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UMTRA
Ground Water Project

# Ground Water Compliance Action Plan and Application for Alternate Concentration Limits for the Canonsburg, Pennsylvania, UMTRA Project Site

February 2000

Prepared by the
U.S. Department of Energy
Grand Junction Office

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UMTRA Ground Water Project

# Ground Water Compliance Action Plan for the Canonsburg, Pennsylvania, UMTRA Project Site

February 2000

Prepared by
U.S. Department of Energy
Grand Junction Office
Grand Junction, Colorado

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*Application for Alternate Concentration Limits for the Canonsburg, Pennsylvania, UMTRA Project Site*

# 1.0 Introduction

This Ground Water Compliance Action Plan (GCAP) along with the attached Application for Alternate Concentration Limits will serve as a stand-alone modification to the *Remedial Action Plan for Stabilization of the Inactive Uranium Mill Tailings Site at Canonsburg, Pennsylvania* (DOE 1983) and is the concurrence document for compliance with Subpart B of 40 CFR 192 for the Canonsburg site. No section in the Remedial Action Plan refers specifically to ground water restoration and the deferral of Subpart B compliance. The initial standards were released by the U.S. Environmental Protection Agency (EPA) in January 1983, just before the Remedial Action Plan was issued, and at that time the focus was primarily on compliance with Subpart A at the disposal site. In the preamble to the final rule for 40 CFR 192 (published in the Federal Register of 11 January 1995 [60 FR 2854]), the EPA considered the Canonsburg site separately in the regulations because the disposal design was based on standards remanded in part in September 1985. Also, the EPA indicated that the Canonsburg site qualifies for an alternate concentration limit (ACL) under 40 CFR 192.02(c)(3)(ii) because any contamination that might seep from the encapsulated tailings will reach the surface within the site boundary, and will then be diluted by water in Chartiers Creek to insignificant levels.

The proposed compliance strategy for the Canonsburg site is based on the "compliance strategy selection framework" following the steps prescribed in Section 2.1 of the *Final Programmatic Environmental Impact Statement for the Uranium Mill Tailings Remedial Action Ground Water Project* (PEIS) (DOE 1996) (Figure 1). The proposed action is presented in the GCAP because a Site Observational Work Plan (SOWP) was not prepared for the site. National Environmental Policy Act (NEPA) issues and environmental concerns are also addressed in the GCAP and this information has been made available to citizens and public officials in the Canonsburg area.

# 2.0 Ground Water Compliance

To achieve compliance with Subpart B of 40 CFR 192 at the Canonsburg site, the U.S. Department of Energy (DOE) proposed action is no remediation in conjunction with the application of ACLs (see the attached ACL Application). The compliance strategy will include ground water monitoring and institutional controls to ensure that the application of ACLs will continue to be protective of human health and the environment. This determination uses a consistent and objective strategy selection framework developed in the PEIS (Figure 1). This strategy is based on site investigation data and computer modeling predictions indicating that natural ground water movement and geochemical attenuation processes will reduce uranium concentrations in ground water to less than the maximum concentration limit (MCL) or background levels within 30 years. Ground water in the uppermost aquifer in the vicinity of the site is not currently and is not projected to become a source for a public water system subject to provisions of the Safe Drinking Water Act.

In applying the decision framework developed in the PEIS as the strategy selection process, DOE has determined that ground water in the uppermost aquifer was contaminated by processing of radioactive materials at the Canonsburg site. The uppermost aquifer qualifies for no remediation in conjunction with the application of ACLs based on (1) water quality results from

