RCRA Facility Investigation Report
for Waste Area Grouping 6 at Oak
Ridge National Laboratory,
Oak Ridge, Tennessee

Volume 4
Technical Memorandums 06-03A,
06-04A, 06-05A, and 06-08A
RCRA Facility Investigation Report for Waste Area Grouping 6 at
Oak Ridge National Laboratory, Oak Ridge, Tennessee

Volume 4: Technical Memorandums 06-03A, 06-04A,
06-05A, and 06-08A

Environmental Restoration Division
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U.S. DEPARTMENT OF ENERGY

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<td>DQOs</td>
<td>data quality objectives</td>
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<td>EWB</td>
<td>Emergency Waste Basin</td>
</tr>
<tr>
<td>GC</td>
<td>gas chromatograph</td>
</tr>
<tr>
<td>PCE</td>
<td>tetrachloroethane</td>
</tr>
<tr>
<td>PID</td>
<td>photoionization detector</td>
</tr>
<tr>
<td>RSD</td>
<td>relative standard deviation</td>
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<tr>
<td>SWMU</td>
<td>Solid Waste Management Unit</td>
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<tr>
<td>SWSA</td>
<td>Solid Waste Storage Area</td>
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<tr>
<td>TCE</td>
<td>trichloroethene</td>
</tr>
<tr>
<td>VOCs</td>
<td>volatile organic compounds</td>
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<tr>
<td>WAG</td>
<td>waste area grouping</td>
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</table>
A soil gas/well headspace survey was conducted from December 1989 to January 1990 in Solid Waste Storage Area (SWSA) 6 and the Emergency Waste Basin (EWB). This survey was a continuation of a previous soil gas sampling effort and was used to identify the presence of volatile organic compounds (VOCs) within support areas of SWSA 6 and EWB. The results confirm the presence of VOCs in WAG 6.
INTRODUCTION

Purpose

A soil gas/well headspace survey was conducted from December 20, 1989 through January 29, 1990 in four areas located in Solid Waste Storage Area (SWSA) 6 [Solid Waste Management Unit (SWMU) 6.1] and the Emergency Waste Basin (EWB) (SWMU 6.2) located within the boundary of Waste Area Grouping (WAG) 6 (Fig. 1). The survey was a continuation of a previous soil gas sampling effort (BNI 1990) and was used to identify the presence of volatile organic compounds (VOCs) within suspect areas of SWSA 6 and the EWB. The results of the soil gas survey were evaluated in conjunction with other nondestructive surveys to better delineate contaminant plumes identified by earlier sampling and indicate groups of trenches or auger holes that may be sources for each plume.

Selection of Sampling Points

Soil gas sampling points were selected to correspond to areas of potential contaminant migration. Figure 1 shows the four areas where samples were collected. Specific sampling points are shown in Figs. 2 through 5. Area 1 was expanded from the previous soil gas survey effort to include a portion of WAG 2 to determine whether or not WAG 6 contaminants were migrating to WAG 2 (BNI 1990). Areas 2, 3 and 4 were selected because of their proximity to trenches and auger holes suspected of being sources of VOC contaminants.

Data Quality Control and Data Quality Objectives

The data quality objectives (DQOs) for this sampling effort were set at Level I, which is defined as field screening. These DQOs and analyses levels are fully explained in the Data Quality Objectives for Remedial Response Activities (EPA 1988a).
Fig. 1. SWSA 6 reference map locating areas 1, 2, 3, and 4 soil gas sampling figures.
Fig. 2. Sampling location summary results soil headspace and gas sampling Area 1.
Fig. 3. Sampling location and summary results soil headspace and gas sampling, Area 2.
Fig. 4. Sampling locations and summary results soil headspace and gas sampling Area 3.
Fig. 5. Sampling locations and summary results soil headspace and gas sampling Area 4.
Selection of Target Compounds

Eleven compounds were selected for analysis based on existing soil gas data from previous soil gas information (BNI 1990). Compound selection was based upon the concentration in soil and the volatility of the respective compounds. The selected VOCs were 1,1-dichloroethene (1,1-DCE), methylene chloride, trans-1,2-dichloroethene (1,2-DCE), chloroform, carbon tetrachloride, naphthalene, benzene, trichloroethene (TCE), toluene, tetrachloroethene (PCE) and total xylenes.

METHODOLOGY

Field Sampling Methodology—Soil Gas/Soil Headspace

Initially, soil gas sampling was conducted using a commercially manufactured sampling apparatus (JMC, Model ESP, Clements Associates). This soil probe was manufactured for shallow soil sampling and with minor modifications was equipped to obtain soil gas samples. The JMC sampler uses a drop hammer to drive a hollow 22-mm (7/8-in.) diameter steel tube into the subsurface. The hollow tube was equipped with a disposable aluminum drive point. Upon insertion to depths between 30.5 cm to 45.7 cm (12 to 18 in.), the tube was withdrawn approximately 15.2 cm (6 in.) with a foot jack to create a cavity for obtaining a soil gas sample. The probe was constructed in 91-cm (3-ft) sections; each threaded section was provided with an O-ring seal to minimize leakage. A low-flow pump was used to purge the drive tube and fill a 1-L Tedlar or 5-layer composite sample bag.

Wet conditions were encountered during sampling, which created difficulties with the sampling apparatus and procedure. An experiment was carried out to determine if equivalent results were achieved using the soil gas sampling method and removing a soil sample for gas chromatograph (GC) analysis. Henceforth, soil samples were collected using the Shelby tube method at each location shown in Figs. 2 through 5.

Soil samples were collected for headspace analysis by driving Shelby tubes to a depth of 30.5 cm to 45.7 cm (12 to 18 in.). After allowing 24 h for equilibrium to be reached, the sample was taken from the end of the Shelby tube and placed into a 125-mL amber container and returned to the Close Support Laboratory (CSL) for analysis.

Field Sampling Methodology—Well Headspace

Piezometer and groundwater quality well air spaces were sampled for VOCs by using a well cap and a 1.5 m (5-ft) long small diameter hollow steel sampling probe. The wells were capped with aluminum foil and sampled with a low-flow pump (200 cc/min) after allowing 10 min for equilibrium to be reached. Samples were collected in 1-L Tedlar bags for analysis. The analytical procedure is the same as previously described for soil gas.
Soil and Well Headspace Analytical Methods

The well headspace samples were collected in 1-L Tedlar bags. Because of the wet conditions during soil gas collection, it was determined that the sampling method should be modified to take soil samples. Soil samples were collected in 125-mL amber glass jars and transported to the CSL where they were analyzed by GC.

Sample preparation before analysis consisted of placing 5 g of soil into each 10-mL vial and adding 3 mL of water to each vial. Each vial was sealed with a crimp top lid using teflon-faced septa. The vial was heated to 60°C for 1 h, or longer, to allow the VOCs to be released into the headspace of the vials and injected into the GC to be analyzed using the photoionization detector (PID) and a Hall detector.

Well headspace and the soil headspace samples were analyzed by GC using the PID and a Hall detector. The following set of target compounds were analyzed using the detectors:

<table>
<thead>
<tr>
<th>Compound</th>
<th>Detector</th>
</tr>
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<tbody>
<tr>
<td>1,1 Dichloroethene</td>
<td>PID and Hall</td>
</tr>
<tr>
<td>Methylene chloride</td>
<td>Hall</td>
</tr>
<tr>
<td>trans-1,2 Dichloroethene</td>
<td>PID and Hall</td>
</tr>
<tr>
<td>Chloroform</td>
<td>Hall</td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>Hall</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>PID</td>
</tr>
<tr>
<td>Benzene</td>
<td>PID</td>
</tr>
<tr>
<td>Trichloroethene</td>
<td>PID and Hall</td>
</tr>
<tr>
<td>Toluene</td>
<td>PID</td>
</tr>
<tr>
<td>Tetrachloroethane</td>
<td>PID and Hall</td>
</tr>
<tr>
<td>Total Xylenes</td>
<td>PID</td>
</tr>
</tbody>
</table>

The PID detects carbon-carbon double bonds found in aromatic and some straight chain molecules while the HALL detects only halogenated molecules.

When a mixed gas or vapor sample is injected into the GC, the sample constituents are first separated within the capillary column. This segregation is based on the physical properties of each constituent and how they interact with the adsorptive powder coating the inner wall. Each constituent then enters the PID chamber, where it is ionized by the ultraviolet light, and the positive ions are collected, amplified, and identified.

A methanol solution of the target compounds at various levels between 1 ng and 200 ng was injected into the GC to calibrate the GC and establish a qualitative and quantitative baseline standard against which to compare field sample analytical results.

At the 1 ng level, most of the compounds could be identified with a 10:1 or better signal to noise ratio. Percent relative standard deviation (%RSD) was calculated over the range of
interest using a linear fit. Results were generally less than 30% RSD. Most of the target compounds in samples were at column levels of 10 ng or lower. Two multi-level calibrations have been performed, one at the end of November 1989, and the second in the middle of January 1990. Multipoint standards were also performed with headspace vials used for soil and water analysis. When suitable chemicals became available, internal and surrogate solutions were added to the samples. Recoveries were calculated and samples were reanalyzed when recoveries exceeded 50%/150% windows. Initially, matrix spikes were run with most daily batches; however, since mid-February a matrix spike has been run with every batch.

**GC Quality Control**

A methanol solution of the target compounds at various levels between 1 ng and 200 ng was injected into the GC to calibrate the GC and establish a qualitative and quantitative baseline standard against which to compare field sample analytical results. At the 1 ng level most of the compounds could be identified with a 10:1 or better signal to noise ratio. Percent relative standard deviation (%RSD) was calculated over the range of interest using a linear fit. Results were generally less than 30% RSD. Most of the target compounds in samples were at column levels of 10 ng or lower. Two multi-level calibrations have been performed, one at the end of November 1989 and the second in the middle of January 1990. Multipoint standards were also performed with headspace vials used for soil and water analysis. When suitable chemicals became available, internal and surrogate standard solutions were added to the samples. Recoveries were calculated and samples were reanalyzed when recoveries exceeded 50%/150% windows. Initially, matrix spikes were run with most daily batches; however, since mid-February a matrix spike has been run with every batch.

**Quality Control**

One mL aliquots of gas bag samples were injected into the GC. The results were directly calculated in ng/mL air by the data system. Standards and method blanks were run daily while matrix spikes were run at a rate of approximately 1 for every 30 samples. Each sample received a 0.1 μL injection of allyl bromide before analysis. The resulting allyl bromide peak was used as a check for retention time and quantitation stability. Quality control for soil headspace has steadily evolved towards more stable and sensitive analysis. External surrogate quantitation was used for the first soil samples run mid-January. A surrogate was injected into each sample. Later, internal standards and surrogate solutions were added to the samples. Recoveries were calculated and samples were reanalyzed when recoveries exceeded 50%/150% windows. Initially, matrix spikes were run with most daily batches; however, since mid-February a matrix spike has been run with every batch.

**SUMMARY**

Soil and well headspace data were examined for areas of significant concentrations of VOCs to aid in the determination of additional well and soil boring locations. Graphic summaries of the positive results are included in Figs. 2 through 5.
Figure 1 shows where areas 1 through 4 are located in WAG 6. Figures 2 through 5 show sampling locations, and the symbols indicate locations where positive results were found. The figures also list positive results for the associated sampling point.

Area 1 was located on the northeast portion of SWSA 6 and a small portion of WAG 2. Elevated levels of VOCs, primarily TCE were found in SG-110, SG-115, and piezometer Well 645. Other compounds detected, include 1,1-DCE, PCE, total references, chloroform, styrene, and napthalene. Unknown VOCs were found in SG-113, SG-118, SG-119, SG-122, and SG-123.

Area 2 was located north of SWSA 6, near the EWB. Sample SG-204 indicated the presence of unknown volatile compounds.

Area 3 was located in the northwest section of SWSA 6. SG-308 and SG-309 and piezometer Well 648 indicated the presence of TCE, PCE and total xylenes.

Area 4 was located in the southwest area of SWSA 6. SG-404 showed a slight presence of TCE and PCE.

CONCLUSIONS

Data from soil and well headspace analysis confirm the presence of VOCs in WAG 6. Area 1 had the most volatile organics present in this area. Elevated levels were found on SWSA 6 and WAG 2. These VOCs were most likely found because of migration from the auger holes. Areas 2, 3 and 4 showed one or two points that were elevated with VOCs which cannot be attributed to a specific source.

REFERENCES


Environmental Protection Agency, Field Screening Methods Catalog, EPA/540/2-88/005, 1988b.
SURFACE RADIOLOGICAL INVESTIGATION
FOR WAG 6, SWMU 6.2, EMERGENCY
WASTE BASIN, (PHASE 1, ACTIVITY 2)

TECHNICAL MEMORANDUM 06-04A

OAK RIDGE NATIONAL LABORATORY
REMEDIAL INVESTIGATION/FEASIBILITY STUDY

JULY 1991

Prepared by
Bechtel National, Inc./CH2M HILL/ERCE/PEER
P. O. Box 350
Oak Ridge, Tennessee 37830
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for

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831

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for the
U. S. DEPARTMENT OF ENERGY
under Contract DE-AC056-84OR21400

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TECHNICAL MEMORANDUM 06-04A

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<td>ORNL</td>
<td>Oak Ridge National Laboratory</td>
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<td>pressurized ionization chamber</td>
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<td>Solid Waste Management Unit</td>
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<td>TM</td>
<td>technical memorandum</td>
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<td>WAG</td>
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EXECUTIVE SUMMARY

A surface radiological survey of the Emergency Waste Basin (EWB) was conducted during December through February 1990. This survey was performed to provide basic radiation field and surface radioactivity characterization of the site. Four types of measurements were taken at the EWB: near-surface gamma radiation measurements, shielded-gamma radiation measurements, and radiation exposure-rate measurements. All types of measurement generally increased within the White Oak Creek area.
DATE: July 9, 1991

TO: A. S. Will III (ORNL)

FROM: J. R. Kannard, Program Manager (BNI)
R. C. Wilson, WAG 6 Project Manager (CH2M HILL)
K. K. Lewis, Principal Author (BNI)

SUBJECT: SURFACE RADIOLOGICAL INVESTIGATION FOR WAG 6,
SWMU 6.2, EMERGENCY WASTE BASIN (EWB) (PHASE 1,
ACTIVITY 2)

INTRODUCTION

Purpose

A surface radiation survey was conducted from December 5, 1989 through
February 16, 1990, at the EWB (SWMU 6.2) located within WAG 6. This activity was
designed to provide basic radiation field and surface radioactivity characterization of the site
(BNI 1988a) and to verify the EWB's radiological status. The quality of data presented in
this technical memorandum has been identified as Data Quality Level 1, in accordance with
the definitions given in Data Quality Objectives for Remedial Response Activities
(EPA 1988). These data are intended only to provide indications of the presence of
contamination.

Background

The EWB is located in Melton Valley, 2 km (1.24 miles) southwest of the Oak Ridge
National Laboratory (ORNL) main plant facilities. The EWB survey area, which includes
a portion of WAG 2, encompasses approximately 5.8 ha (14.33 acres) of land and is
bordered on the south and west by Solid Waste Storage Area (SWSA) 6, on the east by
WAG 2, and on the north by undeveloped land.

The EWB was constructed in 1961-1962 as a low-level waste or process-waste holding
basin to be used whenever ORNL was unable to release wastes to White Oak Creek. The
basin encompasses about 0.81 ha (2 acres), has a volume potential of approximately
57,000 m³ (2,012,955 ft³), and has reportedly never been used for its intended purpose.

In February, April, and May 1988, surface water samples were collected from the EWB.
These analytical results can be found in Technical Memorandum 06-05, "Interim Surface
TECHNICAL MEMORANDUM 06-04A

Water Sampling for the ORNL WAG 6 RFI. Sediment samples were collected in early March. The data is summarized in TM 06-05A, "Surface Water/Sediment Investigation."

The radiation survey presented in this TM represents data gathered in areas that were accessible from December 1989 through February 1990.

SURVEY METHODOLOGY

The elements of the walkover radiation survey are described in the following sections.

Survey Area and Coverage

The survey area and master locator grid map are presented in Fig. 1. The spatial location of each radiological measurement made during the survey is shown in Fig. 2. A survey grid was established over the EWB area by civil survey. The grid consisted of an overlay of 30.5-m (100-ft) by 30.5-m (100-ft) squares. Survey stakes were placed on 30.5-m (100-ft) centers creating a grid of 30.5-m (100-ft) intersects. The center of each grid square was subsequently located and staked. The grid was reproduced as a graphic, and each square was sequentially numbered to provide a locator map for survey use.

Thirteen grid points were inaccessible for the coneshield and HP210 instruments because of high water. Two points that were greater than three times the measured background and an additional four grid points identified for exposure rate measurement were also inaccessible because of high water. These points are labeled "inaccessible" on the data tables in Attachment 1.

Near-Surface Gamma Radiation Survey

A continuous 100% near-surface gamma radiation survey was performed within each grid. The survey covered approximately 100% of the ground surface within each grid. In densely-wooded areas and on steep grades, the survey was performed only at the grid intersect points and center points. The survey was conducted with a 5.08-cm (2-in.) by 5.08-cm (2-in.) sodium iodide scintillation detector (Eberline SPA-3) positioned within 15 cm (5.91 in.) of grade and slowly moved side to side, while walking at approximately 60 cm/s (approximately 2 km/h).

Areas noted to have radiation levels three times above measured site background or more were field marked using a red-flagged surveyor's "pin." Upon completion of the survey of a grid, the area within the emplaced pins was sketched onto the field survey form. Pin locations were determined by measurements using the grid reference points and a 15.2-m (49.85 ft) steel tape. The accuracy of this method of location is estimated to be approximately 30 cm (11.82 in.).
Fig. 1. Survey area and master locator grid map.
Fig. 2. EWB radiological survey measurement locations.
Shielded-Gamma Radiation Measurements

A conical shield providing a downward directional response referred to as a cone shield (constructed to accept the Eberline SPA-3 and similar detectors) was used to obtain fixed-position gamma measurements shielded from air-scattered radiation. Measurements were made at a distance of 30 cm (11.82 in.) above grade at the intersect points and at the centers of each grid square.

Shielded Beta-Gamma Radiation Measurements

A pancake Geiger-Müller (G-M) tube with tungsten-shielded housing (Eberline HP-210T) was used to obtain surface measurements of total beta-gamma radiation levels at each grid intersect point and at the center of each grid. Measurements were made in contact with the local ground surface.

Radiation Exposure Rate Measurements

A gamma radiation exposure rate was obtained at the center of each grid square 1 m (3.28 ft) above the local surface.

The survey plan required that gamma radiation exposure-rate measurements be made at the center of each grid using a Reuter-Stokes Model RSS-111 pressurized ionization chamber (PIC) instrument, or an Eberline SRM-200 (ESP-2 equivalent) with an energy-compensated HP-270 G-M probe.

Before the HP-270 probe was used, a correlation test was conducted between the RSS-111 and the HP-270 probe. The method will be explained in the Radiation Exposure Rate Instrumentation section of this TM.

INSTRUMENTATION AND CALIBRATION OF INSTRUMENTS

Near-Surface Gamma, Shielded Gamma, and Shielded Beta-Gamma Instrumentation

All near-surface measurements were conducted using an Eberline ESP-2 microprocessor-controlled survey meter with the appropriate probes. Three ESP-2 instruments were used (BNI numbers 2021, 2022 and 2023). Each instrument was equipped as indicated in the following:

<table>
<thead>
<tr>
<th>Probe</th>
<th>ESP-2 2021</th>
<th>ESP-2 2022</th>
<th>ESP-2 2023</th>
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<tr>
<td>HP210T Shielded G-M</td>
<td>BNI#1780</td>
<td>BNI#1829</td>
<td>BNI#1822</td>
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<tr>
<td>SPA-3 Sodium Iodide Scintillator</td>
<td>BNI#1821</td>
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- HP210T Shielded G-M
- SPA-3 Sodium Iodide Scintillator
Each instrument was cross-calibrated to use all probes to provide maximum flexibility.

Each instrument and probe combination was calibrated by the ORNL Instrument Calibration Facility. Calibration certificates were issued for the above instrument and probe combinations, and calibrations are traceable to National Bureau of Standards (NBS) materials. Instrument calibrations are contained in Attachment 2 of this TM.

**Radiation Exposure-Rate Instrumentation**

Initially, the Reuter-Stokes Model RSS-111 PIC instrument (BNI number 4029) was selected for use in all exposure-rate measurements. This instrument was cumbersome to transport within the densely-wooded areas and areas with steep grades. The more portable SRM-200 (equivalent to the ESP-2, BNI number for the instrument 4366/probe number 4094) with the HP-270 energy-compensated G-M probe was chosen for use in these difficult access areas.

Before the SRM-200 with the HP-270 probe could be used, a correlation test between the PIC and the HP-270 probe was performed by taking 1-h exposure-rate measurements at 10 center points on the EWB. A linear regression was conducted with the data, and an equation was developed to convert the HP-270 reading to the appropriate PIC reading. This equation is as follows:

\[
\text{PIC reading} = \frac{\text{HP270 reading}}{1.19} - 6.06
\]

The correlation coefficient was 0.99 indicating a strong linear relationship between the PIC and the SRM-200/HP-270 over the range of 3 to 200 μR/h.

Each instrument and probe combination was calibrated by the ORNL Instrument Calibration Facility. Calibration certificates for each instrument and probe combination were issued, and calibrations are traceable to NBS materials. Instrument calibrations are contained in Attachment 3.

**Background Measurements and Response Checks**

City background radiation measurements were obtained for each of the instruments and instrument probe combinations used in the survey. Each background measurement was comprised of five separate readings obtained from a location of known low background at the BNI Oak Ridge office located at 800 Oak Ridge Turnpike. These measurements were averaged and used as the "city" background value for data correction.

Daily site background readings were obtained at the field office before start of field work and at the conclusion of the day's activities to assure that instrument response had not changed.
All background measurements for the city and the site are contained in Attachment 1.

Data Quality Control and Data Quality Objectives

The data quality objectives (DQOs) for this survey were set at Level I, which is defined as field screening or analysis using portable instruments. These DQOs and analyses levels are explained in the Data Quality Objectives for Remedial Response Activities (EPA 1988). Results can indicate if contamination is present, however, they do not identify which radionuclides are present, nor do they provide a quantitative concentration determination.

Quality Control (QC) for this survey included duplicate measurements on 10% of the measurements. The QC applied exceeded DQO Level I requirements (BNI 1988b). See Attachment 2 for a QC data summary.

SUMMARY OF FINDINGS

Near-Surface Shielded-Gamma Radiation Measurement Results

The results of the shielded-gamma measurements are shown in Fig. 3 which presents count rate data corrected for background at the BNI office located at 800 Oak Ridge Turnpike in Oak Ridge, Tennessee. The radiation measurement results are given in Attachment 1.

With the exception of discrete high-activity locations in the northern section of the EWB, highest count rates occurred in the southern section of the site. Generally, count-rate measurements increased within the White Oak Creek area.

Shielded Beta-Gamma Radiation Measurement Results

Shielded beta-gamma count-rate data corrected for background at the BNI office are summarized in Fig. 4. The data are tabulated in Attachment 1.

The White Oak Creek area count rates ranged from 100 to > 500 cpm above background as shown in Fig. 4.

Radiation Exposure Rate

Above background gamma exposure rate measurements ranging from 20 to > 100 $\mu$R/h occurred in the White Oak Creek area as shown in Fig. 5. The tabulated data are given in Attachment 1.
Fig. 5. EWB gamma radiation exposure-rate measurement (1m)
Localized Areas of Higher Activity

Localized areas of activity higher than the average gamma count rate in a given grid were discovered during this survey. For this survey, an elevated area was defined as an initial indication of gamma radiation in excess of three times the background radiation value measured at the field office. Elevated areas were confirmed using the HP-210T G-M probe. Figure 6 presents the location of grids containing one or more valid elevated areas. Count-rate data and probe instrument combinations used for radiation measurements are contained in Attachment 1.

DISCUSSION

Based on the three instrument measurements (shielded-gamma, beta-gamma, and exposure rate), most of the elevated radiation readings occur in the southern area of the EWB in the White Oak Creek floodplain. All instrument measurements were corrected for background taken at 800 Oak Ridge Turnpike. The sources of the elevated readings are unknown at this time.

Elevated areas were observed in grids 384A, 384, 385, 386, 388, 389, 390, 395, and 403 located in the northern area of the site. Shielded-gamma measurements ranged from <5,000 to 10,000 cpm. Beta-gamma count rates ranged from less than background to 25 cpm in this area. Exposure rates ranged from less than background to 20 μR/h.

Count rates in the White Oak Creek area (grids 442, 445, 449, 450, 451, 452 and 453) were greatly elevated as compared to the northern section of the EWB. Shielded-gamma count rates ranged from 10,000 to 100,000 cpm. Beta-gamma count rates ranged from 50 to >500 cpm. Exposure rates in this area were also elevated, ranging from 20 to >100 μR/h. These elevated readings may be attributed to the effects of the WAG 7 sources.

The walkover survey indicated that the EWB area exhibited radiation exposure rates above that measured in a known uncontaminated area. Some measured values exceeded those observed during a similar survey conducted in SWSA 6 (BNI 1990). These data, however, are insufficient to establish risks due to direct exposure to radiation for persons other than site workers. The adjacent SWSA 6 is an active burial ground for radioactive materials. Therefore, the radiological condition of the WAG 6 will remain dynamic until SWSA 6 ceases to accept waste materials for disposal. Thus, radiological characterization of exposure rates and surface contact count rates are valid only for the point in time in which the measurements are made.

