ft. Possible scaling and/or pinholes in intervals 397-490 and 680-760 ft. 	<ul style="list-style-type: none"> Beta between 22 and 45 mCi/L in bottom sample. Elevated nitrate at bottom. Fresh water in top and middle samples. 	<p>High nitrate and very high total beta at bottom indicate infiltration of contaminated grout/filtrate into well. However, contamination has not migrated up the well.</p> <p>There is a potential mixing of fresher water into the well from the Maryville Limestone.</p>	<p>Poorly bonded casing and evidence of Maryville groundwater influx indicate poor well integrity.</p> <p>Well should be considered for P&A as soon as possible.</p>	3	2	2	7

Table 8.1. Continued

Well (Alias) [Fig.]	Well Construction	Chemistry & Contamination	Interpretation	Conclusions	Score ^a			
					C	M P	W I	Total
	<ul style="list-style-type: none"> • Generally poorly bonded casing. • Gamma log indicates contaminated grout from 460 ft to total depth. • SP changes correlated with joints. • Well reported to be artesian. 							
1967 (3W-300R) [Fig. 8.4]	<ul style="list-style-type: none"> • Two breaks in fluid resistivity log, near top and about 520 ft. • One zone of precipitation and/or corrosion in casing. • Good cement bond to bottom of casing (617.8 ft). • Openhole interval in the lower Rutledge Limestone. 	<ul style="list-style-type: none"> • Tritium concentration 2 to 3 mCi/L in middle and top samples; relatively low in bottom. • Beta, gamma, alpha low. • High nitrate at bottom. • Fresh water in top and middle samples. Brine (TDS $\approx$ 110,000 mg/L) in bottom sample. 	<p>High nitrate at bottom (openhole interval) indicates infiltration of grout/filtrate into well. Unusual tritium (highest in middle sample) distribution suggests input from an upper level source.</p> <p>Well presents a potential tritium pathway to seep D.</p>	<p>Tritium contamination in borehole presents possible upward transport pathway. However, casing appears to be in better condition than in 1953 or 1965.</p> <p>Well is a prime candidate for P&A.</p>	2	3	2	7
1956 (3NE-200R) [Fig. 8.5]	<ul style="list-style-type: none"> • Temperature breaks at the top of grout in casing (485 ft) and near the bottom of the cased interval (535 ft). • Enlargement in casing between 365 and 375 ft; cause unknown. • Resistivity breaks between intervals 180 to 204 and 485 to 495 ft. • Bonded (to 500 ft) and unbonded (500 ft to bottom of casing) sections of casing indicated by velocity and variable density log. • Two shallow passive gamma peaks 4 to 6 and 15 to 25 ft (probably from WAG 5 shallow groundwater). • Bottom 50 ft open to lower Rogersville Shale. 	<ul style="list-style-type: none"> • Beta/gamma radioactivity levels are low; C-14 highest in middle sample. Tritium levels decrease towards bottom. • Alpha levels are elevated relative to WAG 5 background in bottom sample. • TDS three orders of magnitude higher in bottom sample (lower Rogersville Shale, TDS $\approx$ 120,000 mg/L) than in top and middle. • Nitrate below detection limit. 	<p>Low radionuclide levels, lack of nitrate, and segregation of brine near the well bottom indicate a lack of transport up the well.</p> <p>Possible influx of C-14 and tritium into the well near the middle of the well.</p> <p>No obvious breaches in the casing are indicated.</p> <p>Brine is present in the lower Rogersville Shale open interval within this well.</p>	<p>Well is ranked low in terms of beta/gamma contamination but is elevated in total alpha. Geochemical evidence does not indicate upward transport.</p> <p>Well integrity is poor. Bonding to 500 ft is good.</p> <p>This well should be considered for P&A or adaptation to water quality monitoring in the lower Rogersville Shale.</p>	2	1	3	6

Table 8.1. Continued

Well (Alias) [Fig.]	Well Construction	Chemistry & Contamination	Interpretation	Conclusions	Score ^a			
					C	M P	W I	Total
1952 (3N-375P) [Fig. 8.6]	<ul style="list-style-type: none"> Temperature breaks at 210 ft, corresponding with a joint; other breaks at 230 and 432 ft. Interval 210-230 indicates a resistivity change (increase in TDS), and an interval of possible corrosion or precipitation in the well, and a peak on the SPR. Casing is well bonded from 60 ft to bottom of casing. Variable diameter casing was used for well construction. Overall poor integrity and construction. Approximately 12 ft of open interval in middle Rutledge Limestone (based on bottom of logged interval and reported total depth). 	<ul style="list-style-type: none"> Tritium concentration exceeds drinking water criteria (35,000 pCi/L) in top sample then decreases with depth. No gamma detected. Beta activity is low but is highest at the top. Low TDS (<4,000 mg/L) at bottom indicative of slightly brackish water. 	<p>Higher tritium and total beta activity at surface, indicative of potential influx of constituents from proximal WAG 5 sources.</p> <p>Poor well construction and geophysical anomalies from 210 to 230 ft indicate this interval may be responsible.</p>	<p>Low levels of beta activity detected in the well do not indicate that it has been significantly affected by grout injection activities. However, the apparent impact from intermediate depth sources and presence of tritium above permissible drinking water levels indicate that the well may be a conduit for upper level cross contamination.</p> <p>This well should be considered for P&A as soon as possible.</p>	2	2	2	6
1963 (3S-200R) [Fig. 8.7]	<ul style="list-style-type: none"> Temperature breaks (155, 283, 477, and 508 ft) correlate with joints/collars. Caliper indicates well is in poor condition; corroded and open at most joints. Well constructed from mix of casing diameters. Resistivity log indicates brine near surface. Cement bond is good from 90 to bottom of casing (600 ft). Open in the lower Rutledge Limestone. 	<ul style="list-style-type: none"> Moderate beta (primarily strontium) contamination in middle and bottom samples. Elevated alpha; higher in middle than in bottom samples. TDS indicates brine levels of contamination from top to bottom (>150,000 mg/L). Nitrate not detected. 	<p>Wellbore contains anomalously high TDS levels throughout. Contaminated by beta and alpha emitting radionuclides in middle to bottom. Although bond log is primarily good, caliper and temperature anomalies suggest corrosion and influx of water.</p>	<p>Contamination at bottom of well indicates well is affected and contamination is higher up in the wellbore than in 1951. Leaks indicate poor well integrity. Well could provide a pathway for uphole spread of contaminants.</p> <p>This well should be considered for P&A.</p>	2	2	1	6
1949 (3N-150) [Fig. 8.8]	<ul style="list-style-type: none"> Casing is generally unbonded. Resistivity log indicates freshening of water between 230 (bottom of surface casing) and 320 ft. Leakage through casing at joints possible between 258 and 283 ft. Possible openings in casing at 170, 205, and 581 ft. Fluid resistivity suggests fresh water at a depth of 700 ft. 	<ul style="list-style-type: none"> Radiochemical contamination low; slightly elevated beta and C-14. No nitrate detection. TDS anomalously low (fresh water TDS <1000 mg/L) for a deep monitoring well possibly cased within the brine. 	<p>Low levels of radionuclide activity and low TDS concentrations indicate fresh water in well to total depth.</p> <p>Poorly bonded casing presents potential for uphole migration through the casing/well annulus, although the gamma log does not indicate waste or grout in the annulus. Presence of fresh water in well indicates good casing integrity.</p>	<p>Lack of contamination in well indicates good casing integrity, but poor casing bond presents potential for migration up the annulus.</p> <p>This well should be considered for P&A.</p>	1	2	2	5

Table 8.1. Continued

Well (Alias) [Fig.]	Well Construction	Chemistry & Contamination	Interpretation	Conclusions	Score ^a			
					C	M P	W I	Total
	<ul style="list-style-type: none"> Neutron source on logging sonde overwhelmed by potential source at 807 ft. Gamma tool also overwhelmed by gamma source from grout sheets. Caliper does not indicate breaching of casing. Bottom $\approx$ 200 ft latex grout cement. Bottom 350 ft butt welded. Well cased to total depth. 							
1945 (3E-300R) [Fig. 8.9]	<ul style="list-style-type: none"> Overall integrity of the well is poor. Caliper indicates openings at most collars. Temperature breaks at 503 and 605 ft correspond to reported cemented interval from 500 to 600 ft. Other temperature breaks are at joints at 193 and 274 ft. Casing moderately well bonded from 20 ft to total depth. Obstructions and scaling are noted over several intervals. Obstructions at 574 and 598 ft are probably grout. Scaling observed in transition zone from fresh to saline water. Openhole interval in the lower Rutledge Limestone. 	<ul style="list-style-type: none"> Low levels of radioactive contamination. TDS indicates brine concentration ($\approx$ 150,000 mg/L) in bottom and middle sample. No nitrate detected in bottom or top sample; middle sample detection limit too high to be conclusive. 	<p>Well does not currently provide a significant pathway for radionuclide migration.</p> <p>It does provide a pathway for brine contamination uphole as evident in brine at a depth of 330 ft. Based on the poor condition of the casing and cement bond, the well does present a potential pathway for upward migration through either the wellbore or the annulus.</p>	<p>Poor construction and casing bond presents potential for uphole migration.</p> <p>This well should be considered for P&A.</p>	1	2	2	5
1950 (3N-200R) [Fig. 8.10]	<ul style="list-style-type: none"> Temperature breaks at 284, 358, 435, 490 (top of casing grout), and 500 ft (in open borehole). Coincidental caliper and SP peaks suggest leakage throughout the hole. Casing is poorly to moderately bonded. Possible void between 65 and 70 ft. Open interval over lower Rogersville Shale and upper Rutledge Limestone. 	<ul style="list-style-type: none"> Low levels of radioactive contamination. Saline TDS concentrations in middle and bottom samples ($\approx$ 89,000 mg/L). No nitrate detected. 	<p>Well is not currently a significant pathway for radionuclide migration. However, based on the condition of the casing and cement bond, it does present a potential pathway for upward migration of "high" saline groundwater through either the wellbore or the well annulus.</p>	<p>Poor construction and casing bond presents potential for uphole migration.</p> <p>This well should be considered for P&A.</p>	1	1	3	5
1951 (3N-275R)	<ul style="list-style-type: none"> Temperature breaks at 215, 302, 427, and 512 ft. 	<ul style="list-style-type: none"> High beta activity in bottom sample. 	<p>Well is moderately contaminated with beta-emitting radionuclides, but</p>	<p>Contamination at bottom of well indicates well is affected, but the migration potential is low.</p>	2	1	2	5

Table 8.1. Continued

Well (Alias) [Fig.]	Well Construction	Chemistry & Contamination	Interpretation	Conclusions	Score ^a			
					C	M P	W I	Total
[Fig. 8.11]	<ul style="list-style-type: none"> Probable leakage at 224 ft near bottom of surface casing and thick grout. Cement bond seems to be good (50 to 549 ft). Abrupt increase in resistivity at 214 ft. Open to lower Rutledge Limestone. 	<ul style="list-style-type: none"> Elevated strontium and C-14. Tritium activity low but is highest in top sample. Saline water in middle and bottom samples ($\approx 88,000$ to $95,000$ mg/L). Nitrate not detected. 	contamination is restricted to lower portion of well. Potential for influx of tritium from upper level sources. Cement bond appears good, but leakage is evident.	<p>Leakage of "high" saline groundwater to shallower (fresher) intervals is possible. Leakage indicates poor well integrity.</p> <p>This well should be considered for P&A.</p>				
1957 (3NE-300P) [Fig. 8.12]	<ul style="list-style-type: none"> Temperature breaks at 392 (associated with a joint) and 431 ft. Most joints have openings or irregularities. SP displays blocky pattern indicative of leaking. Resistivity indicates slightly saline water at top, then transition to saline water at 400 ft. Casing bonding appears good from 42 ft to bottom of cased interval. Bottoms in lower Rogersville Shale. Shallow gamma peaks observed in nearby wells 1955 and 1956 are not present. Well reported to be artesian. 	<ul style="list-style-type: none"> Total gamma activity is moderately high but is highest in the top sample. Tritium concentration is moderately high in the top sample but decreases with depth. Total beta and alpha activity is low but increases with depth. Nitrate not detected. TDS indicates that water varies from brackish (≈ 2000 mg/L) to saline in bottom sample ($\approx 24,000$ mg/L). 	Elevated tritium and gamma activity in top sample together with proximity to WAG 5 trenches suggest influx of contamination from other sources. Blocky SP pattern suggests influx of formation water throughout hole.	<p>Potential influx of contaminants from mid-level sources. Low levels of beta and alpha activity in bottom sample indicate well is not significantly affected by upward transport from hydrofracture activities.</p> <p>Due to the potential for cross contamination from mid-level sources, well should be considered for P&A.</p>	2	1	2	5
1959 (3NW-175R) [Fig. 8.13]	<ul style="list-style-type: none"> Temperature breaks at 160 (base of surface casing) and 480 ft (near bottom of cased interval). Several joints appear to have openings. Possible corrosion and/or precipitation in intervals 196 to 206 ft and 270 to 313 ft. Fluid resistivity decreases to 140 ft to top of "saline" zone. SP not responsive. Casing well bonded from 40 ft to bottom of casing (492.5 ft). Open interval in the lower Rogersville Shale and Rutledge Limestone. 	<ul style="list-style-type: none"> Beta, alpha, gamma radioactivity is low and decreases from bottom to top. Tritium activity is also low but increases from bottom to top. TDS indicates brine in bottom sample ($\approx 115,000$ mg/L). TDS anomalously low (fresh water, ≈ 200 mg/L) in middle sample; however, major ion data indicate high saline/brine is present. Nitrate not detected. 	Low levels of beta, alpha, and gamma radioactivity do not indicate significant contamination. Potential for influx of tritium between middle and bottom samples based on inverted tritium distribution. Briny zone fairly high in this well. Other than caliper information, fresh water in middle sample, and potential tritium influx, nothing indicates poor casing integrity.	<p>Potential influx of tritium from mid-level sources. Low levels of activity in bottom sample indicate well has not been significantly affected by upward transport of contaminants from hydrofracture activities.</p> <p>Due to the potential for cross contamination from mid-level sources, well should be considered for P&A.</p>	1	2	2	5

Table 8.1. Continued

Well (Alias)	Well Construction	Chemistry & Contamination	Interpretation	Conclusions	Score ^a			
					C	M	P	Total
1960 (3NW-250R) [Fig. 8.14]	<ul style="list-style-type: none"> • Temperature break at 237 ft at bottom of surface casing and at 520 ft at bottom of cased interval. • Transition to saline conditions at about 100 ft. • Caliper indicates openings on many joints. • Possible scaling/corrosion over several intervals. • Casing well bonded from 90 to 542 ft (bottom of casing. • Open interval in lower Rutledge Limestone. 	<ul style="list-style-type: none"> • Gamma and beta radioactivity is low; alpha is moderate. All decrease from bottom to top. • Tritium is very low but increases from bottom to top. • TDS represents brine (~ 115,000 mg/L) in middle and bottom sample. 	<p>Low levels of beta, tritium, and gamma contamination. Alpha activity is moderate, but not significant. Brine zone fairly high in this well. Other than caliper information and minor tritium influx, nothing indicates exceptionally poor casing integrity.</p>	<p>Potential influx of tritium from mid-level sources. Low levels of activity in bottom sample indicate well is not significantly impacted by upward transport from hydrofracture.</p> <p>Possible upsection migration of brine possible. Due to the potential for cross contamination from mid-level sources, well should be considered for P&A.</p>	1			4
1961 (3NW-290P) [Fig. 8.15]	<ul style="list-style-type: none"> • Temperature breaks related to bottom of surface casing and near the top of the cased interval. • Caliper indicates separation between some joints. • Precipitation and/or corrosion not as evident. • Good bonding from 195 to 494 ft (bottom of casing). • Resistivity breaks associated with bottom of surface casing and bottom of the surface casing grout plug. 	<ul style="list-style-type: none"> • Gamma, beta, and alpha activity is very low. • Tritium is low but slightly increases from top to bottom. • TDS goes from fresh (~ 700 mg/L) to slightly brackish (~ 1000 mg/L) to saline (~ 17,000 mg/L) in this well. • Low, below detection limit, nitrate hit in middle sample. 	<p>Low levels of radioactive contamination indicate well has not been significantly affected by hydrofracture activities. Increasing concentrations of tritium with depth do not suggest influx from an intermediate depth. Below detection limit estimated nitrate hit (0.93 mg/L) not significant since nitrate was not detected in bottom sample.</p>	<p>Due to relatively clean conditions in the well, well would have a lower priority for P&A activity.</p>	1			4
1955 (3NE-125R) (Fig. 8.16)	<ul style="list-style-type: none"> • Temperature breaks at 350 and 420 ft correlate with resistivity breaks. • Additional temperature breaks at 550 and 590 ft. • Possible precipitation or corrosion in the 65 to 152, 180 to 205, 350 to 358, and 422 to 440 ft intervals. • Separation and potential leakage indicated at most collars. • Casing bonding is good from 23 to 450 ft and moderate from 450 to 499 ft. • Fluid resistivity indicates freshening between 65 and 152 ft possibly indicating influx from the Maryville Limestone. SP response correlates with fresher zone. 	<ul style="list-style-type: none"> • Gamma, beta, and alpha activity is low. • Tritium activity is low but increases from bottom to top. • C-14 and Cs-137 are present and increase from top to bottom. • < 5 mg/L nitrate detected in bottom sample. • TDS reflects fresh water in the upper two samples and brackish water in the bottom sample (~ 2000 mg/L). 	<p>Low levels of radioactive contamination indicate well has not been significantly affected by hydrofracture activities. Slight increase in tritium concentration from bottom to top supports influx of shallow fresh water evident in fluid resistivity and SP logs. However, integrity of well at lower depths is assumed to be better due to lower TDS concentrations relative to other rock cover wells.</p> <p>Medium well integrity ranking due to shallow influx of water and evidence of separation at most couplings.</p>	<p>Well should be considered for P&A due to influx of relatively shallow water. Priority for P&A would be low due to lack of contamination.</p> <p>Well represents a potential vertical migration pathway due to the influx of fresher water from the upper zone.</p>	1	2	1	4

Table 8.1. Continued

Well (Alias) [Fig.]	Well Construction	Chemistry & Contamination	Interpretation	Conclusions	Score ^a			
					C	M P	W I	Total
	<ul style="list-style-type: none"> Openhole over middle Rogersville Shale through upper Rutledge Limestone. 							
1920 (2E-100) [Fig. 8.17]	<ul style="list-style-type: none"> Well is openhole from 27 to 847.2 ft. Open interval is from the Nolichucky Shale into the lower Pumpkin Valley Shale. Natural gamma response is elevated throughout the openhole interval. Major gamma peaks in the upper Pumpkin Valley Shale probably correlate to grout sheets (HF-2). Several other uphole gamma peaks at shaley intervals. The cause of these peaks is unknown. Anomalous SP response from approximately 120 to 145 ft over shaley zone. Well reported to be artesian. 	<ul style="list-style-type: none"> Alpha, beta, and tritium radionuclide levels are low. Gamma radionuclide levels are moderate. Total beta and gamma, C-14, and Cs-137 levels are higher in the middle sample. TDS indicates that the standing water column is brackish (≈ 7000 to $10,000$ mg/L). 	<p>This well is of interest because of the elevated gamma ray response. The response could be caused by either radioactive "mud cake" or contaminated mud filtrate migration through a fracture system.</p> <p>Because of the long open interval of the well, a well integrity score was considered not applicable (NA). The well is essentially a stable borehole.</p>	<p>This well is openhole. The well could be modified and adapted for future monitoring at HF-2.</p> <p>If it is decided that future monitoring is not warranted, the well should be plugged and abandoned.</p>	1	3	N A	4
1947 (3E-320P) {Fig. 8.18}	<ul style="list-style-type: none"> Resistivity indicates fresh water to 460 ft then shift to brackish water (based on TDS). Temperature break and SP fluctuations correlate with resistivity break. Casing is generally well bonded. Casing corrosion likely in the 50 to 75 and 150 to 170 ft intervals. Open section is in the lower Rogersville Shale. 	<ul style="list-style-type: none"> Gamma and alpha concentrations are low; beta is slightly elevated in bottom sample. Beta and alpha concentrations increase from top to bottom. Tritium is low but is higher in the middle than the top and bottom samples. TDS varies from fresh in the upper two samples and brackish in the bottom sample (≈ 6000 mg/L). No nitrate is detected. 	<p>Low levels of radioactive contamination indicate well has not been significantly affected by hydrofracture activities. Increase in tritium concentration in middle sample suggests influx of tritium from a WAG 5 source. Integrity of well at lower depths is good and reflected by the expected TDS concentrations compared to other rock cover wells of poor physical integrity.</p>	<p>Well has a low priority for P&A due to lack of contamination, low TDS concentration, and good well integrity.</p>	1	1	1	3
1943 (2W-600) [Fig.]	<ul style="list-style-type: none"> Well is openhole from 15 to 972.9 ft. Open interval from the Nolichucky Shale into the lower Pumpkin Valley Shale. 	<ul style="list-style-type: none"> Tritium and gamma activity is low. 	<p>This well has a long openhole interval. Condition of the borehole is in general good. Several washouts are noted in the borehole, most common in the Maryville Limestone. One obstruction is present.</p>	<p>The well would be suitable for future monitoring at the HF-2 site. Could be easily equipped for multizone testing/sampling.</p>	2	1	N A	3

Table 8.1. Continued

Well (Alias) [Fig.]	Well Construction	Chemistry & Contamination	Interpretation	Conclusions	Score ^a			
					C	M P	W I	Total
8.19]	<ul style="list-style-type: none"> Numerous borehole enlargements. Obstruction between 260 and 265 ft. Anomalous SP response from approximately 205 to 250 ft over shaley zone. 	<ul style="list-style-type: none"> Alpha and beta activity is moderate. Initially high alpha (9970 pCi/L) not confirmed in two subsequent samples. Saline conditions at bottom. No nitrate detected. 	Because of the long open interval of the well, a well integrity score was considered not applicable (NA). The well is essentially a stable borehole.					