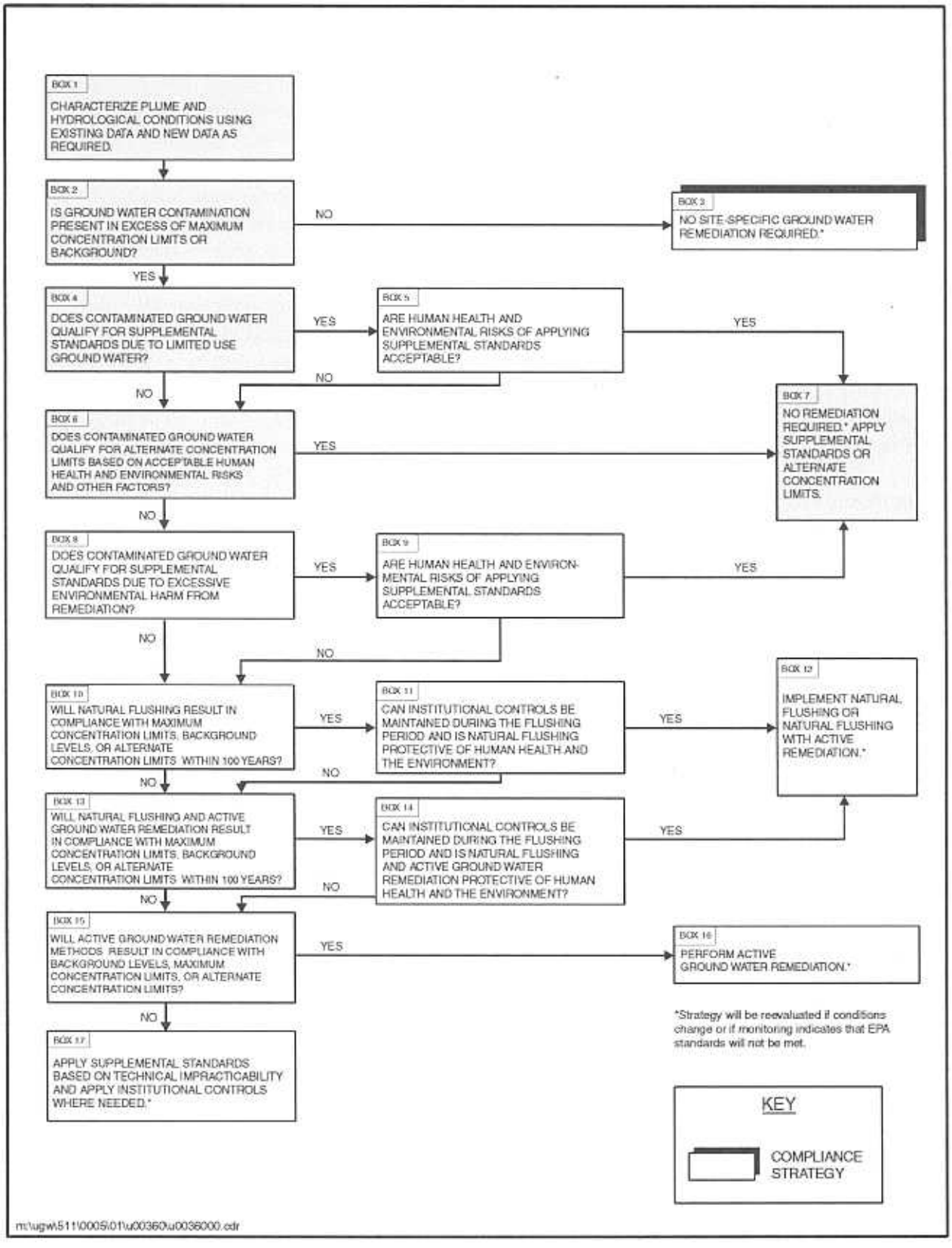


*Figure 1. Compliance Selection Framework, Canonsburg, Pennsylvania, Site*

approximately 17 years of data collection at the site, (2) probabilistic flow and solute transport modeling depicting contaminant concentrations to the year 2027, (3) viability of enforceable institutional controls that will prevent inappropriate uses of contaminated ground water during the period of ACL application, and that will ensure protection of human health and the environment, and (4) compliance monitoring that will verify the decrease in contaminant concentrations as predicted. The framework as applied to the Canonsburg site consists of several evaluative steps that are discussed below.

## 2.1 Assessment of Environmental Data

The first step in the decision process was an assessment of both historical and new environmental data collected to characterize hydrogeological conditions and the extent of ground water contamination related to processing activities at the site. The uppermost aquifer consists of unconsolidated materials, which overlie bedrock of the Pennsylvanian Casselman Formation. Although some ground water is present in the unconsolidated materials and shallow bedrock beneath the site, neither unit is considered a viable aquifer from a water resource perspective. Processing of radioactive materials at the Canonsburg site since the early 1900s has resulted in contamination of ground water in the uppermost aquifer beneath the main site, as well as in Area C (east of the main site). Constituents of potential concern (COPC) in ground water include manganese, molybdenum, and uranium. A number of other constituents have at times been identified in concentrations above MCLs or other benchmark concentrations in ground water since monitoring activities started. Distribution of contaminants in the unconsolidated materials is sporadic, and no well-defined contaminant plumes are apparent. Ground water from the uppermost aquifer discharges to Chartiers Creek, which is adjacent to the site on the west, north, and east sides. COPCs have not exceeded the MCLs or background levels in Chartiers Creek near the site. Evaluation of existing site data and predictive flow and solute transport modeling indicate that sufficient data exist to make an appropriate compliance strategy selection.