Levels of direct gamma radiation were found to be occupationally low (e.g., a worker exposed at the highest of the observed exposure rates for 8 h per day, 5 days per week, 50 weeks per year would receive a whole body dose equivalent of less than 1% of the annual limit for radiation workers of 5 mSv).
TECHNICAL MEMORANDUM 06-04A

REFERENCES


Attachment 1

RADIOLOGICAL SURVEY DATA GENERAL COVERAGE
<p>| 440-4  | CONESHEILD | ESP2-2021 | 1821 | 15500 | CPM | 2110 | 13390 | 1860 | 13640 |
| 440-5  | CONESHEILD | ESP2-2021 | 1821 | 6840 | CPM | 2110 | 4730 | 1860 | 4980 |
| 441-4  | INACCESSIBLE | ESP2-2021 | 1821 | 13200 | CPM | 1680 | 11520 | 1860 | 11340 |
| 442-4  | CONESHEILD | ESP2-2021 | 1821 | 15600 | CPM | 1680 | 15920 | 1860 | 13750 |
| 443-4  | CONESHEILD | ESP2-2021 | 1822 | 15100 | CPM | 1770 | 16130 | 1860 | 13520 |
| 444-4  | CONESHEILD | ESP2-2021 | 1822 | 17900 | CPM | 1770 | 62600 | 1860 | 16040 |
| 445-4  | CONESHEILD | ESP2-2021 | 1822 | 66600 | CPM | 1770 | 5200 | 1860 | 62760 |
| 446-4  | CONESHEILD | ESP2-2021 | 1822 | 7020 | CPM | 1770 | 5200 | 1860 | 5160 |
| 447-4  | CONESHEILD | ESP2-2021 | 1821 | 120000 | CPM | 1680 | 119320 | 1860 | 119140 |
| 448-4  | CONESHEILD | ESP2-2021 | 1821 | 121000 | CPM | 1680 | 119320 | 1860 | 119140 |
| 449-4  | CONESHEILD | ESP2-2021 | 1821 | 15400 | CPM | 1770 | 11520 | 1860 | 13520 |
| 450-4  | CONESHEILD | ESP2-2021 | 1822 | 12800 | CPM | 1770 | 11030 | 1860 | 10950 |
| 451-4  | CONESHEILD | ESP2-2021 | 1822 | 1670 | CPM | 1770 | 16930 | 1860 | 1680 |
| 452-4  | CONESHEILD | ESP2-2021 | 1822 | 7260 | CPM | 1770 | 5660 | 1860 | 5600 |
| 453-4  | CONESHEILD | ESP2-2021 | 1822 | 13200 | CPM | 1680 | 11520 | 1860 | 13520 |
| 454-4  | CONESHEILD | ESP2-2021 | 1821 | 85800 | CPM | 1680 | 84120 | 1860 | 83790 |
| 455-4  | CONESHEILD | ESP2-2021 | 1821 | 118000 | CPM | 1680 | 116320 | 1860 | 116140 |
| 456-4  | CONESHEILD | ESP2-2021 | 1821 | 53300 | CPM | 1680 | 51620 | 1860 | 51440 |
| 457-4  | CONESHEILD | ESP2-2021 | 1822 | 21000 | CPM | 2200 | 18800 | 1860 | 19140 |
| 458-4  | CONESHEILD | ESP2-2021 | 1822 | 17000 | CPM | 2200 | 14800 | 1860 | 15140 |
| 459-4  | CONESHEILD | ESP2-2021 | 1822 | 19500 | CPM | 1930 | 17570 | 1860 | 17640 |
| 460-4  | CONESHEILD | ESP2-2021 | 1822 | 34500 | CPM | 1930 | 32570 | 1860 | 32640 |
| 461-4  | CONESHEILD | ESP2-2021 | 1821 | 14400 | CPM | 1930 | 12470 | 1860 | 12540 |
| 462-4  | CONESHEILD | ESP2-2021 | 1821 | 12700 | CPM | 1930 | 10770 | 1860 | 10840 |
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| 384-2  | HP-2101T | ESP2-2022 | 1829 | 42 | CPM | 38 | 4 | 27 | 15 |
| 384-3  | HP-2101T | ESP2-2022 | 1829 | 53 | CPM | 38 | 15 | 27 | 26 |
| 384-4  | HP-2101T | ESP2-2022 | 1829 | 1308 | CPM | 38 | 1360 | 27 | 1371 |
| 384-5  | HP-2101T | ESP2-2022 | 1829 | 51 | CPM | 38 | 13 | 27 | 24 |
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| 385-4  | HP-2101T | ESP2-2022 | 1780 | 42 | CPM | 31 | 11 | 27 | 15 |
| 385-5  | HP-2101T | ESP2-2022 | 1780 | 42 | CPM | 32 | 11 | 27 | 15 |
| 386-2  | HP-2101T | ESP2-2022 | 1780 | 53 | CPM | 13 | 40 | 27 | 26 |
| 386-4  | HP-2101T | ESP2-2022 | 1780 | 66 | CPM | 13 | 53 | 27 | 39 |
| 386-5  | HP-2101T | ESP2-2022 | 1780 | 61 | CPM | 13 | 45 | 27 | 35 |
| 387-1  | HP-2101T | ESP2-2022 | 1780 | 53 | CPM | 13 | 40 | 27 | 26 |
| 387-4  | INACCESSIBLE | ESP2-2021 | 1780 | 64 | CPM | 13 | 51 | 27 | 37 |
| 387-5  | HP-2101T | ESP2-2022 | 1780 | 53 | CPM | 44 | 9 | 27 | 26 |
| 388-5  | HP-2101T | ESP2-2022 | 1780 | 49 | CPM | 44 | 5 | 27 | 22 |
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| 390-5  | HP-2101T | ESP2-2022 | 1780 | 56 | CPM | 13 | 43 | 27 | 29 |
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| 391-4  | HP-2101T | ESP2-2022 | 1780 | 89 | CPM | 26 | 35 | 27 | 34 |
| 391-5  | HP-2101T | ESP2-2022 | 1780 | 51 | CPM | 26 | 25 | 27 | 26 |
| 392-2  | HP-2101T | ESP2-2022 | 1780 | 65 | CPM | 13 | 36 | 27 | 38 |
| 392-4  | HP-2101T | ESP2-2022 | 1780 | 46 | CPM | 13 | 33 | 27 | 38 |
| 392-5  | HP-2101T | ESP2-2022 | 1780 | 49 | CPM | 13 | 36 | 27 | 38 |
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**449-6 INACCESSIBLE**

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| 449-8 | HP210T | ESP2-2021 | 1780 | 541 | CPM | 30 | 311 | 27 | 314 |
| 449-9 | HP210T | ESP2-2021 | 1780 | 1080 | CPM | 30 | 1050 | 27 | 1053 |
| 449-10 | HP210T | ESP2-2021 | 1780 | 718 | CPM | 30 | 688 | 27 | 691 |
| 449-11 | HP210T | ESP2-2021 | 1780 | 1770 | CPM | 30 | 1740 | 27 | 1743 |

**450-6 INACCESSIBLE**

| 450-7 | HP210T | ESP2-2022 | 1780 | 257 | CPM | 30 | 227 | 27 | 230 |
| 451-6 | HP210T | ESP2-2022 | 1780 | 323 | CPM | 38 | 285 | 27 | 296 |
| 451-7 | HP210T | ESP2-2022 | 1780 | 773 | CPM | 38 | 735 | 27 | 746 |
TECHNICAL MEMORANDUM 06-04A

AI-12


Attachment 2

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<tr>
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<td>869 38</td>
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<td>404-5</td>
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<td>440-5</td>
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<td>50 38</td>
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<td>70 38</td>
<td>32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>443-4</td>
<td>83 31</td>
<td>52</td>
<td>77 38</td>
<td>39</td>
<td></td>
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<tr>
<td>443-5</td>
<td>55 31</td>
<td>24</td>
<td>49 38</td>
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<td></td>
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<td>445-5</td>
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<td>628</td>
<td>592 38</td>
<td>554</td>
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<td>445-7</td>
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<td>1649</td>
<td>1660 38</td>
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<td>448-4</td>
<td>58 31</td>
<td>27</td>
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<tr>
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<td>14</td>
<td>49 38</td>
<td>11</td>
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</tr>
</tbody>
</table>
Attachment 3

INSTRUMENT CALIBRATIONS
**ION CHAMBER CALIBRATION DATA SHEET**

**Instrument type:** Model RS-111  
**Serial Number:** C18-0070-2

**Owner:** Bechtel

**Cal. Date:** January 04, 1990

<table>
<thead>
<tr>
<th>Source Range</th>
<th>Actual Exposure Rate</th>
<th>Response Limits (± 10%)</th>
<th>As-Found</th>
<th>As-Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cs-137</td>
<td>100 mR/hr</td>
<td>103.1 mR/hr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-727</td>
<td>1 mR/hr</td>
<td>1.07 mR/hr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cs-137</td>
<td>5 mR/hr</td>
<td>5.04 mR/hr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-857</td>
<td>10 mR/hr</td>
<td>10.6 mR/hr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cs-137</td>
<td>50 mR/hr</td>
<td>50.5 mR/hr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-857</td>
<td>100 mR/hr</td>
<td>100.4 mR/hr</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Remarks:** The chart recorder has two responses in the field (Dot markings). The other is a straight line marking.
REPORT OF CALIBRATION

SARM 200 S/N 00303
BC RE 4366

Instrument Type: Detector Type:
Model Mdl: HP-110
Serial Number: 1531
BC RE 4277
Probe Type: Pandium GM

Volts 900.
D Time 7.5-5
CC 1.00

The stated efficiencies and calibration factors contained in this report are derived from the instrument's response to various beta emitting nuclides deposited on a stainless steel backing located a distance of 0.1 mm from the front face of the detector. Due to differences in electron backscatter factors and source/detector separations, corrections to these values should be applied to all measurements made on surfaces other than stainless steel and at distances other than 0.1 mm. This calibration is valid only for the instrument/detector combination specified above. Corrections were not made for detector dead time.

<table>
<thead>
<tr>
<th>ISOTOPE</th>
<th>C-14</th>
<th>Pa-147</th>
<th>Tc-99</th>
<th>Cl-36</th>
<th>Bi-210</th>
<th>Br-90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Source Activity (dpa)</td>
<td>322,848</td>
<td>81,003</td>
<td>86,579</td>
<td>40,848</td>
<td>38,524</td>
<td>43,106</td>
</tr>
<tr>
<td>Instrument Response (dpa)</td>
<td>22,000</td>
<td>8,000</td>
<td>16,000</td>
<td>13,000</td>
<td>12,000</td>
<td>29,000</td>
</tr>
<tr>
<td>Calibration Factor (dpa/cpa)</td>
<td>15</td>
<td>10</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Intrinsic Detector Efficiency</td>
<td>7%</td>
<td>10%</td>
<td>20%</td>
<td>32%</td>
<td>31%</td>
<td>67%</td>
</tr>
</tbody>
</table>

Calibrated by SW Nichols
Date 12-15-67
**TECHNICAL MEMORANDUM 06-04A**

**PORTABLE INSTRUMENT CALIBRATION DATA**

<table>
<thead>
<tr>
<th>Instrument No.</th>
<th>CALIBRATED BY</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ac 12# 1984</td>
<td>RE 079</td>
<td>12-18-89</td>
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<table>
<thead>
<tr>
<th>DPM</th>
<th>T. Range</th>
<th>Register Reading</th>
<th>Meter Reading CPM</th>
<th>Probe Factor</th>
<th>D/C Register</th>
<th>Calibration Factor</th>
<th>D/C Meter</th>
</tr>
</thead>
<tbody>
<tr>
<td>570</td>
<td>Int.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.67 X</td>
<td>5.7</td>
</tr>
<tr>
<td>570</td>
<td>500</td>
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<td>100</td>
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</tr>
<tr>
<td>15,358</td>
<td>5,000</td>
<td></td>
<td>2500</td>
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<td>Cal. Factor 6.1</td>
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</tr>
<tr>
<td>56,058</td>
<td>50,000</td>
<td></td>
<td>22500</td>
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</tr>
</tbody>
</table>

**Background Counts/2 min.**

\[
C\bar{C} = 3.1 \times 10^{-1}, \quad V = 1000
\]

\[
D T = 1.2 \times 10^{-5}
\]

---

**FRANKLIN SRM 200**

S/N 003203

240 Probe 01/18/89

**PORTABLE INSTRUMENT CALIBRATION DATA**

<table>
<thead>
<tr>
<th>Unit No.</th>
<th>As Found Meter Reading</th>
<th>Calibration Meter Reading</th>
<th>Final Check</th>
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<tbody>
<tr>
<td>mR/hr</td>
<td>Date By</td>
<td>Date By</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>1.9</td>
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</tr>
<tr>
<td>8</td>
<td>5</td>
<td>5.0</td>
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<tr>
<td>9</td>
<td>8</td>
<td>7.5</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>*50</td>
<td></td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>80</td>
<td>Voltage 900</td>
<td></td>
</tr>
<tr>
<td>260</td>
<td></td>
<td>197</td>
<td>CC 7.62 + 07</td>
</tr>
<tr>
<td>**500</td>
<td></td>
<td>500</td>
<td>d-Time 1.80-4</td>
</tr>
<tr>
<td>800</td>
<td></td>
<td>790</td>
<td></td>
</tr>
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</table>
REPORT OF CALIBRATION

The stated efficiencies and calibration factors contained in this report are derived from the instrument's response to various beta-emitting nuclides deposited on a stainless steel backing located a distance of 0.1 mm from the front face of the detector. Due to differences in electron backscatter factors and source/detector separations, corrections to these values should be applied to all measurements made on surfaces other than stainless steel and at distances other than 0.1 mm. This calibration is valid only for the instrument/detector combination specified above. Corrections were not made for detector dead time.

<table>
<thead>
<tr>
<th>ISOTOPE</th>
<th>C-14</th>
<th>Pd-147</th>
<th>Tc-99</th>
<th>Cl-36</th>
<th>Bi-210</th>
<th>Br-90</th>
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<tr>
<td>Current Source Activity (dpa)</td>
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<td>40,848</td>
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<td>16,000</td>
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<td>12,000</td>
<td>30,000</td>
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<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Intrinsic Detector Efficiency</td>
<td>7%</td>
<td>11%</td>
<td>18%</td>
<td>33%</td>
<td>31%</td>
<td>70%</td>
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Calibrated by

Date 1-15-90
**Pancake Probe Calibration Data Sheet**

**HP Number:** E5P-2 203  
**Serial Number:** 608

**Barcode:** 366.7 1429

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<thead>
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<td>Background</td>
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<td>20 cpm</td>
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<td>C-14</td>
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<tr>
<td>Pm-147</td>
<td>9,000</td>
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</tr>
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<td>Tc-99</td>
<td>16,000</td>
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<tr>
<td>Cl-36</td>
<td>13,500</td>
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<td>Bi-210</td>
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<td>Sr/Y-90</td>
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**Source Response**

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<tbody>
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<td>0.1 mR/hr</td>
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</tr>
<tr>
<td>1.0 mR/hr</td>
<td></td>
</tr>
<tr>
<td>10 mR/hr</td>
<td></td>
</tr>
<tr>
<td>Audio Test</td>
<td>Date: 1/19/90</td>
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</tbody>
</table>

**Reviewed By:**  
**Date:**

\[ CC = 1 \]
\[ DT = 8 \times 10^{-5} \]
\[ HU = 900 \text{V} \]
REPORT OF CALIBRATION

Instrument Type: 
Vendor/Model: 
Serial Number: 
Probe Type: 

The stated efficiencies and calibration factors contained in this report are derived from the instrument's response to various beta-emitting nuclides deposited on a stainless steel backing located at a distance of 0.1 mm from the front face of the detector. Due to differences in electron backscatter factors and source/detector separations, corrections to these values should be applied to all measurements made on surfaces other than stainless steel and at distances other than 0.1 mm. This calibration is valid only for the instrument/detector combination specified above. Corrections were not made for detector dead time.

| ISOTOPES | | | | | | | |
|----------|--------|---------|--------|--------|--------|--------|
| C-14     | Pa-147 | Tc-99   | Cl-36  | Bi-210 | Br-90  |
| Current Source Activity (dpm) | 332,866 | 79,970 | 86,579 | 40,646 | 38,466 | 43,955 |
| Instrument Response (cpsa) | 22,000 | 0,000 | 14,000 | 12,000 | 12,000 | 29,000 |
| Calibration Factor (dpa/cpsa) | 15 | 10 | 6 | 3 | 3 | 1 |
| Intrinsic Detector Efficiency | 71 | 10% | 161 | 292 | 311 | 671 |

Calibrated by [Signature]
Date 1-4-90
<table>
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<th>No.</th>
<th>Product #</th>
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<th>Calibration Meter Reading</th>
<th>Final Check</th>
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<td>SPA-3</td>
<td>Date</td>
<td>By</td>
<td></td>
</tr>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
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<td>100,000 cpm</td>
<td>Voltage 1000</td>
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<td>D. Time 1:40-05</td>
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</tr>
<tr>
<td>3</td>
<td>.1 mV/hr Ra</td>
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</table>
## Technical Memorandum 06-04A

### Portable Instrument Calibration Data

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<th>As Poured Check</th>
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<th>Final Check</th>
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<tbody>
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<td></td>
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<td>By</td>
<td>Date</td>
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<tr>
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<td></td>
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</tr>
</tbody>
</table>

- 60Co = 0.1 m/h本领
- 60Co = 7000 cpm
- 7000 bkg
- 100000 cpm
- 700000 cpm

- DT = 9.98 x 10^-7
- HV = 950 V

- CC = 1
SURFACE WATER AND SEDIMENT SAMPLING FOR THE ORNL WAG 6 RFI (PHASE 1, ACTIVITY 2)

TECHNICAL MEMORANDUM 06-05A

OAK RIDGE NATIONAL LABORATORY REMEDIAL INVESTIGATION/FEASIBILITY STUDY

JULY 1991

Prepared by Bechtel National, Inc./CH2M HILL/ERCE/PEER
P. O. Box 350
Oak Ridge, Tennessee 37830
under Subcontract 30B-99053C

for
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831

Managed by MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the U. S. DEPARTMENT OF ENERGY
under Contract DE-AC05-84OR21400

Access to the information in this report is limited to those indicated on the distribution list, to the U. S. Department of Energy and its contractors, to other Government Agencies and their contractors, and to Tennessee Government Agencies.
TECHNICAL MEMORANDUM 06-05A

FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Topography and drainage patterns</td>
</tr>
<tr>
<td>2</td>
<td>WAG 6 surface water sampling locations</td>
</tr>
<tr>
<td>3</td>
<td>WAG 6 sediment sampling locations</td>
</tr>
<tr>
<td>4</td>
<td>Radionuclide contamination in baseflow waters</td>
</tr>
<tr>
<td>5</td>
<td>Volatile organic contamination dose flow waters</td>
</tr>
<tr>
<td>6</td>
<td>Semivolatile organic contamination in base flow water</td>
</tr>
<tr>
<td>7</td>
<td>Radionuclide contamination in surface waters following a storm (September 26-27, 1989)</td>
</tr>
<tr>
<td>8</td>
<td>Volatile organic contamination in surface waters</td>
</tr>
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<td>Semivolatile organics contamination in surface waters following a storm (September 26-27, 1989)</td>
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<td>Radionuclide contamination in EWB sediments</td>
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<td>Volatile organic contamination in EWB sediments</td>
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<td>12</td>
<td>Semivolatile organic contamination in EWB sediments</td>
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<tr>
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<td>Radionuclide contamination in stream sediments</td>
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<td>Volatile organics contamination in stream sediments</td>
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<td>15</td>
<td>Semivolatile organic contamination in stream sediments</td>
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<tr>
<td>16</td>
<td>Tritium concentration in surface runoff; drainage DA</td>
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</tr>
<tr>
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<td>21</td>
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</tr>
<tr>
<td>22</td>
<td>Strontium-90 concentration in surface runoff drainage</td>
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<td>Lead concentration in surface runoff drainage FB</td>
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TECHNICAL MEMORANDUM 06-05A

ACRONYMS

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<td>ICM</td>
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TECHNICAL MEMORANDUM 06-05A

EXECUTIVE SUMMARY

Technical Memorandum (TM) 06-05A supplements TM 06-05, which also focused on surface water and sediment sampling analyses. This TM presents significant data related to surface water and sediments generated as part of the remedial investigation (RI) and subsequent to TM 06-05.

The results of the two TMs mentioned in the first paragraph form the basis for characterizing the nature and extent of contamination in the WAG 6 Resource Conservation and Recovery Act Facility Investigation (RFI). TM 06-05A also includes the results of surface water sampling and flow measurements that were carried out to calibrate the surface water contaminant transport model described in Sect. 5 of the RFI Report.
INTRODUCTION

Summary

TM 06-05A presents the results of surface water and sediment sampling analyses and supplements an earlier memorandum, TM 06-05 (BNI 1990), on the same subject. The purpose of this TM is to provide a repository for all significant data, displayed in appropriate format, related to surface water and sediments generated as part of the remedial investigation subsequent to release of the earlier TM. Results presented in the two memorandums form the basis for characterizing the nature and extent of contamination in the two media presented in Sect. 4 of the Waste Area Grouping (WAG) 6 RFI Report.

This memorandum also includes the results of intensive surface water sampling and flow measurements undertaken to gather data required for calibrating the surface water contaminant transport model described in Sect. 5 of the RFI Report. The need for this data and its analysis for use in model calibration are also described in that section. This memorandum, therefore, makes no attempt at performing these functions.

Purpose and Scope

This TM presents the results of surface water and sediment sampling analyses, which were performed for three distinct activities:

- Surface water sampling during seasonal low groundwater conditions for a base flow event and a storm event. This activity took place in September 1989 and is part of Phase 1, Activity 1, of the RFI.

- Sediment/soil (hereafter referred to as simply sediment) sampling in the streams and emergency waste basin (EWB). This activity is part of Phase 1, Activity 2, of the RFI and was performed in February and March 1990.
Intensive surface water sampling at four flume locations in the four principal drainageways during two storm events. This was done in conjunction with continuous recording of stream stages at the four flumes. This activity was carried out to gather data required for the calibration of the surface water contaminant transport model described in Chapter 5 of the RFI Report. This activity is part of Phase 1, Activity 2, of the RFI, and was performed in April and May 1990.

The general plan for the RFI, including division of surface water and sediment field investigations into phases and activities, is described in Chapter 2 of the RFI Report.

A predecessor to this TM, TM 06-05, which is part of the Oak Ridge National Laboratory (ORNL) WAG 6 Site Characterization Summary (BNL 1990), presents the remainder of the surface water sampling and analysis results that are part of Phase 1, Activity 1, of the RFI. The activities included in TM 06-05 correspond to seasonal high groundwater conditions. Both base flow and storm events were sampled and analyzed. In addition, one round of samples was collected and analyzed for pre-interim corrective measure (ICM) conditions, i.e., conditions that prevailed before some of the disposal areas were capped.

Synthesis and interpretation of all analytical results of surface water and sediment sampling that include both Activities 1 and 2 of Phase 1 are presented in Sect. 4 of the RFI Report. Analysis of data collected for model calibration is described in Sect. 5 (Contaminant Fate and Transport) of the RFI Report.

SURFACE WATER FEATURES

A detailed description of the WAG 6 surface water hydrology is given in Sect. 3 and 4 of the RFI Report. A brief description of the features that have direct relevance to the sampling activities is given in this TM.

Figure 1 shows the topography and drainage patterns in and around WAG 6. About 70% of the WAG 6 area is drained by the four principal drainage systems designated, starting from the western most drainage system, FA, FB, DA, and DB. These drainage systems are intermittent, with some base flow during high groundwater. Three smaller, ephemeral drainages, designated A, B, and C in the figure, drain the northeastern portion of the site. Drainage A feeds the EWB [Solid Waste Management Unit (SWMU 6.2)].

SAMPLING LOCATIONS

Locations for surface water sampling are shown in Fig. 2. Stream sediment samples were taken at the same locations except in Drainage DB, where no sample was taken at Location WDB1 (Fig. 3). (Location WDB1 was riprapped, and it was difficult to drive the Shelby tube.) Instead, a sediment sample was taken at Location WBD2. Fig. 3 also shows the locations where sediment samples were obtained in and around the EWB.
Fig. 1. Topography and drainage patterns at WAG 6 and adjacent areas.
Fig. 2. WAG 6 Surface water sampling locations.
Fig. 3. WAG 6 Sediment sampling locations.
A description of each surface water sampling location is given in TM 06-05 (BNI 1990).

METHODS AND PROCEDURES

Surface Water Sampling

The strategy and procedure for surface water and sediment sampling are described in the field sampling plan (FSP) of the WAG 6 RFI (BNI 1989) and in TM 06-05 (BNI 1990). Neither document, however, describes the sampling strategy and procedure used in the intensive effort aimed at collecting data required for the calibration of the surface water contaminant transport model described in Sect. 5 of the RFI Report. For this calibration, storm runoff volumes and average concentrations of contaminants of concern in storm runoff are required. To generate this information, four flumes were installed at the downstream end of the four principal drainageways: FA, FB, DA, and DB (Fig. 1). In Drainage FA, a trapezoidal flume, with a 5.08 cm (2-in.) throat and with sides sloping at 60° with respect to the horizontal, was installed. Drainages FB and DB have Parshall flumes each with a 15.24-cm (6-in.) throat. Drainage DB has a large cross-sectional area. A .92-m (3-ft) Parshall flume upstream of the 15.24-cm (6-in.) flume was also installed in this drainage for measuring higher flows. It was, however, not used for the two storms sampled, which were measured at the 15.24-cm (6-in.) flume. Drainage DA has an 45.72-cm (18-in.) Parshall flume. The flumes were sized based on channel geometry and bankfull capacity. All flumes were prefabricated with fiber glass by "Free Flow, Inc.," and came equipped with two stilling wells each, one upstream and the other downstream of the throat. Standard, factory-supplied rating curves were used.

The approximate ranges of flows for the 5.08-cm (2-in.) trapezoidal, (6-in.) Parshall, and 45.72-cm (18-in.) Parshall flumes are respectively 0.02 to 0.8, 0.05 to 3.9, and 0.15 to 24.6 cfs. The lower figure corresponds to about 2.54 cm (1 in.) of flow depth in the throat section, and the higher figure to incipient submergence condition.

The stilling wells were equipped with pressure transducers (2.5 psi) to measure stream stages, which were recorded by Easy Logger Model EL-834. Samples were automatically collected by ISCO Model 2700 samplers. The automatic samplers began operation at a preset stage and collected series of samples spaced at 10- to 20-min. intervals. Samples were taken for several storms; however, only two storms per flume site were chosen for sample analysis and data reduction to reduce analytical cost. Selection of the two storms was done on the basis of the relative success of the automatic sample collection activity. For this activity, a storm was defined as any rainfall event that produced a distinct hydrograph of measurable flows.
Sediment Sampling

Sediment samples were obtained by driving a Shelby tube at the sampling location to "refusal" depth (typically 0.61 m (2 ft)) and retrieving the sample. Sample extrusion was done at the field laboratory before putting the composited aliquots in proper containers as described in the RFI, FSP (BNI 1989).

RESULTS

Surface Water Sampling

Base flow — seasonal low groundwater

Base flow surface water samples could be obtained at only 4 locations out of 16 locations. The rest of the sampling locations were too dry for samples to be collected. The samples were obtained on September 5 and 6, 1989. None of the sampling locations in Drainage FA had sufficient water for sampling. In Drainage FB, only sampling location WFBB1 had sufficient water for sampling; however, the flow was not large enough to be measurable. In Drainage DA, sampling locations W49TS and WDA1 had measurable flows. The EWB in Drainage A had enough water to be sampled. Drainages DB, B, and C were dry.

Table 1 summarizes the analytical results for base flow surface water at the four sampling locations. Samples were analyzed for radionuclides, target analyte list (TAL) metals, target compound list (TCL) organics, and water quality parameters. Only those constituents that were found above quantitation limits are listed. Quantitation limits for the various constituents in water and soil/sediment are presented in the RFI report. Suspected contaminants [(tentatively identified compounds (TICs)] are mentioned in the text, but are not listed. (TICs are those compounds whose mass spectra match, to a certain degree, those in a mass spectra library during a computerized search. TICs are characterized by uncertainty in identity and quantitation.)

Tritium was found to be ubiquitous in base flows ranging in concentration from about 3 million to 14 million pCi/L. In the EWB, its concentration is considerably diluted by relatively clean water collecting in the EWB. The tritium concentration in the EWB was found to be about 190,000 pCi/L.

Drainage FB waters show elevated concentrations (370 pCi/L) of strontium—90 (and hence of gross beta). Figure 4 shows the radionuclide contamination in base flow waters.