^a C = contamination.

MP = migration potential.

WI = well integrity.

Table 8.2. Ranking of WAG 10 OHF wells by maximum radioactivity ¹										
Alpha ²			Beta ³		Gamma ⁴		Tritium ⁵		Total Radioactivity	
Rank	Well	Maximum Activity (pCi/L)	Well	Maximum Activity (pCi/L)	Well	Maximum Activity (pCi/L)	Well	Maximum Activity (pCi/L)	Well	Summed Activity (pCi/L)
1	1946	1,925	1953	77,387,500	1965	1,650,000	1967	3,079,559	1953	77,489,301
2	1963	1,731	1946	45,104,093	1962	128,000	1965	726,685	1946	45,745,730
3	1943	1,581	1965	18,200,000	1953	101,000	1946	591,012	1965	20,578,178
4	1965	1,493	1962	451,963	1946	48,700	1952	34,867	1967	3,093,660
5	1956	951	1958	129,376	1948	31,600	1957	21,546	1962	579,983
6	1953	801	1948	81,512	1958	22,000	1961	9,196	1958	151,404
7	1945	768	1951	56,196	1957	1,310	1959	7,514	1948	114,764
8	1967	724	1964	15,819	1949	877	1956	7,431	1951	61,385
9	1959	688	1963	15,232	1920	691	1964	6,841	1952	35,732
10	1951	387	1967	13,113	1964	691	1951	4,717	1957	23,560
11	1920	149	1955	9,594	1943	294	1963	4,454	1964	23,359
12	1950	52	1947	6,323	1950	273	1955	3,753	1963	21,446
13	1958	28	1949	4,890	1967	264	1948	1,641	1955	13,465
14	1960	23	1943	4,226	1956	132	1947	1,469	1956	11,584
15	1962	21	1945	3,138	1961	105	1960	1,090	1961	9,635
16	1947	19	1956	3,071	1955	103	1943	1,018	1959	9,216
17	1949	18	1960	1,830	1947	96	1945	628	1947	7,906
18	1955	15	1959	1,014	1951	84	1949	277	1943	7,119
19	1957	11	1920	912	1945	57	1950	228	1949	6,061
20	1948	10	1952	855	1960	31	1920	ND	1945	4,591
21	1952	10	1950	706	1963	29	1953	ND	1960	2,974
22	1961	8	1957	694	1952	ND	1958	ND	1920	1,752
23	1964	8	1961	326	1959	ND	1962	ND	1950	1,259

¹ Maximum radioactivity observed in wellbore regardless of sample level.

² Bold total alpha activity exceeds total alpha Safe Drinking Water Act maximum contaminant level (MCL) of 15 pCi/L (Etmier et al. 1993).

³ Bold total beta activity exceeds reference WAG 5 value mean Sr-90 activity of 5.2 pCi/L (BNI 1994).

⁴ Bold total gamma activity exceeds sum of reference WAG 5 Co-60 and Cs-137 mean activities of 22.6 pCi/L (BNI, 1994).

⁵ Bold tritium activity exceed the Safe Drinking MCL of 20,000 pCi/L (Etmier et al. 1993) and the reference WAG 5 value of 1200 pCi/L (BNI 1994). Data in italics only exceed the WAG 5 reference value.

ND = Not detected.

Table 8.3. WAG 10 OHF well minor ion concentrations

Well	Sample Elevation (ft msl)	Sample Level	Ammonium		Bromide		Fluoride		Lithium	
			Result	Qual	Result	Qual	Result	Qual	Result	Qual
1920	767.68	Top					1.56			
1920	335.08	Middle			19.62		16.15			
1943	297.79	Middle			87.79					
1943	761.79	Top			4.34		3.61			
1943	-167.81	Bottom			430.20					
1945	746.42	Top	0.61		0.34		0.80			
1945	185.33	Bottom			766.80					
1946	783.87	Surface	0.48				1.47			
1946	758.27	Top	0.22				1.58			
1946	363.87	Middle	1.35				1.05			
1946	-31.13	Bottom			16,106.24					
1947	744.63	Top	0.49				1.05			
1947	307.77	Bottom			7.05		0.59			
1948	724.89	Top	2.79		0.21		1.06			
1948	343.60	Middle	1.98		0.29		1.03			
1948	164.26	Bottom	2.08		0.42		1.08			
1949	758.57	Top	32.07				2.92			
1949	365.78	Middle	14.58							
1949	-200.12	Bottom	152.83							
1950	729.40	Top			0.69		0.85			
1950	447.99	Middle			404.20					
1950	303.65	Bottom			413.30					
1951	734.46	Top	1.36				0.98			
1951	474.54	Middle			375.40					
1951	214.63	Bottom			425.70					
1952	497.57	Middle	1.00				0.85			
1952	319.32	Bottom	3.19				5.97			
1953	800.84	Surface	1.38		0.34		3.77			
1955	746.35	Top	0.49				7.69			
1955	482.99	Middle	0.81				1.78			
1955	219.63	Bottom			6.94		4.27			
1956	754.12	Top	0.88				0.65			
1956	521.12	Middle			510.40				3.51	
1957	791.06	Top	2.44							
1957	566.06	Middle	0.88				3.50			
1957	341.06	Bottom					35.10			
1958	725.33	Top			0.22		1.16			
1958	251.32	Middle			0.42		1.01			
1958	180.31	Bottom			0.38		1.40			
1959	717.35	Top	0.35							
1959	472.83	Middle			540.54				3.64	
1959	227.31	Bottom							3.68	

Table 8.3. WAG 10 OHF well minor ion concentrations (continued)

Well	Sample Elevation (ft msl)	Sample Level	Ammonium		Bromide		Fluoride		Lithium	
			Result	Qual	Result	Qual	Result	Qual	Result	Qual
1960	715.74	Top	0.25		0.50		1.04			
1960	450.86	Middle			534.50					
1960	231.23	Bottom			414.70					
1961	284.69	Bottom					5.55			
1961	726.53	Top	0.43				1.33			
1961	501.53	Middle	0.76				0.75			
1962	727.46	Top	5.87				3.27		0.37	
1962	419.68	Middle	5.57				3.23		0.37	
1962	178.90	Bottom	5.65		0.23		3.22		0.33	
1963	729.64	Top			788.50					
1963	458.59	Middle			819.30					
1963	187.53	Bottom			838.00					
1964	738.37	Top	0.40				2.39			
1964	214.82	Bottom	0.46							
1965	738.14	Top	14.54				4.78			
1965	343.54	Middle	17.63				1.56			
1965	-25.56	Bottom	628.90		213.10					
1965	-35.96	Bottom	1,271.30		287.20		165.20			
1965	-35.96	Bottom	2,225.00		326.60					
1967	733.35	Top	1.59				1.49			
1967	433.35	Middle	1.43							
1967	136.81	Bottom					140.60			

Table 8.4. CSL VOC detections: regular samples

Well	Sample ID	Sample Elevation (ft msl)	Well Level	Compound	Result ¹	Qual. ²	Date Sampled
1945	4280	451.62	Middle	Naphthalene	7	JB	07-Feb-94
1946	4259	783.87	Surface	Methylene Chloride	11		31-Jan-94
1946	4259	783.87	Surface	Xylene (Total)	9	J	31-Jan-94
1946	4395	758.27	Top	Methylene Chloride	7	J	10-Mar-94
1946	4395	758.27	Top	Xylene (Total)	3	J	10-Mar-94
1946	4568	-31.13	Bottom	Toluene	8	JR	25-May-94
1946	4568	-31.13	Bottom	Xylene (Total)	2	JR	25-May-94
1946	4590	363.87	Middle	Benzene	3	JR	17-May-94
1946	4590	363.87	Middle	Methylene Chloride	9	J	17-May-94
1946	4591	-31.13	Bottom	Benzene	6	JR	17-May-94
1946	4591	-31.13	Bottom	Methylene Chloride	8	J	17-May-94
1947	4265	744.63	Top	Naphthalene	8	JB	01-Feb-94
1947	4269	307.77	Bottom	Benzene	2	J	07-Feb-94
1947	4269	307.77	Bottom	Methylene Chloride	6	J	07-Feb-94
1947	4269	307.77	Bottom	Naphthalene	153		07-Feb-94
1947	4269	307.77	Bottom	Toluene	2	J	07-Feb-94
1947	4269	307.77	Bottom	Xylene (Total)	6	J	07-Feb-94
1948	4398	724.89	Top	Benzene	2	J	14-Mar-94
1948	4399	343.6	Middle	Toluene	2	J	04-Apr-94
1949	4307	758.57	Top	Methylene Chloride	2	J	16-Feb-94
1949	4328	365.78	Middle	Benzene	6	J	16-Feb-94
1949	4328	365.78	Middle	Methylene Chloride	5	J	16-Feb-94
1949	4328	365.78	Middle	Toluene	3	J	16-Feb-94
1949	4328	365.78	Middle	Xylene (Total)	4	J	16-Feb-94
1949	4330	-200.12	Bottom	Benzene	2	J	17-Feb-94
1949	4330	-200.12	Bottom	Methylene Chloride	5	J	17-Feb-94
1949	4330	-200.12	Bottom	Toluene	3	J	17-Feb-94
1949	4330	-200.12	Bottom	Xylene (Total)	4	J	17-Feb-94
1950	4304	729.4	Top	Methylene Chloride	3	J	15-Feb-94
1950	4306	303.65	Bottom	Benzene	2	J	15-Feb-94
1951	4291	734.46	Top	Methylene Chloride	6	J	14-Feb-94
1951	4291	734.46	Top	Xylene (Total)	2	J	14-Feb-94
1951	4292	474.54	Middle	Benzene	2	J	14-Feb-94
1951	4292	474.54	Middle	Methylene Chloride	2	J	14-Feb-94
1951	4292	474.54	Middle	Naphthalene	5	J	14-Feb-94
1951	4292	474.54	Middle	Xylene (Total)	2	J	14-Feb-94
1951	4303	214.63	Bottom	Benzene	2	J	14-Feb-94
1952	4283	497.57	Middle	Naphthalene	5	JB	08-Feb-94
1952	4283	497.57	Middle	Toluene	3	J	08-Feb-94
1952	4284	319.32	Bottom	Methylene Chloride	2	J	09-Feb-94
1952	4284	319.32	Bottom	Naphthalene	13	JB	09-Feb-94
1952	4284	319.32	Bottom	Toluene	5	J	09-Feb-94
1952	4284	319.32	Bottom	Xylene (Total)	5	J	09-Feb-94
1953	4258	800.84	Surface	Methylene Chloride	5	J	31-Jan-94
1953	4437	280.84	Middle	Benzene	4	J	26-Apr-94
1953	4438	-214.16	Bottom	Benzene	2	J	26-Apr-94
1953	4438	-214.16	Bottom	Ethylbenzene	4	J	26-Apr-94
1953	4438	-214.16	Bottom	Xylene (Total)	5	J	26-Apr-94

Table 8.4. CSL VOC detections: regular samples (continued)

Well	Sample ID	Sample Elevation (ft msl)	Well Level	Compound	Result ¹	Qual. ²	Date Sampled
1955	4336	746.35	Top	Benzene	28		28-Feb-94
1955	4336	746.35	Top	Naphthalene	4 J		28-Feb-94
1955	4336	746.35	Top	Xylene (Total)	6 J		28-Feb-94
1955	4357	482.99	Middle	Benzene	2 J		28-Feb-94
1955	4357	482.99	Middle	Methylene Chloride	2 J		28-Feb-94
1955	4363	219.63	Bottom	Benzene	15		03-Mar-94
1955	4363	219.63	Bottom	Xylene (Total)	3 J		03-Mar-94
1956	3929	232.12	Bottom	Benzene	2 J		12-Jan-94
1956	3930	754.12	Top	Methylene Chloride	4 J		11-Jan-94
1956	3930	754.12	Top	Toluene	5 J		11-Jan-94
1956	4238	521.12	Middle	Methylene Chloride	2 J		12-Jan-94
1956	4238	521.12	Middle	Naphthalene	5 J		12-Jan-94
1957	4240	566.06	Middle	Ethylbenzene	2 J		13-Jan-94
1957	4240	566.06	Middle	Naphthalene	11 J		13-Jan-94
1957	4240	566.06	Middle	Toluene	2 J		13-Jan-94
1957	4240	566.06	Middle	Xylene (Total)	12 J		13-Jan-94
1957	4241	341.06	Bottom	Benzene	2 J		13-Jan-94
1957	4241	341.06	Bottom	Ethylbenzene	3 J		13-Jan-94
1957	4241	341.06	Bottom	Naphthalene	14 J		13-Jan-94
1957	4241	341.06	Bottom	Toluene	3 J		13-Jan-94
1957	4241	341.06	Bottom	Xylene (Total)	13 J		13-Jan-94
1958	4434	725.33	Top	Methylene Chloride	2 J		15-Apr-94
1958	4434	725.33	Top	Toluene	4 J		15-Apr-94
1958	4435	251.32	Middle	Toluene	5 J		18-Apr-94
1958	4436	180.31	Bottom	Methylene Chloride	3 J		18-Apr-94
1958	4436	180.31	Bottom	Toluene	2 J		18-Apr-94
1959	4288	717.35	Top	Benzene	2 J		10-Feb-94
1959	4288	717.35	Top	Methylene Chloride	4 J		10-Feb-94
1959	4288	717.35	Top	Xylene (Total)	4 J		10-Feb-94
1959	4289	472.83	Middle	Benzene	2 J		10-Feb-94
1960	4255	715.74	Top	Benzene	2 J		27-Jan-94
1960	4255	715.74	Top	Ethylbenzene	3 J		27-Jan-94
1960	4255	715.74	Top	Methylene Chloride	10		27-Jan-94
1960	4255	715.74	Top	Toluene	17		27-Jan-94
1961	4246	501.53	Middle	Methylene Chloride	2 J		26-Jan-94
1961	4246	501.53	Middle	Naphthalene	13		26-Jan-94
1961	4246	501.53	Middle	Toluene	2 J		26-Jan-94
1961	4246	501.53	Middle	Xylene (Total)	4 J		26-Jan-94
1961	4247	284.69	Bottom	Benzene	3 J		26-Jan-94
1961	4247	284.69	Bottom	Methylene Chloride	2 J		26-Jan-94
1961	4247	284.69	Bottom	Naphthalene	10		26-Jan-94
1961	4247	284.69	Bottom	Xylene (Total)	4 J		26-Jan-94
1962	4401	727.46	Top	Benzene	4 J		05-Apr-94
1962	4401	727.46	Top	Methylene Chloride	16		05-Apr-94
1962	4401	727.46	Top	Toluene	4 J		05-Apr-94
1962	4401	727.46	Top	Xylene (Total)	6 JB		05-Apr-94
1962	4402	419.68	Middle	Benzene	4 J		06-Apr-94
1962	4402	419.68	Middle	Methylene Chloride	18		06-Apr-94

Table 8.4. CSL VOC detections: regular samples (continued)

Well	Sample ID	Sample Elevation (ft msl)	Well Level	Compound	Result ¹	Qual. ²	Date Sampled
1962	4402	419.68	Middle	Toluene	4	J	06-Apr-94
1962	4402	419.68	Middle	Xylene (Total)	3	J	06-Apr-94
1962	4432	178.9	Bottom	Benzene	5	J	13-Apr-94
1962	4432	178.9	Bottom	Ethylbenzene	3	JB	13-Apr-94
1962	4432	178.9	Bottom	Methylene Chloride	18		13-Apr-94
1962	4432	178.9	Bottom	Toluene	5	J	13-Apr-94
1962	4432	178.9	Bottom	Xylene (Total)	4	J	13-Apr-94
1963	4331	729.64	Top	Xylene (Total)	4	J	22-Feb-94
1963	4333	458.59	Middle	Xylene (Total)	2	J	23-Feb-94
1964	4364	738.37	Top	Benzene	3	J	03-Mar-94
1964	4364	738.37	Top	Ethylbenzene	18		03-Mar-94
1964	4364	738.37	Top	Naphthalene	9	J	03-Mar-94
1964	4364	738.37	Top	Toluene	11		03-Mar-94
1964	4364	738.37	Top	Xylene (Total)	72		03-Mar-94
1964	4365	343.47	Middle	Benzene	3	J	07-Mar-94
1964	4365	343.47	Middle	Ethylbenzene	23		07-Mar-94
1964	4365	343.47	Middle	Naphthalene	15		07-Mar-94
1964	4365	343.47	Middle	Toluene	11		07-Mar-94
1964	4365	343.47	Middle	Xylene (Total)	95		07-Mar-94
1964	4391	214.82	Bottom	Benzene	3	J	07-Mar-94
1964	4391	214.82	Bottom	Ethylbenzene	19		07-Mar-94
1964	4391	214.82	Bottom	Naphthalene	13		07-Mar-94
1964	4391	214.82	Bottom	Toluene	9	J	07-Mar-94
1964	4391	214.82	Bottom	Xylene (Total)	79		07-Mar-94
1965	4392	738.14	Top	Ethylbenzene	3	J	08-Mar-94
1965	4392	738.14	Top	Methylene Chloride	2	J	08-Mar-94
1965	4392	738.14	Top	Naphthalene	26		08-Mar-94
1965	4392	738.14	Top	Toluene	4	J	08-Mar-94
1965	4392	738.14	Top	Xylene (Total)	17		08-Mar-94
1965	4393	343.54	Middle	Ethylbenzene	5	J	09-Mar-94
1965	4393	343.54	Middle	Naphthalene	38		09-Mar-94
1965	4393	343.54	Middle	Toluene	5	J	09-Mar-94
1965	4393	343.54	Middle	Xylene (Total)	25		09-Mar-94
1965	4394	-25.56	Bottom	Naphthalene	87	J	09-Mar-94
1965	4394	-25.56	Bottom	Xylene (Total)	26	J	09-Mar-94
1967	4242	733.35	Top	Benzene	3	J	24-Jan-94
1967	4242	733.35	Top	Ethylbenzene	88		24-Jan-94
1967	4242	733.35	Top	Methylene Chloride	37	J	24-Jan-94
1967	4242	733.35	Top	Toluene	2	J	24-Jan-94
1967	4242	733.35	Top	Xylene (Total)	344		24-Jan-94
1967	4244	433.35	Middle	Ethylbenzene	4	J	24-Jan-94
1967	4244	433.35	Middle	Naphthalene	3	J	24-Jan-94
1967	4244	433.35	Middle	Xylene (Total)	15	J	24-Jan-94
1967	4245	136.81	Bottom	Ethylbenzene	5	J	25-Jan-94

¹ All units are in µg/L.² J = Estimated below detection limit.

B = Present in laboratory blank.

R = Rejected data.

Table 8.5. CSL VOC detections: quality control samples

QC Sample Type	Well	Sample ID	Sample Elevation (ft msl)	Well Level	Compound	Result ¹	Qual. ²	Date Sampled
Duplicate	1946	4396	758.27	Top	Methylene Chloride	8	J	10-Mar-94
Duplicate	1946	4396	758.27	Top	Xylene (Total)	4	J	10-Mar-94
Duplicate	1947	4266	744.63	Top	Naphthalene	8	JB	01-Feb-94
Duplicate	1947	4268	526.23	Middle	Toluene	2	J	02-Feb-94
Duplicate	1949	4327	758.57	Top	Methylene Chloride	2	J	16-Feb-94
Duplicate	1949	4329	365.78	Middle	Benzene	6	J	16-Feb-94
Duplicate	1949	4329	365.78	Middle	Methylene Chloride	5	J	16-Feb-94
Duplicate	1949	4329	365.78	Middle	Toluene	3	J	16-Feb-94
Duplicate	1949	4329	365.78	Middle	Xylene (Total)	4	J	16-Feb-94
Duplicate	1955	4358	482.99	Middle	Benzene	2	J	28-Feb-94
Duplicate	1955	4358	482.99	Middle	Methylene Chloride	4	J	28-Feb-94
Duplicate	1955	4362	746.35	Top	Benzene	29		28-Feb-94
Duplicate	1955	4362	746.35	Top	Xylene (Total)	5	J	28-Feb-94
Duplicate	1963	4332	729.64	Top	Xylene (Total)	7	J	22-Feb-94
Field Blank	1955	4361		NA	Methylene Chloride	3	J	24-Feb-94
Trip Blank	1953	4438	-214.16	Bottom	Xylene (Total)	6	J	26-Apr-94

¹ All units are in ug/L.

² J = Estimated below detection limit.

B = Present in laboratory blank.

R = Rejected data.