## 2.2 Ground Water Contaminants

The second step compares the list of ground water contaminants with MCLs or background levels. Manganese, molybdenum, and uranium are the site-related COPCs that are present in concentrations that exceed MCLs or background in ground water downgradient from the disposal cell and in Area C (DOE 1995). Manganese does not have an MCL in Table 1 to Subpart A of 40 CFR 192 but has a secondary drinking water standard (40 CFR 143) that has been exceeded at the site. An ACL is not required for manganese because it does not pose human health or ecological risks from ground water or surface water. In addition, manganese is elevated in background ground water as a result of regional activities unassociated with processing of radioactive materials at the Canonsburg site. Concentrations of molybdenum in ground water have been slightly elevated above the MCL in the past but are currently below the MCL. Uranium is the only constituent that is present at concentrations above the MCL in ground water and that clearly can be attributed to site activities. Therefore, uranium is the COPC at the Canonsburg site and is the focus of ground water modeling and compliance monitoring.

## 2.3 Applicability of Alternate Concentration Limits

The third step determines whether the contaminated ground water qualifies for ACLs based on acceptable human health and environmental risks. A site-specific ACL for a hazardous

constituent may be established if the constituent will not pose a substantial present or potential hazard to human health or the environment as long as the ACL is not exceeded, and if the proposed ACL value is as low as reasonably achievable, after considering practicable corrective actions. At the Canonsburg site, ground water monitoring and institutional controls will be implemented to ensure that the application of ACLs will continue to be protective of human health and the environment.

On the basis of periodic ground water sampling, it is anticipated that concentrations of the COPC (uranium) will be below the ACL and MCL within a limited period of time. Site-related contaminants have not been detected in Chartiers Creek adjacent to the site. Also, numerical modeling of ground water and surface water flow and transport at the site have predicted that concentrations at the point of compliance (POC) wells will be below the MCL in less than 30 years, and concentrations in surface water at the point of exposure (POE) are already well within acceptable concentrations with respect to human health and the environment.

Ground water in the vicinity of the Canonsburg site is not currently used as a drinking water source, nor is it projected to become one. Although limited ground water is present in the unconsolidated materials and shallow bedrock beneath the site, neither unit is considered a viable aquifer from a water resource perspective. Because the materials are not ideal for aquifer formation and the source of recharge to the shallow units is minimal, sustained yield from a well in these units is limited. Also, potable water near the site is available from a municipal water supply.

## 2.4 Compliance Strategy Selection

The fourth and final step in the framework is the selection of an appropriate compliance strategy to meet the EPA ground water protection standards. The selection is to perform no remediation in conjunction with an ACL for uranium (see the attached ACL Application). This strategy will include compliance monitoring and institutional controls to ensure protection of human health and the environment. The uppermost aquifer is not currently and is not projected to be a drinking water source in the vicinity of the site.

# 3.0 Implementation

To demonstrate compliance with the standards, DOE will monitor ground water in the POC wells (412, 413, and 414), monitor well 406, and at the POE (602), to ensure that the ACL for uranium of 1.0 mg/L at the POC and 0.010 mg/L at the POE are not exceeded and that uranium concentrations are decreasing with time (Figure 2). Ground water samples will be collected and analyzed for uranium, molybdenum, and manganese annually for a period no less than 5 years and up to 30 years. Re-evaluation of site conditions will be conducted after the 5 year period. If the compliance strategy is not proceeding as predicted, the site will be re-evaluated and the strategy will be modified as necessary. Termination of ground water monitoring or modification of the ground water compliance action plan strategy will not be made prior to NRC approval. Details of the ground water monitoring program will be incorporated into the revised Long-Term Surveillance Plan (LTSP) for the Canonsburg disposal site (DOE 2000).