Except for trichloroethene (810 µg/L), tetrachloroethene (46 µg/L), 1,1-dichloroethane (4 µg/L), 2-butanone (2 µg/L), chloroform (15 µg/L), and 1,2-dichloroethylene (120 µg/L) found in the 49-Trench (49T) area's french drain waters at W49TS, little organic contamination was found during this round of sampling. Two-hexanone in the EWB (1 µg/L)
Table 1. Surface water sampling—base flow seasonal low groundwater
September 5-6, 1989

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Drainage DA</th>
<th>Drainage FB</th>
<th>Drainage A</th>
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<tbody>
<tr>
<td></td>
<td>W49TS</td>
<td>WDA1</td>
<td>WFBB1</td>
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<tr>
<td>Water Quality</td>
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<td></td>
<td></td>
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<td>21</td>
<td>22</td>
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<td>pH</td>
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<td>7.2</td>
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<td>332</td>
<td>430</td>
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<tr>
<td>Flow mL/s</td>
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<td>0.05</td>
<td>-</td>
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<tr>
<td>Total Kjeldahl nitrogen, mg/L</td>
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<td>-</td>
<td>0.5</td>
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<td>Bicarbonate as CaCO3, mg/L</td>
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<td>170</td>
<td>230</td>
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<tr>
<td>Total dissolved solids, mg/L</td>
<td>329 J</td>
<td>254 J</td>
<td>273 J</td>
</tr>
<tr>
<td>Biochemical oxygen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demand, mg/L</td>
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<td>1</td>
<td>-</td>
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<tr>
<td>Chemical oxygen demand, mg/L</td>
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<td>16</td>
<td>21</td>
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<td>Sulfate, mg/L</td>
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<td>18</td>
<td>10</td>
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<tr>
<td>Nitrate, mg/L</td>
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<td>10</td>
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<td>Cyanide, µg/L</td>
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<td>Fecal coliform (Colonies/L)</td>
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<td>Radionuclides (pCi/L)</td>
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<td></td>
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<tr>
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<td>14,000,000 ±</td>
<td>2,900,000 ±</td>
<td>3,600,000 ±</td>
</tr>
<tr>
<td>1,000,000</td>
<td>300,000</td>
<td>400,000</td>
<td>2000</td>
</tr>
<tr>
<td>Strontium-90</td>
<td>-</td>
<td>6.2 +/- 1.3</td>
<td>370 +/- 40</td>
</tr>
<tr>
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<td>4 +/- 3</td>
<td>-</td>
<td>6 +/- 3</td>
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<tr>
<td>Gross beta</td>
<td>12 +/- 3</td>
<td>9 +/- 3</td>
<td>490 +/- 51</td>
</tr>
<tr>
<td>Radium-228</td>
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<td>55 +/- 8</td>
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<td>Semivolatile organics (µg/L)</td>
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<tr>
<td>Bis(2-Ethylhexyl)-phthalate</td>
<td>-</td>
<td>4 J</td>
<td>-</td>
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<td>Volatile organics (µg/L)</td>
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<tr>
<td>1,2-Dichloroethylene</td>
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<td>Tetrachloroethene</td>
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<td>2-Butanone</td>
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Table 1. (continued)

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<td>3.1 J</td>
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<td>-</td>
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<tr>
<td>Vanadium</td>
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<td>17.2 J</td>
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<td>Zinc</td>
<td>30.4 J</td>
<td>34.4</td>
<td>-</td>
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Metals (unfiltered)                      

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<th>Drainage A</th>
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<td>W49TS</td>
<td>WDA1</td>
<td>WFBB1</td>
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<tr>
<td>Aluminum</td>
<td>134 J</td>
<td>107 J</td>
<td>703</td>
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<tr>
<td>Barium</td>
<td>181 J</td>
<td>87.2 J</td>
<td>52.9 J</td>
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<td>Beryllium</td>
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<td>1.5 J</td>
<td>1.5 J</td>
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<td>Cadmium</td>
<td>2.4 J</td>
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<td>-</td>
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<tr>
<td>Calcium</td>
<td>107000</td>
<td>62100</td>
<td>80700</td>
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<tr>
<td>Chromium</td>
<td>23.2</td>
<td>12.7</td>
<td>16.1</td>
</tr>
<tr>
<td>Iron</td>
<td>27.2 J</td>
<td>94.9 J</td>
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</tr>
<tr>
<td>Lead</td>
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<td>-</td>
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<tr>
<td>Magnesium</td>
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<td>17.3 J</td>
<td>-</td>
<td>12.3 J</td>
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<tr>
<td>Zinc</td>
<td>10.3 J</td>
<td>45.4 J</td>
<td>13.7 J</td>
</tr>
</tbody>
</table>

"J" The associated numerical value is an estimated quantity. J-qualified concentrations are used the same way as positive data for risk assessment.

"." Below quantitation limit (see the RFI Report for quantitation limits).
CONCENTRATIONS IN pCi/L

\[ ^{3}H = 3,600,000 \]

\[ ^{50}Sr = 370 \]

\[ ^{226}Ra = 55 \]

Fig. 4. Radionuclide contamination in base fl
low waters (September 5-6, 1989) seasonal low groundwater.
and 1-bis(2-ethylhexyl)phthalate (4 μg/L) at WDA1 were the only two other organics identified. The presence of several other organics at varying levels of concentration was suspected. These were 1,3,6-trioxocane at WFBB1 and W49TS, 1,2-benzenedicarboxylic acid at WDA1, and 2-hydroxy-2-methyl-4-pentanone at WEWB. Bis (2-ethyl benzyl) phthalate is a laboratory artifact, and its detection in most samples can be attributed to this fact. 2-hydroxy-2-methyl-4-pentanone is an aldol condensate product produced in the preparation and analyses of BNAs. Figures 5 and 6 show volatile and semivolatile organic contamination in base flow waters.

Storm flow sampling

Surface water sampling for a storm event during low groundwater conditions was done on September 26 and 27, 1989. On September 26, the rain gauge at 49T recorded .05 cm (0.02 in.) of rainfall, while no rainfall was recorded at the Engineered Test Facility (ETF) rain gauge (See Fig. 1 for locations of rain gauges). On September 27, both rain gauges recorded no rainfall. On September 25, however, a rainfall of 2.46 cm (0.97 in.) at 49T and of 2.51 cm (0.99 in.) at the ETF was recorded. Thus, this storm event sampling represents residual storm flows from the September 25 storm event. Samples were analyzed for radionuclides, TAL metals, TCL organics and water quality parameters. One sample, taken at station WSP1, was analyzed for the full suite of Appendix IX chemicals.

Table 2 summarizes the analytical results of this sampling effort. No samples could be collected at locations WDB1, SWC1, and SWB1 because of insufficient water. At several other locations, samples could be collected, but the flow was not large enough to be measurable.

In Drainage FA, little organic contamination was found. The presence of 2-hydroxy-2-methyl-4-pentanone at Station WBAB2 was suspected, but not confirmed. Among radionuclides, tritium, strontium-90, and cesium-137 were the only ones found in quantifiable concentrations. Dilution of tritium concentrations from upstream (393,000 pCi/L at Station WBAB2) to downstream (103,000 pCi/L at Station WFBA1) is evident.

In Drainage FB, tetrachloroethene, 1, 2-dichloroethylene, and trichloroethene were the only organics found. Presence of 2-hydroxy-2-methyl-4-pentanone at Station WFBB2 was suspected, but not confirmed. At the next downstream station, Station WFBB1, no organics were found at quantifiable concentrations, probably because of dilution. Besides the ubiquitous tritium, drainage FB showed elevated concentrations of strontium-90. Probable sources for strontium-90 are the high activity trenches at the upstream reaches and the seep at WSP1. A strong tritium source downstream of Station WSP1 is indicated.

In Drainage DA, tetrachloroethene, 1,2-dichloroethylene, 1,1-dichloroethane, trichloroethene were the only organics found in the french drain waters at Station 49TS. At Station WDA1 further downstream, however, no organics were found at quantifiable concentrations probably because of dilution. At Station 49TS, tritium and strontium-90 were
Fig. 5. Volatile organic contamination in base flow water
Table 2. Surface water sampling—storm flow September 26-27, 1989 seasonal low groundwater

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<td>2,320,000 ± 232,000</td>
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<tr>
<td>Strontium-90</td>
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<tr>
<td>Arsenic</td>
<td>-</td>
<td>2 J</td>
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<tr>
<td>Barium</td>
<td>164 J</td>
<td>114 J</td>
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<tr>
<td>Cadmium</td>
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<td>Calcium</td>
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<td>41,100</td>
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<td>19.8</td>
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<td>Lead</td>
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<td>Manganese</td>
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<td>Metals (μg/L)—Unfiltered</td>
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<td>2 J</td>
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<td>Calcium</td>
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<td>3620 J</td>
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the two radionuclides observed. At the downstream station WDA1, tritium concentrations are reduced from about 4 million to about 2 million pCi/L, and strontium-90 fails to show up at quantifiable concentrations. The effect of dilution is indicated.

Drainage A exhibits the least contamination. No organics were found, although presence of 2-hydroxy-2-methyl-4-pentanone was suspected in the EWB waters. Tritium concentration of 2550 pCi/L at Station SWA1 was the lowest found in WAG 6. Some Strontium-90 was found in the EWB waters. Figures 7, 8, and 9 show, respectively, the radionuclides, volatile, and sem-volatile organic contamination in surface waters following a storm.

Sediment Sampling

Emergency waste basin

Sixteen sediment samples in and around the EWB were taken and analyzed for radionuclides, TAL metals and TCL organics. One sample—at EWB14—was analyzed for the full suite of Appendix IX chemicals. The locations for EWB sediment sampling are shown in Fig. 3.

Table 3 summarizes the analytical results for the EWB sediments. Most of the radionuclides identified in the sediments are naturally occurring. Of the man-made radionuclides, tritium and cesium-137 are the principal ones found in the sediments. One sample, at EWB05, showed small amounts of cobalt-60. The source of these radionuclides is probably the runoff from the high-activity and 17-trench areas just south of the northern boundary of WAG 6. The maximum concentration of cesium-137 was found to be less than 5 pCi/g (Station EWB 18). At most places, it is less than 1 pCi/g. Tritium, found in only three samples (EWB 02, EWB 05, and EWB 08), had a maximum concentration of 581 pCi/g. Tritium is present in the water of wet sediments. Figure 10 presents the extent of radionuclide contamination in the EWB sediments.

A variety of organics were observed in the EWB sediments. These include phenol, toluene, chloroform, 2-butanone, 2,6-dinitrotoluene, bis(2-ethylhexyl)phthalate, methylene chloride, 2-propanone, benzoic acid, trichlorofluoromethane, and trichloroethene. The presence of a variety of other organics was suspected, but not confirmed. Chief among these were dioctyl adipate, and 2-hydroxy-2-methyl-4-pentanone.

Maximum concentrations of the principal organics found in the EWB sediments are phenol at 89 μg/kg; toluene at 2 μg/kg; chloroform at 16 μg/kg; 2-butanone at 140 μg/kg; 2,6-dinitrotoluene at 150 μg/kg; methylene chloride at 62 μg/kg; and benzoic acid at 67μg/kg.

Figures 11 and 12 indicate the extent of organic contamination in the EWB sediments.
Fig. 7. Radionuclide contamination in surface waters following a storm (September 26-27, 1989).
Waters following a storm (September 26-27, 1989).
Fig. 9. Semivolatile organic contamination in surface
waters following a storm (September 26-27, 1989).
Table 3. Analytical results for EWB sediments

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<th>Parameters</th>
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<th>EWB06</th>
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<td>518 +/- 53</td>
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<td>15.7 +/- 8.4</td>
<td>16 +/- 7.9</td>
<td>11.7 +/- 6.4</td>
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<tr>
<td>Gross beta</td>
<td>24 +/- 7.2</td>
<td>20.7 +/- 6.1</td>
<td>22.2 +/- 7</td>
<td>21.6 +/- 6.8</td>
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<td>1.21 +/- 0.14</td>
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<td>0.72 +/- 0.077</td>
<td>0.724 +/- 0.077</td>
<td>0.726 +/- 0.081</td>
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<td>1.24 +/- 0.15</td>
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<td>21.4 +/- 2.5</td>
<td>18.9 +/- 2.9</td>
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<td>16</td>
<td>-</td>
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### Table 3. (continued)

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<td>0.884 +/- 0.097</td>
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<td>Phenol</td>
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<td>1.2 +/- 0.18</td>
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For explanatory notes, see Table 1.
Fig. 10. Radionuclide conta...
in a ti (m in WB, element.

CONCENTRATIONS IN PC/6

CONCENTRATIONS IN PC/6

CONCENTRATIONS IN PC/6

LEGEND

SCALE IN FEET

SCALE IN METERS

SEA SECURITY FENCE

WATER BOUNDARY

ROAD

WATER BOUNDARY

WATER BOUNDARY

ALERT ZONE

ALERT ZONE

ALERT ZONE

ALERT ZONE
Fig. 11. Volatile organic cont...
amination in EWB sediments.
Fig. 12. Semivolatile organic
Contamination in EWB sediments.
Streams

Stream bed sediment samples were taken at locations shown in Fig. 3. These were analyzed for radionuclides, TAL metals, and TCL organics. Two samples—one at Station SWA1 and the other at WFBB1 were analyzed for the full suite of Appendix IX chemicals.

Table 4 presents the analytical results for stream sediments. Besides the naturally-occurring radionuclides, the only man-made radionuclides found in stream sediments were tritium, cesium-137, strontium-90 and cobalt-60. (Tritium is actually present in the wet sediments). A variety of organics were also present. Chief among them are bis (2-ethylhexyl) phthalate, toluene, chloroform, 2-butane and trichloroethene. Other organics found in some samples are xylenes; methylene chloride; 2, 6-dinitrotoluene; phenol; cis-1, 3-dichloropropene; 1, 2-dichloropropane; tetrachloroethene; trichlorofluoromethane; butyl benzyl phthalate; N-nitrosodiphenylamine; acetone; di-n-acyl phthalate; and 4-chlorophenyl phenylether.

Drainage FA sediments had small concentrations of tritium (maximum concentration—312 pCi/g) and cesium-137 (maximum concentration = 0.75 pCi/g). Among the organics, toluene, chloroform, 2-butanone and trichloroethene were found in all Drainage FA sediment samples. The maximum concentrations were, respectively, 3, 29, 190 and 3µg/kg. Bis (2-ethylhexyl) phthalate was found in all at locations except WFBA1. Its maximum concentration was 460 µg/kg. Phenol at 59 µg/kg appeared in only one sample, the sample at the most downstream location (WFBA1). The maximum concentration of dinitrotoluene, which appeared in two samples, was 140 µg/kg. Total xylenes at 2 µg/kg and methylene chloride at 21 µg/kg appeared in only one sample (WBAB1).

Tritium, cesium-137, cobalt-60 and strontium-90 were some of the man-made radionuclides found in the sediments of Drainage FB. The maximum concentration of tritium and cesium-137 were, respectively, 840 pCi/g and 1.13 pCi/g. Cobalt-60 at 0.106 pCi/g, and strontium-90 at 25.5 pCi/g appeared at only one location each, at WFBB2 and WFBB1, respectively. Among the organics, bis (2-ethylhexyl) phthalate (maximum concentration at 400 µg/kg), chloroform (maximum concentration at 64 µg/kg), toluene (maximum concentration at 5 µg/kg), 2-butanone (maximum concentration at 270 µg/kg), trichloroethene (maximum concentration at 17 µg/kg), and methylene chloride (maximum concentration at 98 µg/kg) were the most prevalent organics.

For Drainage DA, cesium-137 (maximum concentration at 1.12 pCi/g) and tritium at WDA1 with a concentration of 414 pCi/g were the only man-made radionuclides found. Among the organics, bis (2-ethylhexyl) phthalate was found in both sediment samples (maximum concentration at 330 µg/kg). The only other organic found at W49TS was methylene chloride at 200 µg/kg. The rest of the organics found in Drainage DA sediments were butyl benzyl phthalate, toluene, total xylenes, chloroform, 2-butanone, and trichloroethene.
Table 4. Analytical results for stream sediments

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<tr>
<td>Gross beta</td>
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<td>Radium-224</td>
<td>1.28 +/- 0.18</td>
<td>1.3 +/- 0.185</td>
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<td>0.865 +/- 0.101</td>
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<td><strong>Semivolatile organics (µg/kg)</strong></td>
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<td>3290</td>
<td>3090</td>
</tr>
<tr>
<td>Manganese</td>
<td>1570</td>
<td>1510</td>
<td>1610</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.12 J</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nickel</td>
<td>48.2</td>
<td>32.6</td>
<td>34.1</td>
</tr>
<tr>
<td>Osmium</td>
<td>421 J</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Potassium</td>
<td>1450</td>
<td>1470</td>
<td>1990</td>
</tr>
</tbody>
</table>
Table 4. (continued)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>DRAINAGE A SWA1</th>
<th>DRAINAGE B SWB1</th>
<th>DRAINAGE C SWC1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metals (mg/kg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td>76.8 J</td>
<td>56.1 J</td>
<td>50.5 J</td>
</tr>
<tr>
<td>Tin</td>
<td>71.6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Vanadium</td>
<td>15.6</td>
<td>12.5</td>
<td>16</td>
</tr>
<tr>
<td>Zinc</td>
<td>74.2 J</td>
<td>48 J</td>
<td>51 J</td>
</tr>
</tbody>
</table>

For explanatory notes see Table 1.
For Drainage DB, a stream sediment sample was collected at only one location. Tritium at 66.7 pCi/g and cesium-137 at 0.297 pCi/g were the only man-made radionuclides found. Bis (2-ethylhexyl) phthalate at 200 μg/kg, toluene at 2 μg/kg, 2-butanone at 100 μg/kg and trichloroethene at 2 μg/kg were the only organics found in this sample.

The sediment sample downstream of the EWB in the ephemeral Drainage A had small concentrations of cesium-137 at 0.89 pCi/g and strontium-90 at 0.79 pCi/g. Besides the more prevalent organics, toluene at 2 μg/kg, chloroform at 17 μg/kg, 2-butanone at 340 μg/kg and trichloroethene at 2 μg/kg, n-nitrosodiphenylamine at 46 μg/kg, and trichlorofloromethane at 54 μg/kg were also found.

The sediment sample for the ephemeral Drainage B had tritium at 153 pCi/g and cesium-137 at 0.967 pCi/g. Di-n-octyl phthalate at 80 μg/kg, 4-chlorophenyl phenylether at 70 μg/kg, butyl benzyl phthalate at 58 μg/kg and chloroform at 7 μg/kg were the only organics found.

The sediment sample for Drainage C had tritium at 71 pCi/g, cesium-137 at 2.14 pCi/g, and elevated levels of cobalt-60 at 53.3 pCi/g. Bis (2-ethylhexyl) phthalate at 230 μg/kg, toluene at 2 μg/kg and 2-butanone at 110 μg/kg were the only organics found.

A variety of organics in the stream sediments were suspected, but not confirmed. Chief among these were 1-(chloromethyl) -4-benzene and 1,1,1-tri-chloro-2-propanol.

Figure 13 shows the radionuclide contamination in stream sediments. Figures 14 and 15 show organic volatile and semivolatile contamination in stream sediments.

Results of Field Activities For Surface Water Contaminant Transport Model Calibration

Tables 5 to 12 present flow and concentration data for two selected storms at each of the four flume locations in Drainages DA, DB, FA, and FB. These data are described in the following paragraphs.

Stream hydrograph. Continuous stage hydrographs were recorded at the four flume locations for several storms. Two storms per location were selected for model calibration based primarily on the relative success of automatic sample collection activity. When enough samples could not be collected to adequately describe a concentration hydrograph, the corresponding storm was not selected for model calibration.

The stage hydrographs were converted to discharge hydrographs through appropriate rating curves for the four flumes. (See RFI Report, Sect. 3.4.) One of the selected storms for Drainage FA, that of April 28, 1990, occurred before construction of the flume in this drainage. A stage hydrograph was recorded in a stilling well at a location close to where the
Fig. 13. WAG 6:

![Diagram showing the location of WAG 6 with various measurements and coordinates.](image-url)
Adionuclide contamination in stream sediments.

LEGEND

- WAG 6 BOUNDARY
- PAVED ROAD
- GRAVEL ROAD
- MARSHY AREA
- TRIBUTARY
- WATER BODY
- SWSA SECURITY FENCE

CONCENTRATIONS IN pci/g

0 300 600

1" = 300'

3 H = 153
38 Cs = 0.967
224 Ra = 1.34
40 K = 23.6
226 Ra = 0.729
234 Th = 1.06
228 Ra = 1.34

3 H = 71
38 Cs = 2.14
60 Co = 53.3
224 Ra = 1.25
40 K = 20.7
226 Ra = 1.05

3 H = 66.7
38 Cs = 0.297
224 Ra = 1.15
40 K = 19.1
226 Ra = 0.81
234 Th = 1.45
228 Ra = 1.17

3 H = 840
230 Th = 1.59
38 Cs = 0.46
226 Ra = 1.34
90 Sr = 25.5
228 Ra = 0.752
232 Th = 0.937
Fig. 14. Volatile organics contamination in stream sediments.
Fig. 15. Semivolatile organic co
Contamination in stream sediments.
Table 5. Drainage DA storm event of May 17, 1990

<table>
<thead>
<tr>
<th>Time</th>
<th>Tritium (pCi/L)</th>
<th>Lead (μg/L)</th>
<th>Flow (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6:20</td>
<td>111,000 ± 11,000</td>
<td>5.2</td>
<td>0.39</td>
</tr>
<tr>
<td>6:30</td>
<td>150,000 ± 15,000</td>
<td>--</td>
<td>0.36</td>
</tr>
<tr>
<td>6:40</td>
<td>17,500 ± 1,800</td>
<td>--</td>
<td>4.1</td>
</tr>
<tr>
<td>6:50</td>
<td>1,120,000 ± 110,000</td>
<td>5</td>
<td>2.2</td>
</tr>
<tr>
<td>7:00</td>
<td>92,400 ± 9,300</td>
<td>--</td>
<td>1.09</td>
</tr>
<tr>
<td>7:10</td>
<td>4,200,000 ± 31,000</td>
<td>--</td>
<td>0.71</td>
</tr>
<tr>
<td>8:00</td>
<td>311,000 ± 31,000</td>
<td>--</td>
<td>0.39</td>
</tr>
<tr>
<td>8:50</td>
<td>676,000 ± 67,000</td>
<td>--</td>
<td>0.15</td>
</tr>
</tbody>
</table>

-- Below detection limit
### Table 6. Drainage DA storm event of May 27, 1990

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Tritium Flow (pCi/L)</th>
<th>Flow (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/26/90</td>
<td>22:10</td>
<td>282,000 ± 28,000</td>
<td>0.08</td>
</tr>
<tr>
<td>5/27/90</td>
<td>18:20</td>
<td>50,500 ± 510</td>
<td>2.01</td>
</tr>
<tr>
<td></td>
<td>18:30</td>
<td>31,800 ± 3200</td>
<td>2.74</td>
</tr>
<tr>
<td></td>
<td>18:40</td>
<td>75,700 ± 7600</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>19:20</td>
<td>213,000 ± 11,000</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>20:10</td>
<td>110,000 ± 11,000</td>
<td>0.04</td>
</tr>
<tr>
<td>5/28/90</td>
<td>5:00</td>
<td>80,800 ± 8100</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>5:10</td>
<td>230,000 ± 23,000</td>
<td>0.51</td>
</tr>
</tbody>
</table>
Table 7. Drainage DB storm event of May 17, 1990

<table>
<thead>
<tr>
<th>Time</th>
<th>Tritium (pCi/L)</th>
<th>Lead (µg/L)</th>
<th>Flow (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6:10</td>
<td>11,700 ± 1200</td>
<td>--</td>
<td>0.3</td>
</tr>
<tr>
<td>6:20</td>
<td>19,400 ± 2000</td>
<td>7.8</td>
<td>0.16</td>
</tr>
<tr>
<td>6:30</td>
<td>36,900 ± 3700</td>
<td>16</td>
<td>0.99</td>
</tr>
<tr>
<td>6:40</td>
<td>1,130,000 ± 110,000</td>
<td>10.8</td>
<td>2</td>
</tr>
<tr>
<td>6:50</td>
<td>38,200 ± 3900</td>
<td>15.1</td>
<td>2.19</td>
</tr>
<tr>
<td>7:10</td>
<td>41,200 ± 4200</td>
<td>17.9</td>
<td>1.09</td>
</tr>
<tr>
<td>7:50</td>
<td>2,230,000 ± 230,000</td>
<td>10</td>
<td>0.32</td>
</tr>
<tr>
<td>8:40</td>
<td>3,620,000 ± 360,000</td>
<td>8.9</td>
<td>0.13</td>
</tr>
</tbody>
</table>

-- Below detection limit
Table 8. Drainage DB storm event of May 27, 1990

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Tritium (pCi/L)</th>
<th>Lead (µg/L)</th>
<th>Strontium-90</th>
<th>Flow (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/26/90</td>
<td>21:40</td>
<td>13,500 ± 1400</td>
<td>--</td>
<td>--</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>21:50</td>
<td>14,200 ± 1500</td>
<td>--</td>
<td>--</td>
<td>0.1</td>
</tr>
<tr>
<td>5/27/90</td>
<td>16:40</td>
<td>50,800 ± 5100</td>
<td>--</td>
<td>--</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>16:50</td>
<td>37,400 ± 3800</td>
<td>--</td>
<td>--</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>18:20</td>
<td>28,500 ± 2900</td>
<td>--</td>
<td>9.47 ± 1.6</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>18:30</td>
<td>66,100 ± 6700</td>
<td>--</td>
<td>--</td>
<td>1.81</td>
</tr>
<tr>
<td></td>
<td>18:50</td>
<td>86,100 ± 8700</td>
<td>--</td>
<td>--</td>
<td>1.04</td>
</tr>
<tr>
<td></td>
<td>20:10</td>
<td>121,000 ± 12,000</td>
<td>11.3</td>
<td>--</td>
<td>0.07</td>
</tr>
</tbody>
</table>

-- Below detection limit
Table 9. Drainage FA storm event of April 28, 1990

<table>
<thead>
<tr>
<th>Time</th>
<th>Strontium-90 (pCi/L)</th>
<th>Plutonium-238 (pCi/L)</th>
<th>Radium-224 (pCi/L)</th>
<th>Thorium-234* (pCi/L)</th>
<th>Lead (µg/L)</th>
<th>Flow (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13:40</td>
<td>--</td>
<td>3.06 ± 0.74</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>0.57</td>
</tr>
<tr>
<td>13:50</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>15.6</td>
<td>0.85</td>
</tr>
<tr>
<td>14:00</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>0.85</td>
<td></td>
</tr>
<tr>
<td>14:40</td>
<td>--</td>
<td>--</td>
<td>19.4 ± 9.5</td>
<td>228 ± 60</td>
<td>--</td>
<td>2.27</td>
</tr>
<tr>
<td>14:50</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>4.7</td>
<td>3.11</td>
</tr>
<tr>
<td>15:20</td>
<td>7.12 ± 1.69</td>
<td>--</td>
<td>27.2 ± 10.1</td>
<td>--</td>
<td>--</td>
<td>1.98</td>
</tr>
<tr>
<td>15:40</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1.42</td>
</tr>
<tr>
<td>16:00</td>
<td>6.23 ± 1.64</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1.13</td>
</tr>
</tbody>
</table>

--Below detection limit
* For a discussion of background level of thorium-234, see TM 06-15, Appendix 2.
Table 10. Drainage FA storm event of May 17, 1990

<table>
<thead>
<tr>
<th>Time</th>
<th>Plutonium-238 (pCi/L)</th>
<th>Radium-224 (pCi/L)</th>
<th>Thorium-234* (pCi/L)</th>
<th>Lead (µg/L)</th>
<th>Flow (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6:40</td>
<td>3.73 ± 0.85</td>
<td>15.5 ± 9.5</td>
<td>220 ± 60</td>
<td>14.7</td>
<td>0.38</td>
</tr>
<tr>
<td>6:50</td>
<td>--</td>
<td>20.7 ± 9.5</td>
<td>--</td>
<td>21</td>
<td>0.4</td>
</tr>
<tr>
<td>7:00</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>11.7</td>
<td>0.42</td>
</tr>
<tr>
<td>7:10</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>7.9</td>
<td>0.4</td>
</tr>
<tr>
<td>7:20</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>12</td>
<td>0.38</td>
</tr>
<tr>
<td>7:30</td>
<td>--</td>
<td>21.8 ± 10.2</td>
<td>272 ± 68</td>
<td>7.3</td>
<td>0.34</td>
</tr>
<tr>
<td>7:40</td>
<td>--</td>
<td>--</td>
<td>261 ± 64</td>
<td>7.1</td>
<td>0.31</td>
</tr>
<tr>
<td>7:50</td>
<td>--</td>
<td>--</td>
<td>143 ± 72</td>
<td>5.7</td>
<td>0.28</td>
</tr>
</tbody>
</table>