Table 8.6. Analytical Support Laboratory VOC detections: regular samples								
Well	Sample ID	Sample Elevation (ft msl)	Well Level	Compound	Result ¹	Qual. ²	Date Sampled	Group ³
1946	4568	-31.13	Bottom	Acetone	38	B	26-May-94	VOC
1946	4568	-31.13	Bottom	Benzene	160		26-May-94	VOC
1946	4568	-31.13	Bottom	Bis(2-Ethylhexyl) Phthalate	5	BJ	26-May-94	BNA
1946	4568	-31.13	Bottom	Carbolic Acid	13		26-May-94	BNA
1946	4568	-31.13	Bottom	Di-n-butyl Phthalate	2	BJ	26-May-94	BNA
1946	4568	-31.13	Bottom	Styrene	2	J	26-May-94	VOC
1946	4568	-31.13	Bottom	Toluene	14		26-May-94	VOC
1965	4464	-35.96	Bottom	Acetone	41	B	22-Mar-94	VOC
1965	4464	-35.96	Bottom	Benzene	2	J	22-Mar-94	VOC
1965	4464	-35.96	Bottom	Ethylbenzene	4	J	22-Mar-94	VOC
1965	4464	-35.96	Bottom	Toluene	6	J	22-Mar-94	VOC
1965	4464	-35.96	Bottom	Xylene (Total)	22		22-Mar-94	VOC
1965	4465	-35.96	Bottom	Bis(2-Ethylhexyl) Phthalate	3	J	30-Mar-94	BNA
1965	4465	-35.96	Bottom	Di-n-butyl Phthalate	3	BJ	30-Mar-94	BNA
1965	4465	-35.96	Bottom	Fluorene	2	J	30-Mar-94	BNA
1965	4465	-35.96	Bottom	Naphthalene	25		30-Mar-94	BNA
1965	4465	-35.96	Bottom	Naphthalene, 2-Methyl	34		30-Mar-94	BNA
1965	4465	-35.96	Bottom	p-Nitrophenol	570	D	30-Mar-94	BNA
1965	4465	-35.96	Bottom	Phenanthrene	2	J	30-Mar-94	BNA
1965	4465	-35.96	Bottom	Phenol, 2,4-Dinitro	71		30-Mar-94	BNA
1965	4465	-35.96	Bottom	Phenol, 2-Nitro-	360	D	30-Mar-94	BNA

¹ All units are in µg/L.

² J = Estimated below detection limit.

B = Present in laboratory blank.

R = Rejected data.

D = Diluted.

³ VOC = volatile organic compound

BNA = base/neutral and acid extractable

Table 8.7. Metal analytical results for wells 1946 and 1965					
Analyte	ORNL Well 1946 Sample ID 4568 Depth 815 ft BTOC ¹		ORNL Well 1965 Sample ID 4465 Depth 800 ft BTOC		Units
	Conc.	Qual. ²	Conc.	Qual. ²	
Aluminum	4,170.0		51.2	U	µg/L
Antimony	26.5		37.4	J	µg/L
Arsenic	8.0		8.0	U	µg/L
Barium	11,800.0		4,620.0	J	µg/L
Beryllium	6.8		6.4	J	µg/L
Cadmium	161.0		10.8	UJ	µg/L
Calcium	9,590.0		8,450.0		mg/L
Chromium	91.7		105.0	R	µg/L
Cobalt	20.0		5.8	J	µg/L
Copper	2,050.0		12.6		µg/L
Iron	191,000.0		1,790.0	J	µg/L
Lead	3,350.0		131.0		µg/L
Magnesium	307.0		0.2		mg/L
Manganese	2,960.0		34.1		µg/L
Mercury	1.1		0.5	J	µg/L
Nickel	68.3		30.6	J	µg/L
Potassium	79.2		208.0	J	mg/L
Selenium	70.0		9.0	R	µg/L
Silver	85.0		462.0	R	µg/L
Sodium	19,200.0		23,900.0	J	mg/L
Thallium	55.0		11.0	UJ	µg/L
Vanadium	188.0		2,150.0		µg/L
Zinc	17,800.0		14,000.0		µg/L

¹ BTOC = below top of casing

² J = Estimated below detection limit.

B = Present in laboratory blank.

R = Rejected data.

Table 8.8. Contaminant distribution expected in rock cover well water				
Analyte/Radionuclide	Average	Maximum	Minimum	Unit
Bromide	402.8	838.0	0.3	mg/L
Calcium	5,674.8	24,912.8	3.1	mg/L
Chloride	34,817.8	147,303.9	7.3	mg/L
Fluoride	11.3	140.6	0.6	mg/L
Lithium	3.6	3.7	3.5	mg/L
Magnesium	1,069.8	5,951.4	0.2	mg/L
Nitrate	91.1	442.3	0.9	mg/L
Potassium	47.4	139.0	2.4	mg/L
Sodium	14,629.6	63,108.5	5.5	mg/L
Sulfate	29.8	202.2	0.2	mg/L
TDS	46,165.7	174,220.0	111.0	mg/L
TSS	206.9	1,561.0	2.0	mg/L
Benzene	4.9	28.0	2.0	µg/L
Ethylbenzene	17.5	88.0	2.0	µg/L
Methylene Chloride	6.3	37.0	2.0	µg/L
Naphthalene	19.3	153.0	3.0	µg/L
Toluene	4.6	17.0	2.0	µg/L
Xylene (total)	28.4	344.0	2.0	µg/L
pH	9.4	12.4	5.0	
Alpha	313.6	1,730.5	8.2	pCi/L
Beta	4,518.8	56,196.1	31.5	pCi/L
C-14	1,666.0	7,265.8	206.3	pCi/L
Cs-137	147.1	1,310.0	21.1	pCi/L
Gamma	97.1	1,310.0	0.0	pCi/L
Tot Sr	2,261.9	12,883.1	11.0	pCi/L
Tritium	152,124.6	3,079,558.6	227.9	pCi/L

Table 8.9. Contaminant distribution expected in observation well water. ¹				
Analyte/Radionuclide	Average	Maximum	Minimum	Unit
TDS	11,536.8	56,736.0	130.0	mg/L
Nitrate	7,219.7	12,975.9	4,917.9	mg/L
Bromide	1,941.7	16,106.2	0.3	mg/L
Calcium	2,907.8	23,042.0	6.6	mg/L
Chloride	14,767.0	71,689.7	9.6	mg/L
Fluoride	18.5	165.2	1.1	mg/L
Magnesium	197.2	2,014.7	2.6	mg/L
Potassium	43.8	304.1	1.6	mg/L
Sodium	7,966.6	39,615.5	6.7	mg/L
Sulfate	344.9	2,124.6	0.7	mg/L
TSS	106.9	331.0	2.0	mg/L
Benzene	3.8	6.0	2.0	µg/L
Ethylbenzene	4.0	5.0	3.0	µg/L
Methylene Chloride	6.0	11.0	2.0	µg/L
Naphthalene	50.3	87.0	26.0	µg/L
Toluene	4.6	8.0	3.0	µg/L
Xylene (Total)	10.6	26.0	2.0	µg/L
pH	9.5	11.8	7.1	
Cs-137	128,175.1	1,530,000.0	20.9	pCi/L
Co-60	32,325.0	69,800.0	3,590.0	pCi/L
C-14	5,854,594.8	35,734,504.5	193.7	pCi/L
Alpha	980.1	9,974.3	8.8	pCi/L
Beta	10,687,256.9	77,387,499.9	46.1	pCi/L
Gamma	138,621.2	1,650,000.0	0.0	pCi/L
Tritium	167,349.3	726,684.7	255.0	pCi/L
Tot Sr	10,879,772.9	31,476,602.9	231.1	pCi/L

¹ Does not include 1.25 in. diameter wells ORNL ID Nos. 1948, 1958, 1962, and 1964.

9. CONCLUSIONS

The goals of the WAG 10 OU3 OHF field investigation were to establish which wells are potential candidates for recompletion and which are candidates for P&A, provide data necessary to support the preliminary design of well recompletion and P&A, and refine the WAG 10 conceptual model to support further OU2 planning. The goals were accomplished by assessing the well pressurization and well water contamination, collecting data to support health and safety and waste management considerations to be encountered during well P&A, performing geophysical logging of the wells to evaluate casing and bond integrity, and evaluating the distribution of well contaminants and groundwater constituents to determine the potential for intrawell transport.

A screening-level chemical characterization of the wellbores was performed for each WAG 10 well. The data were used to evaluate and rank the level of contamination, the ability of the casing to prevent an influx of formation water or contamination, and the potential for upward migration of contamination. Headspace pressure data were also collected to assist in evaluating the upward migration potential within the well. Geophysical log interpretation, in combination with the chemical data, was used to rank wells for P&A activities and/or possible future monitoring at the OHF. To standardize the prioritization process, each geophysically logged well was graded based on the nature and level of contamination present, migration potential, and well integrity.

Twenty-three wells were evaluated in this study: 21 are in the OHF area, and 2 (1920 and 1943) are in the HF-2 area east of the OHF. Wellbore water was grab sampled at 3 elevations in all 23 wells and analyzed. Nineteen of the wells were geophysically logged. Four of the observation wells (1948, 1958, 1962, and 1964) could not be logged because of their small-diameter riser casings, so they were not included in the ranking. Wells 1954 and 1966 were not accessible (plugged) and therefore not part of the evaluation.

Ten percent (1953 and 1965) of the wells received the highest ranking (9) and, with qualification, should be plugged and abandoned as soon as possible. Well 1953, however, provides an excellent opportunity for future monitoring/sampling at the OHF because it provides a long openhole interval covering the middle Rogersville Shale through the lower Pumpkin Valley Shale section (injection horizon). Temporary recompletion as a multiport well should be considered with permanent abandonment at a later date. Two other wells (1946 and 1967) received the second highest ranking (7) and should also be considered for immediate P&A.

Approval for drilling of a new monitoring well through the grout sheets is highly unlikely; therefore, it would be prudent to use existing wells to further define deep groundwater conditions. Three of the existing wells (1947, 1950, and 1956) provide an opportunity for retrofitting and sampling/monitoring at the OHF; these wells have openhole intervals that cover the Rogersville Shale and Rutledge Limestone.

Two wells (1920 and 1943), located east of the OHF, should be considered for retrofitting and future sampling/monitoring at HF-2. These wells are both deep with long openhole intervals covering the Maryville Limestone to the Pumpkin Valley Shale. Well 1920 is of special interest

because of the elevated gamma ray log response over the entire borehole. This response is similar to that measured in well 1965, where the high gamma appears to be correlated with shale beds.

Because adequate sampling and logging tools could not be inserted into the small-diameter observation wells, reliable data are limited to conductivity profiles and the low-resolution gamma logs produced during injection. It should be assumed that these wells have similar contamination and integrity as the large-diameter observation wells.

Geologic cross sections were constructed for the OHF area. Interpretations of these and other acquired data reveal that several mechanisms have been active in the spread of radioactive contaminants associated with OHF operations and brine. They are as follows:

- Several of the wells that penetrate the injection interval are contaminated with grout and grout filtrate. These observation wells provide a potential pathway for upsection migration of contaminants.
- Evidence of upsection migration of contaminated grout filtrate was discovered (well 1967) in the Rutledge Limestone. It is unknown whether the contaminants migrated through an open natural fracture/joint system, a reactivated system, or a system created by hydrofracture operations.
- Some wellbores (e.g., well 1963) have provided a pathway for the upsection migration of what appears to be natural brine. It is unknown whether the brine migrated through an open natural fracture/joint system or a reactivated system.

Anomalously high gamma ray log responses in the upper section of well 1965 are correlated with shales and most likely result from circulation of injected waste in the open borehole while the well was being drilled. Preferential sorption of radionuclides on the shales could result in the enhanced gamma activity of the shales. Elevated gamma ray log responses in the lower portions of well 1920 are probably also caused by this process. However, large gamma spikes in the upper 30 ft of the hole are difficult to explain by transport within borehole fluids because they are isolated and very close to the surface. A different source of radioactivity may be responsible.

Pressurized conditions were encountered in three observation wells that intersect the grout sheets. The pressures were not considered to result from biological activity. Because artesian conditions exist in some shallow wells within WAG 5, the pressures could be from the shallow groundwater system. However, several other pieces of evidence support the interpretation that hydrostatic pressures exist at the elevation of the OHF injections: (1) artesian conditions were reported during drilling of the injection well and observation well 1965; (2) artesian conditions were also reported for a deep well associated with the NHF; and (3) independent hydrogeologic investigations indicate that the Rome Formation may be pressurized at depth, which could result in pressurization of the overlying Pumpkin Valley Shale injection horizon. Because artesian conditions were reported before injection, at least some of the observed pressure is probably the result of topographic and structural controls on the deep flow system. It has not been determined to what degree, if any, relict injection pressures are affecting the deep pressure gradient.

The existence of pressures in the injection formations provides the gradient necessary to drive vertical migration, thereby potentially creating a dynamic groundwater flow system. However, data collected in this effort indicate only the potential for contaminant transport within the wells. The OU3 OHF effort was not designed to determine whether transport is actively occurring within the rock matrix, but the increasing trend in radioactivity with depth and the presence of nitrate in some rock cover wells supports the concept that contaminated groundwater has migrated upward approximately 200 ft within the rock from the plane of injection. Furthermore, the presence of nitrate and radionuclides in the NHF rock cover wells also supports the concept of vertical movement induced by fracturing.

Contamination of the rock cover wells from HF injections does not necessarily mean that the groundwater flow system is dynamic. Vertical transport could have occurred only during the injections when injection pressures opened existing planes of weakness in the rock and provided the gradient to move contaminants vertically through rock with a temporarily increased permeability. Dissipation of the pressure may have reduced permeability, thereby trapping contamination within a static flow system.

The impact on the shallow flow system from potential vertical contaminant transport through wells such as 1953 and 1965 has not been determined but will be addressed in the WAG 10 OU2 groundwater investigation. At this time it is not possible to separate potential WAG 10 contaminants from WAG 5 impacts on the shallow flow system.

Based on the likely condition of an upward pressure gradient from the injection zone to the near-surface environment, a re-evaluation of the priorities of Melton Valley remedial activities with respect to the remaining OU3 wells (especially those near the NHF and DM-series wells) and the OU2 investigation would seem prudent. Because of the high volume and short time span in which injections were done at the NHF, the potential for NHF wells requiring P&A is significant.

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WELL 1920
(Alias: 2E-100)

ORNL WELL ID NO. 1920				
ORNL WELL ID NO.:	1920			
ALIAS:	2E-100			
WELL TYPE:	MONITORING WELL			
DRILLING METHOD:	ROTARY?			
EASTING:	31350.55			
NORTHING:	16793.26			
GROUND SURFACE ELEVATION:	786.7			
TOP OF RISER (PRE-MODIFICATION):	787.68			
TOP OF RISER (POST-MODIFICATION):	NA			
CASING MATERIAL:	CARBON STEEL			
		DEPTH (FT) FROM:	DEPTH (FT) TO:	
BOREHOLE 1:	DIAMETER (IN.)			
BOREHOLE 2:	8.75	0	27	
	3.1	27	847.2	
REPORTED DRILLED DEPTH (FT):	910			
OPEN FORMATION:	NOLICHUCKY SHALE TO LOWER PUMPKIN VALLEY SHALE			
		DEPTH (FT) FROM:	DEPTH (FT) TO:	
DIVERTER CASING:	DIAMETER (IN.)			
SURFACE CASING:	NONE APPARENT			
ISOLATION CASING:	3.5	+0.98	27	
	NONE			
		DEPTH (FT) FROM:	DEPTH (FT) TO:	
GROUT 1:	0	0	27	
		DEPTH (FT) FROM:	DEPTH (FT) TO:	QUALITY:
INTERPRETED CEMENT BOND LOG:	0	0	27	BAD

NOTE: THE WELL DETAILS HAVE BEEN RECONSTRUCTED BASED ON GEOPHYSICAL LOG INTERPRETATION.
THE INFORMATION PROVIDED SHOULD BE CONSIDERED AS A BEST ESTIMATE.
TD = TOTAL DEPTH
NA = NOT AVAILABLE
BOC = BOTTOM OF CASING

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS631 7 Phone:(615)574-4558

SPR,SP,Caliper
Neutron,Gamma,App
Den,Fl Temp/Res

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: March 22-28, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1920

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 786.7

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: 910 LOGGED TD: 847.2'

BIT RECORD				CASING RECORD		
RUN	BIT SIZE	FROM	TO	SIZE/WGT/THK.	FROM	TO
110.	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		3.5"	26.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.1'

WATER LEVEL: Flowing artesian

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
SP	5	125	Compro	125	0.2	12	Pb Ring	na	na	none	na	846.6'	0.0'	846.6
Gamma	5	125	Compro	125	0.2	12	NaI Scin	na	na	none	na	840.6'	0.0'	840.6
Neutron	11	101	Compro	101	0.2	12	He3	na	na	AmBe	3 Ci	841.6'	473.8'	367.8
Caliper	11	101	Compro	101	0.2	12	Potential	na	na	none	na	846.2'	4.2'	842.0
SPR	9	102	Compro	102	0.2	13	Pb Ring	na	na	none	na	842.2'	0.0'	842.2
App-Density	9	102	Compro	102	0.2	13	NaI Scin	na	na	Cs137	125mCi	846.2'	4.0'	842.2
Fl-Temp/Res	1234	127	Sopris	127	0.2	6	Trsd/Wen	na	na	none	na	50.0'	854.0'	804.0

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1920.gb0...db0...nb0...td4...xa3

NOTE:

Depths corrected to ground level; casing
stick-up measured from TOC to ground level on
north side of casing. Well not pressurized.

On completion of 1920 all equipment surveyed
& "green tagged" by HP.

(1920C.HDP)

(10w1920.xa3)

1920 WAG 10 OU 3 Phase 1 Composite Plot

(10w1920.xa3)

1920 WAG 10 OU 3 Phase 1 Composite Plot

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

NEAR VDL
FAR Tube-Wave Amp
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: March 22-28, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1920

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 786.7

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: 910 LOGGED TD: 847.2'

BIT RECORD				CASING RECORD		
RUN	BIT SIZE	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		3.5"	26.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.1'

WATER LEVEL: Flowing artesian

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Near VDL	7	111	Sopris	111	0.2	7	Transduc	2	1	none	na	843.2'	473.8'	369.4
Far TW-Amp	7	111	Sopris	111	0.2	7	Computed	3	1	none	na	842.6'	473.8'	368.8
Velocity	7	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	841.6'	473.8'	367.8
Near VDL	8	111	Sopris	111	0.2	7	Transduc	2	1	none	na	479.0'	1.6'	477.4
Far TW-Amp	8	111	Sopris	111	0.2	7	Computed	3	1	none	na	479.0'	1.2'	477.8
Velocity	8	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	479.0'	0.2'	478.8

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1920.sf1.sf2.sf3.sg3.sh3.si3.sw1.sw2.sw3

NOTE:

Depths corrected to ground level; casing
stick-up measured from TOC to ground level on
north side of casing. Well not pressurized.

Files sf1 & sf2 merged into sf3; files sw1 &
sw2 merged into sw3. On completion all
equipment surveyed & "green tagged" by HP.
(10W1920A.HDP)

(10w1920.si3) 1920 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 76 uS)

0w1920.si3) 1920 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 76 uS)

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

FAR VDL
FAR Tube-Wave Amp
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: March 22-28, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1920

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 786.7

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: 910' LOGGED TD: 847.2'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		3.5"	26.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.1'

WATER LEVEL: Flowing artesian

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Far VDL	7	111	Sopris	111	0.2	7	Transduc	3	1	none	na	842.6'	473.8'	368.8
Far TW-Amp	7	111	Sopris	111	0.2	7	Computed	3	1	none	na	842.6'	473.8'	368.8
Velocity	7	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	841.6'	473.8'	367.8
Far VDL	8	111	Sopris	111	0.2	7	Transduc	2	1	none	na	479.0'	1.2'	477.8
Far TW-Amp	8	111	Sopris	111	0.2	7	Computed	3	1	none	na	479.0'	1.2'	477.8
Velocity	8	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	479.0'	0.2'	478.8

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1920.sf1.sf2.sf3.sg3.sh3.sj3.sw1.sw2.sw3

NOTE:

Depths corrected to ground level; casing stick-up measured from TOC to ground level on north side of casing. Well not pressurized.

Files sf1 & sf2 merged into sf3; files sw1 & sw2 merged into sw3. On completion all equipment surveyed & "green tagged" by HP.
(10W1920B.HDP)

(10w1920.sj3) 1920 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 76 uS)

0w1920.sj3) 1920 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 76 uS)

WELL 1920 WAG 10 OU 3 Phase 1

Horizontal Offset (Cased to 25')

WELL 1920 WAG 10 OU 3 Phase 1

Plan View (Cased to 25')

WELL 1920 WAG 10 OU 3 Phase 1

N-S Cross-Section (Cased to 25')

WELL 1920 WAG 10 OU 3 Phase 1

E-W Cross-Section (Cased to 25')

WELL 1943
(Alias: 2W-600)

ORNL WELL ID NO. 1943				
ORNL WELL ID NO.:	1943			
ALIAS:	2W-600			
WELL TYPE:	MONITORING WELL			
DRILLING METHOD:	UNKNOWN			
EASTING:	30672.6			
NORTHING:	16967.52			
GROUND SURFACE ELEVATION:	780.8			
TOP OF RISER (PRE-MODIFICATION):	781.79			
TOP OF RISER (POST-MODIFICATION):	782.8			
CASING MATERIAL:	CARBON STEEL			
		DEPTH (FT) FROM:	DEPTH (FT) TO:	
BOREHOLE 1:	DIAMETER (IN.)			
	8.75	0	15	
BOREHOLE 2:	3.3	15	972.9	
REPORTED DRILLED DEPTH (FT):	977			
OPEN FORMATION:	NOLICHUCKY SHALE TO LOWER PUMPKIN VALLEY SHALE (HOME?)			
		DEPTH (FT) FROM:	DEPTH (FT) TO:	
DIVERTER CASING:	DIAMETER (IN.)			
	NONE APPARENT			
SURFACE CASING:	3.75	+2.0	15	
ISOLATION CASING:	NONE			
		DEPTH (FT) FROM:	DEPTH (FT) TO:	
GROUT 1:	0	0	15	
		DEPTH (FT) FROM:	DEPTH (FT) TO:	QUALITY:
INTERPRETED CEMENT BOND LOG:	0	15		BAD
NOTE: THE WELL DETAILS HAVE BEEN RECONSTRUCTED BASED ON GEOPHYSICAL LOG INTERPRETATION. THE INFORMATION PROVIDED SHOULD BE CONSIDERED AS A BEST ESTIMATE. TD = TOTAL DEPTH NA = NOT AVAILABLE BOC = BOTTOM OF CASING

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

16"SNR,SP,Caliper
Neut,Gam,Bulk Den
Por,FL Temp/Res

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: April 14-19, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1943

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 780.8

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: 977' LOGGED TD: 972.9'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		3.5"	15.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 0.3'

WATER LEVEL: 1'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
16"Norm Res	5	113	Compro	113	0.2	13	Pb Ring	na	na	none	na	450.0'	39.6'	410.4
SP	2	125	Compro	125	0.2	12	Pb Ring	na	na	none	na	972.8'	0.4'	972.4
Gamma	2	125	Compro	125	0.2	12	Nal Scin	na	na	none	na	966.8'	0.0'	966.8'
Neutron	6	101	Compro	101	0.2	12	He3	na	na	ArrBe	3 Ci	972.0'	4.0'	968.0
Caliper	6	101	Compro	101	0.2	12	Potentio	na	na	none	na	967.2'	0.0'	967.2
BulkDen/Por	4	129	Sopris	129	0.2	12	Nal Scin	na	na	Cs137	100mC	972.6'	1.8'	970.8
FI-Temp/Res	1	131	Sopris	131	0.2	6	Trsd/Wen	na	na	none	na	0.0'	261.0'	261.0

CALIBRATED PROBE(S):See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1943.gb0...nb0...bc0...rb0...td0...xa0

NOTE:

Depths corrected to ground level; casing stick-up measured from TOC to ground level on north side of casing. Well not pressurized.