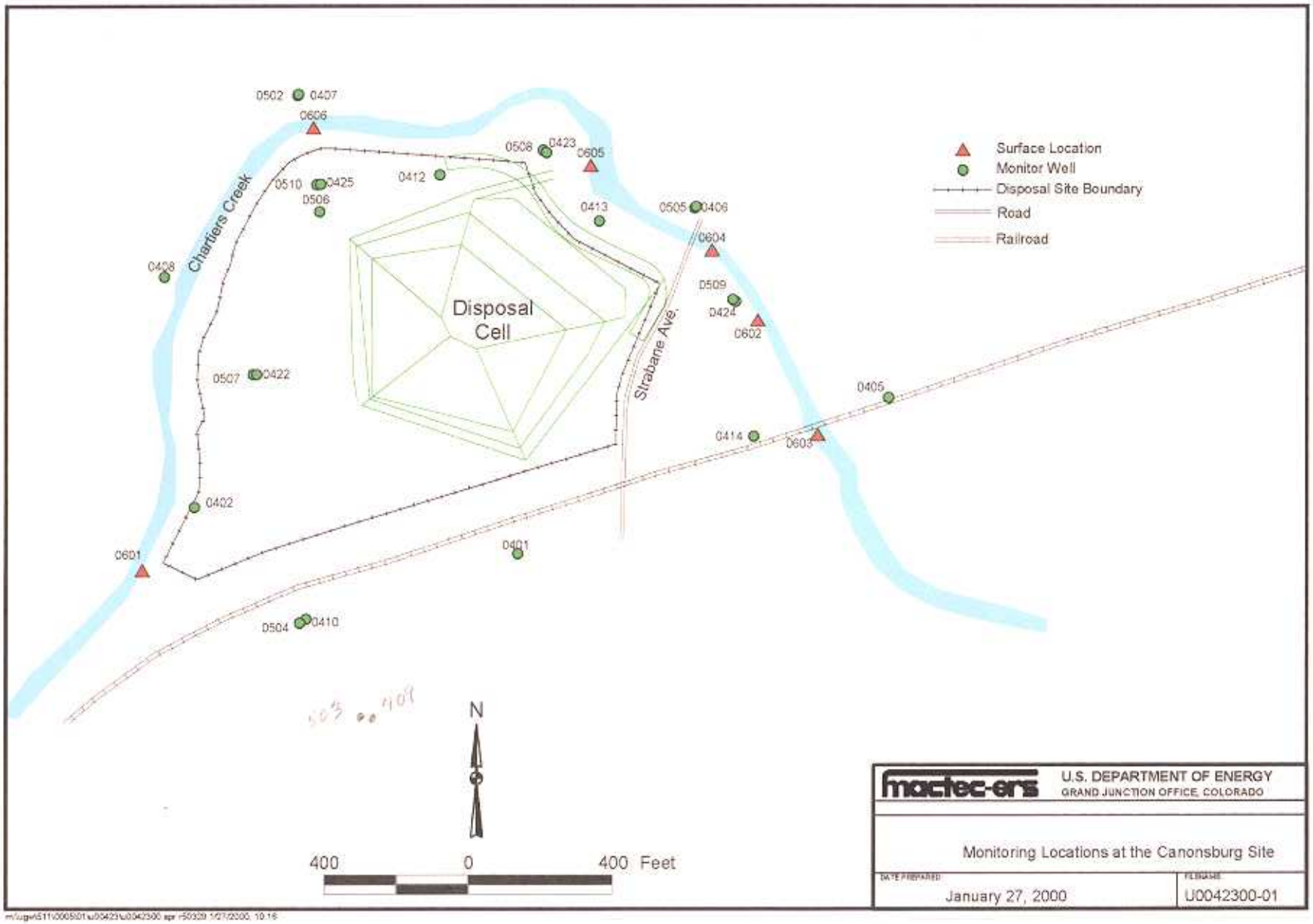


*Figure 2. Monitoring Locations at the Canonsburg, Pennsylvania, Site*

DOE and the Commonwealth of of Pennsylvania will ensure that appropriate institutional controls are put in place to prevent future use of ground water from the uppermost aquifer for whatever period is deemed necessary. These controls will also ensure that no unacceptable risks to human health and the environment are present during the period of ACL application.

# 4.0 Environmental Considerations

To comply with NEPA requirements DOE prepared the PEIS, which was issued in October 1996. A Record of Decision for the PEIS was issued in April 1997. The PEIS assesses the potential programmatic effects of conducting the ground water project, provides a method for determining the site-specific ground water compliance strategies, and provides data and information that can be used to prepare site-specific environmental impact analyses more efficiently. In the proposed action (preferred alternative), ground water compliance strategies are tailored to each site to achieve conditions that protect human health and the environment. The selection framework for determining an appropriate compliance strategy at each site is presented in Section 2.1 of the PEIS and is discussed in Section 2.0 of this GCAP. Relevant areas of environmental concern are discussed below.