-- Below detection limit
* See Table 9
Table 11. Drainage FB storm event of May 17, 1990

<table>
<thead>
<tr>
<th>Time</th>
<th>Plutonium-239/240 (pCi/L)</th>
<th>Thorium-232 (pCi/L)</th>
<th>Thorium-238 (pCi/L)</th>
<th>Strontium (pCi/L)</th>
<th>Tritium (pCi/L)</th>
<th>Lead (μg/L)</th>
<th>Flow (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6:10</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>188 ± 19</td>
<td>1,790,000</td>
<td>4.9</td>
<td>0.13</td>
</tr>
<tr>
<td>6:20</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>169 ± 17</td>
<td>1,420,000 ± 140,000</td>
<td>15.1</td>
<td>0.1</td>
</tr>
<tr>
<td>6:30</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>180 ± 19</td>
<td>1,310,000</td>
<td>11.4</td>
<td>0.24</td>
</tr>
<tr>
<td>6:40</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1.43 ± 0.5</td>
<td>107 ± 11</td>
<td>17</td>
<td>1.65</td>
</tr>
<tr>
<td>6:50</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>164 ± 17</td>
<td>1,110,000</td>
<td>14.9</td>
<td>1.42</td>
</tr>
<tr>
<td>7:00</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1.92 ± 0.62</td>
<td>170 ± 18</td>
<td>892,000</td>
<td>24.7</td>
</tr>
<tr>
<td>7:10</td>
<td>3.16 ± 0.64</td>
<td>1.14 ± 0.41</td>
<td>1.66 ± 0.5</td>
<td>128 ± 14</td>
<td>418,000</td>
<td>31.6</td>
<td>2</td>
</tr>
<tr>
<td>7:20</td>
<td>--</td>
<td>--</td>
<td>1.36 ± 0.45</td>
<td>114 ± 12</td>
<td>466,000</td>
<td>13.8</td>
<td>1.74</td>
</tr>
</tbody>
</table>

--Below detection limit
Table 12. Drainage FB storm event of May 20, 1990

<table>
<thead>
<tr>
<th>Time</th>
<th>Strontium-90 (pCi/L)</th>
<th>Thorium-228 (pCi/L)</th>
<th>Thorium-230 (pCi/L)</th>
<th>Tritium (pCi/L)</th>
<th>Lead (µg/L)</th>
<th>Flow (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:10</td>
<td>365 ± 37</td>
<td>1.63 ± 0.42</td>
<td>--</td>
<td>3,960,000 ± 400,000</td>
<td>--</td>
<td>0.06</td>
</tr>
<tr>
<td>12:20</td>
<td>376 ± 38</td>
<td>--</td>
<td>--</td>
<td>3,950,000 ± 400,000</td>
<td>--</td>
<td>0.06</td>
</tr>
<tr>
<td>16:30</td>
<td>180 ± 18</td>
<td>--</td>
<td>--</td>
<td>1,170,000 ± 120,000</td>
<td>--</td>
<td>0.19</td>
</tr>
<tr>
<td>16:40</td>
<td>215 ± 22</td>
<td>1.57 ± 1.24</td>
<td>1.2 ± 1.11</td>
<td>1,680,000 ± 170,000</td>
<td>--</td>
<td>0.13</td>
</tr>
<tr>
<td>16:50</td>
<td>218 ± 22</td>
<td>--</td>
<td>--</td>
<td>1,710,000 ± 170,000</td>
<td>--</td>
<td>0.1</td>
</tr>
<tr>
<td>17:00</td>
<td>227 ± 24</td>
<td>1.20 ± 0.59</td>
<td>--</td>
<td>1,780,000 ± 180,000</td>
<td>3.1</td>
<td>0.09</td>
</tr>
<tr>
<td>17:10</td>
<td>260 ± 27</td>
<td>--</td>
<td>--</td>
<td>2,100,000 ± 210,000</td>
<td>--</td>
<td>0.1</td>
</tr>
<tr>
<td>17:20</td>
<td>263 ± 27</td>
<td>--</td>
<td>--</td>
<td>2490 ± 250</td>
<td>--</td>
<td>0.11</td>
</tr>
</tbody>
</table>

--Below detection limit
flume was later constructed. The discharge hydrograph for this storm was obtained through correlation of stages at the flume and where the stage hydrograph was recorded.

Figures 16 to 35 show the discharge hydrographs for the selected storms at the four flume locations. Rainfall recorded at the appropriate rain gauge, either ETF or 49T, is also superimposed on this figure. (There was little difference in the rainfall amounts recorded at ETF and 49T rain gauges.)

For Drainage DA, the two selected storms occurred on May 17 and May 27, 1990, with total rainfall amounts of, respectively, 2.08 cm (0.821 in.) and 1.47 cm (0.58 in.). The peak discharges were, respectively, 4.21 cfs and 2.74 cfs.

The same two storms were selected for Drainage DB. The peak discharges for the May 17 and May 27 storms were, respectively, 2.19 cfs and 1.9 cfs.

For Drainage FA, the two selected storms occurred on April 28 and May 17, 1990. The total rainfall for the April 28 storm was 1.75 cm (0.689 in.). The peak discharges for the April 28 and May 17 storms were, respectively, 0.11 cfs and 0.42 cfs.

The two storms selected for Drainage FB occurred on May 17 and May 20, 1990. The total rainfall for the May 20 storm was 0.84 cm (0.33 in.). The peak flows for the May 17 and May 20 storms were, respectively, 2.0 cfs and 0.19 cfs.

Each stream hydrograph was analyzed to characterize the subbasin response to precipitation as described in Sect. 3 of the RFI Report. In addition to the two storms per flume location analyzed for surface water contaminant transport calibration, several other storms were also analyzed.

Concentration hydrographs. As mentioned earlier, a series of water samples was taken during two storms at each of the four sites. For each storm, eight of the samples were selected for analyses. The number of samples was limited to eight to reduce the analytical cost while still providing enough information to characterize the concentrations over a range of flows. Samples were not filtered.

For Drainage DA, all eight samples from the storm of May 17, 1990 had some tritium. A low value of 17,500 pCi/L was measured at the same time as the peak discharge. The peak concentration was 4.2 million pCi/L. Two samples also contained lead with a high value of 5.2 µg/L. Tritium was found in all eight samples from the storm of May 27, 1990. The maximum concentration determined was 282,000 pCi/L, and the minimum was 31,800 pCi/L again at the peak discharge. A plot of the constituent concentrations for Drainage DA is given in Figs. 16, 17, and 18.

Tritium was found in all eight samples from the runoff of Drainage DB during the storm of May 17, 1990. The maximum concentration measured was 3.62 million pCi/L. Lead was
Fig. 16. Tritium concentration in surface runoff; drainage DA; storm of May 17, 1990.
Fig. 17. Lead concentration in surface runoff; drainage DA; storm of May 17, 1990.
Fig. 18. Tritium concentration in surface runoff; drainage DA; storm of May 27, 1990.
Fig. 19. Tritium concentration in surface runoff; drainage DB; storm of May 17, 1990.
Fig. 20. Lead concentration in surface runoff, drainage DB: storm of May 17, 1990.
Fig. 21. Tritium concentration in surface runoff; drainage DB; storm of May 27, 1990.
Fig. 22. Strontium-90 concentration in surface runoff; drainage DB, storm of May 27, 1990.
Fig. 23. Lead concentration in surface runoff; drainage DB; storm of May 27, 1990.
Fig. 24. Strontium-90 concentration in surface runoff; drainage FA; storm of April 28, 1990.
Fig. 25. Plutonium-238 concentration in surface runoff, drainage F11, storm of April 28, 1990.
Fig. 26. Lead concentration in surface runoff; drainage F.A.; storm of April 28, 1990.
Fig. 27. Plutonium-238 concentration in surface runoff; drainage FA; storm of May 17, 1990.
Fig. 28. Lead concentration in surface runoff; drainage FA; storm of May 17, 1990.
Fig. 29. Tritium concentration in surface runoff; drainage FB; storm of May 17, 1990.
Fig. 30. Strontium-90 concentration in surface runoff; drainage FB; storm of May 17, 1990.
Fig. 31. Plutonium-239/240 concentration in surface runoff; drainage FB; storm of May 17, 1990.
Fig. 32. Lead concentration in surface runoff; drainage facility storm of May 17, 1990.
Fig. 33. Tritium concentration in surface runoff; drainage FB; storm of May 20, 1990.
Fig. 34. Strontium-90 concentration in surface runoff; drainage FB; storm of May 20, 1990.
Fig. 35. Lead concentration in surface runoff; drainage FR; storm of May 20, 1990.
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also detected in seven of the samples with a peak concentration of 17.9 \( \mu g/L \). Tritium was again found in all eight samples from the storm of May 27, 1990 with a maximum measured concentration of 121,000 pCi/L. Both strontium-90 and lead were detected in one sample with concentrations of 9.47 pCi/L and 11.3 \( \mu g/L \) respectively. The plots are shown in Figs. 19 through 23.

Drainage FA was not tested for the presence of tritium because of sample volume limitations. Based on the results of Phase 1, Activity 1 sampling, Drainage FA samples were the only ones analyzed for cesium-137. The additional sample volume required for cesium-137 analysis left insufficient volume for tritium analysis. In the storm of April 28, 1990, two samples showed strontium-90 with a high concentration of 7.12 pCi/L, and another sample contained 3.06 pCi/L of plutonium-238. Lead was also found with a high concentration of 15.6 \( \mu g/L \).

Plutonium-238 was again detected in a sample of the storm of May 17, 1990, with a concentration 3.73 \( \mu g/L \). Lead was detected in all eight samples, and the peak concentration was measured to be 21 \( \mu g/L \). Plots of the Drainage FA concentrations are given in Fig. 24 through 28.

All the samples from Drainage FB taken during the storm of May 17, 1990, showed tritium, strontium-90, and lead with maximum measured concentrations of 1.79 million pCi/L, 188 pCi/L, and 31.6 \( \mu g/L \) respectively. Plutonium-239/240 was detected in one sample with a concentration of 3.16 pCi/L. The storm of May 20, 1990, also contained tritium and strontium-90 in all of the samples. Tritium had a maximum concentration of 3.96 million pCi/L, and strontium-90 had a peak of 376 pCi/L. Lead was found in one sample at 3.1 \( \mu g/L \). The concentration hydrographs of Drainage FB are shown in Figs. 29 through 35.

CONCLUDING REMARKS

Results of WAG 6 surface water and sediment sampling analyses performed subsequent to the issuance of TM 06-05 (BNI 1990) have been presented in this technical memorandum. Characterization data and data generated for surface water contaminant transport model calibration have been presented. The data have been presented using various formats for best display of information. Synthesis and interpretation of the characterization data, however, has not been attempted in this TM, but is done in Sect. 4 of the RFI Report. Analysis of model calibration data likewise has not been attempted in this TM, but is done in Sect. 5 of the RFI Report.

ACKNOWLEDGMENTS

Considerable and valuable assistance was provided by D. M. Borders, S. M. Gregory, and D. S. Wickliff of the ORNL for all activities undertaken in connection with data
generation required for the calibration of the surface water contaminant transport model. BNI gratefully acknowledges this assistance.

REFERENCES


WAG 6 RFI WELL INSTALLATION (PHASE 1, ACTIVITY 2)

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OAK RIDGE NATIONAL LABORATORY
REMEDIAL INVESTIGATION/FEASIBILITY STUDY

JULY 1991

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#### ACRONYMS

<table>
<thead>
<tr>
<th>Abbreviation</th>
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<tr>
<td>FAC</td>
<td>field activities coordinator</td>
</tr>
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<td>FS</td>
<td>feasibility study</td>
</tr>
<tr>
<td>HHMS</td>
<td>hydraulic head monitoring station</td>
</tr>
<tr>
<td>HP</td>
<td>health physicist</td>
</tr>
<tr>
<td>HSA</td>
<td>hollow stem auger</td>
</tr>
<tr>
<td>ID</td>
<td>inside diameter</td>
</tr>
<tr>
<td>OD</td>
<td>outside diameter</td>
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<td>ORNL</td>
<td>Oak Ridge National Laboratory</td>
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<td>OVA</td>
<td>organic vapor analyses</td>
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<td>RCRA</td>
<td>Resource Conservation and Recovery Act</td>
</tr>
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<td>RFI</td>
<td>Resource Conservation and Recovery Act Facility Investigation</td>
</tr>
<tr>
<td>RI</td>
<td>remedial investigation</td>
</tr>
<tr>
<td>STL</td>
<td>sample team leader</td>
</tr>
<tr>
<td>TIC</td>
<td>technical integration committee</td>
</tr>
<tr>
<td>TM</td>
<td>technical memorandum</td>
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<tr>
<td>VOC</td>
<td>volatile organic compounds</td>
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<td>waste area grouping</td>
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EXECUTIVE SUMMARY

Thirteen groundwater monitoring wells were installed between January 10, 1990, and May 11, 1990, as part of the waste area grouping (WAG) 6 Resource Conservation and Recovery Act Facility Investigation (RFI) (Phase I, Activity 2). Shallow groundwater wells, completed in the soil or weathered bedrock, were installed based on data gaps identified in Phase I, Activity 1, and in part on soil headspace results from the current activity. Deep groundwater wells, completed in unweathered bedrock, were installed to assess groundwater quality of the deeper flow component of the shallow aquifer system.

Wells 1234 and 1249 form a well pair to monitor the deep groundwater (1234) and an apparent discrete water-bearing zone (1249) identified at an intermediate depth from geophysical logs. Well 1235 was completed as a shallow overburden well straddling the water table. Well 1236, located in the southwestern portion of WAG 6, provides water quality data from the deep bedrock portion of the shallow aquifer system. Wells 1237 and 1238 form a well pair in the western portion of WAG 6. Well 1238 was completed in the deep bedrock and Well 1237 in a discrete water-bearing zone at an intermediate bedrock depth. Monitoring Well 1239 is located outside the WAG 6 boundary west of Highway 95 to provide reference water quality data for the deep flow component of the shallow aquifer system. Wells 1240 and 1241 are located upgradient and downgradient, respectively, of the Emergency Waste Basin (EWB). These wells are designed to cross the seasonal water table. Monitoring Wells 1242, 1243, 1244, and 1245 were installed downgradient of auger holes historically used for solvent disposal. These wells provide data to determine the vertical and lateral extent of an apparent solvent plume from the auger holes.

Core from the bedrock wells and geophysical logs provided information on the geologic structure underlying WAG 6 and data related to hydrogeologic conditions. Core from Well 1234 indicated a fault zone from approximately 17.08 to 21.35 m (56 to 70 ft) correlatable to Fault A identified by Oak Ridge National Laboratory (ORNL) scientists. Water level measurements taken in Well 1245 indicated an upward gradient. The well is located along a drainage area and represents discharge conditions. The presence of discrete water-bearing zone in Wells 1234, 1249, 1237, and 1238 suggest possible localized semi-confined conditions in the deeper portion of the shallow aquifer system.
INTRODUCTION

Purpose and Scope

This technical memorandum (TM) presents the results of the borehole drilling and well installation program carried out at WAG 6 during Phase 1, Activity 2 of the ORNL WAG 6 RFI. This program included the borehole drilling; geophysical logging; monitoring well installation; well development, water level measurements and collection of soil, bedrock, and groundwater samples for laboratory and visual analysis. This document includes the monitoring well site selection rationale and describes the procedures, equipment, and materials used in well drilling, installation, and development. Results of the soil sample collection activities, the geophysical logging program, and the groundwater sample collection activities are presented under separate covers.

The TM is organized into six sections with five attachments. The Introduction section provides a brief overview of the WAG 6 RFI well installation program. The Well-Siting Criteria section presents the rationale for the selection of well locations and depths. The Methods and Materials section provides a detailed description of methods and procedures used in the well installation and development. The Decontamination of Drilling and Sampling Equipment section describes the methods and procedures used for decontamination of equipment. The Management of RFI-Derived Waste section provides a brief narrative of the waste management process for the well installation program. The Observations section discusses key findings observed during the well installation program. Monitoring well locations are shown in Fig. 1. Field records are presented in attachments as follows: Attachment 1—Geologic Logs; Attachment 2—Well Installation Forms; Attachment 3—Sand Certification; Attachment 4—Core Photographs; and Attachment 5—Well Development Logs.
1. All coordinates are based on the ORNL grid system. The angle of declination of the ORNL grid to true north is taken from the approximate center of the WAG.

LEGEND

- RCHA Water Quality Monitor Well
- Groundwater Monitoring Well
- WAG & Boundary
- Paved Road
- Gravel Road
- Marshy Area
- Tributary
- Water Body
- SWSA Security Fence
- Cap Boundary

Fig. 1. Location of BNI groundwater wells installed during Phase 1, Activity 1.
Overview

The overall activity planning, rationale, and objectives of the investigation are described in the WAG 6 RFI Plan (BNI 1988a).

Thirteen groundwater monitoring wells were installed between January 10, 1990, and May 11, 1990, as part of the WAG 6 RFI Phase 1, Activity 2. The monitoring well locations and completion depths were selected based on analysis of data collected during previous investigations, including the WAG 6 RFI Phase 1, Activity 1, and the initial soil gas results documented in TM 06-03A, Soil Gas Survey (BNI 1991a). All monitoring well locations and completions were selected by the project hydrogeologist with concurrence of the ORNL Technical Integration Committee (TIC).

Generally, the site consists of a thin soil layer, weathered bedrock, and bedrock: groundwater in these materials is hydrogeologically connected. Shallow groundwater wells, completed in soil or weathered bedrock, were installed based on data gaps identified in Phase 1, Activity 1, and in part upon soil headspace results from the current activity. Deep groundwater wells, completed in unweathered bedrock, were installed to assess groundwater quality of the deeper flow component of the shallow aquifer system. With the exception of the deep bedrock wells and one shallow well (1235), the monitoring wells were completed across the water table to intercept seasonal high and low levels. Deep bedrock wells were installed to investigate the deep groundwater systems; Well 1235 intercepts the storm flow zone.

Borehole drilling and monitoring well installations were performed in accordance with one or more of the methods described in the Methods and Materials section of this TM. Borehole depths ranged from 7.68 to 52.4 m (25.2 to 171.9 ft), with a total drilled footage of 326.50 m (1070.5 ft). Monitoring well completion depths ranged as follows: 7.19 to 8.38 m (23.60 ft to 27.50 ft) in the shallow overburden; 8.33 m (27.32 ft) in the contact zone; 7.68 to 21.60 m (25.2 ft to 70.9 ft) in the intermediate bedrock; and 45.48 to 49.3 m (149.2 ft to 161.8 ft) in the deep bedrock.

Borehole drilling and well installation were accomplished using a truck-mounted drill rig operated by a driller and a driller’s helper. A Bechtel National, Inc. (BNI) Team geologist, who was designated Sample Team Leader (STL), and a health physicist (HP) were present providing technical supervision, health physics and health and safety monitoring. Other field and office personnel were involved in the field effort by assisting in sample acquisition, equipment decontamination, and waste management.

Soil and weathered bedrock samples were collected to unweathered bedrock by hollow stem auger drilling and split-spoon sampling. As each split spoon was removed from the hole and opened, discrete samples were selected and immediately placed in the appropriate containers. The soils were then visually classified and recorded by the site geologist. A detailed description of the soil sampling procedure is given in TM 06-12A, Soil Sampling (BNI 1991b). Following soil classification, the remainder of soil in each split spoon was discarded in plastic-lined, 55-gal drums located at each drill site for disposal of drill cuttings.
Final disposition of waste soil, air rotary cuttings, and rock core cuttings is discussed in the *Management of RFI-Derived Waste* section of this TM.

**WELL-SITING CRITERIA**

Monitoring wells were installed at various depths and have been categorized as follows: (1) shallow overburden wells completed in the soils and weathered bedrock, (2) contact zone wells completed in the weathered and unweathered bedrock contact, (3) intermediate bedrock wells completed in the upper portion of the unweathered bedrock, and (4) deep bedrock wells completed in the unweathered bedrock. All well locations were selected by the project hydrogeologist in concurrence with the ORNL TIC. The locations of the deep wells were chosen in agreement with R. Dreier of ORNL. Table 1 outlines the rationale used to site these wells.

The 13 wells are numbered from 1234 to 1245 and 1249 (originally 1234A). Wells 1235 and 1240 were completed in the shallow overburden; Well 1242 was completed in the contact zone; Wells 1237, 1241, 1243, 1244, 1245, and 1249 were completed in the intermediate bedrock; and Wells 1234, 1236, 1238, and 1239 were completed in the deep bedrock. Table 2 summarizes well location, completion intervals, and zones. Also included in Table 2 are formations in which the wells are screened. Well locations are shown in Fig. 1. Geologic logs and well installation diagrams are presented in Attachments 1 and 2.

Monitoring well locations were selected to provide geologic information, water level data, and water quality data in specific areas as described below. Well completion zones were selected based on information from geologic logs, interpolation of the water level data from existing wells, and interpretation of geophysical logs from selected deep boreholes.

Monitoring Wells 1234 and 1249 are located near the east fence in the central portion of WAG 6. They were installed as a well pair to monitor the deep groundwater (1234) and an apparent discrete water-bearing interval (1249) identified at intermediate depths on geophysical logs from Borehole 1234. Well 1234 was completed from 39.07 to 45.17 m (128.2 to 148.2 ft) below the top of the concrete pad in the deep bedrock, and Well 1249 was completed from 16.73 to 21.3 m (54.9 to 69.9 ft) below the top of the concrete pad in the intermediate bedrock. These wells were installed to provide water level information, water quality data, and to provide information of the geologic structure below WAG 6.

Monitoring Well 1235 is located adjacent to Well 1230 and the Hydraulic Head Monitoring Station (HHMS) No. 4 well cluster. Well 1230 was installed during Activity 1 and is completed above the water table to monitor storm flow. Wells in the HHMS No. 4 well cluster were installed in 1986 and monitor discrete water bearing zones. Well 1235 was completed within the weathered bedrock 3.75 to 8.02 m (12.3 to 27.3 ft) below the top of the concrete pad as a shallow overburden well to straddle the water table.

Monitoring Well 1236 is located near the west fence in the southwest portion of WAG 6 and was completed in the deep bedrock to provide water quality data and geologic structure information beneath the WAG.
### Table 1. Well-siting rationale

<table>
<thead>
<tr>
<th>Well number</th>
<th>Siting rationale</th>
</tr>
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<tbody>
<tr>
<td>1234</td>
<td>Located near east fence. Installed to monitor deep groundwater. Forms pair with Well 1249.</td>
</tr>
<tr>
<td>1235</td>
<td>Located near Well 1230 and HHMS Number 4 cluster. Completed in weathered bedrock to monitor shallow overburden.</td>
</tr>
<tr>
<td>1236</td>
<td>Located near west fence. Completed in deep bedrock to monitor deep groundwater quality.</td>
</tr>
<tr>
<td>1237</td>
<td>Installed in northeastern portion of WAG to provide groundwater quality data of discrete water-bearing zone and geologic structure data. Forms pair with Well 1238.</td>
</tr>
<tr>
<td>1238</td>
<td>Located in northwestern portion of WAG to furnish deep groundwater quality data and information on geologic structure. Forms pair with Well 1237.</td>
</tr>
<tr>
<td>1239</td>
<td>Located west of Hwy 95 outside WAG boundary. Furnishes reference groundwater quality data for deep groundwater.</td>
</tr>
<tr>
<td>1241</td>
<td>Installed downgradient of the Emergency Waste Basin as bedrock well to provide groundwater quality data and flow characteristics.</td>
</tr>
<tr>
<td>1242</td>
<td>Installed in northeastern portion of WAG downgradient of solvent-disposal auger holes. Screened across the weathered-unweathered bedrock interface.</td>
</tr>
<tr>
<td>1243</td>
<td>Installed in northeastern portion of WAG downgradient of solvent-disposal auger holes. Screened in intermediate unweathered bedrock.</td>
</tr>
<tr>
<td>1244</td>
<td>Installed downgradient of solvent-disposal auger holes along eastern portion of WAG east of stream. Completed in unweathered bedrock.</td>
</tr>
<tr>
<td>1245</td>
<td>Installed downgradient of solvent-disposal auger holes each of stream along eastern boundary of WAG. Completed in unweathered bedrock at interval equivalent to the completion zone in Well 842.</td>
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<tr>
<td>1249</td>
<td>Located near east fence and completed in bedrock of intermediate depth. Forms pair with Well 1234.</td>
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*Sites for Wells 1242, 1243, 1244, and 1245 were chosen on basis of high volatile organic content of Monitoring Well 842, and from results of soil gas survey. These wells were designed to determine vertical and lateral extent of apparent solvent plume.*
Table 2. WAG 6 RFI groundwater monitoring wells\textsuperscript{a}

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<th>Well number</th>
<th>North</th>
<th>East</th>
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<th>Base screen</th>
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<td>16969.58</td>
<td>25244.09</td>
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<td>70.90</td>
<td>54.90</td>
<td>69.90</td>
<td>A</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Measured relative to top of concrete pad.

\textsuperscript{b}Top of concrete pad elevation.

\textsuperscript{c}Formation
A Maryville Bedrock
B Maryville Regolith
C Nolichucky Bedrock
D Nolichucky Regolith

\textsuperscript{d}Well 1249 was originally named Well 1234A ft/3.28 = m.
Monitoring Wells 1237 and 1238 were installed as a well pair near the north fence in the western portion of WAG 6 (Fig. 1). Well 1237 was initially drilled to be completed in deep bedrock, but a blocked core barrel precluded attaining the planned total depth, and the borehole was completed in the intermediate bedrock 12.89 to 17.46 m (42.3 to 57.3 ft) below the top of the concrete pad. Subsequent geophysical logging of Well 1238 indicated that 1237 was completed in a discrete water-bearing zone. Well 1238 was completed in the deep bedrock 39.92 to 46.02 m (131.0 to 151.0 ft) below the top of the concrete pad. These wells were installed to provide water quality data and geologic structure information.

Monitoring Well 1239, completed from 41.18 to 47.28 m (135.10 to 155.1 ft) BTOP in deep bedrock, is located outside of the WAG 6 boundary west of Highway 95. This well provides reference water quality at depth for the deep flow component of the shallow aquifer system.

Monitoring Wells 1240 and 1241 were located adjacent to the Emergency Waste Basin (EWB) north of the northeastern WAG 6 security fence (Fig. 1). These wells were located and designed to provide data points for water quality and flow characteristics in the vicinity of the EWB. Well 1240, located northeast and upgradient of the EWB, is completed within the weathered bedrock [2.32 to 6.89 m (7.6 to 22.6 ft) below the top of the concrete pad] as a shallow overburden well; and Well 1241, located southwest and downgradient of the EWB, is completed in the intermediate bedrock [4.54 to 10.64 m (14.9 to 34.9 ft) below the top of the concrete pad]. Both well completions were designed to cross the seasonal water table.

Monitoring Wells 1242, 1243, 1244, and 1245 were installed downgradient of auger holes historically used for solvent disposal. The wells provide data to determine the vertical and lateral extent of an apparent solvent plume from the auger holes suspected from the high volatile organic compound (VOC) in Well 842 and data from the soil gas survey. Well locations were selected based on high VOC concentrations in Well 842, located downgradient of the auger holes (Fig. 1); and results from the soil gas survey (BNI 1991a), indicating a VOC anomaly in the stream drainage area. Wells 1242 and 1243 flank Well 842 in the northeast portion of WAG 6 along the east fence. Wells 1244 and 1245 are downgradient of Well 842 and east of the security fence along the east side of the stream separating WAG 6 and WAG 7.