On completion of logging 1943 all equipment surveyed & "green tagged" by HP.

(1943C.HDP)

1943 WAG 10 OU 3 Phase 1 Temperature

1943 WAG 10 OU 3 Phase 1 Temperature

1943 WAG 10 OU 3 Phase 1 Temperature

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831 -6317
BUILDING 3504 MS631 7 Phone:(615)574-4558

NEAR VDL
FAR Tube-Wave Amp
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: April 14-19, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1943

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 780.8

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: 977' LOGGED TD: 972.9'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		3.5"	15.0'	Surface±
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 0.3'

WATER LEVEL: 1'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Near VDL	3	111	Sopris	111	0.2	7	Transduc	2	1	none	na	970.0'	1.8'	968.2
Far TW-Amp	3	111	Sopris	111	0.2	7	Computed	3	1	none	na	969.4'	1.4'	968.0
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	968.4'	0.6'	967.8'

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1943.sf0...sg0...sh0...si0...sj0...sw0

NOTE:

Depths corrected to ground level; casing stick-up measured from TOC to ground level on north side of casing. Well not pressurized.

On completion of logging 1943 all equipment surveyed & "green tagged" by HP.

(10W1943A.HDP)

(10w1943.sj0) 1943 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 76 uS)

(10w1943.sj0) 1943 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 76 uS)

TW-Amplitude

Amp Units

Velocity

Ft/Sec

250

28000

Records

Microseconds Transit Time Tx to Near Receiver

Pointer

100

200

300

400

500

600

700

800

900

1

450

500

550

600

650

700

750

800

850

(10w1943.sj0) 1943 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 76 μ S)

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

FAR VDL
FAR Tube-Wave Amp
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: April 14-19, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1943

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 780.8

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: 977' LOGGED TD: 972.9'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		3.5"	15.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 0.3'

WATER LEVEL: 1'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Far VDL	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	969.4'	1.4'	968.0
Far TW-Amp	3	111	Sopris	111	0.2	7	Computed	3	1	none	na	969.4'	1.4'	968.0
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	968.4'	0.6'	967.8'

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1943.sf0...sg0...sh0...si0...sk0...sw0

NOTE:

Depths corrected to ground level; casing stick-up measured from TOC to ground level on north side of casing. Well not pressurized.

On completion of logging 1943 all equipment surveyed & "green tagged" by HP.

(10W1943B.HDP)

(10w1943.sk0) 1943 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 76 uS)

1943 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 76 uS)

TW-Amplitude

Records

Pointer

Amp Units

250

Microseconds Transit Time Tx to Far Receiver

Velocity

Ft/Sec

28000

100

200

300

400

500

600

700

800

900

450

500

550

600

650

700

750

800

850

jw1943.sk0) 1943 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 76 μ S)

WELL 1943 WAG 10 OU 3 Phase 1

Horizontal Offset (Cased to 15')

WELL 1943 WAG 10 OU 3 Phase 1

Plan View (Cased to 15')

WELL 1943 WAG 10 OU 3 Phase 1

N - S Cross-Section (Cased to 15')

WELL 1943 WAG 10 OU 3 Phase 1

E - W Cross-Section (Cased to 15')

WELL 1944
(Alias: 3-Inject)

ORNL WELL ID NO. 1944

ORNL WELL ID NO.:	1944
ALIAS:	3-INJECT
WELL TYPE:	INJECTION WELL
DRILLING METHOD:	ROTARY
EASTING:	28617.0
NORTHING:	17155.0
GROUND SURFACE ELEVATION:	799.0
TOP OF RISER (PRE-MODIFICATION):	NA
TOP OF RISER (POST-MODIFICATION):	NA
CASING MATERIAL:	CARBON STEEL
CASING STRING (FT):	25 & 30
CONCRETE PAD	CELL FLOOR
GUARD POSTS	NONE

BOREHOLE 1:	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
BOREHOLE 2:	12.25	0	160
	8.75	160	1058

REPORTED DRILLED DEPTH (FT):	1058
OPEN FORMATION:	NO OPEN INTERVAL
	(UPPER PUMPKIN VALLEY SHALE)

DIVERTER CASING:	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
SURFACE CASING:	NONE APPARENT		
ISOLATION CASING:	9.63	0	158
	5.5	0	1038

CENTRALIZERS (FT):	SEVERAL
--------------------	---------

GROUT 1:	DEPTH (FT) FROM:	DEPTH (FT) TO:
GROUT 2:	0	160
	0	1058

DEPTH (FT) FROM:	DEPTH (FT) TO:	QUALITY:

INTERPRETED CEMENT BOND LOG:	NA
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NOTE: THE WELL DETAILS HAVE BEEN RECONSTRUCTED BASED ON GEOPHYSICAL LOG INTERPRETATION AND CONSTRUCTION SPECIFICATIONS FOUND IN W. de Laguna 1968. THE INFORMATION PROVIDED SHOULD BE CONSIDERED AS A BEST ESTIMATE.
 TO = TOTAL DEPTH
 NA = NOT AVAILABLE
 BOC = BOTTOM OF CASING

WELL 1945
(Alias: 3E-300R)

ORNL WELL ID NO. 1945

ORNL WELL ID NO.:	1945		
ALIAS:	3E-300R		
WELL TYPE:	ROCK COVER		
DRILLING METHOD:	ROTARY		
EASTING:	28890.39		
NORTHING:	17004.46		
GROUND SURFACE ELEVATION:	780.3		
TOP OF RISER (PRE-MODIFICATION):	781.83		
TOP OF RISER (POST-MODIFICATION):	NA		
CASING MATERIAL:	CARBON STEEL		
CASING STRING (FT):	30		
CONCRETE PAD	NONE		
GUARD POSTS	NONE		
	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
BOREHOLE 1:	14.75	0	20
BOREHOLE 2:	8.75	20	175
BOREHOLE 3:	6.75	175	598
BOREHOLE 4:	3.6	598	630.3
REPORTED DRILLED DEPTH (FT):	650		
OPEN FORMATION:	LOWER RUTLEDGE LIMESTONE		
	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
DIVERTER CASING:	10	0	20
SURFACE CASING:	7	+1.53	175
ISOLATION CASING:	4.2	0	598
CENTRALIZERS (FT):	67		
	381		
	DEPTH (FT) FROM:	DEPTH (FT) TO:	
GROUT 1:	0	20	
GROUT 2:	0	175	
GROUT 3:	0	598	
	DEPTH (FT) FROM:	DEPTH (FT) TO:	QUALITY:
INTERPRETED CEMENT BOND LOG:	11	20	BAD
	20	598(BOC)	GOOD

NOTE: THE WELL DETAILS HAVE BEEN RECONSTRUCTED BASED ON GEOPHYSICAL LOG INTERPRETATION.
 THE INFORMATION PROVIDED SHOULD BE CONSIDERED AS A BEST ESTIMATE.
 TO = TOTAL DEPTH
 NA = NOT AVAILABLE
 BOC = BOTTOM OF CASING

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

SPR,SP,Caliper
Neutron,Gamma,App
Den,FI Temp/Res

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: June 13-14, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1945

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 780.3

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 630.8'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	598.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.3'

WATER LEVEL: 11'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprabe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
SPR	2	103	Compr	103	0.2	12	Pb Ring	na	na	none	na	626.4'	0.2'	626.2
Gamma	2	103	Compr	103	0.2	12	Nal Scin	na	na	none	na	629.8'	3.6'	626.2
Neutron	5	101	Compr	101	0.2	12	He3	na	na	AmBe	3 Ci	629.8'	4.2'	625.6
Caliper	5	101	Compr	101	0.2	12	Potentio	na	na	none	na	624.8'	0.0'	624.8
SP	5	101	Compr	101	0.2	12	Pb Ring	na	na	none	na	625.8'	0.2'	625.6
App-Density	6	102	Compr	102	0.2	12	Nal Scin	na	na	Cs137	125mC	629.6'	4.2'	625.4
FI-Temp/Res	1	127	Sopris	127	0.2	6	Trsd/Wen	na	na	none	na	0.0'	630.8'	630.8

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1945.gb0...db0...nb0...td0...xa0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1945 all equipment surveyed & "green tagged" by HP.

(1945C.HDP)

(10w1945.xa0)

1945 WAG 10 OU 3 Phase 1 Composite Plot

(10w1945.xa0)

1945 WAG 10 OU 3 Phase 1 Composite Plot

SPR			Apparent Density			Fluid Resistivity		
50	OHMS	200	1.4	Gm/cc	2.8	-5	OHM-M	30
SP			Gamma			Temperature		
-700	mVolts	-500	0	CPS	100	55	Degrees F	62
Caliper			Neutron			Residual Temperature		
0.0	Inches	5.0	0	CPS	1000	-1.0	Degrees F	1.0

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

NEAR VDL
FAR Amplitude
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: June 13-14, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1945

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 780.3

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 630.8'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	598.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.3'

WATER LEVEL: 11'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Near VDL	3	111	Sopris	111	0.2	7	Transduc	2	1	none	na	627.2'	9.6'	617.6
Amplitude	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	626.8'	9.2'	617.6
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	625.8'	8.2'	617.6

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1945.sf0...sg0...sh0...si0...sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1945 all equipment surveyed & "green tagged" by HP.

(10W1945A.HDP)

w1945.si0) 1945 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 98 uS)

(10w1945.si0) 1945 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 98 uS)

Amplitude
Arrp Units 250
Velocity
Ft/Sec 28000

Records Pointer

Microseconds Transit Time Tx to Near Receiver

3000 28000 100 200 300 400 500 600 700 800 900 1

ORNL GEOPHYSICS GROUP

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BUILDING 3504 MS6317 Phone:(615)574-4558

FAR VDL
FAR Amplitude
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: June 13-14, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1945

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 780.3

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 630.8'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	598.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.3'

WATER LEVEL: 11'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Far VDL	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	626.8'	9.2'	617.6
Amplitude	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	626.8'	9.2'	617.6
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	625.8'	8.2'	617.6

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1945.sf0...sg0...sh0...sj0...sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1945 all equipment surveyed & "green tagged" by HP.

(10W1945B.HDP)

1945.sj0) 1945 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 98 μ S)

1945.sj0 1945 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 98 uS)

WELL 1945 WAG 10 OU 3 Phase 1

Horizontal Offset (Cased to 600')

WELL 1946
(Alias: 3E-320)

ORNL WELL -ID NO. 1946

ORNL WELL ID NO.:	1946		
ALIAS:	3E-320		
WELL TYPE:	OBSERVATION WELL		
DRILLING METHOD:	ROTARY/CONVENTIONAL CORE?		
EASTING:	28918.38		
NORTHING:	17013.89		
GROUND SURFACE ELEVATION:	782.4		
TOP OF RISER (PRE-MODIFICATION):	783.87		
TOP OF RISER (POST-MODIFICATION):	NA		
CASING MATERIAL:	CARBON STEEL		
CASING STRING (FT):	30		
CONCRETE PAD	NONE		
GUARD POSTS	NONE		
BOREHOLE 1:	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
BOREHOLE 2:	14.75	0	35
BOREHOLE 3:	8.75	35	400
	3.75	400	830
REPORTED DRILLED DEPTH (FT):	840		
OPEN FORMATION:	CASED TO TO		
DIVERTER CASING:	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
SURFACE CASING:	10	0	35
ISOLATION CASING:	7	+1.47	400
	2.5	0	830
CENTRALIZERS (FT):	NONE APPARENT		
	DEPTH (FT) FROM:	DEPTH (FT) TO:	
GROUT 1:	0	35	
GROUT 2:	0	400	
GROUT 3:	0	690	
GROUT 4:	690	830	
			LATEX GROUT
	DEPTH (FT) FROM:	DEPTH (FT) TO:	QUALITY:
INTERPRETED CEMENT BOND LOG:	8	50	BAD
	50	400	MODERATE
	400	830 (BOC)	BAD

NOTE: THE WELL DETAILS HAVE BEEN RECONSTRUCTED BASED ON GEOPHYSICAL LOG INTERPRETATION.
 THE INFORMATION PROVIDED SHOULD BE CONSIDERED AS A BEST ESTIMATE.
 TO = TOTAL DEPTH
 NA = NOT AVAILABLE
 BOC = BOTTOM OF CASING

ORNL GEOPHYSICS GROUP

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BUILDING 3504 MS6317 Phone:(615)574-4558

SPR,SP,Caliper,Bk
Neutron,Gamma,App
Den,Fl Temp/Res

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: Jul 28-Aug 3, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1946

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 782.4

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 830.2'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		2.5"	830.4'+	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 3.0'

WATER LEVEL: Flowing artesian

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
SPR	2	103	Compr	103	0.2	12	Pb Ring	na	na	none	na	825.2'	0.2'	825.0
Gamma	2	103	Compr	103	0.2	12	Nal Scin	na	na	none	na	828.6'	3.6'	825.0
Neutron	4	101	Compr	101	0.2	12	He3	na	na	ArrBe	3 Ci	829.4'	4.4'	825.0
Caliper/SP	4	101	Compr	101	0.2	12	Pot/Pb	na	na	none	na	824.6'	0.2'	824.4
Background	6	102	Compr	102	0.2	12.5	Nal Scin	na	na	none	na	827.8'	4.4'	823.4
Cor App-Den	7	102	Compr	102	0.2	12.5	Nal Scin	na	na	Cs137	125mC	827.8'	4.4'	823.4
Fl-Temp/Res	1	127	Sopris	127	0.2	6	Trsd/Wen	na	na	none	na	1.2'	830.2'	829.0

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1946.gb0...dc2...nb0...td0...xo0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was pressurized (approx 30 psi). On completion of logging 1946 cable & sondes were "yellow tagged" & moved to Bechtel's decon facility for clean-up. (1946C.HDP)

(10w1946.xao)

1946 WAG 10 OU 3 Phase 1 Composite Plot

1946 WAG 10 OU 3 Phase 1 Composite Plot

1946 WAG 10 OU 3 Phase 1 Composite Plot

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

NEAR VDL
FAR Amplitude
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: Jul 28-Aug 3, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1946

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 782.4

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 830.2'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		2.5"	830.4'+	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 3.0'

WATER LEVEL: Flowing artesian

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Near VDL	5	111	Sopris	111	0.2	7.5	Transduc	2	1	none	no	826.8'	5.6'	821.2
Amplitude	5	111	Sopris	111	0.2	7.5	Transduc	3	1	none	no	826.2'	5.2'	821.0
Velocity	5	111	Sopris	111	0.2	7.5	Computed	2/3	1	none	no	825.2'	4.2'	821.0

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1946.sf0...sg0...sh0...si0...sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was pressurized (approx 30 psi). On completion of logging 1946 cable & sondes were "yellow tagged" & moved to Bechtel's decon facility for clean-up. (10W1946A.HDP)

1946 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 76 uS)

1946 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 76 uS)

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

FAR VDL
FAR Amplitude
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: Jul 28-Aug 3, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1946

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 782.4

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 830.2'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		2.5"	830.4'+	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 3.0'

WATER LEVEL: Flowing artesian

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Far VDL	5	111	Sopris	111	0.2	7.5	Transduc	3	1	none	na	826.2'	5.2'	821.0
Amplitude	5	111	Sopris	111	0.2	7.5	Transduc	3	1	none	na	826.2'	5.2'	821.0
Velocity	5	111	Sopris	111	0.2	7.5	Computed	2/3	1	none	na	825.2'	4.2'	821.0

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1946.sf0...sg0...sh0...sj0...sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was pressurized (approx 30 psi). On completion of logging 1946 cable & sondes were "yellow tagged" & moved to Bechtel's decon facility for clean-up. (10W1946B.HDP)

0w1946.sj0) 1946 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 76 μ S)

10w1946.sj0) 1946 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 76 uS)

WELL 1946 WAG 10 OU 3 Phase 1

Horizontal Offset (Cased to 830')

WELL 1947
(Alias: 3E-320P)

ORNL WELL ID NO. 1947			
ORNL WELL ID NO.:	1947		
ALIAS:	3E-320P		
WELL TYPE:	UNFINISHED ROCK COVER		
DRILLING METHOD:	ROTARY		
EASTING:	28921.18		
NORTHING:	16999.96		
GROUND SURFACE ELEVATION:	780.9		
TOP OF RISER (PRE-MODIFICATION):	782.77		
TOP OF RISER (POST-MODIFICATION):	NA		
CASING MATERIAL:	CARBON STEEL		
CASING STRING(FT):	30		
CONCRETE PAD	NONE		
GUARD POSTS	NONE		
	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
BOREHOLE 1:	14.75	0	20
BOREHOLE 2:	8.75	20	80
BOREHOLE 3:	6.75	80	524
REPORTED DRILLED DEPTH (FT):	500?		
OPEN FORMATION:	LOWER ROGERSVILLE SHALE		
	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
DIVERTER CASING:	10	0	20
SURFACE CASING:	7	+1.87	80
ISOLATION CASING:	4.2	0	502
CENTRALIZERS (FT):	NONE APPARENT		
	DEPTH (FT) FROM:	DEPTH (FT) TO:	
GROUT 1:	0	20	
GROUT 2:	0	80	
GROUT 3:	0	502	
	DEPTH (FT) FROM:	DEPTH (FT) TO:	QUALITY:
INTERPRETED CEMENT BOND LOG:	12	60	BAD
	60	502 (BOC)	GOOD
NOTE: THE WELL DETAILS HAVE BEEN RECONSTRUCTED BASED ON GEOPHYSICAL LOG INTERPRETATION. THE INFORMATION PROVIDED SHOULD BE CONSIDERED AS A BEST ESTIMATE. TD = TOTAL DEPTH NA = NOT AVAILABLE BOC = BOTTOM OF CASING

ORNL

ORNL GEOPHYSICS GROUP

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 BUILDING 3504 MS6317 Phone:(615)574-4558

SPR,SP,Caliper
 Neutron,Gamma,App
 Den,FI Temp/Res

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: June 8-13, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1947

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 780.9

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 524.0'

RUN		BIT RECORD			CASING RECORD		
NO.	Bit Size	From	To	Size/Wgt/Thk.	From	To	
1	N/A	Ground Level		4.2"	502.0'	Surface+	
2	N/A			N/A			
3	N/A			N/A			
4	N/A			N/A			

DRILL METHOD: N/A

CASING STICK UP: 1.8'

WATER LEVEL: 11.5'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
SPR	2	103	Compro	103	0.2	12	Pb Ring	na	na	none	na	500.6'	0.2'	500.4
Gamma	2	103	Compro	103	0.2	12	Nal Scin	na	na	none	na	504.0'	3.4'	500.6
Neutron	5	101	Compro	101	0.2	12	He3	na	na	ArrBe	3 Ci	504.6'	4.2'	500.4
Caliper	5/7	101	Compro	101	0.2	12	Potentio	na	na	none	na	520.2'	0.0'	520.2
SP	5	101	Compro	101	0.2	12	Pb Ring	na	na	none	na	500.6'	0.2'	500.4
App-Density	6	102	Compro	102	0.2	12	Nal Scin	na	na	Cs137	125mC	524.0'	4.0'	520.0
FI-Temp/Res	1	127	Sopris	127	0.2	6	Trsd/Wen	na	na	none	na	0.0'	505.0'	505.0

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1947.gb0...db0...nb2...td0...xa0

NOTE:

Depths corrected to ground level; casing
 stick-up was measured from TOC to metal rod
 placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1947 all equipment
 surveyed & "green tagged" by HP.

(1947C.HDP)

1947 WAG 10 OU 3 Phase 1 Composite Plot

(10w1947.xa0)

1947 WAG 10 OU 3 Phase 1 Composite Plot

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

NEAR VDL
FAR Amplitude
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: June 8-13, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1947

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 780.9

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 524.0'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	502.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.8'

WATER LEVEL: 11.5'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Near VDL	3	111	Sopris	111	0.2	7	Transduc	2	1	none	na	502.0'	10.0'	492.0
Amplitude	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	501.6'	9.6'	492.0
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	500.6'	8.6'	492.0'

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1947.sf0...sg0...sh0...si0...sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1947 all equipment surveyed & "green tagged" by HP.