Environmental issues and resources potentially affected by the proposed action may include the following:

- Risk to human health and the environment.
- Ground water use.
- Surface water use.
- Land use.
- Cultural resources.
- Socioeconomic and environment justice.

Environmental impacts from the proposed action on these issues and resources have been assessed in several of the referenced documents (DOE 1983, 1995, and 1996). Results are summarized below.

- The potential risk to human health is primarily through ingestion of ground water or surface water. Ground water use will be restricted through the implementation of institutional controls in the disposal area and in Area C. Analytical results have shown that concentrations of the COPC (uranium) have always been substantially below the MCL in surface water because of the significant dilution by Chartiers Creek. Therefore, surface water quality at the POE is not affected by site-related contamination. (See Sections 6 and 8 of DOE 1995 and Section 2.3 of the ACL Application).

- Based on available data, site-related contamination does not appear to pose a risk to ecological receptors from ground water, surface water, or sediments. (See Sections 7 and 8 of DOE 1995 and Section 2.3 of the ACL Application).

- DOE controls land and ground water use at the disposal site and the Commonwealth of Pennsylvania controls Area C. Institutional controls will be in place to restrict land and ground water use in Area C to perpetuate protection of human health and the environment.

- Cultural resources in the vicinity of the Canonsburg site have been inventoried, and there will be no impacts related to the application of ACLs. (See Section 6 of DOE 1995).

- There are no anticipated impacts to human populations. Therefore, there are no disproportionate affects to minority and low income populations. There are no impacts to the socioeconomic base of the neighborhoods in the vicinity of the site, since the contaminated surficial aquifer is not currently nor projected to be used by any population within a mile radius of the site. (See Section 6 of DOE 1995).

The cumulative effects analysis for the proposed compliance strategy is as follows:

- Based on the use of institutional controls, the presence of a small incremental effect to the ground water resulting from no remediation would not contribute to impacts resulting from other past, present, or reasonably foreseeable actions taken by the public and private entities in the area of the contamination. Contaminated ground water is not used for agriculture, irrigation, or drinking water (DOE 1995). Therefore, there would be no human health risks. There will be a long-term beneficial effect through natural attenuation processes that will result in acceptable ground water quality.

- Similarly, the presence of a small incremental effect to the surface water quality resulting from no ground water remediation would not significantly contribute to impacts from other past, present, or reasonably foreseeable actions taken by the public and private entities in the area of the reclaimed site. Acid mine drainage has contributed most of the surface water contamination in the region. Existing contaminated ground water is expected to migrate to Chartiers Creek. Surface water concentrations would remain below detection limits due to mixing, dilution, and dispersion (DOE 1995).

- The effects of no ground water remediation, when combined with those effects of other actions in the neighborhood of the reclaimed site do not result in cumulatively significant impacts (DOE 1996 and Section 5.0 of the ACL Application).

To accommodate the NEPA obligation to make relevant environmental information available to public officials and citizens before decisions are made and before actions are implemented, DOE has distributed relevant environmental documents, which are available for review in Pennsylvania and the Canonsburg area. Interaction with the stakeholders on the DOE ground water compliance strategy decision for the Canonsburg site was undertaken in the fall of 1998 in the Canonsburg area.

# 5.0 References

U.S. Department of Energy (DOE), 1983. *Remedial Action Plan for Stabilization of the Inactive Uranium Mill Tailings Site at Canonsburg, Pennsylvania*, UMTRA–DOE/AL–140, prepared by Jacobs Engineering Group, Inc.

———, 1995. *Baseline Risk Assessment of Ground Water Contamination at the Uranium Mill Tailings Site Near Canonsburg, Pennsylvania*, DOE/AL/62350–149, Rev. 1, prepared by Jacobs Engineering Group, Inc.

———, 1996. *Final Programmatic Environmental Impact Statement for the Uranium Mill Tailings Remedial Action Ground Water Project*, DOE/EIS–0198, prepared by the U.S. Department of Energy Grand Junction Projects Office, October.