Well 1242 is completed across the weathered and unweathered bedrock contact [3.39 to 7.96 m (11.1 ft to 26.1 ft) BGS] and Well 1243 is completed immediately below the contact in intermediate unweathered bedrock [3.63 to 8.20 m (11.9 ft to 26.9 ft) BGS]. Both well completions were designed to intersect the seasonal water table.

Well 1244 is completed immediately below the contact in the intermediate unweathered bedrock [2.80 to 7.38 m (9.20 to 24.20 ft) BTOP] and will also assess the stream as a flow boundary. Well 1245 was completed from 16.73 to 21.3 m (54.9 to 69.9 ft) below the top of the concrete pad in the intermediate unweathered bedrock. This completion zone is approximately equivalent to the completion zone in Well 842.
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Well 1244 is completed immediately below the contact in the intermediate unweathered bedrock [2.80 to 7.38m (9.20 to 24.20 ft) below the top of the concrete pad] and will also assess the stream as a flow boundary. Well 1245 was completed from 16.73 to 21.3 m (54.9 to 69.9 ft) below the top of the concrete pad in the intermediate unweathered bedrock. This completion zone is approximately equivalent to the completion zone in Well 842.

METHODS AND MATERIALS

The wells were installed in accordance with Method ESP-600, "Groundwater Sampling Procedures: Well Installation, Development, and Abandonment" (Energy Systems 1988a). The following paragraphs provide a brief summary of the methods of drilling, sampling, and well installation. The well drilling data for the 13 monitoring wells installed at WAG 6 during this phase of the RFI are provided in Table 3. Groundwater well depths and screen intervals were predetermined by the project hydrogeologist and the WAG Manager, based on offset well water level data as described in Well-Siting Criteria section.

Drilling Methods

The wells were drilled using one or more of the following methods, according to depth and circumstances of each well. Environmental Safety and Health (ES&H) methods are also described to document the entire drilling sequence. Table 3 includes a breakdown of drilling methods and intervals on each well.

Split-spoon/hollow-stem augering

The split spoon/hollow stem auger method used a truck-mounted drill rig and 10.16 cm (4-in.) inside diameter (ID) [15.24-cm (6-in.) borehole diameter] hollow stem augers and 7.62 cm (3-in.) outside diameter (OD) split spoons. Upon positioning the drill rig at the well location, a controlled access area was established around the rig by the HP. Each boring was begun by driving the split spoon .61 m (2 ft) BGS. The spoon was then withdrawn. The contents of the split spoon were first scanned by the HP for VOCs with an photoionizing detector and/or an organic vapor analyzer (OVA) and for radioactivity using Eberline beta-gamma and alpha detectors, then sampled, and finally classified by the geologist as described in the Borehole Logging section of this TM. Before a split spoon was reinserted into the borehole, the hollow stem auger (HSA) was advanced .61 m (2 ft). The spoon was then reinserted into the inside annulus of the HSA and driven another .61 m (2 ft). This alternating advancement of the split spoon and the HSA was continued until both the split spoon and the HSA met refusal. Spoon refusal was defined as that point beyond which the spoon could not be driven 15.24 cm (6 in.) with 50 blows of the hammer. Auger refusal was defined as that point that the auger showed little or no advancement in 10 min of drilling. Once the borehole had reached the predetermined depth it was reamed by a continuous up-down movement of the auger flight which removed most loose soil from the sides of the borehole.
Table 3. Well drilling summary (BNI WAG 6 wells)

<table>
<thead>
<tr>
<th>Well number</th>
<th>Split spoon hollow stem auger&lt;sup&gt;b&lt;/sup&gt; sampling interval (ft)</th>
<th>Air rotary surface casing&lt;sup&gt;c&lt;/sup&gt; interval (ft)</th>
<th>Bulldog bit auger&lt;sup&gt;d&lt;/sup&gt; interval (ft)</th>
<th>Rock coring&lt;sup&gt;e&lt;/sup&gt; interval (ft)</th>
<th>Air rotary/tricone bit well hole&lt;sup&gt;f&lt;/sup&gt; interval (ft)</th>
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<tbody>
<tr>
<td>1234</td>
<td>0-21.0</td>
<td>21.0-38.0</td>
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<td>38.0-129.2</td>
<td>38.0-150.5</td>
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<td>N/A</td>
<td>N/A</td>
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<td>32.6-58.8</td>
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<td>N/A</td>
<td>N/A</td>
<td>32.3-171</td>
</tr>
<tr>
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<td>N/A</td>
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<td>N/A</td>
<td>N/A</td>
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<td>N/A</td>
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<td>N/A</td>
<td>34.4-60&lt;sup&gt;g&lt;/sup&gt;</td>
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<td>0-42</td>
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<td>N/A</td>
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</tbody>
</table>

<sup>a</sup>ft/3.28 = m; in. x 2.54 > cm
<sup>b</sup>6-in. diameter
<sup>c</sup>10 5/8-in. diameter
<sup>d</sup>6-in. diameter
<sup>e</sup>3.65-in. diameter
<sup>f</sup>6 1/4 in. diameter
<sup>g</sup>8 5/8 in. diameter
The triple tube core barrel consists of an outer barrel and bit impregnated with industrial diamonds, an inner barrel, and a non-rotating, free-floating inner sleeve, consisting of a longitudinally split stainless steel sleeve. The triple tube barrel is attached to a series of metal drill rods and rotated under a controlled downward pressure. The cutting of the rock produced a cylindrical core within the core barrel. Potable water was used to facilitate coring by cooling the core barrel and lifting the cuttings to the surface. All water and cuttings were recirculated using a recirculation trough. Water in the trough was changed out as necessary and placed in drums pending sampling and disposal.

Recovery of the core was facilitated by removal of the inner core barrel through the drill string by a wireline, leaving the outer barrel and drill rods in the hole. Upon removal from the hole, the inner sleeve was removed from the inner barrel and scanned by the HP for radioactivity and VOCs. After being scanned, the inner sleeve was opened and logged by the geologist as described in the Borehole Logging section. The core was then marked and placed in core boxes by the sample technician as described in the Project Procedure 1643, "Rock Coring" (BNL 1990). Once the borehole reached the predetermined depth, the core rig was moved from the site.

Rock coring using the above mentioned equipment was performed on Well 1234 between 12.2 m (40 ft) and 39.35 m (129 ft), and on Well 1237 to a depth of 17.08 m (56 ft). This method of rock coring was abandoned because of scheduling constraints and logistical problems in the course of the coring. Coring was attempted using a conventional 15.24 cm (6-in.) diameter double tube barrel on Wells 1242 and 1243. The cores were logged, but not retained. The double tube core barrel works essentially the same way as the triple tube barrel. Coring using the double tube barrel was discontinued in favor of air rotary drilling because of poor core recovery and poor core condition, and because the core would stick in the barrel. The core from Wells 1234 and 1237 has been scanned for radioactivity, tagged as clean (green tagged) and stored in Bldg 7878 within the boundaries of WAG 6. Selected photographs of the cores are presented in Attachment 3.

**Air rotary**

This method used a truck-mounted air rotary rig using a 27-cm (10-5/8-in.) diameter bit to install a 17.78-cm (7-in.) surface casing and a 15.87 cm (6.25 in.) diameter bit to perform the reaming and drilling. In the case of Well 1245, a 16.83 cm (8 5/8 in.) diameter borehole was air-rotary drilled to accommodate 4-in. stainless steel casing. The isolation casing was seated into bedrock to provide a seal. The bits were tricone roller bits and water was circulated through the drill bit and drill string (inside the rods) for cooling. The rig used a rotary table to turn and advance the bit. A diverter head and diverter discharge pipe was connected to the diverter casing. Cuttings passed through the diverter head to a portable containment box provided by ORNL that was used to contain the cuttings and water from the drilling operation. The containment box system was used for all air rotary drilling and used a high efficiency particulate air (HEPA) filter system to preclude the dispersal of airborne contaminants. When the box was full, it was transported from the drilling site to the decontamination area for the removal of the cuttings. The containment box was sampled
before removal of its contents to determine if any precautions were needed during the removal and decontamination process.

The use of this containment system prevented the observation of cuttings for lithological description. The combination of hammering and rotation causes the bit to cut the rock, and the resulting cuttings are forced by air pressure up the surface casing to the attached containment box.

Well Installation

Wells were installed using one or more of several methods according to the depth and/or requirements of the well. Shallow wells are those wells set into the overburden. Contact zone wells, completed across the weathered and unweathered bedrock contact, and intermediate bedrock wells, completed in the upper portion of the unweathered bedrock, generally were installed in the same manner as the deep bedrock wells. Deep bedrock wells are those that were set into the bedrock, generally to a depth of 45.48 to 49.31 m (149.2 to 161.8 ft) below the top of the concrete pad. The exceptions to this are Wells 1249, 1237, 1243, 1244, and 1245. These wells were set with air rotary to a depth of 21.61 m (70.9 ft) or less. Deep wells (1234, 1236, 1238, and 1239) were drilled as follows:

- Split spoon/hollow stem augering to refusal
- Drilling/setting a 29.85 cm (11 3/4 in.) carbon steel diverter casing using air rotary
- Air rotary drilling a 26.98 cm (10 5/8 in.) hole to set a 17.78-cm (7-in.) surface casing a minimum of 1.53 to 3.05 m (5 to 10 ft) into competent rock
- Setting a 17.78-cm (7-in.) surface casing using displacement grouting method
- Drilling out concrete plug
- Rock coring and/or air rotary drilling/reaming 15.88-cm (6-1/4 in.) or 21.95 cm (8-5/8 in.) hole to total depth

Some wells (1235, 1236, 1238, 1239, 1241, 1242, and 1243) were overdrilled to determine water table depth and to allow additional depth into which to lower the geophysical logging tools, then plugged back to the desired depth using either silica sand or granulated bentonite. Table 4 presents water levels at preinstallation and predevelopment stages. Table 5 lists total depth drilled and plug back depths and construction data.

Bentonite seals were installed in all wells to prevent the grout from leaching into the sand pack or screened interval and to provide maximum isolation of the monitoring interval selected.

Shallow well installation

The method used to install the well screen and riser pipe was to raise the auger flight 0.31 m (1 ft) to 0.61 m (2 ft) off the bottom of the hole, then pour or tremie approximately 0.31 m (1 ft) of clean silica sand into the hole through the hollow stem augers.
Table 4. Water levels in wells (BNI WAG 6 wells)\(^a\)

<table>
<thead>
<tr>
<th>Well number</th>
<th>Pre-installation</th>
<th>Post-installation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Well depth(^b) (ft)</td>
<td>Date drilled</td>
</tr>
<tr>
<td>1234</td>
<td>149.20</td>
<td>2/28/90</td>
</tr>
<tr>
<td>1235</td>
<td>27.50</td>
<td>01/10/90</td>
</tr>
<tr>
<td>1236</td>
<td>161.8</td>
<td>02/28/90</td>
</tr>
<tr>
<td>1237</td>
<td>57.3</td>
<td>04/05/90</td>
</tr>
<tr>
<td>1238</td>
<td>152.0</td>
<td>03/07/90</td>
</tr>
<tr>
<td>1239</td>
<td>156.1</td>
<td>01/18/90</td>
</tr>
<tr>
<td>1240</td>
<td>23.60</td>
<td>03/16/90</td>
</tr>
<tr>
<td>1241</td>
<td>35.90</td>
<td>04/11/90</td>
</tr>
<tr>
<td>1242</td>
<td>25.00</td>
<td>04/17/90</td>
</tr>
<tr>
<td>1243</td>
<td>27.90</td>
<td>04/17/90</td>
</tr>
<tr>
<td>1244</td>
<td>25.20</td>
<td>04/09/90</td>
</tr>
<tr>
<td>1245</td>
<td>58.40</td>
<td>04/12/90</td>
</tr>
<tr>
<td>1249</td>
<td>70.90</td>
<td>05/11/90</td>
</tr>
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</table>

\(^a\)ft/3.28=m
\(^b\)Depth in ft below surface concrete pad
\(^c\)Elevation in ft above mean sea level
<table>
<thead>
<tr>
<th>Well number</th>
<th>Date well installed</th>
<th>Ground surface elevation$^b$ (ft)</th>
<th>Bedrock elevation$^c$ (ft)</th>
<th>Drillers total depth BGS$^c$ (ft)</th>
<th>Plug back total depth$^c$ (ft)</th>
<th>Top of riser elevation$^c$ (ft)</th>
<th>Top of protector casing$^d$ elevation (ft)</th>
<th>Bottom of screen$^e$ elevation (ft)</th>
<th>Top of screen$^e$ elevation (ft)</th>
<th>Sand pack interval elevation (ft)</th>
<th>Bentonite seal interval elevation (ft)</th>
<th>Diameter of riser screen$^f$ (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1234</td>
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<td>751.32</td>
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<td>149.2</td>
<td>774.56</td>
<td>774.74</td>
<td>624.12</td>
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<td>803.86</td>
<td>804.22</td>
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<td>673.85</td>
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<td>725.04 - 721.04</td>
<td>2.00</td>
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</table>

$^a$ft/3.28 = m  
$^b$Surveyed as top of concrete pad  
$^c$Measured relative to top of concrete pad  
$^d$Casing is 6 5/8 in. carbon steel  
$^e$Screen slot size is 0.010 in.  
$^f$All well risers and screens are 316 stainless steel
The well assembly consisted of a stainless steel 0.025-cm (0.010-in.) slotted screen, generally a 4.58 m (15-ft) section, an attached stainless steel flush-threaded riser, a 0.31 m (1-ft) sump used as a sediment trap, and a threaded bottom cap. All wells consisted of 5.08-cm (2-in.) OD, 4.57 cm (1.8-in.) ID stainless steel, except for Well 1245, which consisted of 10.16 cm (4-in.) OD stainless steel. After the assembly was placed into the borehole, it was hand pushed a few inches into the silica sand. After placement of the screen and riser, clean silica sand was slowly poured or tremied into the hollow stem augers while the augers were simultaneously raised to allow the sandpack to completely fill the open hole left by the removal of the augers. Shallow wells were either installed through the augers without centralizers, or the auger flights were removed and centralizers used to center the assembly. The sandpack was installed to extend a minimum of 0.31 m (1 ft) above the top of the well screen. Certification documentation for the silica sand is included with this TM as Attachment 4. A well construction summary is provided in Table 5.

Following the placement of the sandpack around the well screen and riser, 0.31 m (1 ft) to 0.61 m (2 ft) of bentonite pellets were added to the borehole to form a seal. If needed, a minimum amount of organic-free water was added to the bentonite to cause it to hydrate. The seal was then allowed to cure for a minimum of 8 h. The remainder of the open hole was grouted to the surface with a Portland cement (Type I) and granulated bentonite mixture containing no more than 3% bentonite. The grout/bentonite mixture was then allowed to cure for a minimum of 24 h. The geologist used a "mud scale," a balance device to estimate cement/moisture ratio, to help him determine whether the grout mixture was correct.

A 16.82-cm (6.63-in.) OD protective carbon steel casing was inserted over the riser pipe into the cement/bentonite grout to complete the well. The casing was installed between 0.31 m (1 ft) and 0.61 m (2 ft) below the surface and grouted to the top of the seal with enough casing left above the ground surface to cover the height of the riser pipe. In some instances, either the protective casing or the riser pipe was cut off, so that an appropriate height above the ground surface and vertical distance between riser and casing was maintained for later sampling. A fitted aluminum alloy cap was placed on top of each riser pipe and each protective casing. A water tight screw-on cap was installed at all well locations where inundation by water might be suspected.

Following installation of the wells, a 0.92 by 0.92 m (3- by 3-ft) by approximately 7.62 m (3-in.) thick concrete pad was poured around the protective casing. Four 1.5-m (5-ft) steel guard posts were set in concrete-filled auger holes on the outside of the pad. The guard posts were painted yellow for high visibility. Locks were attached to the protective casing of all wells with all locks keyed alike.

Deep bedrock well installation

The method used to install the deep bedrock wells differs from the shallow wells in that a 17.78-cm (7-in.) mild steel surface casing was installed before air rotary drilling in bedrock across the unconsolidated regolith, thus allowing the removal of all downhole equipment before well installation. After the removal of the downhole equipment, granulated bentonite was placed as needed to plug back the borehole to the desired depth. The next step was to
Deep bedrock well installation

The method used to install the deep bedrock wells differs from the shallow wells in that a 17.78-cm (7-in.) mild steel surface casing was installed before air rotary drilling in bedrock across the unconsolidated regolith, thus allowing the removal of all downhole equipment before well installation. After the removal of the downhole equipment, granulated bentonite was placed as needed to plug back the borehole to the desired depth. The next step was to tremie or pour .31 to .61 m (1 to 2 ft) of silica sand into the hole, followed by the placement of the predetermined lengths of stainless steel screen and riser with centralizers attached to keep the well centered within the borehole. The centralizers were spaced immediately above and below the screen, and thereafter every 6.1 m (20 ft) to the surface. The assembly, consisting of riser, screen, and sump, was pushed a few inches into the sand, and then the sand filter pack was placed to a depth corresponding to .31 m (1 ft) or .61 m (2 ft) above the screen. Pelletized bentonite was then placed above the filter pack and, if needed, a minimum amount of organic-free water was placed to hydrate the bentonite. The remainder of the open hole was then tremie grouted with a Portland cement (Type I), granulated bentonite mix, with the bentonite not exceeding 3%. The STL closely monitored the grout specifications during placement of the grout. The wells were then completed using the same methods as described in the Shallow Well Installation section of this TM.

Well Development

The purpose of well development is to rid the filter pack and screen of particles that can become suspended in the water within the well, to improve the hydraulic connection between the well and the aquifer, and to redistribute the sandpack. The particles suspended in the water come from the walls of the borehole and from adjacent formation materials. A properly developed well will yield the maximum amount of flow with the least amount of turbidity. At WAG 6, the 13 groundwater wells were developed using a surge and pump method as described below. Attachment 5 presents development data for the wells.

The 13 wells were developed from March 27, 1990, through May 24, 1990, using a 5.08 cm (2-in.) diameter QED Sample Pro Well Development submersible pump. Air discharge was provided to the submersible pump by a gasoline-powered Well-Wizard oil-less compressor. The general plan for well development was to surge and pump each well until the pH, conductivity, and temperature stabilized to within a 10% margin. The wells were developed in accordance with the project procedures (Energy Systems 1988a). Data were logged into the STL’s logbook, then transcribed onto well development forms, included in this TM as Attachment 5. Well 1235, which did not recharge significantly because of low water levels, was not developed.

At each well, the submersible Sample Pro pump was attached to the Well Wizard compressor using a rubber discharge and air hose. The 1.53-m (5-ft) long assembly had stainless steel surge rings at the upper and lower end. This assembly was lowered into the well to the bottom of the sump. The Well Wizard was then started and, simultaneously, the submerged assembly was repeatedly raised and lowered in even intervals, providing a surging action. This was performed over the entire length of the screen. Two settings on the Well
Wizard controlled the refill time of the well and the length of time for each discharge. By adjusting these settings for each well, the risk of pumping the well dry during development was reduced or eliminated. The discharged water was pumped out of the well and into a 55-gallon collection drum. The amount of water pumped during development is given on the well development forms for each well, as are conductivity, pH, and temperature readings taken during well development.

**Well Abandonment**

Coreholes that were initially drilled and then subsequently abandoned included initial attempts to install Wells 1235, 1242, and 1243. The abandonment process was basically to tremie grout the boreholes with a Portland cement/bentonite grout mixture. Well 1235 was abandoned because of well installation problems and redrilled adjacent to the original location. Wells 1242 and 1243 were initially drilled using the split spoon/hollow stem auger method early in the effort, then abandoned when the conventional core barrel became stuck in the core hole and the temporary casings installed for the coring were only tagged instead of grouted. They were subsequently relocated adjacent to the original site locations.

**Borehole Logging**

The logging of the boreholes was accomplished in compliance with ORNL RI/FS Project Procedures 1648, "Borehole Logging," (BNI 1988b) and 1646, "Soil and Rock Classification" (BNI 1988b). Borehole logging was supplemented by Project Procedure 1643, "Rock Coring" (BNI 1990). The logbooks used during the course of well installation and development consisted of a daily activities log combined with the borehole/corehole lithological logs. The STL was responsible for maintaining the logbooks during working hours, and placed them in the custody of the Field Activities Coordinator (FAC) when not in use.

Other documentation of field activities included a well installation form and a well development form. These two forms are included in this TM as attachments. ES&H logbooks were maintained by HP personnel and contain the complete records of on-site monitoring, including toxic gas and radiation measurements. Following completion of the field work, the maintenance of logbooks was done by the BNI RI/FS Project Document Control Center.

**DECONTAMINATION OF DRILLING AND SAMPLING EQUIPMENT**

Decontamination of drilling and sampling equipment employed in the WAG 6 RFI well installation program was performed in accordance with ESP-900, "Cleaning and Decontamination of Sample Containers and Sampling Devices," (Energy Systems 1988b) and ESP-901, "Equipment Decontamination" (Energy Systems 1988c). The following paragraphs describe the specific methods employed in ESP-900 and ESP-901, decontamination quality assurance/quality control procedures, and additional information as appropriate for documentation purposes.
Before the drill rigs and associated drilling tools entered WAG 6 for the well installation program, they were decontaminated in accordance with ESP-901. The drill rig was steam-cleaned to remove soil, grease, oil, etc., adhering to the rig exterior. Bits, auger flights, drill rods, core barrels, and air rotary equipment were cleaned with detergent (Alconox) followed by a tap water rinse, a deionized water rinse, and an isopropanol rinse. Following the final rinse, the equipment was allowed to air dry for approximately 24 h before being admitted to the WAG 6 work areas. Stainless steel split spoon samplers were cleaned and wrapped in foil in accordance with ESP-900, Attachment 2, Section II, "Cleaning Procedures for Stainless Steel or Metal Sampling Equipment Used for the Collection of Samples for Trace Organic Compounds and/or Metals Analyses" (Energy Systems 1988b).

A decontamination trailer was used for decontamination of equipment during drilling operations and was located next to Bldg 7878 within the WAG 6 boundary. Used split spoons were periodically collected from the drill rig and transported to the decontamination trailer as drilling progressed. Augers, drill rods, and other drilling equipment was transported to the trailer following the completion of each borehole/corehole. Before transport from each drill site to the trailer, drilling equipment was wrapped in plastic and appropriately tagged after screening for radiation and organic contamination by the ES&H technician.

The procedures employed for decontaminating drilling equipment are described in ESP-900, Attachment 2, Section VI, "Field Equipment Cleaning Procedures" (Energy Systems 1988b). An additional first step that used the capability of the decontamination trailer was followed during well installation. This initial step consisted of a coarse grit power spray that effectively removed any caked-on mud or clay adhering to the split spoons, auger flights, and other drilling equipment as needed. Following the grit blast, the equipment was washed with an Alconox solution and then rinsed in tap water, followed by an isopropanol rinse and finally an organic-free water rinse. A smear was taken of each piece of equipment to check for radioactive contamination and the smears counted prior to the equipment being released for reuse on the drill rig.

When the drill rig was taken off-site at the conclusion of the drilling program, it was cleaned in accordance with ESP-901 (Energy Systems 1988c). Scrapers were used to remove soil adhering to the rig, then the rig was steam-cleaned to remove any other materials adhering to the rig. Following cleaning, the rig was smeared and subsequently tagged for release in accordance with Project Procedure "Release of Equipment for Unrestricted Use" (BNI 1988d). All drilling equipment was decontaminated in accordance with ESP-900, Attachment 2, Section VI, "Field Equipment Cleaning Procedures," before release from the site.

MANAGEMENT OF RFI-DERIVED WASTE

Management of wastes derived from the WAG 6 well installation program was performed in accordance with ORNL RI/FS Project Procedures 1401, 1402, 1403, 1404, and 1405 (BNI 1988e-h; BNI 1989). The following paragraphs provide a brief narrative of the waste management process for the well installation program.
Wastes generated during the well installation program include compactable wastes, decontamination fluids, soil cuttings, and groundwater. Compactable wastes were segregated into categories according to Project Procedure 1401, "Waste Categorization for Solid Wastes" (BNI 1988a). As bags were filled, they were surveyed for radiological contamination and appropriately tagged by the ES&H technician. Uncontaminated compactable waste was green tagged and placed in a sanitary dumpster at the entrance to WAG 6. No low-level waste was generated during the WAG 6 well installation program.

Waste fluids were generated during equipment decontamination in the field, at Bldg 7878, and at the decontamination trailer. These fluids were placed in drums as they were generated. Samples were obtained from each drum and were composited and submitted for Resource Conservation and Recovery Act (RCRA) characteristics and radiological analyses to determine the final waste classification for disposal purposes. Final disposal was in accordance with Project Procedure 1402, "Waste Handling" (BNI 1988f).

Soil wastes derived from borehole/corehole cuttings were segregated into the following categories based on the results of field radiological and organic vapor surveys:

- Apparently uncontaminated soil
- Potentially radioactive soil
- Potentially hazardous soil
- Potentially mixed (radioactive and hazardous) soil

Following completion of the well installation, drilling soils and cuttings were composited according to category in 3.5 m³ (125-ft³) B-25 bins. Samples were obtained from each bin and submitted for RCRA characteristic and radiological analyses to determine the final waste classification for disposal purposes. Final disposal was in accordance with Project Procedure 1402, "Waste Handling" (BNI 1988e).

Waste fluid accumulated during well development was contained at the well site in 55-gal drums. Following completion of well development, the drums were taken to Bldg 7878 where the waste water in each drum was sampled, analyzed for RCRA characteristics, and screened for radiological contamination. The analyses were negative; and under the direction of ORNL, the wastewater from the wells was combined with decontamination wastes that had been previously analyzed. The wastewater containing trace amounts of Alconox and isopropanol was disposed in an ORNL sanitary waste treatment system pond.

**OBSERVATIONS**

Several observations were made during the well installation program. First, the core from Well 1234 indicated a fault zone from approximately 17.08 to 21.35 m (56 to 70 ft), evidenced by numerous healed fractures and other features, and a fault plane, noted by truncated breccia zones occurring at 17.39 m (57 ft). This fault is correlatable to Fault A identified by Dreier and Toran (1989). Second, water levels in Well 1245 recorded before and after well installation are indicative of upward gradients. The well is located along a
drainage area and represents discharge conditions. Third, after isolating a water-bearing zone through setting a well, the increase of water levels in Wells 1234, 1236, 1238, and 1239 ranged from .92 to 2.14 m (3 to 7 ft), indicating possible localized semi-confined conditions exist in the deeper portion of the shallow aquifer system.

REFERENCES


Attachment 1
GEOLOGIC LOGS
### GEOLOGIC LOG

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### CORING BOXES

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Hole named using air rotary from 40-47.2 feet. No information.

Coring begins at 47.2 feet—change of scale.