(10W1947A.HDP)

w1947.si0) 1947 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 98 uS)

w1947.si0) 1947 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 98 uS)

Amplitude

Records

Pointer

Amp Units

250

Microseconds Transit Time Tx to Near Receiver

Velocity

100

200

300

400

500

600

700

800

900

1

3000

Ft/Sec

28000

450

500

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

FAR VDL
FAR Amplitude
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: June 8-13, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1947

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 780.9

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 524.0'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	502.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.8'

WATER LEVEL: 11.5'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
For VDL	3	111	Sopris	111	0.2	7	Transduc	3	1	none	no	501.6'	9.6'	492.0
Amplitude	3	111	Sopris	111	0.2	7	Transduc	3	1	none	no	501.6'	9.6'	492.0
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	no	500.6'	8.6'	492.0

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1947.sf0...sg0...sh0...sj0...sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1947 all equipment surveyed & "green tagged" by HP.

(10W1947B.HDP)

1947.sj0) 1947 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 98 uS)

0w1947.sj0) 1947 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 98 μ S)

WELL 1947 WAG 10 OU 3 Phase 1

Horizontal Offset (Cased to 500')

WELL 1948
(Alias: 3N-100)

ORNL WELL ID NO. 1948			
ORNL WELL ID NO.:	1948		
ALIAS:	3N-100		
WELL TYPE:	OBSERVATION WELL		
DRILLING METHOD:	ROTARY		
	CONVENTIONAL CORE	UNKNOWN DEPTHS	
EASTING:	28614.93		
NORTHING:	17257.19		
GROUND SURFACE ELEVATION:	785.1		
TOP OF RISER (PRE-MODIFICATION):	787.8		
TOP OF RISER (POST-MODIFICATION):	787.31		
CASING MATERIAL:	CARBON STEEL		
CASING STRING (FT):	UNKNOWN		
CONCRETE PAD	NONE		
GUARD POSTS	NONE		
BOREHOLE 1:	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
BOREHOLE 2:	UNKNOWN	UNKNOWN	UNKNOWN
BOREHOLE 3:	UNKNOWN	UNKNOWN	UNKNOWN
REPORTED DRILLED DEPTH (FT):	1034		
OPEN FORMATIONS:	NA		
DIVERTER CASING:	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
SURFACE CASING:	UNKNOWN	UNKNOWN	UNKNOWN
ISOLATION CASING (1):	7	UNKNOWN	UNKNOWN
ISOLATION CASING (2):	4	UNKNOWN	UNKNOWN
	1.25	UNKNOWN	UNKNOWN
CENTRALIZER (FT):	NONE APPARENT		
GROUT 1:	DEPTH (FT) FROM:	DEPTH (FT) TO:	
GROUT 2:	0	UNKNOWN	
GROUT 3:	0	UNKNOWN	
INTERPRETED CEMENT BOND LOG:	NA		
<p>NOTE: THE WELL DETAILS HAVE BEEN RECONSTRUCTED BASED ON SURFACE FEATURES AND AVAILABLE DATA. THE INFORMATION PROVIDED SHOULD BE CONSIDERED AS A BEST ESTIMATE.</p> <p>TO = TOTAL DEPTH NA = NOT AVAILABLE BOC = BOTTOM OF CASING</p>

1951.si0) 1951 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 76 us)

(10w1951.si0) 1951 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 76 us)

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

FAR VDL
FAR Amplitude
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: June 28-29, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1951

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 776.7

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 593.6'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	549.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1'

WATER LEVEL: 17'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Far VDL	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	590.0'	14.4'	575.6
Amplitude	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	590.0'	14.4'	575.6
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	589.0'	13.4'	575.6

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1951.sf0...sg0...sh0...sj0...sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1951 all equipment surveyed & "green tagged" by HP.

(10W1951B.HDP)

Amplitude
Amp Units
0 250

Records

Pointer

Microseconds Transit Time Tx to Far Receiver

Velocity
Ft/Sec
3000 28000

100 200 300 400 500 600 700 800 900 1000

(10w1951.sj0) 1951 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 76 uS)

Amplitude 0 250
Amp Units
Velocity 3000 28000
Ft/Sec
Records 100 200 300 400 500 600 700 800 900 1000
Microseconds Transit Time Tx to Far Receiver
Pointer

WELL 1951 WAG 10 OU 3 Phase 1

Horizontal Offset (Cased to 550')

WELL 1949
(Alias: 3N-150)

ORNL WELL ID NO. 1949

ORNL Well ID No.:	1949		
Alias:	3N-150		
Well Type:	Observation Well		
Drilling Method:	Cable/Conventional Core?		
Eastings:	28609.38		
Northings:	17312.28		
Ground Surface Elevation:	784.7		
Top of Riser (Pre-Modification):	787.98		
Top of Riser (Post-Modification):	787.93		
Casing Material:	Carbon Steel		
Casing String (ft):	30		
	Diameter (in.)	Depth (ft) from:	Depth (ft) to:
Borehole 1:	8.75	0	230
Borehole 2:	6.75	230	1023.6
Reported Drilled Depth (ft):	1050		
Open Formation:	Cased to TD		
	Diameter (in.)	Depth (ft) from:	Depth (ft) to:
Diverter Casing:	None Apparent		
Surface Casing:	7	+3.23	230
Isolation Casing:	2.5	0	1023.6
Centralizer (ft):	620		
	Depth (ft) from:	Depth (ft) to:	
Grout 1:	0	230	
Grout 2:	0	700	
Grout 3:	700	1023.6 (1050)	Latex Grout
	Depth (ft) from:	Depth (ft) to:	Quality:
Interpreted Cement Bond Log:	16	230	Bad
	230	630	Moderate
	630	1023.6 (BOC)	Bad

Note: The well details have been reconstructed based on geophysical log interpretation.
The information provided should be considered as a best estimate.
Possible break in casing at 555 ft.

TD = Total Depth
NA = Not Available

BOC = Bottom of Casing

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS631 7 Phone:(615)574-4558

SPR,SP,Caliper,Bk
Neutron,Gamma,App
Den,Fl Temp/Res

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: May 23-25, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1949

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 784.7

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 1022.6'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		2.5"	1023.6'+	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 3.3'

WATER LEVEL: 14'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
SPR	2	103	Compro	103	0.2	12	Pb Ring	na	na	none	na	1013.2	0.2	1013.0
Gamma	2	103	Compro	103	0.2	12	Nal Scin	na	na	none	na	1016.6	3.6	1013.0
Neutron	3	101	Compro	101	0.2	12	He3	na	na	AmBe	3 Ci	1022.6	4.4	1018.2
Caliper/SP	3	101	Compro	101	0.2	12	Pot/Pb	na	na	none	na	1017.8	0.2	1017.6
Background	4	102	Compro	102	0.2	12	Nal Scin	na	na	none	na	1019.6	604.0	415.6
App-Density	5	102	Compro	102	0.2	12	Nal Scin	na	na	Cs137	125mC	1021.2	4.2	1017.0
Fl-Temp/Res	1	127	Sopris	127	0.2	6	Trsd/Wen	na	na	none	na	0.2	699.0	698.8

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1949.gb0...dc2...nb0...td0...xa0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1949 all equipment surveyed & "green tagged" by HP.

(1949C.HDP)

(10w1949.xa0)

1949 WAG 10 OU 3 Phase 1 Composite Plot

(10w1949.xa0)

1949 WAG 10 OU 3 Phase 1 Composite Plot

rw1949.xao)

1949 WAG 10 OU 3 Phase 1 Composite Plot

ORNL

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
 BUILDING 3504 MS6317 Phone:(615)574-4558

NEAR VDL
 FAR Amplitude
 Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: May 23-25, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1949

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 784.7

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 1022.6'

BIT RECORD				CASING RECORD		
RUN NO.	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		2.5"	1023.6'+	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 3.3'

WATER LEVEL: . 14'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Near VDL	7	111	Sopris	111	0.2	7	Transduc	2	1	none	no	1009.8	14.0	995.8
Amplitude	7	111	Sopris	111	0.2	7	Transduc	3	1	none	no	1009.2	13.4	995.8
Velocity	7	111	Sopris	111	0.2	7	Computed	2/3	1	none	no	1008.2	12.4	995.8

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1949.sf0...sg0...sh0...si0...sj0...sw0

NOTE:

Depths corrected to ground level; casing
 stick-up was measured from TOC to metal rod
 placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1949 all equipment
 surveyed & "green tagged" by HP.

(10W1949A.HDP)

iw1949.sj0) 1949 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 76 uS)

(10w1949.sj0) 1949 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 76 μ S)

Amplitude

Amp Units

250

Records

Microseconds Transit Time Tx to Near Receiver

Pointer

Velocity

Ft/Sec

28000

100

200

300

400

500

600

700

800

900

1

450

500

550

600

650

700

750

800

850

(10w1949.sj0) 1949 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 76 μ S)

ORNL

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
 BUILDING 3504 MS6317 Phone:(615)574-4558

FAR VDL
 FAR Amplitude
 Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: May 23-25, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1949

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 784.7

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 1022.6'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		2.5"	1023.6'+	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 3.3'

WATER LEVEL: 14'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Far VDL	7	111	Sopris	111	0.2	7	Transduc	3	1	none	na	1009.2	13.4	995.8
Amplitude	7	111	Sopris	111	0.2	7	Transduc	3	1	none	na	1009.2	13.4	995.8
Velocity	7	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	1008.2	12.4	995.8

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1949.sf0...sg0...sh0...si0...sk0...sw0

NOTE:

Depths corrected to ground level; casing
 stick-up was measured from TOC to metal rod
 placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1949 all equipment
 surveyed & "green tagged" by HP.

(10W1949B.HDP)

jw1949.sk0) 1949 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 76 uS)

(10w1949.sk0) 1949 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 76 uS)

(10w1949.sk0) 1949 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 76 μ S)

WELL 1949 WAG 10 OU 3 Phase 1

Horizontal Offset (Cased to 1050')

WELL 1950
(Alias: 3N-200R)

ORNL WELL ID NO. 1950

ORNL WELL ID NO.:	1950		
ALIAS:	3N-200R		
WELL TYPE:	ROCK COVER		
DRILLING METHOD:	ROTARY		
EASTING:	28643.21		
NORTHING:	17361.74		
GROUND SURFACE ELEVATION:	790.3		
TOP OF RISER (PRE-MODIFICATION):	791.55		
OP OF RISER (POST-MODIFICATION):	792.03		
CASING MATERIAL:	CARBON STEEL		
CASING STRING (FT):	30		
CONCRETE PAD	NONE		
GUARD POSTS	NONE		
	WELL DIA. (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
BOREHOLE 1:	14.75	0	UNKNOWN
BOREHOLE 2:	8.75	UNKNOWN	60
BOREHOLE 3:	6.75	60	499
BOREHOLE 4:	3.25	499	596.6
REPORTED DRILLED DEPTH (FT):	650?		
OPEN FORMATION:	LOWER ROGERSVILLE SHALE/ UPPER RUTLEDGE LIMESTONE		
	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
DIVERTER CASING:	10	0	UNKNOWN
SURFACE CASING:	7	+1.73	60
ISOLATION CASING:	4.2	0	499
CENTRALIZERS (FT):	NONE APPARENT		
	DEPTH (FT) FROM:	DEPTH (FT) TO:	
GROUT 1:	0	UNKNOWN	
GROUT 2:	0	60	
GROUT 3:	0	499	
	DEPTH (FT) FROM:	DEPTH (FT) TO:	QUALITY:
INTERPRETED CEMENT BOND LOG:	36	200	BAD
	200	499 (BOC)	MODERATE

NOTE: THE WELL DETAILS HAVE BEEN RECONSTRUCTED BASED ON GEOPHYSICAL LOG INTERPRETATION.
THE INFORMATION PROVIDED SHOULD BE CONSIDERED AS A BEST ESTIMATE.
TO = TOTAL DEPTH
NA = NOT AVAILABLE
BOC = BOTTOM OF CASING

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS631 7 Phone:(615)574-4558

SPR,SP,Caliper
Neutron,Gamma,App
Den,Fl Temp/Res

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: May 9-10, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1950

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 790.3

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 596.8'

RUN		BIT RECORD		CASING RECORD		
NO.	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	499.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.7'

WATER LEVEL: 35'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
SPR	2	103	Compro	103	0.2	12	Pb Ring	na	na	none	na	592.4'	0.2'	592.2
Gamma	2	103	Compro	103	0.2	12	Nal Scin	na	na	none	na	595.8'	3.4'	592.4
Neutron	4	101	Compro	101	0.2	12	He3	na	na	AmBe	3 Ci	595.8'	4.2'	591.6
Caliper	4	101	Compro	101	0.2	12	Potential	na	na	none	na	590.8'	0.2'	590.6
SP	4	101	Compro	101	0.2	12	Pb Ring	na	na	none	na	591.8'	0.2'	591.6
App-Density	6	102	Compro	102	0.2	12	Nal Scin	na	na	Cs137	125mCi	595.0'	3.8'	591.2
Fl-Temp/Res	1	127	Sopris	127	0.2	6	Trsd/Wen	na	na	none	na	0.2'	596.8'	596.6

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1950.gb0...db0...nb0...td0...xa0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1950 all equipment surveyed & "green tagged" by HP.

(1950C.HDP)

(10w1950.xa0)

1950 WAG 10 OU 3 Phase 1 Composite Plot

(10w1950.xa0)

1950 WAG 10 OU 3 Phase 1 Composite Plot

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

NEAR VDL
FAR Amplitude
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: May 9-10, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1950

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 790.3

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 596.8'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	499.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.7'

WATER LEVEL: 35'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprabe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Near VDL	3	111	Sopris	111	0.2	7	Transduc	2	1	none	na	593.0'	35.0'	558.0
Amplitude	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	592.6'	34.4'	558.2
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	591.6'	33.4'	558.2

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1950.sf0...sg0...sh0...si0...sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1950 all equipment surveyed & "green tagged" by HP.

(10W1950A.HDP)

(10w1950.si0) 1950 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 98 μ S)

Amplitude
Amp Units 250
Velocity
Ft/Sec 3000 28000

Records Pointer

Microseconds Transit Time Tx to Near Receiver

100 200 300 400 500 600 700 800 900 1000

(10w1950.si0) 1950 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 98 uS)

ORNL

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
 BUILDING 3504 MS6317 Phone:(615)574-4558

FAR VDL
 FAR Amplitude
 Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: May 9-10, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1950

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 790.3

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 596.8'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	499.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.7'

WATER LEVEL: 35'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Far VDL	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	592.6'	34.4'	558.2
Amplitude	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	592.6'	34.4'	558.2
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	591.6'	33.4'	558.2

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1950.sf0...sg0...sh0...sj0...sw0

NOTE:

Depths corrected to ground level; casing
 stick-up was measured from TOC to metal rod
 placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1950 all equipment
 surveyed & "green tagged" by HP.

(10W1950B.HDP)

(10w1950.sj0) 1950 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 98 μ S)

(10w1950.sj0) 1950 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 98 uS)

WELL 1950 WAG 10 OU 3 Phase 1

Horizontal Offset (Cased to 500')

WELL 1951
(Alias: 3N-275R)

ORNL WELL ID NO. 1951				
ORNL WELL ID NO.:	1951			
ALIAS:	3N-27SR			
WELL TYPE:	ROCK COVER			
DRILLING METHOD:	ROTARY?			
EASTING:	28614.2			
NORTHING:	17432.29			
GROUND SURFACE ELEVATION:	776.7			
TOP OF RISER (PRE-MODIFICATION):	777.63			
OP OF RISER (POST-MODIFICATION):	777.62			
CASING MATERIAL:	CARBON STEEL			
CASING STRING (FT):	30			
CONCRETE PAD	NONE			
GUARD POSTS	NONE			
	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:	
BOREHOLE 1:	14.75	0	UNKNOWN	
BOREHOLE 2:	8.75	UNKNOWN	65	
BOREHOLE 3:	6.75	65	549	
BOREHOLE 4:	3.25	549	594.2	
REPORTED DRILLED DEPTH (FT):	600			
OPEN FORMATION:	LOWER RUTLEDGE			
	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:	
DIVERTER CASING:	10	0	UNKNOWN	
SURFACE CASING:	7	+0.92	65	
ISOLATION CASING:	4.2	0	549	
CENTRALIZERS (FT):	150			
	194			
	DEPTH (FT) FROM:	DEPTH (FT) TO:		
GROUT 1:	0	UNKNOWN		
GROUT 2:	0	192		
GROUT 3:	0	549		
	DEPTH (FT) FROM:	DEPTH (FT) TO:	QUALITY:	
INTERPRETED CEMENT BOND LOG:	17	50	BAD	
	50	549 (BOC)	GOOD	
NOTE: THE WELL DETAILS HAVE BEEN RECONSTRUCTED BASED ON GEOPHYSICAL LOG INTERPRETATION. THE INFORMATION PROVIDED SHOULD BE CONSIDERED AS A BEST ESTIMATE.				
TO = TOTAL DEPTH				
NA = NOT AVAILABLE				
BOC = BOTTOM OF CASING

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

SPR,SP,Caliper
Neutron,Gamma,App
Den,FI Temp/Res

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: June 28-29, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1951

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 776.7

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 593.6'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	549.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1'

WATER LEVEL: 17'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
SPR	2	103	Compro	103	0.2	12	Pb Ring	na	na	none	na	590.2'	0.2'	590.0
Gamma	2	103	Compro	103	0.2	12	Nal Scin	na	na	none	na	593.6'	3.6'	590.0
Neutron	4	101	Compro	101	0.2	12	He3	na	na	AmBe	3 Ci	593.2'	4.2'	589.0
Caliper	4	101	Compro	101	0.2	12	Potentio	na	na	none	na	588.4'	0.2'	588.2
SP	4	101	Compro	101	0.2	12	Pb Ring	na	na	none	na	589.2'	0.2'	589.0
App-Density	5	102	Compro	102	0.2	12	Nal Scin	na	na	Cs137	125mC	593.2'	4.2'	589.0
FI-Temp/Res	1	127	Sopris	127	0.2	6	Trsd/Wen	na	na	na	none	0.2'	552.4'	552.2

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1951.gb0...db0...nb0...td0...xa0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1951 all equipment surveyed & "green tagged" by HP.

(1951 C.HDP)

(10w1951.xa0)

1951 WAG 10 OU 3 Phase 1 Composite Plot

0w1951.xa0)

1951 WAG 10 OU 3 Phase 1 Composite Plot

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

NEAR VDL
FAR Amplitude
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: June 28-29, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1951

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 776.7

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 593.6'

RUN		BIT RECORD		CASING RECORD		
NO.	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	549.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1'

WATER LEVEL: 17'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Near VDL	3	111	Sopris	111	0.2	7	Transduc	2	1	none	na	590.6'	14.8'	575.8
Amplitude	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	590.0'	14.4'	575.6
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	589.0'	13.4'	575.6

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1951.sf0...sg0...sh0...si0...sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1951 all equipment surveyed & "green tagged" by HP.

(10W1951A.HDP)

WELL 1952
(Alias: 3N-375P)

ORNL WELL ID NO. 1952				
ORNL WELL ID NO.:	1952			
ALIAS:	3N-375P			
WELL TYPE:	UNFINISHED ROCK COVER			
DRILLING METHOD:	ROTARY			
EASTING:	28645.48			
NORTHING:	17518.95			
GROUND SURFACE ELEVATION:	771.5			
TOP OF RISER (PRE-MODIFICATION):	772.17			
TOP OF RISER (POST-MODIFICATION):	773.54			
CASING MATERIAL:	CARBON STEEL			
CASING STRING (FT):	25 & 30			
CONCRETE PAD	NONE			
GUARD POSTS	NONE			
BOREHOLE 1:	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:	
BOREHOLE 2:	8.75	0	78	
	6.75	78	488.6	
REPORTED DRILLED DEPTH (FT):	500			
OPEN FORMATION:	NO OPEN INTERVAL			
	(MIDDLE RUTLEDGE LIMESTONE)			
DIVERTER CASING:	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:	
SURFACE CASING:	NONE APPARENT			
ISOLATION CASING:	7	+2.04	78	
	4.2	0	488.6	
CENTRALIZERS (FT):	125			
GROUT 1:	DEPTH (FT) FROM:	DEPTH (FT) TO:		
GROUT 2:	0	78		
	0	488.6		
	DEPTH (FT) FROM:	DEPTH (FT) TO:	QUALITY:	
INTERPRETED CEMENT BOND LOG:	50	60	BAD	
	60	488.6 (BOC)	GOOD	
NOTE: THE WELL DETAILS HAVE BEEN RECONSTRUCTED BASED ON GEOPHYSICAL LOG INTERPRETATION.				
THE INFORMATION PROVIDED SHOULD BE CONSIDERED AS A BEST ESTIMATE.				
TD = TOTAL DEPTH				
NA = NOT AVAILABLE				
BOC = BOTTOM OF CASING

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS631 7 Phone:(615)574-4558

SPR,SP,Caliper
Neutron,Gamma,App
Den,FI Temp/Res

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: May 5-9, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1952

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 771.5

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 489.2'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	489.4'+	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 0.6'

WATER LEVEL: 51'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
SPR	3	103	Compro	103	0.2	12	Pb Ring	na	na	none	na	484.4'	0.2'	484.2
Gamma	3	103	Compro	103	0.2	12	Nal Scin	na	na	none	na	487.8'	3.4'	484.4
Neutron	5	101	Compro	101	0.2	12	He3	na	na	AmBe	3 Ci	487.6'	4.6'	483.0
Caliper	5	101	Compro	101	0.2	12	Potential	na	na	none	na	482.8'	0.2'	482.6
SP	5	101	Compro	101	0.2	12	Pb Ring	na	na	none	na	483.6'	0.6'	483.0
App-Density	6	102	Compro	102	0.2	12	Nal Scin	na	na	Cs137	125mCi	487.2'	4.2'	483.0
FI-Temp/Res	1	127	Sopris	127	0.2	6	Trsd/Wen	na	na	none	na	0.2'	489.2'	489.0

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1952.gb0...db0...nb0...td0...xa0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1952 all equipment surveyed & "green tagged" by HP.