———, 2000 (in progress). *Long-Term Surveillance Plan for the U.S. Department of Energy Canonsburg Uranium Mill Tailings Disposal Site, Canonsburg, Pennsylvania.*

End of current text

UMTRA Ground Water Project

# Application for Alternate Concentration Limits for the Canonsburg, Pennsylvania, UMTRA Project Site

February 2000

**Attachment to the**
**Ground Water Compliance Action Plan**

Prepared for
U.S. Department of Energy
Grand Junction Office
Grand Junction, Colorado

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# 1.0 General Information

## 1.1 Introduction

The Uranium Mill Tailings Remedial Action (UMTRA) Project was authorized by the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978 (42 *United States Code* [USC] §7901 *et seq.*), as amended (42 USC §7922 *et seq.*). The UMTRA Project is regulated by Title 40 of the *Code of Federal Regulations* [CFR] Part 192, "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings," promulgated by the U.S. Environmental Protection Agency (EPA) in 1983 and made final in 1995. Standards for the inactive uranium mill sites (Title I) are addressed in Subpart A (surface remediation) and Subpart B (ground water restoration). Subpart C provides guidance for implementation of Subparts A and B.

The UMTRA Project regulations provide for several ways to comply with the ground water protection standards for Subpart B of 40 CFR 192.12(c). These include meeting the provisions of 40 CFR 192.02(c)(3) or a supplemental standard established under 40 CFR 192.22. The provisions of 40 CFR 192.02(c)(3) include (1) the background level of the constituent in ground water, (2) the maximum concentration limit (MCL) for any constituents listed in Table 1 to Subpart A, or (3) an alternate concentration limit (ACL) established pursuant to paragraph (c)(3)(ii) of that section. An ACL may be applied if the constituent concentration is elevated above background or the MCL and will not pose a substantial present or potential hazard to human health and the environment as long as the ACL is not exceeded. A consideration of the ACLs' present or potential hazard to human health and the environment will also include an evaluation of the potential adverse effects on ground water quality and on hydraulically connected surface-water quality.

In the preamble to the final rule for 40 CFR Part 192, which was published in the Federal Register of 11 January 1995 (60 FR 2854), the EPA indicated that the Canonsburg site qualifies for an ACL under 40 CFR 192.02(c)(3)(ii) because any contamination that might seep from the encapsulated tailings will reach the surface within the site boundary, and then will be diluted by water in Chartiers Creek to insignificant levels.

The U.S. Nuclear Regulatory Commission (NRC) issued a final staff technical position (STP) on ACL applications for Title II sites in January 1996 (NRC 1996). The guidance in this STP is based on and is generally consistent with EPA's *Alternate Concentration Limit Guidance, Part 1: ACL Policy and Information Requirements* (EPA 1987). Although the STP is primarily intended for review of ACL applications for Title II sites, the same technical approach outlined in the STP may be used in reviewing ACL applications for Title I sites, with modifications to reflect the difference between the Title I and Title II programs. In making the present and potential hazard finding, the NRC will consider 19 factors, of which 9 are related to potential adverse effects on ground water quality and 10 are related to hydraulically connected surface water quality [40 CFR 192.02(c)(3)(ii)(B)(1) and (2) and Table 1 in the STP (NRC 1996)]. These factors are considered throughout this ACL application, and the relevant factors are summarized in Section 5.0. The NRC review process will focus primarily on the three hazard assessment and five corrective-action assessment elements that are discussed in Section 3.0 of the STP and are also summarized in Section 5.0 of this document.

To comply with the requirements of the National Environmental Policy Act and to address the options to ensure compliance with the ground water protection standards in 40 CFR Part 192 at the UMTRA Project sites, DOE prepared the *Programmatic Environmental Impact Statement for the Uranium Mill Tailings Remedial Action Ground Water Project* (PEIS) (DOE 1996). A Record of Decision was issued in April 1997 in which the DOE selected the "proposed-action" alternative for conducting the UMTRA Ground Water Project. The proposed-action alternative gave the DOE the option of implementing the compliance strategy best suited for each site. The compliance strategies outlined under the proposed-action alternative were active remediation, natural flushing, no ground water remediation, or any combination of the three. The EPA ground water protection standards for these compliance strategies include background levels of hazardous constituents, maximum concentration limits listed in Table 1 to Subpart A in 40 CFR 192.02, or the use of ACLs. To obtain approval for the use of ACLs as ground water protection standards, it must be demonstrated that the hazardous constituents detected in the ground water will not pose a potential future hazard to human health and the environment if the ACLs are not exceeded.