Bedding at 45°
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HOLE NO. 1234

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**52 = SPLIT SPOON**  
**HX = ROCK CORING**  
**AR = AIR ROTARY**  

**3.5 1984 27**
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**NOTES**

Bedding at 30°  
Bedding at 15°  
Bedding at 30°  
Bedding at 15°  
Bedding at 15°  
Bedding at 10°  
Bedding at 45°  
Bedding at 30°  
Bedding at 45°
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**Sample Types:**
- HX: Rock Coring
- AR: Air Rotary

**Checked By:**

**Hole No.:** 1234
## GEOLOGIC LOG

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**Bedding at 15°**

**Bedding at 0°-30°**

**Bedding at 15°-30°**

**Bedding at 0°-20°**

**Bedding at 10°-45°**

**Bedding at 0°-60°**

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**CHECKED BY:**

**HOLE NO.** 1234
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**S3 = SPLIT SPOON**  
**HX = ROCK CORING**  
**AR = AIR ROTARY**
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To 150.5
Total depth = 150.5

S3 = SPLIT SPOON
HX = ROCK CORING
AR = AIR ROTARY

CHECKED BY:

HOLE NO. 1234
# GEOLOGIC LOG

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## SAMPLES INTERVALS FOR SCREEN

### DESCRIPTION AND CLASSIFICATION

- **BILLY-SLATE:** (0-0.5), nonuniform, slightly plastic, yellow red, soft to firm, damp, shale fragments (CL-M).
- **BILLY-SLATE:** (0.5-1.0), uniform, plastic, yellow brown, firm, damp, (CL-M), some black nodules, semi-permeable.
- **VERY WEATHERED SHALE:** uniform, nonplastic, yellow brown, soft to stiff, damp, (CL), permeable along partings.
- **VERY WEATHERED SHALE:** uniform, nonplastic, brownish yellow with black stains along partings, stiff to hard, damp, (CL), permeable along partings.
- **WEATHERED SHALE:** uniform, nonplastic, yellowish brown to strong brown, stiff to hard, damp, permeable along partings. Bed of red-brown weathered shale at 9.5'
- **WEATHERED SHALE:** uniform, nonplastic, yellow-brown, stiff to hard, damp, (CL), permeable along partings. BILLY-SLATE (1.0-1.5), uniform, slightly plastic, black, damp, permeable.
- **VERY WEATHERED SHALE:** uniform, nonplastic, dusky red brown, stiff, damp, (CL), to BILLY-SLATE, uniform, plastic, yellowish gray brown, hard, damp, with soft black nodules and streaks in partings, highly permeable.
- **VERY WEATHERED BILLY-SLATE:** nonuniform, nonplastic, dusky red brown to yellow gray brown, firm to stiff, damp to dry, slightly permeable (CL-M).
- **BILLY-SLATE:** nonuniform, nonplastic, red yellow to yellow gray brown, hard, moist, slightly permeable, interbedded with small slates, nonuniform, plastic, black, soft, moist, slightly permeable (CL-M).
- **BILLY-SLATE:** uniform, nonplastic, grayish-yellowish brown with red yellow mottles, stiff, damp to dry, slightly permeable, (CL), rust to black stains along partings.
- **BILLY-SLATE:** nonuniform, nonplastic, red-yellow to gray-yellow to dark dusky red brown, stiff to hard, damp, (CL-M), slightly permeable.
- **BILLY:** (22.0-22.3), nonuniform, nonplastic, black, soft, moist, permeable.
- **BILLY-SLATE:** (22.0-24.3), nonuniform, nonplastic, dark yellowish gray to dusky red brown, soft to firm, damp to moist, (CL-ML), slightly permeable.
- **BILLY-SLATE:** (24.0-25.0), nonuniform, nonplastic, grayish yellow brown to grayish yellow, soft, damp, (CL-ML), slightly permeable.
- **BILLY:** (25.0-26.0), nonuniform, nonplastic, dark brown to black, soft, wet.
- **BILLY:** (26.0-28.0), nonuniform, nonplastic, dark brown to black, soft, wet.
- **BILLY-SLATE:** (28.0-30.0), nonuniform, nonplastic, dusky red brown, soft to hard, damp to moist, (CL-M), permeable.

**NOTES:**

- TOP OF PAI ELEVATION SURVEYED AS GROUND ELEVATION.
<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>DESCRIPTION AND CLASSIFICATION</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>S3</td>
<td>nonuniform, nonplastic, dark yellowish brown, hard, damp, (CL: 4-ML), slightly permeable.</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>nonuniform, nonplastic, dark yellowish brown, hard, damp, (CL: 4-ML), slightly permeable.</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>nonuniform, nonplastic, dusty red to greenish brown with some yellowish brown, firm to stiff, damp to moist, (CL: 4-ML), permeable, stains along partings.</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>nonuniform, nonplastic, dark dusty red to brownish brown to greenish brown, firm to hard, moist, (CL: 4-ML), staining evident.</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>no recovery.</td>
<td>No spoon-drilled through rock lens.</td>
</tr>
<tr>
<td>S3</td>
<td>nonuniform, nonplastic, dark dusty red brown, hard, brittle, damp, (CL: 4-ML), permeable.</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>nonuniform, nonplastic, dark dusty red brown, hard, brittle, damp, (CL: 4-ML), permeable.</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>nonuniform, nonplastic, dark dusty red brown, hard, brittle, damp, (CL: 4-ML), permeable.</td>
<td></td>
</tr>
</tbody>
</table>

Auger refusal at 47.3
GEOLOGIC LOG

ORNL RID FIS
JOE 19118

GROUNDB DEP.
801.55
TOTAL DEPTH
171.9'
BEGAN
12/20/93
COMPLETED
2/28/94
BOREHOLE DEVIATION
NO DATA
BEDROCK DEPT./ELEV.
48.25/753.3

DRILLER
EDGE
HIGHLAND
HIGHLAND

DRILL MAKER/MODEL
ATV RIG
IR X L750
IR X L750

TYPE DRILLING
HSA
AIR ROTARY
AIR ROTARY

INTERVAL
0-50'
0-64.5'
0-64.5'

HOLE Diam.
6'
10.5/8'
6 1/4'

DEPTH TO GROUNDWATER / ELEV. / DATA
/ / NO DATA
/ / NO DATA
/ / NO DATA

CORE BOXES
N/A

SAMPLES INTERVALS FOR SCREENING
0-48.25

SAMPLES INTERVAL FOR FIXED BASE LAB
0-6, 6-12, 30-36, 42-48

LOGGED BY:
BOOKER/CROWN

S3 2.0 1.6
S3 2.0 1.7
S3 2.0 1.8
S3 1.9 0.9
S3 1.7 1.2
S3 1.7 1.7
S3 1.0 1.0
S3 1.0 1.0
S3 0.4 0.4
S3 0.8 0.8
S3 1.1 1.1
S3 1.1 1.1
S3 1.4 1.4
S3 1.1 1.1

DESCRIPTION AND CLASSIFICATION

TOP SOIL (0-0.5)
- nonuniform, plastic, red-brown to reddish yellow with light gray and rust-orange mottles, soft to firm, damp. (CL) some roots
- CLAY (0.3-0.8), nonuniform, plastic, dark red-brown to gray-black, soft to firm, damp to dry. (CL)

SILTY-CLAY (4.4-4.4)
- nonuniform, plastic to slightly plastic, yellow brown, soft to firm, damp to dry (CL)

VERY WEATHERED SHALE (4.6-5.8)
- nonuniform, nonplastic, yellow-gray brown with black stains along partings, hard, dampy to dry. (CL-ML) brittle, some soft black inclusions
- VERY WEATHERED SULFUR SHALE, nonuniform, nonplastic, yellow-grayish brown, with dark brown to rust stains in partings, hard, damp to dry. (CL-ML) brittle

WEATHERED SHALE, nonuniform, nonplastic, yellow-grayish brown with dark brown to black to olive green bands, yellowish red to yellow to light gray mottles, hard, damp to dry (CL-ML)

WEATHERED SHALE, nonuniform, nonplastic, yellowish brown with dark brown and dark reddish brown stains along partings, hard, damp to dry. (CL-ML)

WEATHERED SHALE, nonuniform, nonplastic, yellowbrown to dusky rose to very dark brown, hard, damp to dry. (CL-ML)

WEATHERED SHALE, nonuniform, nonplastic, yellowbrown to grayish brown with black stains along partings, hard, damp to dry. (CL-ML)

WEATHERED SHALE, nonuniform, nonplastic, yellowgrayish brown with bands of dark brown and yellow, also black stains along partings, hard, damp to dry. (CL-ML)

WEATHERED SHALE, nonuniform, nonplastic, yellowbrown to grayish brown with orange mottles, black stains on mottles, hard, damp to dry. (CL-ML) brittle

SILT (22-22.3), dark brown to black

SILT (22.3-23.1), nonuniform, nonplastic, yellowgray to grayish brown, hard, damp. (CL-ML)

SILT (23.2-23.1), nonuniform, nonplastic, grayish brown to dark brown with bands of dark red brown, hard, damp to dry. (CL-ML) brittle

SILT (23.2-23.1), nonuniform, nonplastic, dusky red brown to grayish brown yellow brown with band of black and yellow, hard, damp to dry (CL-ML)

S3 = SPLIT SPOON
HX = ROCK CORING
AR = AIR ROTARY
NOTE SURFACE ELEVATION = TOP F' PAD

CHECKED BY

HOLE NO
1236
<table>
<thead>
<tr>
<th>SAMPLE TYPE</th>
<th>CORE LENGTH</th>
<th>CORE REC</th>
<th>% REC</th>
<th>ROD</th>
<th>SAMPLE DISCR</th>
<th>SCREENING</th>
<th>INTERNAL</th>
<th>DESCRIPTION AND CLASSIFICATION</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>S3</td>
<td>1.1</td>
<td>1.1</td>
<td></td>
<td>42</td>
<td></td>
<td></td>
<td></td>
<td>Very Weathered Shale, nonuniform, nonplastic, grayish brown to dark brown with lenses of dark red brown, hard, damp to dry. (CL-M-L). Bore</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>1.2</td>
<td>1.2</td>
<td></td>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td>Very Weathered Shale, nonuniform, nonplastic, dusty red brown to grayish yellow brown with band of black and yellow, hard, damp to dry (CL-M-L). Bore</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>2.0</td>
<td>1.0</td>
<td></td>
<td>35</td>
<td></td>
<td></td>
<td></td>
<td>Very Weathered Shale, nonuniform, nonplastic, grayish-yellow brown, hard, damp to dry, (CL-M-L). Bore</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>0.5</td>
<td>0.5</td>
<td></td>
<td>38</td>
<td></td>
<td></td>
<td></td>
<td>Very Weathered Shale, nonuniform, nonplastic, grayish-brown to grey brown, dark rust to black stains between partings, firm to hard, dense to moist, (CL-M-L). Nonporous, bedding evident</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>0.3</td>
<td>0.3</td>
<td></td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td>Very Weathered Shale, nonuniform, nonplastic, grayish-brown to grey brown, orange-rust stains between partings, hard, moist, (CL-M-L). Nonporous, bedding evident.</td>
<td></td>
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<tr>
<td>S3</td>
<td>0.1</td>
<td>0.1</td>
<td></td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td>Weathered Shale, nonuniform, nonplastic, dark yellowish brown to dark dusty red brown, gold and orange stains in partings, hard, moist, (CL-M-L). Nonporous.</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>0.6</td>
<td>0.6</td>
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<td>50</td>
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<td></td>
<td></td>
<td>Weathered Shale, nonuniform, nonplastic to slightly plastic, grayish yellow-brown, iron stained in partings, hard, moist, (CL-M-L). Nonporous, brittle, some clay.</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>0.25</td>
<td>0.25</td>
<td></td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td>Weathered Shale, nonuniform, nonplastic, yellowish brown to grey brown, orange to dark brown to black stains, in partings, hard, moist. (CL-M-L). Nonporous.</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>0.3</td>
<td>0.3</td>
<td></td>
<td>100</td>
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<td></td>
<td></td>
<td>Weathered Shale, nonuniform, slightly plastic, yellowish brown to grey brown with orange stains along partings, hard, moist. (CL-M-L). Nonporous.</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>0.7</td>
<td>0.7</td>
<td></td>
<td>34</td>
<td></td>
<td></td>
<td></td>
<td>Weathered Shale, nonuniform, nonplastic to slightly plastic, layers of yellow gray, yellow brown, and black, with orangy, black, and yellow brown mottinges, hard, dense to moist, (CL-M-L). Nonporous, bedding evident.</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>0.25</td>
<td>0.25</td>
<td></td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td>Weathered Shale, nonuniform, nonplastic, yellowish brown to dark rusty red brown with some mottinges, hard, moist, (CL-M-L). Nonporous.</td>
<td></td>
</tr>
<tr>
<td>AR</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>Auger Failure at 43.25</td>
<td></td>
</tr>
</tbody>
</table>

**GEOLOGIC LOG**

**ORNL R/FS JOB 19118**

**DESCRIPTION AND CLASSIFICATION**

**NOTES**

**CHECKED BY:**

**HOLE NO.:**

**1236**

**5.5 1984.3**
### GEOLOGIC LOG

<table>
<thead>
<tr>
<th>SAMPLE TYPE &amp; DIAMETER</th>
<th>CORE LENGTH</th>
<th>% REC</th>
<th>% ROD</th>
<th>SLOW COUNTER RATE OF PEN</th>
<th>RUN NO.</th>
<th>BOX NO.</th>
<th>FRAC.TURE FT.</th>
<th>SAMPLE INT.</th>
<th>SCREENING INTERVAL</th>
<th>DEPTH</th>
<th>DESCRIPTION AND CLASSIFICATION</th>
<th>NOTES</th>
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<td>3.5</td>
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<td>60</td>
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<tr>
<td>0.75</td>
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<td></td>
<td>65</td>
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<td>6</td>
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<td></td>
<td></td>
<td></td>
<td>70</td>
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<td></td>
</tr>
</tbody>
</table>

**Notes:**
- Harder Rock
- Soft
- Hard
- Soft

Surface Casing set at 64.5'
- No Data for 64.5-171.9'

**Checked By:**

**HOLE NO.:**

1236
<table>
<thead>
<tr>
<th>SAMPLE TYPE</th>
<th>SAMPLE INT.</th>
<th>CORE LENGTH</th>
<th>CORE REC.</th>
<th>% REC</th>
<th>BLOW N.</th>
<th>BLOW (PSI)</th>
<th>BORE NO.</th>
<th>RING NO.</th>
<th>FRACTURE/FT.</th>
<th>SAMPLE INT. 2</th>
<th>SCREENING INTERVAL</th>
<th>DESCRIPTION AND CLASSIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>S3</td>
<td>2.0</td>
<td>1.5</td>
<td>5</td>
<td>7</td>
<td>12</td>
<td>18</td>
<td>6</td>
<td>22</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>TOPSOIL (0-0.5), nonuniform, slightly plastic, medium yellow brown with yellow mottles, decayed leaves, grass</td>
</tr>
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<td></td>
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<td></td>
<td></td>
<td>GRAVEL (0.5-0.8), LIMESTONE</td>
</tr>
<tr>
<td>S3</td>
<td>2.0</td>
<td>1.7</td>
<td>7</td>
<td>7</td>
<td>14</td>
<td>15</td>
<td>22</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>CLAY (0.8-2.0), uniform, plastic, red-yellow to yellow-brown mottles, damp, soft nonpermeable, (CL)</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>CLAY, uniform, plastic, red-yellow to yellow-brown mottles, damp, soft to firm, nonpermeable, (CL)</td>
</tr>
<tr>
<td>S3</td>
<td>2.0</td>
<td>1.3</td>
<td>12</td>
<td>12</td>
<td>17</td>
<td>16</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>Silty clay nonuniform, plastic, dark red-yellow to light red-yellow with layers of brown, damp, soft to firm, slightly permeable (CL-ML)</td>
</tr>
<tr>
<td>S3</td>
<td>2.0</td>
<td>1.9</td>
<td>17</td>
<td>17</td>
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<td>16</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>Silt clay nonuniform, nonplastic, yellow brown with red-yellow mottles with some olive brown and black mottles, damp, firm, slightly permeable, traces of a shiny mineral, (CL-ML)</td>
</tr>
<tr>
<td>S3</td>
<td>1.95</td>
<td>1.25</td>
<td>23</td>
<td>23</td>
<td>24</td>
<td>16</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>Weathered silt clay nonuniform, nonplastic, yellow brown with layers of dusty red, dark brown, red yellow, damp, hard, crystals intergrown, slightly permeable, (CL-ML)</td>
</tr>
<tr>
<td>S3</td>
<td>1.8</td>
<td>1.8</td>
<td>16</td>
<td>16</td>
<td>17</td>
<td>16</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>Very weathered silt shale, nonuniform, nonplastic, alternating layers of medium brown, dusty red, yellow brown, damp, firm, traces of shiny mineral, slightly permeable, (CL-ML)</td>
</tr>
<tr>
<td>S3</td>
<td>2.0</td>
<td>2.0</td>
<td>16</td>
<td>16</td>
<td>17</td>
<td>16</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>Very weathered silt shale, nonuniform, nonplastic, dark brown to dark red brown, yellow, gray, olive gray mottles and streaks, firm to hard, slightly permeable, (CL-ML)</td>
</tr>
<tr>
<td>S3</td>
<td>2.0</td>
<td>2.0</td>
<td>16</td>
<td>16</td>
<td>17</td>
<td>16</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>Weathered silt shale, nonuniform, nonplastic, alternating layers of yellow brown, and dark rusty brown with light gray and black mottles, damp, very firm, slightly permeable, (CL-ML)</td>
</tr>
<tr>
<td>S3</td>
<td>2.0</td>
<td>1.7</td>
<td>17</td>
<td>17</td>
<td>17</td>
<td>16</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>Very weathered silt shale, nonuniform, nonplastic, yellow brown with alternating layers of olive gray and yellow gray, damp to dry, firm brittle, slightly permeable, (CL-ML)</td>
</tr>
<tr>
<td>S3</td>
<td>2.0</td>
<td>1.3</td>
<td>17</td>
<td>17</td>
<td>17</td>
<td>16</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>Very weathered silt shale, nonuniform, nonplastic, strong brown to yellow brown with layers of rust brown, damp to dry, firm, slightly permeable, (CL-ML)</td>
</tr>
<tr>
<td>S3</td>
<td>1.75</td>
<td>1.0</td>
<td>16</td>
<td>16</td>
<td>17</td>
<td>16</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>Very weathered silt shale, nonuniform, nonplastic, strong brown to yellow brown with layers of rust brown, firm to dry, firm to hard, slightly permeable, (CL-ML)</td>
</tr>
<tr>
<td>S3</td>
<td>0.2</td>
<td>0</td>
<td>&gt;50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>LIMESTONE, dark gray to medium gray, hard, crystalline, angular fragments, stained</td>
</tr>
</tbody>
</table>

**GEOLOGIC LOG**

- **ORNL R/FS JOB 19118**
- **GROUND EL.**: 825.47
- **TOTAL DEPTH**: 58.8'
- **BOREHOLE DEVIATION**: 0
- **BETWEEN 1/290**:
- **BEDROCK DEPTH/ELEV.**: 26.27/92.27'

**DRILLER**
- **HIGHLAND**
- **EDGE**

**SAMPLE INTERVALS FOR SCREENING**
- **0-26'**

**SAMPLE INTERVAL FOR FIXED BASE LAB**
- **18-24'**

**LOGGED BY**: OWENS

**NOTES**
- **S3 - SPLIT SPOON**
- **HX - ROCK CORING**

**CHECKED BY**: 1237

**HOLE NO.**: 1237
<table>
<thead>
<tr>
<th>SAMPLE TYPE &amp; DIAMETER</th>
<th>SAMPLE INT.</th>
<th>SAMPLE DESC.</th>
<th>% REC</th>
<th>BLOW</th>
<th>COUNTS OR RATE OF PEN</th>
<th>RUN NO.</th>
<th>BOX NO.</th>
<th>FRACTURE/S</th>
<th>CORE LENGTH</th>
<th>CORE REC.</th>
<th>% REC</th>
<th>DESCRIPTION AND CLASSIFICATION</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Alternating soft and hard drilling</td>
<td>Surface casing set using air rotary from 0-32.6'. Little data collected</td>
</tr>
<tr>
<td>HX</td>
<td>5.0</td>
<td>1.4</td>
<td>28</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>Grout and cuttings</td>
<td>Coring begins at 32.6'</td>
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<tr>
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<td>Mixing (33.8 - 35.8)</td>
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<td>90</td>
<td>56</td>
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<td>LIMESTONE, dark gray, hard, fine-grained, calcite filled fractures, shale filled fracture at 36.4'</td>
<td>Bedding at 30°</td>
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<td>Mixing (36.5 - 37.6)</td>
<td>Bedding at 30° - 45°</td>
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<td>4&gt;10</td>
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<td>LIMESTONE, dark gray, hard, fine-grained, calcite filled fractures, shale filled fracture, interbedded with SHALE</td>
<td>Bedding at 30°</td>
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<td>LIMESTONE, dark gray, hard, fine-grained, calcite filled fractures, shale filled fracture, interbedded with SHALE, lamina, dark gray, soft, fine-grained</td>
<td>Bedding at 30°</td>
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<tr>
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<td>9.0</td>
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<td>1&gt;10&gt;10</td>
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<td>8&gt;10</td>
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<td>LIMESTONE, dark gray, hard, fine-grained, calcite filled fractures, shale filled fracture, interbedded with SHALE, dark gray to black, soft, fine-grained, noncalcareous, slightly weathered, contorted bedding at 41.5 - 41.6'</td>
<td>Bedding at 45°</td>
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<td>(45.2 - 46.2) Brecciated zone, convoluted bedding, healed fractures</td>
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<td>LIMESTONE, dark gray, hard, fine-grained, calcite filled fractures, shale filled fracture, interbedded with SHALE, dark gray to black, soft, fine-grained, noncalcareous, many calcite and shale filled fractures</td>
<td>Coring ends at 53.6'</td>
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<td>Air rotary reaming from 32.6 to 58.8'.</td>
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<td>Borehole total depth: 58.8'</td>
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</tbody>
</table>
## GEOLOGIC LOG

### ORNL GRID LOCATION
- Ground El: 824.85
- Total Depth: 171'
- Began: 2/6/80
- Completed: 5/8/80
- Borehole Deviation: 0
- Bedrock Depth/Elevation: 27.0' / 797.85

### DRILLER
- HIGHLAND
  - Drill Make/Model: IR X L-750
  - Type Drilling: Air Rotary
  - Interval: 0-32.3'
  - Hole Diam: 10 5/8'
  - Depth to Groundwater/Elev./Data: No Data

### Core Boxes
- 1

### SAMPLES INTERVALS FOR SCREENING
- None

### SAMPLES INTERVAL FOR FIXED BASE LAB
- None

### DESCRIPTION AND CLASSIFICATION
- No Data Due to Use of Air Rotary Equipment from 0 to 171 ft
- 0-25': Soft Drilling

### BOTTOM OF HOLE AT 171'

---

**NOTES**

**CHECKED BY:**

HOLE NO: 1238
<table>
<thead>
<tr>
<th>SAMPLE NO.</th>
<th>SAMPLE TYPE</th>
<th>SAMPLE INT.</th>
<th>SAMPLE REC.</th>
<th>% REC</th>
<th>BLOW</th>
<th>BLOW CORR.</th>
<th>% BLOW</th>
<th>RATE OF PENETRATION</th>
<th>SAMPLE INT.</th>
<th>SCREENING</th>
<th>DESCRIPTION AND CLASSIFICATION</th>
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<tbody>
<tr>
<td>S3</td>
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<td></td>
<td>4</td>
<td></td>
<td>100</td>
<td>41.5</td>
<td></td>
<td></td>
<td>TOPSOIL (0-0.5), nonuniform, nonplastic, dark brown to gray brown, damp, soft, permeable, (CL), decayed leaves, roots.</td>
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<tr>
<td>S3</td>
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<td>1.2</td>
<td></td>
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<td>100</td>
<td>41.5</td>
<td></td>
<td></td>
<td>SILTY CLAY (0.5-2.0), uniform, slightly plastic, yellow brown to red yellow, damp, firm, slightly permeable, (CL).</td>
</tr>
<tr>
<td>S3</td>
<td>2.0</td>
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<td>41.5</td>
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<td></td>
<td>SANDY CLAY. (CL), uniform, nonplastic, red-yellow brown to red yellow, damp, soft to firm, permeable, (CL).</td>
</tr>
<tr>
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<td>1.6</td>
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<td>26</td>
<td></td>
<td>100</td>
<td>41.5</td>
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<td>CLAY (nonuniform, plastic, light gray, damp, soft, (CL).</td>
</tr>
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<td>SAND (nonuniform, nonplastic, alternating layers of yellow red, dark red brown, and light gray, damp, stiff, permeable.</td>
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<td>SILTY CLAY (0.5-2.0), uniform, slightly plastic, yellow brown to red yellow, damp, firm, slightly permeable, (CL).</td>
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<td>100</td>
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<td>CLAY (9.7-10), nonuniform, plastic, brick red, damp, stiff, slightly permeable, (CL).</td>
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<tr>
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<td>SILTY CLAY (0.5-2.0), uniform, slightly plastic, yellow brown to red yellow, damp, firm, slightly permeable, (CL).</td>
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Surface casing set using air rotary from 0-55'. No data collected except for ROP.
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<th>SAMPLING METHOD</th>
<th>% REC</th>
<th>RQD</th>
<th>BLOW RATE OR RATE OF PEN.</th>
<th>BOX NO.</th>
<th>fractures</th>
<th>DRILLING INTERVAL</th>
<th>DESCRIPTION AND CLASSIFICATION</th>
<th>NOTES</th>
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Air Rotary drilled hole to 171’
ROP is only data available

Bottom of Hole - 171’
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<th>CORE LENGTH</th>
<th>CORE REC.</th>
<th>% REC</th>
<th>ROD</th>
<th>BLOW/DR</th>
<th>RATE OF PNL</th>
<th>BOX NO.</th>
<th>FRAC/FT.</th>
<th>SAMPLE INT</th>
<th>CORE</th>
<th>INTERVAL</th>
<th>DEPTH TO GROUNDWATER</th>
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<td>95</td>
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<td>95.12</td>
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</table>

**DESCRIPTION AND CLASSIFICATION**

- **CLAY**, nonuniform, low plasticity, brown with yellow brown mottles, damp, slightly permeable (CL), some shale fragments.
- **CLAY (2.0-2.5)**, nonuniform, low plasticity, brown with yellow brown mottles, damp, slightly permeable (CL), some shale fragments.
- **WEATHERED SHALE (2.5-4.0)**, nonuniform, low plasticity, brown, damp, slightly permeable, fossil.
- **WEATHERED SHALE** uniform, low plasticity, light brown, stains along partings, damp, slightly permeable.
- **WEATHERED SHALE**, uniform, nonplastic, brown, stained along bedding planes, dry, thin-bedded, permeable along fractures.
- **WEATHERED SHALE**, uniform, nonplastic, brown, stained along bedding planes, dry, thin-bedded, permeable along fractures.
- **WEATHERED SHALE**, uniform, nonplastic, brown, stained along bedding planes, dry, thin-bedded, permeable along fractures.
- **WEATHERED SHALE**, uniform, nonplastic, brown, stained along bedding planes, dry, thin-bedded, permeable along fractures.
- **LIMONITE**, gray, hard, crystalline, dry, 0.5" diameter fragment.