(1952C.HDP)

(10w1952.xa0)

1952 WAG 10 OU 3 Phase 1 Composite Plot

(10w1952.xa0)

1952 WAG 10 OU 3 Phase 1 Composite Plot

SPR			Apparent Density			Fluid Resistivity		
60	OHMS	260	1.3	Gm/cc	2.7	-5	OHM-M	45
SP			Gamma			Temperature		
-600	mVolts	-200	0	CPS	100	57	Degrees F	61
Caliper			Neutron			Residual Temperature		
0.0	Inches	5.0	0	CPS	1000	-1.0	Degrees F	1.0

ORNL

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
 BUILDING 3504 MS6317 Phone:(615)574-4558

NEAR VDL
 FAR Amplitude
 Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: May 5-9, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1952

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 771.5

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 489.2'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	489.4'+	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 0.6'

WATER LEVEL: 51'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Near VDL	2	111	Sopris	111	0.2	7	Transduc	2	1	none	na	485.2'	50.4'	434.8
Amplitude	2	111	Sopris	111	0.2	7	Transduc	3	1	none	na	484.8'	50.0'	434.8
Velocity	2	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	483.8'	49.0'	434.8

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1952.sf0...sg0...sh0...si0...sw0

NOTE:

Depths corrected to ground level; casing
 stick-up was measured from TOC to metal rod
 placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1952 all equipment
 surveyed & "green tagged" by HP.

(10W1952A.HDP)

(10w1952.si0) 1952 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 98 uS)

Jw1952.si0) 1952 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 98 uS)

ORNL

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

FAR VDL
FAR Amplitude
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: May 5-9, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1952

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 771.5

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 489.2'

BIT RECORD				CASING RECORD		
RUN NO.	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	489.4'+	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 0.6'

WATER LEVEL: 51'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Far VDL	2	111	Sopris	111	0.2	7	Transduc	3	1	none	na	484.8'	50.0'	434.8
Amplitude	2	111	Sopris	111	0.2	7	Transduc	3	1	none	na	484.8'	50.0'	434.8
Velocity	2	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	483.8'	49.0'	434.8

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1952.sf0...sg0...sh0...sj0...sw0

NOTE:

Depths corrected to ground level; casing
stick-up was measured from TOC to metal rod
placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1952 all equipment
surveyed & "green tagged" by HP.

(10W1952B.HDP)

(10w1952.sj0) 1952 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 98 uS)

Amplitude
Amp Units 250
Velocity
Ft/Sec 3000 28000

Records Pointer

Microseconds Transit Time Tx to Far Receiver
100 200 300 400 500 600 700 800 900 10

WELL 1952 WAG 10 OU 3 Phase 1

Horizontal Offset (Cased to 500')

WELL 1953
(Alias: 3NE-100)

ORNL WELL ID NO. 1953				
ORNL WELL ID NO.:	1953			
ALIAS:	3NE-100			
WELL TYPE:	GROUT SHEET			
DRILLING METHOD:	ROTARY	500 ft		
	CONVENTIONAL CORE	500-1040 ft		
EASTING:	28721.06			
NORTHING:	17228.88			
GROUND SURFACE ELEVATION:	799.7			
TOP OF RISER (PRE-MODIFICATION):	800.84			
OP OF RISER (POST-MODIFICATION):	802.24			
CASING MATERIAL:	CARBON STEEL			
CASING STRING (FT):	20			
CONCRETE PAD	NONE			
GUARD POSTS	NONE			
	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:	
BOREHOLE 1:	14.75	0	UNKNOWN	
BOREHOLE 2:	8.75	UNKNOWN	147	
BOREHOLE 3:	6.75	147	497.5	
BOREHOLE 4:	3.5	497.5	1039.8	
REPORTED DRILLED DEPTH (FT):	1040			
OPEN FORMATION:	LOWER ROGERSVILLE SHALE			
	RUTLEDGE LIMESTONE			
	UPPER PUMPKIN VALLEY SHALE			
	LOWER PUMPKIN VALLEY SHALE			
	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:	
DIVERTER CASING:	10	0	UNKNOWN	
SURFACE CASING:	7	+1.14	147	
ISOLATION CASING:	4.2	0	497.5	
CENTRALIZERS (FT):	NONE APPARENT			
	DEPTH (FT) FROM:	DEPTH (FT) TO:		
GROUT 1:	0	UNKNOWN		
GROUT 2:	0	147		
GROUT 3:	0	497.5		
	DEPTH (FT) FROM:	DEPTH (FT) TO:	QUALITY:	
INTERPRETED CEMENT BOND LOG:	5	147	BAD	
	147	497.5 (BOC)	GOOD	
NOTE: THE WELL DETAILS HAVE BEEN RECONSTRUCTED BASED ON GEOPHYSICAL LOG INTERPRETATION.				
THE INFORMATION PROVIDED SHOULD BE CONSIDERED AS A BEST ESTIMATE.				
TD = TOTAL DEPTH				
NA = NOT AVAILABLE				
BOC = BOTTOM OF CASING

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

SPR,SP,Caliper
Neutron,Gamma
FI Temp/Res

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: Jul 19-25, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1953

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 799.7

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 1038.8'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	497.5'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.4'

WATER LEVEL: Flowing artesian

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
SPR	2	103	Compr	103	0.2	12	Pb Ring	na	na	none	na	1034.4	4.2	1030.2
Gamma	2	103	Compr	103	0.2	12	Nal Scin	na	na	none	na	1038.0	7.6	1030.4
Neutron	5	101	Compr	101	0.2	12	He3	na	na	AmBe	3 Ci	1038.8	9.0	1029.8
Caliper	5	101	Compr	101	0.2	12	Potentio	na	na	none	na	1034.0	4.2	1029.8
SP	5	101	Compr	101	0.2	12	Pb Ring	na	na	none	na	1034.8	5.0	1029.8
FI Temp/Res	1	127	Sopris	127	0.2	6	Trsd/Wen	na	na	none	na	0.2	1038.0	1037.8

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1953.gb0...nb1...td0...xo0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was pressurized (approx 30 psi).
On completion of logging 1953 cable & sondes were "yellow tagged"(5,000-150,000 CPM).
(1953C.HDP)

(10w1953.xa0)

1953 WAG 10 OU 3 Phase 1 Composite Plot

(10w1953.xa0)

1953 WAG 10 OU 3 Phase 1 Composite Plot

(10w1 953.xa0)

1953 WAG 10 OU 3 Phase 1 Composite Plot

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

NEAR VDL
FAR Amplitude
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: Jul 19-25, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1953

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 799.7

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 1038.8'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	497.5'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.4'

WATER LEVEL: Flowing artesian

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Near VDL	4	111	Sopris	111	0.2	7	Transduc	2	1	none	na	1037.8	4.8	1033.0
Amplitude	4	111	Sopris	111	0.2	7	Transduc	3	1	none	na	1037.4	4.4	1033.0
Velocity	4	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	1036.4	3.4	1033.0

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1953.sf0..sg0..sh0..si0..sj0..sk0..sl0..sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was pressurized (approx 30 psi).
On completion of logging 1953 cable & sondes were "yellow tagged" (5,000-150,000 CPM).
(10W1953A.HDP)

v1953.sl0) 1953 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 98 uS)

0w1953.sl0) 1953 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 98 μ S)

(10w1953.s10) 1953 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 98 μ S)

ORNL

ORNL GEOPHYSICS GROUP

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 BUILDING 3504 MS6317 Phone:(615)574-4558

FAR VDL
 FAR Amplitude
 Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: Jul 19-25, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1953

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 799.7

DEPTH REF. G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 1038.8'

BIT RECORD				CASING RECORD		
RUN NO.	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	+97.5'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.4'

WATER LEVEL: Flowing artesian

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Far VDL	4	111	Sopris	111	0.2	7	Transduc	3	1	none	na	1037.4	4.4	1033.0
Amplitude	4	111	Sopris	111	0.2	7	Transduc	3	1	none	na	1037.4	4.4	1033.0
Velocity	4	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	1036.4	3.4	1033.0

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1953.sf0..sg0..sh0..sj0..sk0..sm0..sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was pressurized (approx 30 psi).
 On completion of logging 1953 cable & sondes were "yellow tagged" (5,000-150,000 CPM).
 (10W1953B.HDP)

1w1953.sm0) 1953 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 98 μ S)

0w1953.sm0) 1953 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 98 uS)

WELL 1953 WAG 10 OU 3 Phase 1

Horizontal Offset (Cased to 500')

WELL 1953 WAG 10 OU 3 Phase 1

Plan View (Cased to 500')

WELL 1953 WAG 10 OU 3 Phase 1

N - S Cross-Section (Cased to 500')

WELL 1953 WAG 10 OU 3 Phase 1

E - W Cross-Section (Cased to 500')

(10w1953.sm0) 1953 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 98 μ S)

Amplitude Records Pointer
0 Amp Units 250 Microseconds Transit Time Tx to Far Receiver
3000 Velocity 28000 100 200 300 400 500 600 700 800 900 1

WELL 1955
(Alias: 3NE-125R)

ORNL WELL ID NO. 1955

ORNL WELL ID NO.:	1955		
ALIAS:	3NE-125R		
WELL TYPE:	ROCK COVER		
DRILLING METHOD:	ROTARY		
EASTING:	28688.53		
NORTHING:	17189.76		
GROUND SURFACE ELEVATION:	794.3		
TOP OF RISER (PRE-MODIFICATION):	794.63		
OP OF RISER (POST-MODIFICATION):	800.78		
CASING MATERIAL:	CARBON STEEL		
CASING STRING (FT):	30		
CONCRETE PAD	YES		
GUARD POSTS	NONE		
	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
BOREHOLE 1:	14.75	0	UNKNOWN
BOREHOLE 2:	8.75	UNKNOWN	UNKNOWN
BOREHOLE 3:	6.75	0	499
BOREHOLE 4:	3.2	499	598.4
REPORTED DRILLED DEPTH (FT):	600		
OPEN FORMATION:	MIDDLE ROGERSVILLE SHALE		
	UPPER RUTLEDGE LIMESTONE		
	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
DIVERTER CASING:	10	0	UNKNOWN
SURFACE CASING:	7	0	UNKNOWN
ISOLATION CASING:	4.2	0	499
CENTRALIZER (FT):	410		
	DEPTH (FT) FROM:	DEPTH (FT) TO:	
GROUT 1:	0	UNKNOWN	
GROUT 2:	0	UNKNOWN	
GROUT 3:	0	499	
	DEPTH (FT) FROM:	DEPTH (FT) TO:	QUALITY:
INTERPRETED CEMENT BOND LOG:	23	450	GOOD
	450	499 (BOC)	MODERATE

NOTE: THE WELL DETAILS HAVE BEEN RECONSTRUCTED BASED ON GEOPHYSICAL LOG INTERPRETATION.
 THE INFORMATION PROVIDED SHOULD BE CONSIDERED AS A BEST ESTIMATE.
 TD = TOTAL DEPTH
 NA = NOT AVAILABLE
 BOC = BOTTOM OF CASING

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

SPR,SP,Caliper
Neutron,Gamma,App
Den,FI Temp/Res

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: May 17-19, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1955

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 794.3

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 598.6'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	499.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.2'

WATER LEVEL: 22'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
SPR	2	103	Compro	103	0.2	12	Pb Ring	na	na	none	na	594.0'	0.2'	593.8
Gamma	2	103	Compro	103	0.2	12	Nal Scin	na	na	none	na	597.4'	3.4'	594.0
Neutron	3	101	Compro	101	0.2	12	He3	na	na	AmBe	3 Ci	597.4'	4.2'	593.2
Caliper	3	101	Compro	101	0.2	12	Potentio	na	na	none	na	592.6'	0.2'	592.4
SP	3	101	Compro	101	0.2	12	Pb Ring	na	na	none	na	593.4'	0.2'	593.2
App-Density	4	102	Compro	102	0.2	12	Nal Scin	na	na	Cs137	1.25mC	597.0'	4.0'	593.0
FI-Temp/Res	1	127	Sopris	127	0.2	6	Trsd/Wen	na	na	none	na	0.2'	598.6'	598.4

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1955.gb0...db0...nb0...td0...xa0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1955 all equipment surveyed & "green tagged" by HP.

(1955C.HDP)

(10w1955.xa0)

1955 WAG 10 OU 3 Phase 1 Composite Plot

1955 WAG 10 OU 3 Phase 1 Composite Plot

1955 WAG 10 OU 3 Phase 1 Composite Plot

ORNL

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
 BUILDING 3504 MS6317 Phone:(615)574-4558

NEAR VDL
 FAR Amplitude
 Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: May 17-19, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1955

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 794.3

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 598.6'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	499.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.2'

WATER LEVEL: 22'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprrobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Near VDL	5	111	Sopris	111	0.2	7	Transduc	2	1	none	na	594.8'	21.8'	573.0
Amplitude	5	111	Sopris	111	0.2	7	Transduc	3	1	none	na	594.2'	21.2'	573.0
Velocity	5	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	593.2'	20.2'	573.0

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1955.sf0...sg0...sh0...si0...sw0

NOTE:

Depths corrected to ground level; casing
 stick-up was measured from TOC to metal rod
 placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1955 all equipment
 surveyed & "green tagged" by HP.

(10W1955A.HDP)

1955.sio) 1955 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 98 US)

(10w1955.si0) 1955 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 98 uS)

ORNL

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558FAR VDL
FAR Amplitude
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: May 17-19, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1955

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 794.3

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 598.6'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	499.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.2'

WATER LEVEL: 22'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Far VDL	5	111	Sopris	111	0.2	7	Transduc	3	1	none	no	594.2'	21.2'	573.0
Amplitude	5	111	Sopris	111	0.2	7	Transduc	3	1	none	no	594.2'	21.2'	573.0
Velocity	5	111	Sopris	111	0.2	7	Computed	2/3	1	none	no	593.2'	20.2'	573.0

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1955.sf0...sg0...sh0...sj0...sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1955 all equipment surveyed & "green tagged" by HP.

(10W1955B.HDP)

v1955.sj0) 1955 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 98 μ S)

Amplitude

Amp Units

Velocity

Ft/Sec

Records

Microseconds Transit Time Tx to Far Receiver

Pointer

0

250

3000

28000

100

200

300

400

500

600

700

800

900

50

100

150

200

250

300

350

400

(10w1955.sj0) 1955 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 98 uS)

WELL 1955 WAG 10 OU 3 Phase 1

Horizontal Offset (Cased to 500')

WELL 1956
(Alias: 3NE-200R)

ORNL WELL ID NO. 1956			
ORNL WELL ID NO.:	1956		
ALIAS:	JNE-200R		
WELL TYPE:	ROCK COVER		
DRILLING METHOD:	ROTARY		
EASTING:	28759.6		
NORTHING:	17301.33		
GROUND SURFACE ELEVATION:	806.1		
TOP OF RISER (PRE-MODIFICATION):	807.12		
OP OF RISER (POST-MODIFICATION):	807.06		
CASING MATERIAL:	CARBON STEEL		
CASING STRING (FT):	30		
CONCRETE PAD	YES		
GUARD POSTS	NONE		
	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
BOREHOLE 1:	14.75		UNKNOWN
BOREHOLE 2:	8.75	UNKNOWN	130
BOREHOLE 3:	6.75		549
BOREHOLE 4:	3.6	549	598.4
REPORTED DRILLED DEPTH (FT):	600		
OPEN FORMATION:	LOWER ROGERSVILLE SHALE		
	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
DIVERTER CASING:	10		UNKNOWN
SURFACE CASING:	7	+0.96	130
ISOLATION CASING:	4.2	0	549
CENTRALIZER (FT):	70		
	DEPTH (FT) FROM:	DEPTH (FT) TO:	
GROUT 1:	0	UNKNOWN	
GROUT 2:	0	130	
GROUT 3:	130	549	
	DEPTH (FT) FROM:	DEPTH (FT) TO:	QUALITY:
INTERPRETED CEMENT BOND LOG:	27	500	GOOD
	500	549 (BOC)	BAD
NOTE: THE WELL DETAILS HAVE BEEN RECONSTRUCTED BASED ON GEOPHYSICAL LOG INTERPRETATION. THE INFORMATION PROVIDED SHOULD BE CONSIDERED AS A BEST ESTIMATE.			
TD = TOTAL DEPTH			
NA = NOT AVAILABLE			
BOC = BOTTOM OF CASING

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

SPR,SP,Caliper
Neutron,Gamma,App
Den,FI Temp/Res

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: May 12-17, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1956

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 806.1

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 589.6'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	499.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.1'

WATER LEVEL: 26.5'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
SPR	2	103	Compr	103	0.2	12	Pb Ring	na	na	none	na	585.0'	0.2'	584.8
Gamma	2	103	Compr	103	0.2	12	NaI Scin	na	na	none	na	588.4'	3.6'	584.8
Neutron	5	101	Compr	101	0.2	12	He3	na	na	AmBe	3 Ci	588.0'	4.2'	583.2
Caliper	5	101	Compr	101	0.2	12	Potentio	na	na	none	na	583.0'	0.2'	582.8
SP	5	101	Compr	101	0.2	12	Pb Ring	na	na	none	na	584.0'	0.2'	583.8
App-Density	6	102	Compr	102	0.2	12	NaI Scin	na	na	Cs137	1.25mC	588.0'	4.0'	584.0
FI-Temp/Res	1	127	Sopris	127	0.2	6	Trsd/Wen	na	na	na	na	0.2'	589.6'	589.4

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1956.gb0...db0...nb0...td0...xa0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1956 all equipment surveyed & "green tagged" by HP.

(1956C.HDP)

(10w1956.xa0)

1956 WAG 10 OU 3 Phase 1 Composite Plot

w1956.xa0)

1956 WAG 10 OU 3 Phase 1 Composite Plot

ORNL

ORNL GEOPHYSICS GROUP

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 BUILDING 3504 MS6317 Phone:(615)574-4558

NEAR VDL
 FAR Amplitude
 Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: May 12-17, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1956

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 806.1

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 589.6'

RUN	BIT RECORD			CASING RECORD		
NO.	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	499.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.1'

WATER LEVEL: 26.5'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Near VDL	3	111	Sopris	111	0.2	7	Transduc	2	1	none	no	585.8'	26.4'	559.4
Amplitude	3	111	Sopris	111	0.2	7	Transduc	3	1	none	no	585.4'	25.8'	559.5
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	no	584.4'	24.8'	559.6

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1956.sf0...sg0...sh0...si0...sw0

NOTE:

Depths corrected to ground level; casing
 stick-up was measured from TOC to metal rod
 placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1956 all equipment
 surveyed & "green tagged" by HP.

(10W1956A.HDP)

(10w1956.si0) 1956 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 98 μ S)

Amplitude Records Pointer
0 Amp Units 250 Microseconds Transit Time Tx to Near Receiver
3000 Velocity 28000 100 200 300 400 500 600 700 800 900 10

Jw1956.si0) 1956 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 98 uS)

ORNL

ORNL GEOPHYSICS GROUP

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 BUILDING 3504 MS6317 Phone:(615)574-4558

FAR VDL
 FAR Amplitude
 Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: May 12-17, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1956

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 806.1

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 589.6'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	499.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.1'

WATER LEVEL: 26.5'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprabe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Far VDL	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	585.4'	25.8'	559.6
Amplitude	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	585.4'	25.8'	559.6
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	584.4'	24.8'	559.6

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1956.sf0...sg0...sh0...sj0...sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1956 all equipment, surveyed & "green tagged" by HP.