Based on the PEIS risk-based compliance strategy selection framework, DOE's proposed action for the Canonsburg site is no remediation in conjunction with the application of ACLs to ground water contamination at the site. This will include incorporation of ground water monitoring and institutional controls to ensure that the application of ACLs will continue to be protective of human health and the environment. This compliance decision is documented in the Ground Water Compliance Action Plan (GCAP).

- The ACL will be established at a point of compliance (POC), which will consist of monitor wells 412 and 413 downgradient from the disposal cell and monitor well 414 in Area C. A point of exposure (POE) will be the surface water in Chartiers Creek adjacent to the site.

- Manganese, molybdenum, and uranium are the site-related constituents of potential concern (COPC) that are present in concentrations that exceed MCLs or background in ground water downgradient from the disposal cell and in Area C (DOE 1995b). Manganese does not have an MCL in Table 1 to Subpart A of 40 CFR 192, but has a secondary drinking water standard (40 CFR Part 143) that has been exceeded at the site. An ACL is not required for manganese because it does not pose human health or ecological risks from ground water or surface water. In addition, manganese is elevated in background ground water as a result of regional activities unassociated with processing of radioactive materials at the Canonsburg site. Concentrations of molybdenum in ground water have been slightly elevated above the MCL in the past, but are currently below the MCL. Uranium is the only constituent that is present at concentrations above the MCL in ground water, and that clearly can be attributed to processing site activities. Therefore, uranium is the COPC at the Canonsburg site, and is the focus of ground water modeling and compliance monitoring.

- The ACL will be protective of human health and the environment. Based on the site characterization information and the Baseline Risk Assessment (BLRA) (DOE 1995b) no human health risks are currently associated with contaminated ground water at the Canonsburg site. Institutional controls will be in place to prevent any use of the contaminated ground water near the processing site and in Area C.

- Numerical modeling to predict ground water flow and contaminant transport supports the conclusion that site-related contaminants present no current or future risk to human health and the environment. Modeling indicates that contaminants will be flushed from the system in less than 30 years.

- Compliance monitoring of ground water at the POC and surface water at the POE will be undertaken annually for a period no less than 5 years and up to 30 years, with reevaluation of site conditions after the 5-year period. If the compliance strategy is not proceeding as predicted, the site will be reevaluated and the strategy will be modified as necessary. Termination of ground water monitoring or modification of the ground water compliance strategy will not be made prior to NRC approval.

## 1.2 Facility Description

### 1.2.1 Historical Perspective

The DOE Canonsburg facility is in the Borough of Canonsburg, in northern Washington County, Pennsylvania, approximately 20 miles (mi) (32 kilometers [km]) southwest of Pittsburgh (Figure 1–1). The site encompasses about 18.5 acres (7.4 hectares) and is adjacent to Chartiers Creek (Figure 1–2). The facility was originally used by the Standard Chemical Company from 1911 to 1922 for extracting radium as bromide and sulfate from carnotite ore. Vitro Manufacturing Company acquired the plant in 1930 for the purpose of extracting radium and uranium salts from on-site residues and carnotite ore. These operations continued until 1942, when Vitro began work for the federal government to recover uranium from various ores, concentrates, and scrap materials. Processing operations at the site ceased in 1957.

During its years of operation, the site was separated into several areas of interest (Figure 1–2). To the northwest of the site was a residential area. To the west of the site was another commercial facility, operated by other corporations with dissimilar activities (e.g., Georges Pottery Co. and later the Chemical & Solvents Co.). Area A, in the center of the site, was the main processing plant, which was retrofitted into the Canon Industrial Park from 1962 to 1982. Area B, on the northeast portion of the site, received some contaminants from the ore processing. Area C, on the southeast portion of the site, was a low-lying wetland area that was used for disposal of liquid processing wastes. Between 1962 and 1964 an effort was made to decontaminate the immediate plant area, and contaminated materials were stockpiled in Area A. In 1965 the stockpile was moved to Area C and covered with a relatively impermeable layer of clean fill material.