**CHECKED BY:**

**NOTE:**

- Augmented to 18.5' - No recovery
- SHALE, uniform, nonplastic, gray, wet, thin-bedded, permeable along fractures
- No Recovery
- No Recovery
- SHALE, uniform, nonplastic, gray, wet, thin-bedded, permeable along fractures

**HOLE NO.**

1240
<table>
<thead>
<tr>
<th>DESCRIPTION AND CLASSIFICATION</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Sample</td>
<td></td>
</tr>
</tbody>
</table>

Auger refusal at 29.0'
### GEOLOGIC LOG

**ORNL GRID LOCATION:**
N 17913.50 E 25097.59

**GROUND EL.:**
805.70

**TOTAL DEPTH:**
45.0

**BEGAN:**
4/11/90

**COMPLETED:**
4/12/90

**BOREHOLE DEVIATION:**
0

**BEDROCK DEPTH/ELEV.:**
7.2/788.5

**DRILLER:**
EDGE

**DRILL MAKER/MODEL:**
CME-55

**TYPE DRILLING:**
HSA

**INTERVAL:**
0-7.2'

**HOLE DIAM.:**
6'

**DEPTH TO GROUNDWATER/ELEV./DATA:**
NO DATA / 767.8

**CORE BOXES:**
N/A

**SAMPLES INTERVAL FOR SCREENING:**
0-7'

**SAMPLES INTERVAL FOR FIXED BASE LAB:**
NONE

**LOGGED BY:**
BAXTER

<table>
<thead>
<tr>
<th>SAMPLE TYPE &amp; DIAMETER</th>
<th>SAMPLE NO.</th>
<th>SAMPLE RECORDED</th>
<th>% REC.</th>
<th>BLOW/FT.</th>
<th>BREAKING BOUNDARY</th>
<th>FRACTURE LOCATION</th>
<th>SCREENING INCHES</th>
<th>DEPTH</th>
<th>DESCRIPTION AND CLASSIFICATION</th>
<th>NOTES</th>
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<tbody>
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<td>6</td>
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<tr>
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<td>CLAY (2.0-4.4), uniform, slightly plastic, brown to yellow, damp, stiff, low to medium permeability.</td>
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<td>WEATHERED SHALE, nonuniform, nonplastic, yellowish brown, thin to medium bedded, permeable along bedding planes.</td>
<td>-------</td>
</tr>
<tr>
<td>S3</td>
<td>1.0</td>
<td>1.2</td>
<td>4</td>
<td>8</td>
<td>12</td>
<td></td>
<td></td>
<td>7</td>
<td>WEATHERED SHALE, uniform, nonplastic, pale brown, stained along partings, permeable along bedding planes. Spoon refusal at 7.2</td>
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</tr>
<tr>
<td>B6</td>
<td></td>
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<td></td>
<td></td>
<td>WEATHERED SHALE, light tan, fragments.</td>
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<td>WEATHERED SHALE, brown, slightly calcareous, fragments.</td>
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<td>WEATHERED SHALE, brown, damp, fragments.</td>
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**CHECKED BY:**
HOLE NO.
1241

S3 - SPLIT SPOON;
B6 - BULLDOG BIT AUGER

5.5 1964.15
<table>
<thead>
<tr>
<th>SAMPLE TYPE</th>
<th>SAMPLE INT</th>
<th>CORE LENGTH</th>
<th>% REC</th>
<th>ROD</th>
<th>BLOW COUNTS OR HOLE OF PEN</th>
<th>RUN NO</th>
<th>BOX NO</th>
<th>FRACUR/SET</th>
<th>SAMPLE INT</th>
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<th>DEPTH</th>
<th>DESCRIPTION AND CLASSIFICATION</th>
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Bottom of Hole - 45.0'
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<td>Auger refusal at 16.3 feet</td>
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Bull Bit Auger
From 16.3 to 40.2

No Lithologic Data Available
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<th>ROD</th>
<th>ELEV.</th>
<th>RATE</th>
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<th>FRACTURE</th>
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<td>0 - 0.3 Limestone: gravel</td>
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<tr>
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<td>10</td>
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<td>0.3 - 1.0 Silty-clay: nonuniform, low plasticity, brown with black and yellow mottles, damp, soft, slightly permeable</td>
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<td>5</td>
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<td>S3</td>
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<td>Auger refusal at 10.2'</td>
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<td>Bull Bit Auger from 10.3 to 13.0'</td>
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<td>Air Rotary to 35.3'</td>
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<td>ORNL GRID LOCATION</td>
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<td>TOTAL DEPTH</td>
<td>BEGAN</td>
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<td>BOREHOLE DEVIATION</td>
<td>BEDROCK DEPTH</td>
<td>ELEV.</td>
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<td>17155.4E 25459.0</td>
<td>25.2</td>
<td>4/6/90</td>
<td>4/9/90</td>
<td>0'</td>
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<td>7.0/748.49</td>
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**Driller**

<table>
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<tr>
<th>DRILLER</th>
<th>DRILL MAKEMODEL</th>
<th>TYPE DRILLING</th>
<th>INTERVAL</th>
<th>HOE DIAM</th>
<th>DEPTH TO GROUNDWATER / ELEV. / DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIGHLAND</td>
<td>IR XL 750</td>
<td>AIR ROTARY</td>
<td>0-25.2'</td>
<td>6.1/4'</td>
<td>10.0 / 745.49</td>
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**Core Boxes**

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<tr>
<th>CORE BOXES</th>
<th>SAMPLE INTERVALS FOR SCREENING</th>
<th>SAMPLES INTERVAL FOR FIXED BASE LAB</th>
<th>LOGGED BY</th>
<th>NOTES</th>
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**Sample Type & Diameter**

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<th>% REC</th>
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<th>CORE REC.</th>
<th>ROD</th>
<th>ROD</th>
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<th>FRAC DIRECT</th>
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10' Bouncer.

14' - Smooth drilling

Boring complete at 25.2'
## GEOLOGIC LOG

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<th>ORNL GRID LOCATION</th>
<th>GROUND EL.</th>
<th>TOTAL DEPTH</th>
<th>Began</th>
<th>Completed</th>
<th>BOREHOLE DEVIATION</th>
<th>BEDROCK DEPTH/ELEV.</th>
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<td>16900.21F 25424.11</td>
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<td>7.5/745.53</td>
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</table>

### DRILLER
- **HIGHLAND**
- **DRILL TYPE/MAKE/MODEL**: IR XL 750
- **TYPE OF DRILLING**: AIR ROTARY
- **INTERVAL**: 0-34.4'
- **HOLE DIAM**: 10.5/8'
- **DEPT TO GROUNDWATER / ELEV. / DATA**: 4.0' / 749.03' /

### CORE BOXES
- **NONE**

### SAMPLES INTERVALS FOR SCREENING
- **NONE**

### SAMPLES INTERVAL FOR FIXED BASE LAB
- **NONE**

### DESCRIPTION AND CLASSIFICATION

No data due to use of air rotary equipment

### NOTES

Boring complete at 60.0'

---

**S3 = SPLIT SPOON**

**HX = ROCK CORING**

**ROP (Rate of Penetration) is in feet per minute**

**CHECKED BY:**

**HOLE NO.:**

1245
## GEOLOGIC LOG

**ORNL GRID LOCATION**: 16969 SW 26244.09

### JOB 19118

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### DRILLER

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<td>AIR ROTARY</td>
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### INTERVALS FOR SCREENING

### SAMPLES INTERVAL FOR FIXED BASE LAB

### LOGGED BY:

**CROWNED**

### SAMPLES INTERVALS FOR SCREENING

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<td>Boring complete at 72.0'</td>
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</table>

### NOTES

- 7' Surface casing set at 42 ft.
- No data after 40'
Attachment 2

WELL INSTALLATION FORMS
DRILLING METHOD 6 IN AUGER 21 LF
3.65 IN CORING 91.3 LF
10.625 IN ROTARY 38.3 LF
6.25 IN ROTARY 110.5 LF

MATERIALS USED

- LBS BENTONITE PELLETS (SURFACE CASING SEAL) 40 FT OF __ 7 IN SURFACE CASING
- SACKS OF CEMENT (SURFACE CASING)
- LBS OF POWDERED BENTONITE (SURFACE CASING)
- GALLONS OF WATER (SURFACE CASING) 130.4 FT OF __ 2 IN DIA (S.S. CASING)
- 20 FT OF __ 2 IN DIA (S.S. SCREEN)
- 4 SACKS OF SAND
- 85 LBS OF BENTONITE PELLETS (WELL CASING)
- 17 SACKS OF CEMENT (WELL CASING)
- 65 LBS OF BENTONITE (S.S. CASING SEAL)
- GALLONS OF WATER (WELL CASING) 5 FT OF __ 6.5/8 IN STEEL PROTECTIVE CASING

MATERIALS MFG./TYPE

LUBRICANT(S) N/A
CEMENT DIXIE CEMENT/PORTLAND TYPE I
SAND SIZE 0.45-0.55 mm
SCREEN SIZE 0.010
BENTONITE (POWDERED) Baroid/Benseal
BENTONITE (PELLETS) Baroid/Hole plug
OTHER

NOTES *SS-HSA drilled by EDGE, logged by Crowner,
coring by EDGE, logged by Owens, air rotary
by Highland, logged by Crowner

NOT TO SCALE
NOTES: Hole plugged back with 100 pounds of Holeplug
WELL INSTALLATION FORM

WELL NO.: 1236
STAKED COORDS: N 16195.25 E 23195.49
INSTALLATION DATES: 5-9-90
LOGGED BY: Crowner DRILLED BY: Highland
DRILLER: Baker HELPER: Copeman

DRILLING METHOD: 6 IN. AUGER 48.3 LF
- IN. CORING __ LF
10 5/8 IN. ROTARY 64.5 LF
6 1/4 IN. ROTARY 103 LF

MATERIALS USED

VOL.
- LBS BENTONITE PELLETS (SURFACE CASING SEAL) 64.5 FT OF __ 7 IN. SURFACE CASING
- SACKS OF CEMENT (SURFACE CASING)
- LBS OF POWDERED BENTONITE (SURFACE CASING)
- GALLONS OF WATER (SURFACE CASING) 144.1 FT OF __ 2 IN. DIA. (S.S. CASING)
20 FR. OF __ 2 IN. DIA. (S.S. SCREEN)
5 1/2 SACKS OF SAND
80 LBS OF BENTONITE PELLETS (WELL CASING)
20 SACKS OF CEMENT (WELL CASING)
77 LBS OF BENTONITE (S.S. CASING SEAL)
- GALLONS OF WATER (WELL CASING)
7 FT OF __ 6.5 IN. STEEL PROTECTIVE CASING

MATERIALS MFG./TYPE

LUBRICANT(S) N/A
CEMENT DIXIE CEMENT/PORTLAND TYPE I
SAND SIZE 0.45-0.55 mm
SCREEN SIZE 0.010
BENTONITE (POWDERED) Baroid/Benseal
BENTONITE (PELLETS) Baroid/Hole plug
OTHER

NOTES: SS-HSA by EDGE, logged by Booker, air rotary by Highland, logged by Crowner

Hole plugged back to 165.8' with 5 bags bentonite

CHECKED BY: TFZ 8/91

5.22.4736.3
**WELL INSTALLATION FORM**

**DRILLING METHOD:**
- 10.6/8 in. ROTARY 32.3 LF
- 6 1/4 in. ROTARY 138.7 LF

**MATERIALS USED**
- 72 LBS BENTONITE PELLETS (SURFACE CASING SEAL)
- 32.3 FT OF 7 IN. SURFACE CASING
- 134.3 FT OF 2 IN. DIA. (S.S. CASING)
- 20 FT OF 2 IN. DIA. (S.S. SCREEN)
- 6 SACKS OF SAND
- 53 ROLLS OF BENTONITE PELLETS (WELL CASING)
- 127 LBS OF BENTONITE (S.S. CASING SEAL)
- 5 FT OF 5.5 IN. IN STEEL PROTECTIVE CASING
- 57,000 GALLONS OF WATER (WELL CASING)
- 57,000 GALLONS OF WATER (WELL CASING)

**MATERIALS MFG./TYPE**
- LUBRICANT(S): N/A
- CEMENT: DIXIE CEMENT/PORTLAND TYPE I
- SAND SIZE: 0.45-0.55 mm
- SCREEN SIZE: 0.010
- BENTONITE (POWDERED): Baroid/Benseal
- BENTONITE (PELLETS): Baroid/Hole plug

**NOTES:**
- SS-HSA by EDGE, logged by Booker; coring by EDGE, logged by Owens, air rotary by Highland;
- logged by Crowner
- Hole plugged back to 154' with 7 bags Bentonite

**ELEV. PAD:** 824.85
**RISER:** 827.15
**CASING:** 827.57

**NOTE:** ALL DEPTHS RELATIVE TO TOP OF PAD

**PROTECTIVE CASING:**
- 6 1/4 in. DIAMETER STEEL PROTECTIVE CASING
- CONCRETE PA:
  - 16 IN. DIAMETER BOREHOLE
- 11 1/4 IN. DIAMETER DIVERTER STEEL CASING
- 7 IN. DIAMETER SURFACE CASING FROM 0 TO 32.3 FT
- CEMENT GROUT FROM 0 TO 32.3 FT

**CENTRALIZERS:**
- 1, 100.00, 110.122, 5 TO 122.5 IN
- 2 IN. DIAMETER STAINLESS STEEL RISER CASING FROM 126.5 TO 126.5 FT
- BENTONITE SEAL FROM 126.5 TO 126.5 FT
- SAND PACK 126.5 TO 154.0
- 2 IN. DIAMETER STAINLESS STEEL SLOTTED/CONTINUOUS WELL SCREEN (0.010 IN SLOT) FROM 131.1 TO 151.1 FT
- 2 IN. DIAMETER BLANK STAINLESS STEEL SILT TRAP FORM 151.1 TO 152.0 FT
- PLUGGED BACK TO 154.0 FT

**TOTAL DEPTH OF BOREHOLE:** 171 FT

**BOTTOM WELL CAP:** 152.0 FT

**NOT TO SCALE**

**CHECKED BY:** TFZ 8/91
### WELL INSTALLATION FORM

**WAG**: 6  
**WELL NO.**: 1239  
**GEOLOGIC LOG BORING NO.**: 1239

**STAKED COORDS**: N 17013.86  E 22449.10  
**INSTALLATION DATES**: 5-2-90

**LOGGED BY**: Crowner  
**DRILLED BY**: Highland  
**DRILLER**: Baker  
**HELPER**: Copeman

### DRILLING METHOD

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<tr>
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<th>QTY</th>
<th>UNIT</th>
<th>DEPTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN. AUGER 24.3 LF</td>
<td>6</td>
<td>LF</td>
<td>54.7 FT OF 7 IN. SURFACE CASING</td>
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<tr>
<td>IN. CORING 53 LF</td>
<td>10</td>
<td>LF</td>
<td>58 LBS BENTONITE PELLETS (SURFACE CASING SEAL)</td>
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<td>IN. ROTARY 115 LF</td>
<td>6.1/4</td>
<td>LF</td>
<td>28 LBS OF CEMENT (SURFACE CASING)</td>
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<td>137.7 FT OF 2 IN. DIA. (S.S. CASING)</td>
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<td>5 FT OF 6 5/8 IN. STEEL PROTECTIVE CASING</td>
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### MATERIALS MFG./TYPE

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<td>SAND SIZE</td>
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<td>SCREEN SIZE</td>
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<td>BENTONITE (POWDERED)</td>
<td>Baroid/Benseal</td>
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<tr>
<td>BENTONITE (PELLETS)</td>
<td>Baroid/Hole plug</td>
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<td>OTHER</td>
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### MATERIENS USED

- 54.7 FT OF 7 IN. SURFACE CASING
- 58 LBS BENTONITE PELLETS (SURFACE CASING SEAL)
- 28 LBS OF CEMENT (SURFACE CASING)
- 137.7 FT OF 2 IN. DIA. (S.S. CASING)
- 5 FT OF 6 5/8 IN. STEEL PROTECTIVE CASING

### WATER LEVEL

- DEPTH TO BEDROCK 24.3 FT
- TOTAL DEPTH OF BOREHOLE 171 FT

---

**NOT TO SCALE**

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**CHECKED BY**: TFZ 8/91
### WELL INSTALLATION FORM

**ORNL RIFS**  
**JOB 19118**

**WAG** 6  
**WELL NO.:** 1240  
**GEOLOGIC LOG BORING NO.:** 1240

**STAKED COORDS:** N 18066.23  
**E 25183.90**  
**INSTALLATION DATES:** 3-19-90  
**LOGGED BY:** Owens  
**DRILLED BY:** Edge  
**DRILLER:** Aiken  
**HELPER:** Cable

### DRILLING METHOD:
- **6 IN. AUGER** 29.0 LF
- **IN. CORING**
- **IN. ROTARY**
- **IN. ROTARY**

### ELEV. PAD: 797.73  
**RISER:** 800.34  
**PROTECTIVE CASING:** 800.60  
**NOTE:** ALL DEPTHS ARE RELATIVE TO TOP OF PAD

### MATERIALS USED

<table>
<thead>
<tr>
<th>LBS BENTONITE PELLETS (SURFACE CASING SEAL)</th>
<th>FT OF _ _ IN. SURFACE CASING</th>
<th>SACKS OF CEMENT (SURFACE CASING)</th>
<th>_ _ LBS OF POWDERED BENTONITE (SURFACE CASING)</th>
<th>_ _ GALLONS OF WATER (SURFACE CASING)</th>
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<tr>
<td>25</td>
<td>10.2 FT OF 2 IN. DIA. (S.S. CASING)</td>
<td>15 FT OF 2 IN. DIA. (S.S. SCREEN)</td>
<td>4 SACKS OF SAND</td>
<td>25 LBS OF BENTONITE PELLETS (WELL CASING)</td>
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<td>USED</td>
<td>5 FT OF 6.5 FT IN. STEEL PROTECTIVE CASING</td>
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<td>8 LBS OF BENTONITE (S.S. CASING SEAL)</td>
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<td>10 GALLONS OF WATER (WELL CASING)</td>
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<td></td>
<td>5 FT OF 6.5 FT IN. STEEL PROTECTIVE CASING</td>
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### MATERIALS MFG./TYPE

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<tr>
<td>CEMENT</td>
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<td>SAND SIZE</td>
<td>0.45-0.55 mm</td>
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<td>SCREEN SIZE</td>
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<td>BENTONITE (POWDERED)</td>
<td>Baroid/Benseal</td>
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<tr>
<td>BENTONITE (PELLETS)</td>
<td>Baroid/Holeplug</td>
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<tr>
<td>OTHER</td>
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</table>

### NOTES


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**TOP CONCRETE PAD**  
**GROUND SURFACE**  
**LOCKING STEEL CAP**  
**INNER CAP**  
**CENTRALIZERS**
- 7 FEET (1)  
- 23 FEET (2)  
- 160 FEET (4)

**BENTONITE CEMENT GROUT**
- 0 TO 6 FT

**BENTONITE SEAL**
- 6.5 TO 8.5 FT

**SAND PACK**
- 8.6 TO 24.1 FT

**BOTTOM WELL CAP** 20 FT

**SMOOTH BORE**
- 29.8 FT

**PLUGGED BACK TO** 23 FT

---

**CHECKED BY:** TFZ 8/91  
**5.22 4738.2**
WELL INSTALLATION FORM

DRILLING METHOD:
- 6 IN AUGER: 45 LF
- IN. AUGER: 45 LF
- IN. CORING: 0 LF
- IN. ROTARY: 0 LF
- IN. ROTARY: 0 LF

MATERIALS USED

- VOL. USED:
  - LBS BENTONITE PELLETS (SURFACE CASING SEAL)
  - FT OF _ IN. SURFACE CASING
  - SACKS OF CEMENT (SURFACE CASING)
  - LBS OF POWDERED BENTONITE (SURFACE CASING)
  - GALLONS OF WATER (SURFACE CASING)
  - 17.4 FT OF _ IN. DIA. (S.S. CASING)
  - 20 FT OF _ IN. DIA. (S.S. SCREEN)
  - 5 SACKS OF SAND
  - 39 LBS OF BENTONITE PELLETS (WELL CASING)
  - 2.5 SACKS OF CEMENT (WELL CASING)
  - 9 LBS OF BENTONITE (S.S. CASING SEAL)
  - GALLONS OF WATER (WELL CASING)
  - 5 FT OF _ IN. STEEL PROTECTIVE CASING

MATERIALS MFG./TYPE

- LUBRICANT(S): N/A
- CEMENT: DIXIE CEMENT/PORTLAND TYPE I
- SAND SIZE: 0.45-0.55 mm
- SCREEN SIZE: 0.010
- BENTONITE (POWDERED): Baroid/Benseal
- BENTONITE (PELLETS): Baroid/Hole plug
- OTHER: 

NOTES:
- Plugback used 500 pounds sand covered by 75 pounds pelletized bentonite

CHECKED BY: TFZ 8/91
**WELL INSTALLATION FORM**

**WAG:** 6  **WELL NO.:** 1242  **GEOLOGIC LOG BORING NO.:** 1242

**STAKED COORDS:** N 17367.94  E 25344.78  **INSTALLATION DATES:** 4-17-90

**LOGGED BY:** Owens  **DRILLED BY:** Edge  **DRILLER:** Jenkins  **HELPER:** Snow

**DRILLING METHOD:**
- 6 IN. AUGER 16.3 LF
- 6 1/4 IN. ROTARY 40 LF

**MATERIALS USED**

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<th>VOL. USED</th>
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<tbody>
<tr>
<td>LBS BENTONITE PELLETS (SURFACE CASING SEAL)</td>
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<tr>
<td>FT OF IN. SURFACE CASING</td>
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<tr>
<td>SACKS OF CEMENT (SURFACE CASING)</td>
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<tr>
<td>LBS OF POWDERED BENTONITE (SURFACE CASING)</td>
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<tr>
<td>GALLONS OF WATER (SURFACE CASING)</td>
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<tr>
<td>13.9 FT OF 2 IN. DIA. (S.S. CASING)</td>
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<tr>
<td>15 FT OF 2 IN. DIA. (S.S. SCREEN)</td>
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<tr>
<td>4 SACKS OF SAND</td>
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<tr>
<td>25 LBS OF BENTONITE PELLETS (WELL CASING)</td>
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<tr>
<td>3 1/2 SACKS OF CEMENT (WELL CASING)</td>
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<tr>
<td>14 LBS OF BENTONITE (S.S. CASING SEAL)</td>
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<td>GALLONS OF WATER (WELL CASING)</td>
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<tr>
<td>7 FT OF 6 5/8 IN. STEEL PROTECTIVE CASING</td>
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</table>

**MATERIALS MFG./TYPE**

| LUBRICANT(S) | N/A  |
| CEMENT | DIXIE CEMENT/PORTLAND TYPE I  |
| SAND SIZE | 0.45-0.55 mm  |
| SCREEN SIZE | 0.010  |
| BENTONITE (POWDERED) | Baroid/Benseal  |
| BENTONITE (PELLETS) | Baroid/Benseal  |
| OTHER |  |

**NOTES:** Plugback used 550 pounds sand covered by 200 pounds pelletized bentonite

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**ELEV. PAD:** 775.11  **RISER:** 777.32  **PROTECTIVE CASING:** 777.62

**TOD OF BEDROCK** 16.3 FT B.G.S.

**TOTAL DEPTH OF BOREHOLE** 40.2 FT

**NOT TO SCALE**

5.22 4738.1

Checked by: TFZ 8/91
WELL INSTALLATION FORM

WAG: 6 WELL NO.: 1243 GEOLOCIC LOG BORING NO.: 1243
STAKED COORDS: N 17085.60 E 25239.04 INSTALLATION DATES: 4-18-90
LOGGED BY: Owens DRILLED BY: EDGE DRILLER: Jenkins HELPER: Snow

DRILLING METHOD:

- 6 IN. AUGER 13.0 LF
- 6 1/4 IN. ROTARY 22.3 LF
- 6 1/4 IN. ROTARY 22.3 LF

MATERIALS USED

- ___ LBS BENTONITE PELLETS (SURFACE CASING SEAL)
- ___ FT OF ___ IN. SURFACE CASING
- ___ SACKS OF CEMENT (SURFACE CASING)
- ___ LBS OF POWDERED BENTONITE (SURFACE CASING)
- ___ GALLONS OF WATER (SURFACE CASING)
- 15.1 FT OF 2 IN. DIA. (S.S. CASING)
- 15 FT OF 2 IN. DIA. (S.S. SCREEN)
- 6 SACKS OF SAND
- 19 LBS OF BENTONITE PELLETS (WELL CASING)
- 1 1/2 SACKS OF CEMENT (WELL CASING)
- 5 LBS OF BENTONITE (S.S. CASING SEAL)
- ___ GALLONS OF WATER (WELL CASING)
- 12 FT OF 6 5/8 IN. STEEL PROTECTIVE CASING

MATERIALS MFG./TYPE

LUBRICANT(S) N/A
CEMENT DIXIE CEMENT/PORTLAND TYPE I
SAND SIZE 0.45-0.55 mm
SCREEN SIZE 0.010
BENTONITE (POWDERED) Baroid/Benseal
BENTONITE (PELLETS) Baroid/Hole plug
OTHER

NOTES: Plugback used 450 pounds sand
Air rotary logged by Howze, drilled by Highland

ELEV: PAD: 778.65 RISER: 781.55 CASING: 781.64

LOCKING STEEL CAP
INNER CAP
TOP CONCRETE PAD
GROUND SURFACE

6 5/8 IN. O.D. STEEL PROJECTIVE CASING 2.99 FT ABOVE PAD

6 1/4 IN. DIAMETER BOREHOLE

CENTRALIZERS
12 FEET (1)
20 FEET (2)
29 FEET (3)
29.7 FEET (4)

2 IN. DIAMETER STAINLESS STEEL RISER CASING 2.99 FT TO 12.2 FT

TOP OF BEDROCK 10.2 FT B.L.S.

BENTONITE-CEMENT GROUT
0 TO 3.4 FT

BENTONITE SEAL
9.3 TO 11.3 FT

SAND PACK
11.3 TO 29.7 FT

2 IN. DIAMETER STAINLESS STEEL SLOTTED/CONTINUOUS WELL SCREEN (.010 SLOT SIZE) 12.2 TO 27.2 FT

2 IN. DIAMETER STAINLESS STEEL BLANK Silt Trap 27.2 TO 29.2 FT

BOTTOM WELL CAP 28.2 FT

TOTAL DEPTH OF BOREHOLE 35.3 FT

PLUGGED BACK TO 29.7 FT

NOT TO SCALE

Checked by: ____________________________

4736.1
WELL INSTALLATION FORM

WAG: 6 WELL NO.: 1245 GEOLOGIC LOG BORING NO.: 1245
STAKED COORDS: N 16800,21 E 25424,11 INSTALLATION DATES: 4-13-90
LOGGED BY: Crower DRILLED BY: Highland DRILLER: Baker HELPER: Keys

DRILLING METHOD:

- IN. AUGER 22 LF
- 10 5/8 IN. ROTARY 22 LF
- 8 5/8 IN. ROTARY 38 LF

MATERIALS USED

- VOL. LBS BENTONITE PELLETS (SURFACE CASING SEAL)
- 21 FT OF 10 5/8 IN. SURFACE CASING
- 50 SACKS OF CEMENT (SURFACE CASING)
- 50 LBS OF POWDERED BENTONITE (SURFACE CASING)
- 41.2 FT OF 4 IN. DIA. (S.S. CASING)
- 20 FT OF 4 IN. DIA. (S.S. SCREEN)
- 10 SACKS OF SAND
- 50 LBS OF BENTONITE PELLETS (WELL CASING)
- 13 SACKS OF CEMENT (WELL CASING)
- 50 LBS OF BENTONITE (S.S. CASING SEAL)
- 90 GALLONS OF WATER (WELL CASING)
- 5 FT OF 6 5/8 IN. STEEL PROTECTIVE CASING

MATERIALS MFG./TYPE

- LUBRICANT(S) N/A
- CEMENT DIXIE CEMENT/PORTLAND TYPE I
- SAND SIZE 0.45-0.55 mm
- SCREEN SIZE 0.010
- BENTONITE (POWDERED) Baroid/Benseal
- BENTONITE (PELLETS) Baroid/Hole plug
- OTHER

NOTES:

- CHECKED BY: TFZ 8/91

6.25 1978.3

PLUGGED BACK TO 58 4 FT

TOTAL DEPTH OF BOREHOLE 60 FT

BOTTOM WELL CAP 58 4 FT

SAND PACK 36 4 TO 58 4

BENTONITE SEAL FROM 36 4 TO 58 4

STAINLESS STEEL SLT TRAP FORM TO FT

IN. DIAMETER BLANK

STAINLESS STEEL SLOTTED/CONTINUOUS WELL SCREEN 0.122 IN. SLOTTED FROM 36 4 TO 58 4 FT

4 IN. DIAMETER STAINLESS STEEL CASING FROM 36 4 TO 58 4 FT

CENTRALIZERS @: 17, 37, 57

TOP CONCRETE PAD

GROUND SURFACE

LOCKING CAP

INNER CAP

6 5/8 IN. DIAMETER STEEL PROTECTIVE CASING

CONCRETE PA 10 IN. DIAMETER BOREHOLE

11 3/4 IN. DIAMETER DIVERTER STEEL CASING

10 5/8 IN. DIAMETER SURFACE CASING FROM 0 TO 21 FT

CEMENT GROUT FROM 0 TO 21 FT

10 5/8 IN. DIAMETER BOREHOLE FROM 0 TO 21 FT

BENTONITE/CEMENT GROUT FROM 0 TO 34 4 FT

8 5/8 IN. DIAMETER BOREHOLE

NOT TO SCALE
NOTES: Hole plugged back with 100 pounds of Hole plug
Attachment 3

SAND CERTIFICATION
December 14, 1989

Drillers Service Inc.
4004 Governor John Sevier Hwy.
Knoxville, TN 37914

Gentlemen,

We hereby certify the filter media designated as .45-.55mm as being:

(1) Graded
(2) Sub angular
(3) 99% pure silica
(4) Conforming to the following Sieve Analysis

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<th>U.S. Sieve No.</th>
<th>% Passing</th>
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Please let me know if we can be of further assistance.