(10W1956B.HDP)

(10w1956.sj0) 1956 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 98 μ S)

Amplitude	Records	Pointer
0		
250		
3000		
28000		

Microseconds Transit Time Tx to Far Receiver

100	200	300	400	500	600	700	800	900	1000
-----	-----	-----	-----	-----	-----	-----	-----	-----	------

(10w1956.sj0) 1956 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 98 uS)

Amplitude
0 250
Amp Units
Records
Pointer
Velocity
3000 28000
Ft/Sec
Microseconds Transit Time Tx to Far Receiver
100 200 300 400 500 600 700 800 900 10

WELL 1956 WAG 10 OU 3 Phase 1

Horizontal Offset (Cased to 550')

WELL 1957
(Alias: 3NE-300P)

ORNL WELL ID NO. 1957

ORNL WELL ID NO.:	1957		
ALIAS:	3NE-300P		
WELL TYPE:	UNFINISHED ROCK COVER		
DRILLING METHOD:	ROTARY		
EASTING:	28837.15		
NORTHING:	17379.59		
GROUND SURFACE ELEVATION:	814.8		
TOP OF RISER (PRE-MODIFICATION):	816.06		
OP OF RISER (POST-MODIFICATION):	815.98		
CASING MATERIAL:	CARBON STEEL		
CASING STRING (FT):	25		
CONCRETE PAD	YES		
GUARD POSTS	NONE		
		DIAMETER (IN.)	DEPTH (FT) FROM: DEPTH (FT) TO:
BOREHOLE 1:	10		0 42
BOREHOLE 2:	6.75		42 493
REPORTED DRILLED DEPTH (FT):	500		
OPEN FORMATION:	NO OPEN INTERVAL (LOWER ROGERSVILLE SHALE)		
		DIAMETER (IN.)	DEPTH (FT) FROM: DEPTH (FT) TO:
DIVERTER CASING:	NONE APPARENT		
SURFACE CASING:	7	+1.18	42
ISOLATION CASING:	4.2	0	493
CENTRALIZER (FT):	NONE APPARENT		
		DEPTH (FT) FROM: DEPTH (FT) TO:	
GROUT 1:	0		42
GROUT 2:	0		493
		DEPTH (FT) FROM: DEPTH (FT) TO:	QUALITY:
INTERPRETED CEMENT BOND LOG:	2	42	BAD
	42	493 (BOC)	GOOD

NOTE: THE WELL DETAILS HAVE BEEN RECONSTRUCTED BASED ON GEOPHYSICAL LOG INTERPRETATION.
 THE INFORMATION PROVIDED SHOULD BE CONSIDERED AS A BEST ESTIMATE.
 TD = TOTAL DEPTH
 NA = NOT AVAILABLE
 BOC = BOTTOM OF CASING

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

SPR,SP,Caliper
Neutron,Gamma,App
Den,FI Temp/Res

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: May 11-12, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1957

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 814.8

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 493.0'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	493.4'+	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.3'

WATER LEVEL: 1.5'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
SPR	2	103	Compr	103	0.2	12	Pb Ring	na	na	none	na	489.2'	0.2'	489.0
Gamma	2	103	Compr	103	0.2	12	NaI Scin	na	na	none	na	492.6'	3.6'	489.0
Neutron	5	101	Compr	101	0.2	12	He3	na	na	AmBe	3 Ci	492.4'	4.2'	488.2
Caliper	5	101	Compr	101	0.2	12	Potentio	na	na	none	na	487.6'	0.2'	487.4
SP	5	101	Compr	101	0.2	12	Pb Ring	na	na	none	na	488.4'	0.2'	488.2
App-Density	6	102	Compr	102	0.2	12	NaI Scin	na	na	Cs137	125mC	491.6'	4.0'	487.6
FI-Temp/Res	1	127	Sopris	127	0.2	6	Trsd/Wen	na	na	na	na	0.2'	493.0'	492.8

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1957.gb0...db0...nb0...td0...xa0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1957 all equipment surveyed & "green tagged" by HP.

(1957C.HDP)

(10w1957.xa0)

1957 WAG 10 OU 3 Phase 1 Composite Plot

(10w1957.xa0)

1957 WAG 10 OU 3 Phase 1 Composite Plot

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

NEAR VDL
FAR Amplitude
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: May 11-12, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1957

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 814.8

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 493.0'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	493.4'+	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.3'

WATER LEVEL: 1.5'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Near VDL	3	111	Sopris	111	0.2	7	Transduc	2	1	none	na	491.0'	2.2'	488.8
Amplitude	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	490.4'	1.6'	488.8
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	489.4'	0.6'	488.8

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1957.sf0...sg0...sh0...si0...sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1957 all equipment surveyed & "green tagged" by HP.

(10W1957A.HDP)

1957 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 98 μ S)

Amplitude
Amp Units

250

Records

Pointer

Velocity
Ft/Sec

28000

Microseconds Transit Time Tx to Near Receiver

100

200

300

400

500

600

700

800

900

1000

(10w1957.si0) 1957 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 98 μ S)

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

FAR VDL
FAR Amplitude
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: May 11-12, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1957

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 814.8

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 493.0'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	493.4'+	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.3'

WATER LEVEL: 1.5'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Far VDL	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	490.4'	1.6'	488.8
Amplitude	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	490.4'	1.6'	488.8
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	489.4'	0.6'	488.8

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1957.sf0...sg0...sh0...sj0...sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.
On completion of logging 1957 all equipment surveyed & "green tagged" by HP.
(10W1957B.HDP)

(10w1957.sj0) 1957 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 98 uS)

Amplitude
Amp Units
Velocity
Ft/Sec

250

28000

Records

Microseconds Transit Time Tx to Far Receiver

Pointer

100

200

300

400

500

600

700

800

900

10

0

50

100

150

200

250

300

350

400

(10w1957.sj0) 1957 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 98 μ S)

WELL 1957 WAG 10 OU 3 Phase 1

Horizontal Offset (Cased to 500')

WELL 1958
(Alias: 3NW-100)

ORNL WELL ID NO. 1958

ORNL WELL ID NO.:	1958		
ALIAS:	3HW-100		
WELL TYPE:	OBSERVATION WELL		
DRILLING METHOD:	ROTARY		
	CONVENTIONAL CORE	UNKNOWN DEPTHS	
EASTING:	28544.63		
NORTHING:	17226.40		
GROUND SURFACE ELEVATION:	776.9		
TOP OF RISER (PRE-MODIFICATION):	NA		
TOP OF RISER (POST-MODIFICATION):	778.31		
CASING MATERIAL:	CARBON STEEL		
CASING STRING (FT):	UNKNOWN		
CONCRETE PAD	NONE		
GUARD POSTS	NONE		
	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
BOREHOLE 1:	UNKNOWN	UNKNOWN	UNKNOWN
BOREHOLE 2:	UNKNOWN	UNKNOWN	UNKNOWN
BOREHOLE 3:	UNKNOWN	UNKNOWN	UNKNOWN
REPORTED DRILLED DEPTH(FT):	1026		
OPEN FORMATIONS:	NA		
	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
DIVERTER CASING:	UNKNOWN	UNKNOWN	UNKNOWN
SURFACE CASING:	7	UNKNOWN	UNKNOWN
ISOLATION CASING (1):	4	UNKNOWN	UNKNOWN
ISOLATION CASING (2):	1.25	UNKNOWN	UNKNOWN
CENTRALIZER (FT):	NONE APPARENT		
	DEPTH (FT) FROM:	DEPTH (FT) TO:	
GROUT 1:	0	UNKNOWN	
GROUT 2:	0	UNKNOWN	
GROUT 3:	0	UNKNOWN	
INTERPRETED CEMENT BOND LOG:	NA		
NOTE: THE WELL DETAILS HAVE BEEN RECONSTRUCTED BASED ON SURFACE FEATURES AND AVAILABLE DATA. THE INFORMATION PROVIDED SHOULD BE CONSIDERED AS A BEST ESTIMATE.			
TO = TOTAL DEPTH			
NA = NOT AVAILABLE			
BOC = BOTTOM OF CASING

WELL 1959
(Alias: 3NW-175R)

ORNL WELL ID NO. 1959				
ORNL WELL ID NO.:	1959			
ALIAS:	3NW-175R			
WELL TYPE:	ROCK COVER			
DRILLING METHOD:	ROTARY			
EASTING:	28491.97			
NORTHING:	17280.53			
GROUND SURFACE ELEVATION:	771.5			
TOP OF RISER (PRE-MODIFICATION):	772.31			
TOP OF RISER (POST-MODIFICATION):	773.67			
CASING MATERIAL:	CARBON STEEL			
CASING STRING (FT):	30			
CONCRETE PAD	YES			
GUARD POSTS	NONE			
	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:	
BOREHOLE 1:	14.75	0	40	
BOREHOLE 2:	8.75	40	120	
BOREHOLE 3:	6.75	120	492.5	
BOREHOLE 4:	3	492.5	597	
REPORTED DRILLED DEPTH (FT):	5702			
OPEN FORMATION:	LOWER ROGERSVILLE SHALE RUTLEDGE LIMESTONE			
	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:	
DIVERTER CASING:	10	0	40	
SURFACE CASING:	7	+2.17	120	
ISOLATION CASING:	4.2	0	492.5	
CENTRALIZER (FT):	185			
	DEPTH (FT) FROM:	DEPTH (FT) TO:		
GROUT 1:	0	40		
GROUT 2:	0	120		
GROUT 3:	0	492.5		
	DEPTH (FT) FROM:	DEPTH (FT) TO:	QUALITY:	
INTERPRETED CEMENT BOND LOG:	29	40	BAD	
	40	492.5 (BOC)	GOOD	
NOTE: THE WELL DETAILS HAVE BEEN RECONSTRUCTED BASED ON GEOPHYSICAL LOG INTERPRETATION. THE INFORMATION PROVIDED SHOULD BE CONSIDERED AS A BEST ESTIMATE. TD = TOTAL DEPTH NA = NOT AVAILABLE BOC = BOTTOM OF CASING

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

SPR,SP,Caliper
Neutron,Gamma,App
Den,Fl Temp/Res

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: April 26-28, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1959

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 771.5

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 597.0'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	492.5'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 0.9'

WATER LEVEL: 28'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
SPR	2	103	Compro	103	0.2	12	Pb Ring	na	na	none	na	592.4'	0.2'	592.2
Gamma	2	103	Compro	103	0.2	12	Nal Scin	na	na	none	na	595.8'	3.6'	592.2
Neutron	4	101	Compro	101	0.2	12	He3	na	na	AmBe	3 Ci	596.0'	4.2'	591.8
Caliper	4	101	Compro	101	0.2	12	Potentio	na	na	none	na	591.2'	0.2'	591.0
SP	4	101	Compro	101	0.2	12	Pb Ring	na	na	none	na	592.0'	0.2'	591.8
App-Density	5	102	Compro	102	0.2	12	Nal Scin	na	na	Cs137	125mC	594.8'	4.0'	590.8
Fl-Temp/Res	1	127	Sopris	127	0.2	6	Trsd/Wen	na	na	none	na	0.2'	597.0'	596.8

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1959.gb0...db0...nb0...td0...xa0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1959 all equipment surveyed & "green tagged" by HP.

(1959C.HDP)

(10w1959.xa0)

1959 WAG 10 OU 3 Phase 1 Composite Plot

(10w1959.xa0)

1959 WAG 10 OU 3 Phase 1 Composite Plot

50	SPR	200	1.3	Apparent Density	3.0	-5	Fluid Resistivity	65
	OHMS			Gm/cc			OHM-M	
-900	SP	-100	0	Gamma	100	58	Temperature	62
	mVolts			CPS			Degrees F	
0.0	Caliper	5.0	0	Neutron	1000	-1.0	Residual Temperature	1.0
	Inches			CPS			Degrees F

ORNL

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
 BUILDING 3504 MS631 7 Phone:(615)574-4558

NEAR VDL, FAR Amp
 FAR Tube-Wave Amp
 Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: April 26-28, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1959

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 771.5

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 597.0'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	492.5'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 0.9'

WATER LEVEL: 28'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Near VDL	3	111	Sopris	111	0.2	7	Transduc	2	1	none	na	590.4'	28.8'	561.6
Far TW-Amp	3	111	Sopris	111	0.2	7	Computed	3	1	none	na	590.0'	28.4'	561.6
Amplitude	3	111	Sopris	111	0.2	7	Computed	3	1	none	na	590.0'	24.8'	565.2
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	589.0'	27.4'	561.6

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1959.sf0.sg0.sh0.si0.sj0.sk0.sl0.sr0.sw0

NOTE:

Depths corrected to ground level; casing
 stick-up was measured from TOC to metal rod
 placed in the ground on north side of casing.

This well was not pressurized.
 On completion of logging 1959 all equipment
 surveyed & "green tagged" by HP.
 (10W1959A.HDP)

0w1959.sm0) 1959 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 76 uS)

(10w1959.sm0) 1959 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 76 uS)

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

FAR VDL, FAR Amp
FAR Tube-Wave Amp
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: April 26-28, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1959

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 771.5

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 597.0'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	492.5'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 0.9'

WATER LEVEL: 28'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Far VDL	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	590.0'	24.8'	565.2
Far TW-Amp	3	111	Sopris	111	0.2	7	Computed	3	1	none	na	590.0'	28.4'	561.6
Amplitude	3	111	Sopris	111	0.2	7	Computed	3	1	none	na	590.0'	24.8'	565.2
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	589.0'	27.4'	561.6

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1959.sf0.sg0.sh0.si0.sj0.sk0.sl0.sn0.sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.
On completion of logging 1959 all equipment surveyed & "green tagged" by HP.
(10W1959B.HDP)

0w1959.sn0) 1959 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 76 uS)

(10w1959.sn0) 1959 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 76 uS)

WELL 1959 WAG 10 OU 3 Phase 1

Horizontal Offset (Cased to 500')

WELL 1960
(Alias: 3NW-250R)

ORNL WELL ID NO. 1960

ORNL WELL ID NO.:	1960		
ALIAS:	3NW-250R		
WELL TYPE:	ROCK COVER		
DRILLING METHOD:	ROTARY		
EASTING:	28438.32		
NORTHING:	17332.62		
GROUND SURFACE ELEVATION:	759.3		
TOP OF RISER (PRE-MODIFICATION):	760.98		
TOP OF RISER (POST-MODIFICATION):	760.85		
CASING MATERIAL:	CARBON STEEL		
CASING STRING (FT):	30		
CONCRETE PAD:	NONE		
GUARD POSTS:	NONE		
	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
BOREHOLE 1:	14.75	0	30
BOREHOLE 2:	8.75	30	90
BOREHOLE 3:	6.75	90	542
BOREHOLE 4:	3.5	542	557.8
REPORTED DRILLED DEPTH (FT):	600		
OPEN FORMATION:	SHORT OPEN INTERVAL (LOWER RUTLEDGE LIMESTONE)		
	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
DIVERTER CASING:	10	0	30
SURFACE CASING:	7	+1.55	90
ISOLATION CASING:	4.2	0	542
CENTRALIZER (FT):	285		
	DEPTH (FT) FROM:	DEPTH (FT) TO:	
GROUT 1:	0	0	30
GROUT 2:	0	30	90
GROUT 3:	0	542	
	DEPTH (FT) FROM:	DEPTH (FT) TO:	QUALITY:
INTERPRETED CEMENT BOND LOG:	18	90	BAD
	90	542 (BOC)	GOOD

NOTE: THE WELL DETAILS HAVE BEEN RECONSTRUCTED BASED ON GEOPHYSICAL LOG INTERPRETATION.
 THE INFORMATION PROVIDED SHOULD BE CONSIDERED AS A BEST ESTIMATE.
 TO = TOTAL DEPTH
 NA = NOT AVAILABLE
 BOC = BOTTOM OF CASING

ORNL GEOPHYSICS GROUP P. O. BOX 2008, OAK RIDGE, TN.37831-6317 BUILDING 3504 MS6317 Phone:(615)574-4558	SPR,SP,Caliper Neutron,Gamma,App Den,FI Temp/Res
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PROJECT: WAG 10 OU 3 Phase 1 DATE LOGGED: May 2-4, 1994
 CLIENT: BECHTEL/ER WELL NUMBER: 1960
 LOCATION: OHF, X-10, Oak Ridge National Laboratory
 STATE: Tennessee COUNTY: Roane ELEV: 759.3 DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A
 DRILLER TD: N/A LOGGED TD: 557.8'

RUN	BIT RECORD			CASING RECORD		
NO.	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	542.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A
 CASING STICK UP: 1.6' WATER LEVEL: 17.5'
 DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris UNIT/TRUCK: UNIT-1/E09848
 LOGGING ENGINEER: R. O. Kennard
 GEOPHYSICIST: R. Kim Davis
 OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
SPR	2	103	Compro	103	0.2	12	Pb Ring	na	na	none	na	554.4'	0.2'	554.2
Gamma	2	103	Compro	103	0.2	12	Nal Scin	na	na	none	na	557.8'	3.6'	554.2
Neutron	4	101	Compro	101	0.2	12	He3	na	na	AmBe	3 Ci	556.8'	4.2'	552.6
Caliper	4	101	Compro	101	0.2	12	Potential	na	na	none	na	552.0'	0.2'	551.8
SP	4	101	Compro	101	0.2	12	Pb Ring	na	na	none	na	552.8'	0.2'	552.6
App-Density	5	102	Compro	102	0.2	12	Nal Scin	na	na	Cs137	125mCi	556.0'	4.2'	551.8
FI-Temp/Res	1	127	Sopris	127	0.2	6	Trsd/Wen	na	na	none	na	0.2'	557.8'	557.6

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1960.gb0...db0...nb0...td0...xa0

NOTE:

Depths corrected to ground level; casing
 stick-up was measured from TOC to metal rod
 placed in the ground on north side of casing.

This well was not pressurized.
 On completion of logging 1960 all equipment
 surveyed & "green tagged" by HP.
 (1960C.HDP)

(10w1960.xa0)

1960 WAG 10 OU 3 Phase 1 Composite Plot

(10w1960.xa0)

1960 WAG 10 OU 3 Phase 1 Composite Plot

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

NEAR VDL
FAR Amplitude
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: May 2-4, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1960

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 759.3

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 557.8'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	542.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.6'

WATER LEVEL: 17.5'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Near VDL	3	111	Sopris	111	0.2	7	Transduc	2	1	none	na	554.6'	17.4'	537.2
Amplitude	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	554.0'	17.0'	537.0
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	553.0'	16.0'	537.0

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1960.sf0...sg0...sh0...si0...sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1960 all equipment surveyed & "green tagged" by HP.

(10W1960A.HDP)

w1960.si0) 1960 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 98 uS)

Jw1960.si0) 1960 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 98 uS)

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

FAR VDL
FAR Amplitude
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: May 2-4, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1960

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 759.3

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 557.8'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	542.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.6'

WATER LEVEL: 17.5'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Far VDL	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	554.0'	17.0'	537.0
Amplitude	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	554.0'	17.0'	537.0
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	553.0'	16.0'	537.0

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1960.sf0...sg0...sh0...sj0...sw0

NOTE:

Depths corrected to ground level; casing
stick-up was measured from TOC to metal rod
placed in the ground on north side of casing.

This well was not pressurized.
On completion of logging 1960 all equipment
surveyed & "green tagged" by HP.
(10W1960B.HDP)

0w1960.sj0) 1960 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 98 uS)

WELL 1960 WAG 10 OU 3 Phase 1

Horizontal Offset (Cased to 540')

WELL 1961
(Alias: 3NW-290P)

ORNL WELL ID NO. 1961			
ORNL WELL ID NO.:	1961		
ALIAS:	3NW-290P		
WELL TYPE:	UNFINISHED ROCK COVER		
DRILLING METHOD:	ROTARY		
EASTING:	28409.97		
NORTHING:	17360.35		
GROUND SURFACE ELEVATION:	758.9		
TOP OF RISER (PRE-MODIFICATION):	759.69		
TOP OF RISER (POST-MODIFICATION):	759.69		
CASING MATERIAL:	CARBON STEEL		
CASING STRING (FT):	30		
CONCRETE PAD	NONE		
GUARD POSTS	NONE		

	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
BOREHOLE 1:	14.75	0	40
BOREHOLE 2:	8.75	40	195?
BOREHOLE 3:	6.75	195?	494

REPORTED DRILLED DEPTH (FT):	500		
OPEN FORMATION:	NO OPEN INTERVAL		
	(UPPER RUTLEDGE LIMESTONE)		

	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
DIVERTER CASING:	10	0	40
SURFACE CASING:	7	+0.79	195?
ISOLATION CASING:	4.2	0	494
CENTRALIZER (FT):	125		

	DEPTH (FT) FROM:	DEPTH (FT) TO:	
GROUT 1:	0	40	
GROUT 2:	0	195?	
GROUT 3:	0	494	

	DEPTH (FT) FROM:	DEPTH (FT) TO:	QUALITY:
INTERPRETED CEMENT BOND LOG:	10	60	BAD
	60	195	MODERATE
	195	494 (BOC)	GOOD

NOTE: THE WELL DETAILS HAVE BEEN RECONSTRUCTED BASED ON GEOPHYSICAL LOG INTERPRETATION.
 THE INFORMATION PROVIDED SHOULD BE CONSIDERED AS A BEST ESTIMATE.

TD = TOTAL DEPTH
 NA = NOT AVAILABLE
 BOC = BOTTOM OF CASING

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

SPR,SP,Caliper
Neutron,Gamma,App
Den, FI Temp/Res

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: April 21-25, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1961

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 758.9

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 494.0'

BIT RECORD				CASING RECORD		
RUN NO.	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	494.0'+	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.2'

WATER LEVEL: 10'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
SPR	2	103	Compro	103	0.2	12	Pb Ring	na	na	none	na	490.0'	0.2'	489.8
Gamma	2	103	Compro	103	0.2	12	NaI Scin	na	na	none	na	493.4'	3.4'	490.0
Neutron	4	101	Compro	101	0.2	12	He3	na	na	AmBe	3 Ci	493.0'	4.0'	489.0
Caliper	4	101	Compro	101	0.2	12	Potential	na	na	none	na	488.2'	0.2'	488.0
SP	4	101	Compro	101	0.2	12	Pb Ring	na	na	none	na	489.0'	0.2'	488.8
App-Density	5	102	Compro	102	0.2	12	NaI Scin	na	na	Cs137	125mCi	492.8'	4.0'	488.8
FI-Temp/Res	1	127	Sopris	127	0.2	6	Trsd/Wen	na	na	none	na	10.0'	498.2'	488.2

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1961.gb0...db0...nb0...td0...xa0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1961 all equipment surveyed & "green tagged" by HP.

(1961 C.HDP)

(10w1961.xa0)

1961 WAG 10 OU 3 Phase 1 Composite Plot

(10w1961.xa0)

1961 WAG 10 OU 3 Phase 1 Composite Plot

ORNL

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
 BUILDING 3504 MS6317 Phone:(615)574-4558

NEAR VDL

FAR Amplitude
 Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: April 21-25, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1961

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 758.9

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 494.0'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	494.0'+	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.2'

WATER LEVEL: 10'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Near VDL	3	111	Sopris	111	0.2	7	Transduc	2	1	none	na	490.4'	8.4'	482.0
Amplitude	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	489.8'	8.0'	481.8
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	488.8'	7.0'	481.8

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1961.sf0...sg0...sh0...si0...sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1961 all equipment surveyed & "green tagged" by HP.