Kindest regards,

C. Tommy Jones
CTJ/aw
### PHYSICAL AND CHEMICAL CHARACTERISTICS – TEXAS SAND

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<tr>
<th>Chemical Determination Description</th>
<th>Concentrate</th>
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<td>0.02</td>
<td>0.03</td>
</tr>
<tr>
<td>MnO</td>
<td>0.00</td>
<td>0.03</td>
<td>0.02</td>
<td>0.00</td>
<td>0.01</td>
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<td>Total</td>
<td>99.87</td>
<td>99.95</td>
<td>100.18</td>
<td>100.12</td>
<td>100.07</td>
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### ADDITIONAL EXOTIC SAND TESTS

<table>
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<tr>
<th>Test</th>
<th>Results</th>
<th>API SPECS</th>
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<tr>
<td>Sphericity</td>
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<td>0.6</td>
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<tr>
<td>Roundness</td>
<td>0.6</td>
<td>0.6</td>
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<tr>
<td>Turbidity</td>
<td>48</td>
<td>250</td>
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<tr>
<td>*Crush Resistance, Percent Loss</td>
<td>5.4 (5.4, 5.2, 5.5)</td>
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<tr>
<td>*Acid Solubility, Percent Loss</td>
<td>0.61</td>
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**Note:** Materials processed to your Uniformity Coefficient and Effective Size, by separate quotation.

**A Word of Caution**—Since test results do vary, it is recommended that you confirm with your own lab your specification requirements and the physical and chemical characteristics of this product. We give no warranty for our products either expressed or implied.

### COMMON APPLICATIONS OF CSSI TEXAS RESCREENED PRODUCTS:

- Water Well Gravel Pack
- Industrial Grout
- Waste Water Treatment Filtration
- Swimming Pool Filtration
- Water Filtration
- Oil and Gas Well Gravel Pack
- E.S. and U.C.’s to your spec’s

**WARNING:** This material contains free silica—do not breathe dust. May cause delayed lung injury. Wear government approved respirators and follow OSHA Safety and Health Standards for Silica. Do not use this material for sandblasting purposes.

*API Frac Test*
Attachment 4

CORE PHOTOGRAPHS FROM COREHOLE 1234
RUN HQ-3, COREBOX 1, WELL 1234
RUN HQ-17, COREBOX 5, WELL 1234
(127.2 – 126.5')
Attachment 5

WELL DEVELOPMENT LOGS
WELL DEVELOPMENT

HYG 103

WORK RELEASE NO.: WAG/SWMU: 6 WELL NO.: 1234 PAGE 1 OF 1

PREPARED BY: K.E. Owens DATE: 6/8/90

HOLE DIAMETER (in.): \( d_s = 8.56 \) WELL VOLUME CALCULATION:

WELL CASING:
- INSIDE DIAMETER (in.): \( d_{w-ID} = 7 \)
- OUTSIDE DIAMETER (in.): \( d_{w-OD} = 2.17 \)

DEPTH TO:
- WATER LEVEL (ft.): \( H = 16.2 \)
- BASE OF SEAL (ft.): \( S = 124 \)

BASE OF WELL (ft.): \( TD = 149 \)

ESTIMATED FILTER PACK POROSITY: \( P = 0.3 \)

GROUNDSURFACE

TOTAL WELL VOLUME = \( V_f = V_i + V_s = 548 + 1.54 = 2.09 \) \( \pi \) \( r^2 \times h = 18.8 \) gal.

DEVELOPMENT LOG

<table>
<thead>
<tr>
<th>DATE</th>
<th>TIME BEGIN</th>
<th>METHOD</th>
<th>WATER REMOVED</th>
<th>GALLERS</th>
<th>TOTAL REMOVED</th>
<th>WATER CHARACTER</th>
<th>COMMENTS</th>
</tr>
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<tbody>
<tr>
<td>5/16/90</td>
<td>1145</td>
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<td>22</td>
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<td>22</td>
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METHOD: (A)IRLIFT (B)AILER (C)OVERPUMPING (D)URGE BLOCK (E)OTHER (P)UMP AND SURGE

TURBIDITY: (C)LEAR (M)UDDY (S)LIGHTLY CLOUDY MODERATELY (T)URBID

5.6 215m 2
**WELL DEVELOPMENT**

**HYG 103**

**PREPARED BY:** K.E. Owens  
**DATE:** 6/6/90

**HOLE DIAMETER (in.):** d_s = 6.56

**WELL CASING INSIDE DIAMETER (in.):** d_c ID = 7

**OUTSIDE DIAMETER (in.):** d_c OD = 2.177

**DEPTH TO WATER LEVEL (ft.):** H = 21.71

**BASE OF SEAL (ft.):** S = 133.1

**BASE OF WELL (ft.):** TD = 167

**ESTIMATED FILTER PACK POROSITY:** P = 0.3

---

**WELL VOLUME CALCULATION:**

- **CASING VOLUME:** V_c = π \left( \frac{d_{c-ID}}{2} \right)^2 \left( \frac{TD-H}{2} \right) \left( \frac{H-21.71}{2} \right) = 2.86

- **FILTER PACK PORE VOLUME:** V_p = \pi \left[ \left( \frac{d_{c-ID}^2}{2} \right) - \left( \frac{d_{c-OD}^2}{2} \right) \right] \left( \frac{TD-S or H}{2} \right) = 1.78

- **TOTAL PORE VOLUME:** V_p = 2.86 + 1.78 = 2.89 + 1.78 = 4.67 ft^3 x 7.48 = 34.6 gal.

---

**DEVELOPMENT LOG**

<table>
<thead>
<tr>
<th>DATE (5/17/90)</th>
<th>TIME BEGIN</th>
<th>METHOD</th>
<th>WATER REMOVED</th>
<th>GAL</th>
<th>WATER VOLUMES</th>
<th>WELL</th>
<th>pH</th>
<th>CONDUCTIVITY</th>
<th>TURBIDITY</th>
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<tbody>
<tr>
<td></td>
<td>1240</td>
<td>P</td>
<td>70</td>
<td>70</td>
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<td></td>
<td>10.8</td>
<td>475</td>
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</table>

**METHOD:** (A) AIRLIFT  (M) TRAILER  (D) OVERPUMPING  (S) SURGE BLOCK  (X) OTHER  (P)UMP AND SURGE

**TURBIDITY:** (C)LEAR  (M)UDDY  (S)LIGHTLY CLOUDY  MODERATELY (T)URBID

**WATER CHARACTER**

<table>
<thead>
<tr>
<th>DATE</th>
<th>TIME BEGIN</th>
<th>METHOD</th>
<th>WATER REMOVED</th>
<th>GAL</th>
<th>WATER VOLUMES</th>
<th>WELL</th>
<th>pH</th>
<th>CONDUCTIVITY</th>
<th>TURBIDITY</th>
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<td>1240</td>
<td>P</td>
<td>70</td>
<td>70</td>
<td>2</td>
<td></td>
<td>10.8</td>
<td>475</td>
<td>S</td>
</tr>
</tbody>
</table>
**WELL DEVELOPMENT**

**HYG 103**

**PREPARED BY:** K.E. Owens

**DATE:** 6/8/90

---

**HOLE DIAMETER (in.):** 6.94

**WELL CASING INSIDE DIAMETER (in.):** 2

**OUTSIDE DIAMETER (in.):** 3.17

**DEPTH TO WATER LEVEL (ft):** 24.7

**BASE OF SEAL (ft):** 39

**BASE OF WELL (ft):** 56.8

**ESTIMATED FILTER PACK POROSITY:** 0.3

---

**WELL VOLUME CALCULATION:**

- **Casing Volume:**
  \[ V_c = \pi \left( \frac{d_{ID}}{2} \right)^2 \left( T_D - H \right) \]
  \[ \left( \frac{0.187}{2} \right)^2 (56.8 - 24.7) = \frac{86}{1000} \]

- **Filter Pack Pore Volume:**
  \[ V_f = \pi \left( \frac{d_{OD}}{2} \right)^2 \left( T_D - (S \text{ or } H) \right) \]
  \[ \left( \frac{3.17}{2} \right)^2 (56.8 - 39) \left( \frac{0.3}{1000} \right) = \frac{1.1}{1000} \]

**Total Well Volume:**
\[ V_T = V_f + V_a = \frac{86}{1000} \times 7.48 = 13.2 \text{ gal.} \]

---

**DEVELOPMENT LOG**

**CUMULATIVE TOTAL REMOVED**

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<thead>
<tr>
<th>DATE</th>
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<th>METHOD</th>
<th>WATER REMOVED</th>
<th>GAL.</th>
<th>WELLS VOLUMES</th>
<th>pH</th>
<th>CONDUCTIVITY</th>
<th>TURBIDITY</th>
<th>COMMENTS</th>
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<tbody>
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<td>4/27/90</td>
<td>1250</td>
<td>1515</td>
<td>P</td>
<td>16</td>
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<tr>
<td>5/2/90</td>
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<td>1545</td>
<td>P</td>
<td>5</td>
<td>21</td>
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<td>8.3</td>
<td>520</td>
<td>T</td>
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<tr>
<td>5/3/90</td>
<td>1450</td>
<td>1520</td>
<td>P</td>
<td>6</td>
<td>27</td>
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<td>8.4</td>
<td>520</td>
<td>C</td>
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<td>P</td>
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<td>32</td>
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<td>8.4</td>
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**METHOD:** (A) AIRLIFT  (B) BAILER  (C) OVERPUMPING  (S) SURGE BLOCK  (O) OTHER  (P) PUMP AND SURGE

**TURBIDITY:** (C) CLEAR  (M) MUDDY  (S) LIGHTLY CLOUDY  MODERATELY (T) TURBID

---

**S & 21595**
WELL DEVELOPMENT

HYG 103

PREPARED BY: K.E. Owens
DATE: 6/8/90

HOLE DIAMETER (in.)
WELL CASING:
INSIDE DIAMETER (in.)
OUTSIDE DIAMETER (in.)
DEPTH TO WATER LEVEL (ft.)
BASE OF SEAL (ft.)
BASE OF WELL (ft.)
ESTIMATED FILTER PACK POROSITY

WELL VOLUME CALCULATION:
Casing Volume: \( V_c = \pi \left( \frac{d_{c, ID}}{2} \right)^2 \left( \text{TD-H} \right) \)

Filter Pack Pore Volume: \( V_p = \pi \left( \frac{d_{p, OD}}{2} \right)^2 \left( \text{TD-S or H} \right) \)

Total Well Volume: \( V_t = V_c + V_p \)

DEVELOPMENT LOG

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<th>DATE</th>
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<th>TIME END</th>
<th>METHOD</th>
<th>WATER REMOVED</th>
<th>GAL/LITERS</th>
<th>WELL VOLUMES</th>
<th>pH</th>
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<th>TURBIDITY</th>
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<tbody>
<tr>
<td>5/17/90</td>
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<td>P</td>
<td>45</td>
<td>45</td>
<td>1.5</td>
<td></td>
<td>-</td>
<td>S</td>
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<td>285</td>
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<td>7.41</td>
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METHOD: (A)AIRLIFT  (B)BAILER  (C)OVERPUMPING  (S)URGE BLOCK  (X)OTHER  (P)UMP AND SURGE
TURBIDITY: (C)CLEAR  (M)UDDY  (S)LIGHTLY CLOUDY  MODERATELY (T)URBID
WELL DEVELOPMENT

HYG 103

<table>
<thead>
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<th>DATE</th>
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WELL VOLUME CALCULATION:

Casing Volume: 
\[ V_c = \pi \left( \frac{d_w^{2}}{2} - \left( \frac{d_o^{2}}{2} \right) \right) (TD-H) \]

Filter Pack Pore Volume: 
\[ V_f = \pi \left[ \left( \frac{d_w^{2}}{2} - \left( \frac{d_o^{2}}{2} \right) \right) \right] (TD-(S or H)) (P) \]

Total Well Volume: 
\[ V_t = V_c + V_f + V_s \]

COMMENTS:

METHOD: (A) IRRI (B) AIL (C) OVERPUMPING (D) SURGE BLOCK (E) OTHER (P) PUMP AND SURGE

TURBIDITY: (C) CLEAR (M) MUDDY (S) LIGHTLY CLOUDY MODERATELY (T) TURBID

5.5 2156.7
**WELL DEVELOPMENT**

**HYG 103**

**PREPARED BY:** K.E. Owens  
**DATE:** 6/8/90

**HOLE DIAMETER (in.):** 
**WELL CASING INSIDE DIAMETER (in.):** 
**WELL CASING OUTSIDE DIAMETER (in.):** 
**DEPTH TO WATER LEVEL (ft.):** 
**BASE OF SEAL (ft.):** 
**BASE OF WELL (ft.):** 
**ESTIMATED FILTER PACK POROSITY:**

**WELL VOLUME CALCULATION:**

<table>
<thead>
<tr>
<th>CASING VOLUME</th>
<th>FILTER PACK PORE VOLUME</th>
<th>TOTAL WELL VOLUME</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_c = \pi \left( \frac{d_{c, ID}}{2} \right)^2 (TD-H) )</td>
<td>( V_i = \pi \left[ \left( \frac{d_p}{2} \right)^2 - \left( \frac{d_{OD}}{2} \right)^2 \right] (TD-(S or H)) (P) )</td>
<td>( V_I = V_i + V_o = 24 + 71 = 95 ) ft(^3 \times 7.48 = 71 ) gal</td>
</tr>
</tbody>
</table>

**DEVELOPMENT LOG**

<table>
<thead>
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<th>DATE</th>
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<th>TIME END</th>
<th>METHOD</th>
<th>WATER REMOVED</th>
<th>GAL. LITERS</th>
<th>WATER VOLUMES</th>
<th>PH</th>
<th>CONDUCTIVITY</th>
<th>TURBIDITY</th>
<th>COMMENTS</th>
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<tr>
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<td>4</td>
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<td>88</td>
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<td>7.7</td>
<td>500</td>
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**METHOD:** (A)AIRLIFT (B)AILER (C)OVERPUMPING (S)URGE BLOCK (X)OTHER (P)UMP AND SURGE

**TURBIDITY:** (C)LEAR (M)UDDY (S)LIGHTLY CLOUDY (M)ODERATELY (T)URBID
## WELL DEVELOPMENT

### HYG 103

**PREPARED BY:** K.E. Owens  
**DATE:** 6/8/90

---

### WELL VOLUME CALCULATION:

- **Casing Volume:**
  \[ V_c = \pi \left( \frac{d_{c, ID}}{2} \right)^2 \left( H - d_{TD-H} \right) \]

- **Filter Pack Pore Volume:**
  \[ V_f = \pi \left[ \left( \frac{d_{p, ID}}{2} \right)^2 - \left( \frac{d_{p, OD}}{2} \right)^2 \right] \left( H - S \right) \]

*(IF S > H USE S, IF S < H USE H.)*

- **Total Well Volume:**
  \[ V_t = V_c + V_f = 3.14 \left[ \left( \frac{5.52}{2} \right)^2 - \left( \frac{2.17}{2} \right)^2 \right] \left( 19.7 - 11.8 \right) (0.3) = 1.02 \text{ ft}^3 \times 7.48 = 12.2 \text{ gallons}.

---

### DEVELOPMENT LOG

<table>
<thead>
<tr>
<th>DATE</th>
<th>TIME BEGIN</th>
<th>TIME END</th>
<th>METHOD</th>
<th>WATER REMOVED</th>
<th>GAL VOLUMES</th>
<th>WELL VOLUMES</th>
<th>PH</th>
<th>CONDUCTIVITY</th>
<th>TURBIDITY</th>
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<td>8.1</td>
<td>550</td>
<td>M</td>
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<tr>
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<td>4.4</td>
<td>8.1</td>
<td>460</td>
<td>S</td>
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</tbody>
</table>

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**METHOD:** (A) LIFT (B) BAILEY (C) OVERPUMPING (S) SURGE BLOCK (X) OTHER (P) JUMP AND SURGE  
**TURBIDITY:** (C) CLEAR (M) MUDDY (S) LIGHTLY Cloudy MODERATELY (T) TURBID

---

5.5 21569
## WELL DEVELOPMENT

**HYG 103**

**PREPARED BY:** K.E. Owens

**DATE:** 6/8/90

### HOLE DIAMETER (in.):
- \( d_2 \) = 6.58

### WELL CASING INSIDE DIAMETER (in.):
- \( d_{w, ID} \) = 

### OUTSIDE DIAMETER (in.):
- \( d_{w, OD} \) = 2.157

### DEPTH TO WATER LEVEL (ft.):
- \( H \) = 14.2

### BASE OF SEAL (ft.):
- \( S \) = 9

### BASE OF WELL (ft.):
- \( TD \) = 27.3

### ESTIMATED FILTER PACK POROSITY:
- \( P \) = 0.3

### WELL VOLUME CALCULATION:

- **Casing Volume**:
  \[ V_c = \pi \left( \frac{d_{w, ID}}{2} \right)^2 (TD - H) = 3.14 \left( \frac{14.1}{2} \right)^2 (27.3 - 14.2) = 27 \]

- **Filter Pack Volume**:
  \[ V_i = \pi \left( \frac{d_{w, OD}}{2} \right)^2 (TD - (S or H)) = \]

- **Total Well Volume**:
  \[ V_t = V_c + V_i = 27 + 81 = 108 \text{ ft}^3 \times 7.48 = 811 \text{ gal.} \]

### DEVELOPMENT LOG

<table>
<thead>
<tr>
<th>DATE</th>
<th>TIME BEGIN</th>
<th>TIME END</th>
<th>METHOD</th>
<th>WATER REMOVED</th>
<th>GAL / LITERS</th>
<th>pH</th>
<th>CONDUCTIVITY</th>
<th>TURBIDITY</th>
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**METHOD:** (A)RIFFT (B)AILER (C)OVERPUMPING (S)URGE BLOCK (X)OTHER (P)UMP AND SURGE

**TURBIDITY:** (C)LEAR (M)UDDY (S)LIGHTLY CLOUDY MODERATELY (T)URBID

**COMMENTS:**
**WELL DEVELOPMENT**

**HYG 103**

**PREPARED BY:** K.E. Owens  
**DATE:** 6/8/90

### HOLE DIAMETER (m.)
- \( d_s = 6.54 \) m

### WELL CASING
- **INSIDE DIAMETER (m.)** \( d_{i, ID} = 2 \) m
- **OUTSIDE DIAMETER (m.)** \( d_{i, OD} = 2.17 \) m

### DEPTH TO:
- **WATER LEVEL (m.)** \( H = 17.1 \) m
- **BASE OF SEAL (m.)** \( S = 10.9 \) m
- **BASE OF WELL (m.)** \( TD = 27.9 \) m

### ESTIMATED FILTER PACK POROSITY
- \( P = 0.3 \)

#### WELL VOLUME CALCULATION:

- **Casing Volume** \( V_c = \pi \left( \frac{d_{i, ID}}{2} \right)^2 \left( TD-H \right) = 3.14 \left( \frac{2}{2} \right)^2 \left( 27.9-17.1 \right) = 22 \)**

- **Filter Pack Pore Volume** \( V_f = \pi \left[ \left( \frac{d_{i, ID}}{2} \right)^2 - \left( \frac{d_{i, OD}}{2} \right)^2 \right] \left( TD - (S \text{ or } H) \right) \left( P \right) = \)

\[ 3.14 \left( \frac{2}{2} \right)^2 - \left( \frac{2.17}{2} \right)^2 \left( 27.9-17.1 \right) \left( 0.3 \right) = 87 \]

- **Total Well Volume** \( V = V_c + V_f = 22 + 87 = 109 \text{ m}^3 \times 7.48 = 817 \text{ gal.} \)

### DEVELOPMENT LOG

<table>
<thead>
<tr>
<th>DATE</th>
<th>TIME BEGIN</th>
<th>METHOD</th>
<th>WATER REMOVED</th>
<th>VOL. LITERS</th>
<th>WELL VOLUMES</th>
<th>WATER CHARACTER</th>
<th>pH</th>
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<th>TURBIDITY</th>
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<tr>
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<td>P</td>
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<td>8.1</td>
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**METHOD:** (A) RIFFLE  (B) BAILER  (C) OVERPUMPING  (S) SURGE BLOCK  (O) OTHER  (P) JUMP AND SURGE

**TURBIDITY:** (C) CLEAR  (M) MUDDY  (S) LIGHTLY CLOUDY  MODERATELY (T) TURBID
## WELL DEVELOPMENT

### HYG 103

- **Work Release No.:** [Unreadable]
- **WAG/SWMU:** 6
- **WELL NO.:** 1244
- **Date:** 6/8/90

**PREPARED BY:** K.E. Owens

### WELL VOLUME CALCULATION:

- **Casing Volume:**
  
  \[ V_c = \pi \left( \frac{d_{c, ID}}{2} \right)^2 \left( TD - H \right) = 3.14 \left( \frac{4.5}{2} \right)^2 (64.1 - 14.2) = 70 \]  

- **Filter Pack Pore Volume:**
  
  \[ V_p = \pi \left[ \left( \frac{d_{p, ID}}{2} \right)^2 - \left( \frac{d_{p, OD}}{2} \right)^2 \right] (TD - (S or H)) (P) = \]  

- **Total Well Volume:**
  
  \[ \text{TOTAL WELL VOLUME} = V_f = V_c + V_p + \frac{0.81}{3.14} \times 7.48 = 51 \text{ gal.} \]

### DEVELOPMENT LOG

<table>
<thead>
<tr>
<th>DATE</th>
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<th>METHOD</th>
<th>WATER REMOVED</th>
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**METHOD:** (A)AILIFT \ (B)AILER \ (C)OVERPUMPING \ (S)URGE BLOCK \ (O)THER \ (P)UMP AND SURGE

**TURBIDITY:** (C)LEAR \ (M)UDDY \ (S)LIGHTLY CLOUDY \ (M)ODERATELY (TURBID

---

**COMMENTS:**

- Cumulative Water Character Development:}

- Total Removed
## WELL DEVELOPMENT

**HYG 103**

**PREPARED BY:** K.E. Owens  
**DATE:** 6/8/90

### HOLE DIAMETER (in.):
- \( d_1 = 5.5/8 \)

### WELL CASING

- **INSIDE DIAMETER (in.):** \( d_{c,i} = 4' \)
- **OUTSIDE DIAMETER (in.):** \( d_{c,o} = 4 1/2' \)

### DEPTH TO:
- **WATER LEVEL (ft.):** \( H = 141'' \)
- **BASE OF SEAL (ft.):** \( S = 37 \)
- **BASE OF WELL (ft.):** \( TD = 58.1 \)
- **ESTIMATED FILTER PACK POROSITY:** \( P = 0.3 \)

### WELL VOLUME CALCULATION:

- **CASING VOLUME:** \( V_c = \pi \left( \frac{d_{c,i}}{2} \right)^2 \left( TD - H \right) = 3.14 \left( \frac{4}{2} \right)^2 (38.1 - 1.4) = 5.89 \)

- **FILTER PACK VOLUME:** \( V_f = \pi \left[ \left( \frac{d_{c,o}}{2} \right)^2 - \left( \frac{d_{c,i}}{2} \right)^2 \right] \left( TD - (S \text{ or } H) \right) \)

  - (If \( S > H \) use \( S \), if \( S < H \) use \( H \))

  \( 3.14 \left[ \left( \frac{4.5}{2} \right)^2 - \left( \frac{4.1}{2} \right)^2 \right] (58.1 - 37) (0.3) = 9.2 \)

- **TOTAL WELL VOLUME:** \( V_T = V_c + V_f = 5.95 + 9.2 = 5.81 H^3 \times 7.48 = 44.2 \text{ gal} \)

### DEVELOPMENT LOG

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<thead>
<tr>
<th>DATE</th>
<th>BEGIN</th>
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<th>METHOD</th>
<th>WATER REMOVED</th>
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<th>pH</th>
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**METHOD:** (A) LIFT  
**TURBIDITY:** (C) CLEAR  
**(D) PUMP AND SURGE**

**WATER CHARACTER:**
- **PH:** 8.4  
- **CONDUCTIVITY:** 230  
- **TURBIDITY:** M

---

**NOTE:**
- Water level: 141''
- Base of seal: 37 feet
- Base of well: 58.1 feet
- Filter pack porosity: 0.3

---

**FACTS:**
- Water treatment: Lift method
- Turbidity: Clear

---

**CONCLUSION:**
- Total well volume: 44.2 gallons

---

**DOCUMENT:**
- Technical Memorandum 06-08A
- ORNL R/FS JOB 19118
- Page 1 of 1

---

**REFERENCES:**
- EPA Record Book
- SWMU: WAG/SWMU: 6
- WELL NO.: 1245

---

**DATE:** 6/8/90

---

**SIGNATURE:**
- K.E. Owens

---

**STAMP:**
-erichel
WELL DEVELOPMENT
HYG 103

PREPARED BY: K.E. Owens
DATE: 6/8/90

HOLE DIAMETER (in.): d_h = 6 5/8
WELL CASING ID = 7
OUTSIDE DIAMETER (in.): d_w OD = 2 1/2
DEPTH TO WATER LEVEL (ft): H = 39.5
BASE OF SEAL (ft): S = 51
BASE OF WELL (ft): TD = 70.5
ESTIMATED FILTER PACK POROSITY: P = 0.3

WELL VOLUME CALCULATION:
CASING VOLUME = V_c = \pi \left( \frac{d_w \text{ OD}}{2} \right)^2 \left( \text{TD} - H \right) = 3.14 \left( \frac{2.5}{2} \right)^2 \left( 70.5 - 39.5 \right) = 0.88
FILTER PACK PORE VOLUME = V_p = \pi \left[ \left( \frac{d_w \text{ OD}}{2} \right)^3 - \left( \frac{d_w \text{ ID}}{2} \right)^3 \right] \left( \text{TD} - (S \text{ or } H) \right) (P) = 
(\text{IF } S > H \text{ USE } S, \text{ IF } S < H \text{ USE } H)
TOTAL WELL VOLUME = V_t = V_c + V_p + 1.2 = 1.88 \text{ ft}^3 \times 7.48 \text{ gal}.

DEVELOPMENT LOG

<table>
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<tr>
<th>DATE</th>
<th>TIME</th>
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<th>WATER REMOVED</th>
<th>GAL/LITERS</th>
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METHOD: (A) AIRLIFT (B) BAILER (C) OVERTURBID (D) SURGE BLOCK (X) OTHER (P) PUMP AND SURGE
TURBIDITY: (C) CLEAR (M) MUDDY (S) SLIGHTLY CLOUDY (M) MODERATELY (T) TURBID

5.6 2159.3
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