(10W1961A.HDP)


```

w1961.si0) 1961 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 98 uS)

```

Amp Units

Velocity

Records

Pointer

Microseconds Transit Time Tx to Near Receiver

3000

$$\frac{\text{Velocity}}{\text{Ft/Sec}}$$

28000

100

200

300

400

500

600

700

800

900

10 |

ORNL

ORNL GEOPHYSICS GROUP

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 BUILDING 3504 MS6317 Phone:(615)574-4558

FAR VDL
 FAR Amplitude
 Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: April 21-25, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1961

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 758.9

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 494.0'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	494.0'+	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 1.2'

WATER LEVEL: 10'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Far VDL	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	489.8'	8.0'	481.8
Amplitude	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	489.8'	8.0'	481.8
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	488.8'	7.0'	481.8

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1961.sf0...sg0...sh0...sj0...sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1961 all equipment surveyed & "green tagged" by HP.

(10W1961B.HDP)

0w1961.sj0) 1961 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 98 uS)

WELL 1961 WAG 10 OU 3 Phase 1

Horizontal Offset (Cased to 500')

WELL 1962
(Alias: 3S-100)

ORNL WELL ID NO. 1962				
ORNL WELL ID NO.:	1962			
WELL TYPE:	OBSERVATION WELL			
DRILLING METHOD:	ROTARY			
EASTING:	28615.50			
NORTHING:	17056.67			
GROUND SURFACE ELEVATION:	784.8			
TOP OF RISER (PRE-MODIFICATION):	787.3			
TOP OF RISER (POST-MODIFICATION):	786.9			
CASING MATERIAL:	CARBON STEEL			
CASING STRING (FT):	UNKNOWN			
CONCRETE PAD	NONE			
GUARD POSTS	NONE			
BOREHOLE 1:	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:	
BOREHOLE 2:	UNKNOWN	UNKNOWN	UNKNOWN	
BOREHOLE 3:	UNKNOWN	UNKNOWN	UNKNOWN	
REPORTED DRILLED DEPTH (FT):	1032			
OPEN FORMATIONS:	NA			
DIVERTER CASING:	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:	
SURFACE CASING:	UNKNOWN	UNKNOWN	UNKNOWN	
ISOLATION CASING (1):	7.25	UNKNOWN	UNKNOWN	
ISOLATION CASING (2):	3.5	UNKNOWN	UNKNOWN	
	1.25	UNKNOWN	UNKNOWN	
CENTRALIZER (FT):	NONE APPARENT			
GROUT 1:	DEPTH (FT) FROM:	DEPTH (FT) TO:		
GROUT 2:	0	UNKNOWN		
GROUT 3:	0	UNKNOWN		
INTERPRETED CEMENT BOND LOG:	NA			
<p>NOTE: THE WELL DETAILS HAVE BEEN RECONSTRUCTED BASED ON SURFACE FEATURES AND AVAILABLE DATA. THE INFORMATION PROVIDED SHOULD BE CONSIDERED AS A BEST ESTIMATE. TD = TOTAL DEPTH NA = NOT AVAILABLE BOC = BOTTOM OF CASING</p>

WELL 1963
(Alias: 3S-200R)

ORNL WELL ID NO. 1963

ORNL WELL ID NO.:	1963		
ALIAS:	35-200R		
WELL TYPE:	ROCK COVER		
DRILLING METHOD:	ROTARY		
EASTING:	28615.84		
NORTHING:	16955.21		
GROUND SURFACE ELEVATION:	761.8		
TOP OF RISER (PRE-MODIFICATION):	762.53		
TOP OF RISER (POST-MODIFICATION):	764.12		
CASING MATERIAL:	CARBON STEEL		
CASING STRING (FT):	30		
CONCRETE PAD	NONE		
GUARD POSTS	NONE		

	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
BOREHOLE 1:	14.75	0	45
BOREHOLE 2:	8.75	45	92
BOREHOLE 3:	6.75	92	600
BOREHOLE 4:	3	600	641.4

REPORTED DRILLED DEPTH (FT): 6007

OPEN FORMATION: LOWER RUTLEDGE LIMESTONE

	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
DIVERTER CASING:	10	0	45
SURFACE CASING:	7	+2.32	92
ISOLATION CASING:	4.2	0	600

CENTRALIZER (FT): NOT APPARENT

	DEPTH (FT) FROM:	DEPTH (FT) TO:	
GROUT 1:	0	45	
GROUT 2:	0	92	
GROUT 3:	0	600	
INTERPRETED CEMENT BOND LOG:	8	90	BAD
	90	600 (BOC)	GOOD

NOTE: THE WELL DETAILS HAVE BEEN RECONSTRUCTED BASED ON GEOPHYSICAL LOG INTERPRETATION. THE INFORMATION PROVIDED SHOULD BE CONSIDERED AS A BEST ESTIMATE.

TO = TOTAL DEPTH
 NA = NOT AVAILABLE
 BOC = BOTTOM OF CASING

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

SPR,SP,Caliper
Neutron,Gamma,App
Den, FI Temp/Res

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: June 15-22, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1963

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 761.8

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 641.4'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	600.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 2.4'

WATER LEVEL: 8.5'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
SPR	2	103	Compro	103	0.2	12	Pb Ring	na	na	none	na	603.2'	0.2'	603.0
Gamma	2	103	Compro	103	0.2	12	Nal Scin	na	na	none	na	606.6'	3.6'	603.0
Neutron	3	101	Compro	101	0.2	12	He3	na	na	AmBe	3 Ci	640.4'	4.2'	636.2
Caliper	3	101	Compro	101	0.2	12	Potentio	na	na	none	na	635.6'	0.2'	635.4
SP	3	101	Compro	101	0.2	12	Pb Ring	na	na	none	na	636.4'	0.2'	636.2
App-Density	6	102	Compro	102	0.2	12	Nal Scin	na	na	Cs137	125mC	639.8'	4.2'	635.6
FI-Temp/Res	1	127	Sopris	127	0.2	6	Trsd/Wen	na	na	none	na	0.2'	607.4'	607.2

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1963.gb0...db0...nb0...tg0...xa0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1963 all equipment surveyed & "green tagged" by HP.

(1963C.HDP)

(10w1963.xa0)

1963 WAG 10 OU 3 Phase 1 Composite Plot

(10w1963.xa0)

1963 WAG 10 OU 3 Phase 1 Composite Plot

ORNL GEOPHYSICS GROUP

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BUILDING 3504 MS6317 Phone:(615)574-4558

NEAR VDL
FAR Amplitude
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: June 15-22, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1963

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 761.8

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 641.4'

RUN		BIT RECORD		CASING RECORD		
NO.	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	600.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 2.4'

WATER LEVEL: 8.5'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Near VDL	5	111	Sopris	111	0.2	7	Transduc	2	1	none	no	638.8'	7.6'	631.2
Amplitude	5	111	Sopris	111	0.2	7	Transduc	3	1	none	no	638.2'	7.0'	631.2
Velocity	5	111	Sopris	111	0.2	7	Computed	2/3	1	none	no	637.2'	6.0'	631.2

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1963.sf0...sg0...sh0...si0...sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1963 all equipment surveyed & "green tagged" by HP.

(10W1963A.HDP)

0w1963.si0) 1963 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 98 uS)

(10w1963.si0) 1963 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 98 uS)

ORNL GEOPHYSICS GROUP

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BUILDING 3504 MS6317 Phone:(615)574-4558

FAR VDL
FAR Amplitude
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: June 15-22, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1963

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 761.8

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 641.4'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	600.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 2.4'

WATER LEVEL: 8.5'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Far VDL	5	111	Sopris	111	0.2	7	Transduc	3	1	none	na	638.2'	7.0'	631.2
Amplitude	5	111	Sopris	111	0.2	7	Transduc	3	1	none	na	638.2'	7.0'	631.2
Velocity	5	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	637.2'	6.0'	631.2

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1963.sf0...sg0...sh0...sj0...sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1963 all equipment surveyed & "green tagged" by HP.

(10W1963B.HDP)

(10w1963.sj0) 1963 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 98 uS)

WELL 1963 WAG 10 OU 3 Phase 1

Horizontal Offset (Cased to 600')

WELL 1964
(Alias: 3S-220)

1964
35-270

ROTARY
OBSERVATION FILE

28615.9
CONVENTIONAL CORE

16935.1
761.5

763.9

CARBON STEEL

NON
NON
NON

3NON

DIAMETER (IN.)

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242

INREPLY

DEPTN (FT) FROM:

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0

YN

TO : TOTAL DEPTH
NY : NOT AVAILABLE
DOC : BOTTOM OF CASING

WELL 1965
(Alias: 3S-220W)

ORNL WELL ID NO. 1965

ORNL WELL ID NO.:	1965		
ALIAS:	35-220W		
WELL TYPE:	OBSERVATION WELL		
DRILLING METHOD:	ROTARY	600FT	
	CONVENTIONAL CORE	600-864+	
EASTING:	28593.44		
NORTHING:	16939.27		
GROUND SURFACE ELEVATION:	761.3		
TOP OF RISER (PRE-MODIFICATION):	764.04		
OP OF RISER (POST-MODIFICATION):	765.13		
CASING MATERIAL:	CARBON STEEL		
CASING STRING (FT):	30		
CONCRETE PAD	NONE		
GUARD POSTS	NONE		
BOREHOLE 1:	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
BOREHOLE 2:	14.75	0	UNKNOWN
BOREHOLE 3:	8.75	UNKNOWN	57
BOREHOLE 4:	6.75	57	600
	3	600	813+
REPORTED DRILLED DEPTH (FT):	840		
OPEN FORMATIONS:	CASED TO TO		
DIVERTER CASING:	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
SURFACE CASING:	10	0	UNKNOWN
ISOLATION CASING (1):	7	+3.83	57
ISOLATION CASING (2):	4.2	0	600
	2.5	0	813+
CENTRALIZER (FT):	NONE APPARENT		
GROUT 1:	DEPTH (FT) FROM:	DEPTH (FT) TO:	
GROUT 2:	0	UNKNOWN	
GROUT 3:	0	57	
GROUT 4:	0	600	
GROUT 5:	0	727	
	727	TO	
INTERPRETED CEMENT BOND LOG:	34	813+ (BOC)	BAD GOOD
NOTE: THE WELL DETAILS HAVE BEEN RECONSTRUCTED BASED ON GEOPHYSICAL LOG INTERPRETATION. THE INFORMATION PROVIDED SHOULD BE CONSIDERED AS A BEST ESTIMATE. TD = TOTAL DEPTH NA = NOT AVAILABLE BOC = BOTTOM OF CASING

ORNL GEOPHYSICS GROUP

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BUILDING 3504 MS6317 Phone:(615)574-4558

SPR,SP,Caliper,Bk
Neutron,Gamma,App
Den,FI Temp/Res

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: June 30-July 7, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1965

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 761.3

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TO: N/A LOGGED TO: 813.2'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		2.5"	813.2'+	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 3.9'

WATER LEVEL: 33'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprabe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
SPR	2	103	Compr	103	0.2	12	Pb Ring	na	na	none	na	809.2'	0.2'	809.0
Gamma	2	103	Compr	103	0.2	12	Nal Scin	na	na	none	na	812.6'	3.6'	809.0
Neutron	5	101	Compr	101	0.2	12	He3	na	na	AmBe	3 Ci	812.2'	4.2'	808.0
Caliper/SP	5	101	Compr	101	0.2	12	Potentio	na	na	none	na	807.4'	0.2'	807.2
Background	6	102	Compr	102	0.2	12	Nal Scin	na	na	none	na	603.4'	4.2'	599.2
Cor App-Den	7	102	Compr	102	0.2	12	Nal Scin	na	na	Cs137	125mC	603.4'	4.2'	599.2
FI-Temp/Res	1	127	Sopris	127	0.2	6	Trsd/Wen	na	na	none	na	0.2'	812.4'	812.2

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1965.gb0...dd1...nb0...td0...xa0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1965 cable & sondes were "yellow tagged" (400 - 4000).

(1965C.HDP)

(10w1965.xao)

1965 WAG 10 OU 3 Phase 1 Composite Plot

(10w1965.xa0)

1965 WAG 10 OU 3 Phase 1 Composite Plot

ORNL

ORNL GEOPHYSICS GROUP

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 BUILDING 3504 MS6317 Phone:(615)574-4558

NEAR VDL
 FAR Amplitude
 Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: June 30-July 7, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1965

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 761.3

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 813.2'

RUN	BIT RECORD			CASING RECORD		
NO.	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		2.5"	813.2'+	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 3.9'

WATER LEVEL: 33'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN.		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Near VDL	3	111	Sopris	111	0.2	7	Transduc	2	1	none	na	809.4'	31.6'	777.8
Amplitude	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	809.0'	31.0'	778.0
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	808.0'	30.0'	778.0

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1965.sf0...sg0...sh0...si0...sw0

NOTE:

Depths corrected to ground level; casing
 stick-up was measured from TOC to metal rod
 placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1965 cable & sondes
 were "yellow tagged" (400 - 4000).

(10W1965A.HDP)

(10w1965.si0) 1965 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 76 uS)

(10w1965.si0) 1965 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 76 uS)

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

FAR VDL
FAR Amplitude
Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: June 30-July 7, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1965

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 761.3

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 813.2'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		2.5"	813.2'+	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 3.9'

WATER LEVEL: 33'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Far VDL	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	809.0'	31.0'	778.0
Amplitude	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	809.0'	31.0'	778.0
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	808.0'	30.0'	778.0

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1965.sf0...sg0...sh0...sj0...sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1965 cable & sondes were "yellow tagged" (400 - 4000 cpm).

(10W1965B.HDP)

(10w1965.sj0) 1965 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 76 uS)

Amplitude
Amp Units 250
Velocity
Ft/Sec 3000 28000
Records
Microseconds Transit Time Tx to Far Receiver
Pointer
100 200 300 400 500 600 700 800 900 10

(10w1965.sj0) 1965 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 76 uS)

Records: Pointer
Amplitude
Amp Units 250
Velocity
Ft/Sec 28000
Microseconds Transit Time Tx to Far Receiver
3000 100 200 300 400 500 600 700 800 900 1000

WELL 1965 WAG 10 OU 3 Phase 1

Horizontal Offset (Cased to 840')

WELL 1967
(Alias: 3W-300R)

ORNL WELL ID NO. 1967

ORNL WELL ID NO.:	1967		
WELL TYPE:	3W-300R		
DRILLING METHOD:	ROCK COVER		
EASTING:	28324.76		
NORTHING:	17111.07		
GROUND SURFACE ELEVATION:	761.2		
TOP OF RISER (PRE-MODIFICATION):	761.81		
TOP OF RISER (POST-MODIFICATION):	763.27		
CASING MATERIAL:	CARBON STEEL		
CASING STRING (FT):	30		
CONCRETE PAD:	NONE		
GUARD POSTS:	NONE		
	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
BOREHOLE 1:	14.75	0	UNKNOWN
BOREHOLE 2:	8.75	UNKNOWN	20
BOREHOLE 3:	6.75	20	602
BOREHOLE 4:	3	602	617.8
REPORTED DRILLED DEPTH (FT):	650		
OPEN FORMATION:	LOWER RUTLEDGE LIMESTONE		
	DIAMETER (IN.)	DEPTH (FT) FROM:	DEPTH (FT) TO:
DIVERTER CASING:	10	0	UNKNOWN
SURFACE CASING:	7	+2.07	20
ISOLATION CASING:	4.2	0	602
CENTRALIZER (FT):	NONE APPARENT		
	DEPTH (FT) FROM:	DEPTH (FT) TO:	
GROUT 1:	0	UNKNOWN	
GROUT 2:	0	20	
GROUT 3:	0	602	
INTERPRETED CEMENT BOND LOG:	2	602 (BOC)	GOOD
NOTE: THE WELL DETAILS HAVE BEEN RECONSTRUCTED BASED ON GEOPHYSICAL LOG INTERPRETATION. THE INFORMATION PROVIDED SHOULD BE CONSIDERED AS A BEST ESTIMATE.			
TO = TOTAL DEPTH			
NA = NOT AVAILABLE			
BOC = BOTTOM OF CASING

ORNL

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
BUILDING 3504 MS6317 Phone:(615)574-4558

SPR,SP,Caliper
Neutron,Gamma,App
Den,FI Temp/Res

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: June 23-27, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1967

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 761.2

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 617.8'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	602.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 2.4'

WATER LEVEL: 2'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN.		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
SPR	2	103	Compro	103	0.2	12	Pb Ring	na	na	none	na	613.8'	0.2'	613.5
Gamma	2	103	Compro	103	0.2	12	NaI Scin	na	na	none	na	617.2'	3.6'	613.5
Neutron	3	101	Compro	101	0.2	12	He3	na	na	AmBe	3 Ci	616.8'	4.4'	612.4
Caliper	3	101	Compro	101	0.2	12	Potential	na	na	none	na	612.0'	0.2'	611.2
SP	3	101	Compro	101	0.2	12	Pb Ring	na	na	none	na	612.8'	0.4'	612.4
App-Density	5	102	Compro	102	0.2	12	NaI Scin	na	na	Cs137	125mCi	616.8'	4.2'	612.5
FI-Temp/Res	1	127	Sopris	127	0.2	12	Trsd/Wen	na	na	none	na	0.2'	618.0'	617.3

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1967.gb0...db0...nb0...td0...xa0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.
On completion of logging 1967 all equipment surveyed & "green tagged" by HP.
(1967C.HDP)

(10w1967.xa0)

1967 WAG 10 OU 3 Phase 1 Composite Plot

(10w1967.xa0)

1967 WAG 10 OU 3 Phase 1 Composite Plot

ORNL

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
 BUILDING 3504 MS6317 Phone:(615)574-4558

NEAR VDL
 FAR Amplitude
 Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: June 23-27, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1967

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 761.2

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TD: N/A LOGGED TD: 617.8'

RUN NO:	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	602.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 2.4'

WATER LEVEL: 2'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Near VDL	3	111	Sopris	111	0.2	7	Transduc	2	1	none	na	613.8'	1.8'	612.0
Amplitude	3	111	Sopris	111	0.2	7	Transduc	3	1	none	na	613.2'	1.4'	611.8
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	na	612.2'	0.4'	611.8

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1967.sf0...sg0...sh0...si0...sw0

NOTE:

Depths corrected to ground level; casing
 stick-up was measured from TOC to metal rod
 placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1967 all equipment
 surveyed & "green tagged" by HP.

(10W1967A.HDP)

(10w1967.si0) 1967 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 76 μ S)

(10w1967.si0) 1967 WAG 10 OU 3 Phase 1 Sonic Near Rec (Delay = 76 uS)

ORNL

ORNL GEOPHYSICS GROUP

P. O. BOX 2008, OAK RIDGE, TN.37831-6317
 BUILDING 3504 MS6317 Phone:(615)574-4558

FAR VDL
 FAR Amplitude
 Velocity

PROJECT: WAG 10 OU 3 Phase 1

DATE LOGGED: June 23-27, 1994

CLIENT: BECHTEL/ER

WELL NUMBER: 1967

LOCATION: OHF, X-10, Oak Ridge National Laboratory

STATE: Tennessee

COUNTY: Roane

ELEV: 761.2

DEPTH REF: G.L.

BOREHOLE DATA

DRILLING CONTRACTOR: N/A

DRILLER TO: N/A LOGGED TO: 617.8'

RUN NO.	BIT RECORD			CASING RECORD		
	Bit Size	From	To	Size/Wgt/Thk.	From	To
1	N/A	Ground Level		4.2"	602.0'	Surface+
2	N/A			N/A		
3	N/A			N/A		
4	N/A			N/A		

DRILL METHOD: N/A

CASING STICK UP: 2.4'

WATER LEVEL: 2'

DEPTHS WHERE CIRCULATION WAS LOST OR VARIABLE:

GENERAL DATA

INSTRUMENTATION: ORNL, Comprobe, Mount Sopris

UNIT/TRUCK: UNIT-1/E09848

LOGGING ENGINEER: R. O. Kennard

GEOPHYSICIST: R. Kim Davis

OTHER SERVICES: Borehole deviation log.

LOGGING DATA

LOG FUNCTION	RUN NO.	EQUIPMENT			LOGGING		DETECTOR TYPE	SPACING		SOURCE		LOGGED INTERVAL		
		ORNL S.N.	MODEL	PROBE S.N.	DIG INT FEET	SPEED FT./MIN		Tx-Rx FEET	Rx-Rx FEET	TYPE	SIZE CURIE	FROM	TO	INT. FEET
Far VDL	3	111	Sopris	111	0.2	7	Transduc	3	1	none	no	613.2'	1.4'	611.8
Amplitude	3	111	Sopris	111	0.2	7	Transduc	3	1	none	no	613.2'	1.4'	611.8
Velocity	3	111	Sopris	111	0.2	7	Computed	2/3	1	none	no	612.2'	0.4'	611.8

CALIBRATED PROBE(S): See Field Acquisition Records.

DIGITAL FILENAME(S): 10w1967.sf0...sg0...sh0...sj0...sw0

NOTE:

Depths corrected to ground level; casing stick-up was measured from TOC to metal rod placed in the ground on north side of casing.

This well was not pressurized.

On completion of logging 1967 all equipment surveyed & "green tagged" by HP.

(10W1967B.HDP)

(10w1967.sj0) 1967 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 76 uS)

(10w1967.sj0) 1967 WAG 10 OU 3 Phase 1 Sonic Far Rec (Delay = 76 μ S)

WELL 1967 WAG 10 OU 3 Phase 1

Horizontal Offset (Cased to 600')