In 1979 the Canonsburg site was designated as eligible for remedial action under UMTRCA. In 1980 DOE and the Commonwealth of Pennsylvania entered into a cooperative agreement for the remedial action. In 1982 Pennsylvania acquired the Canonsburg site in accordance with the cooperative agreement, and DOE was granted ownership. Between 1984 and 1986 DOE removed the buildings, contaminated soils, and materials from the site and stabilized these materials in a permanent disposal cell (Figure 1–3). The disposal cell covers approximately 6 acres (2.4 hectares) and contains about 172,000 cubic yards ($yd^3$) (132,000 cubic meters [$m^3$]) of contaminated materials (MK-Ferguson 1986). Areas A and B are fenced, but area C is not. The remainder of the site outside the disposal cell was evenly and smoothly graded to provide site drainage and was then revegetated with native grasses (DOE 1983, 1985, and 1995b). The site is currently being monitored according to the *Long-Term Surveillance Plan for the Canonsburg,*

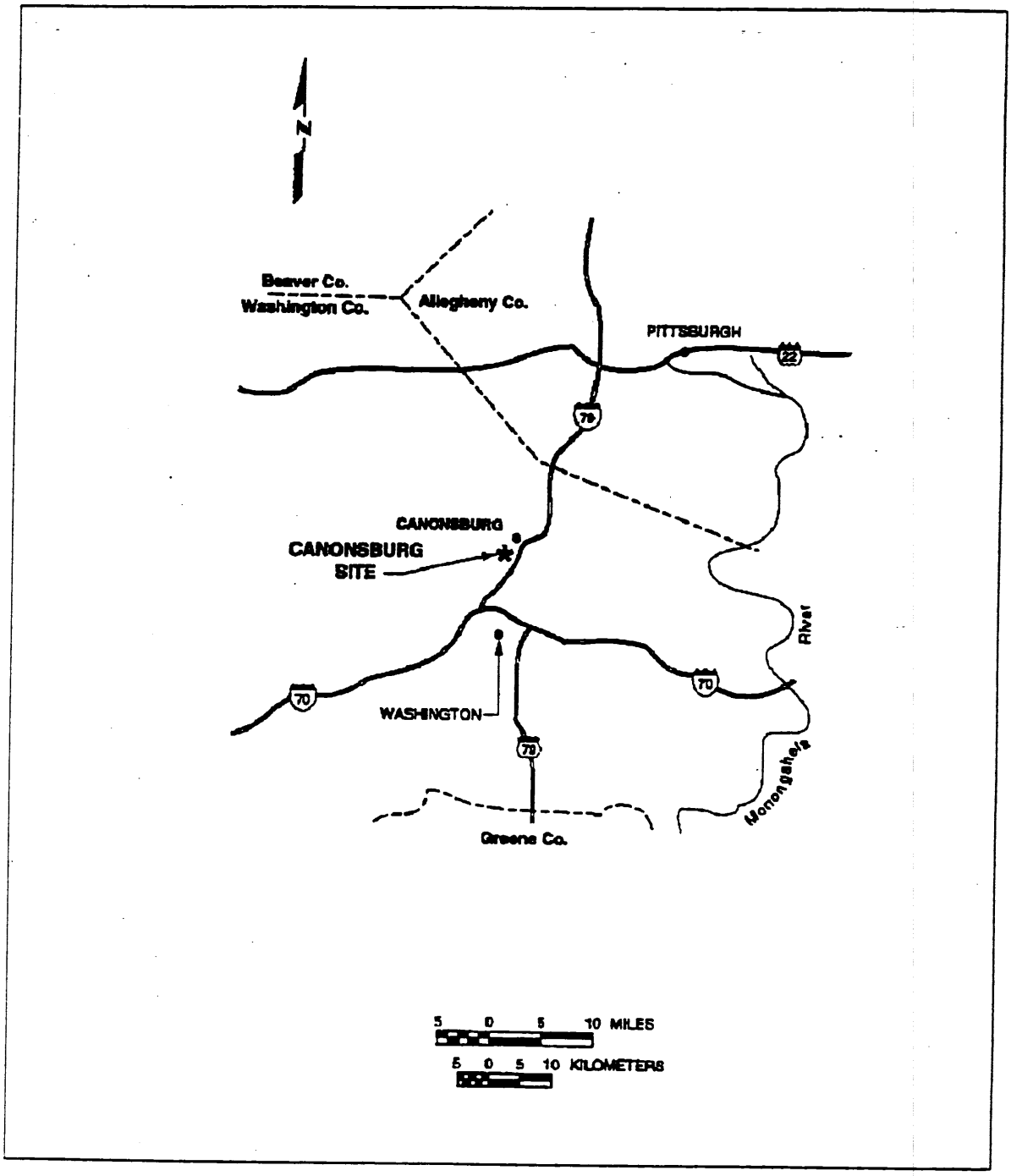


*Figure 1–1. Canonsburg, PA UMTRA Mill Tailings Facility Site Location Map*

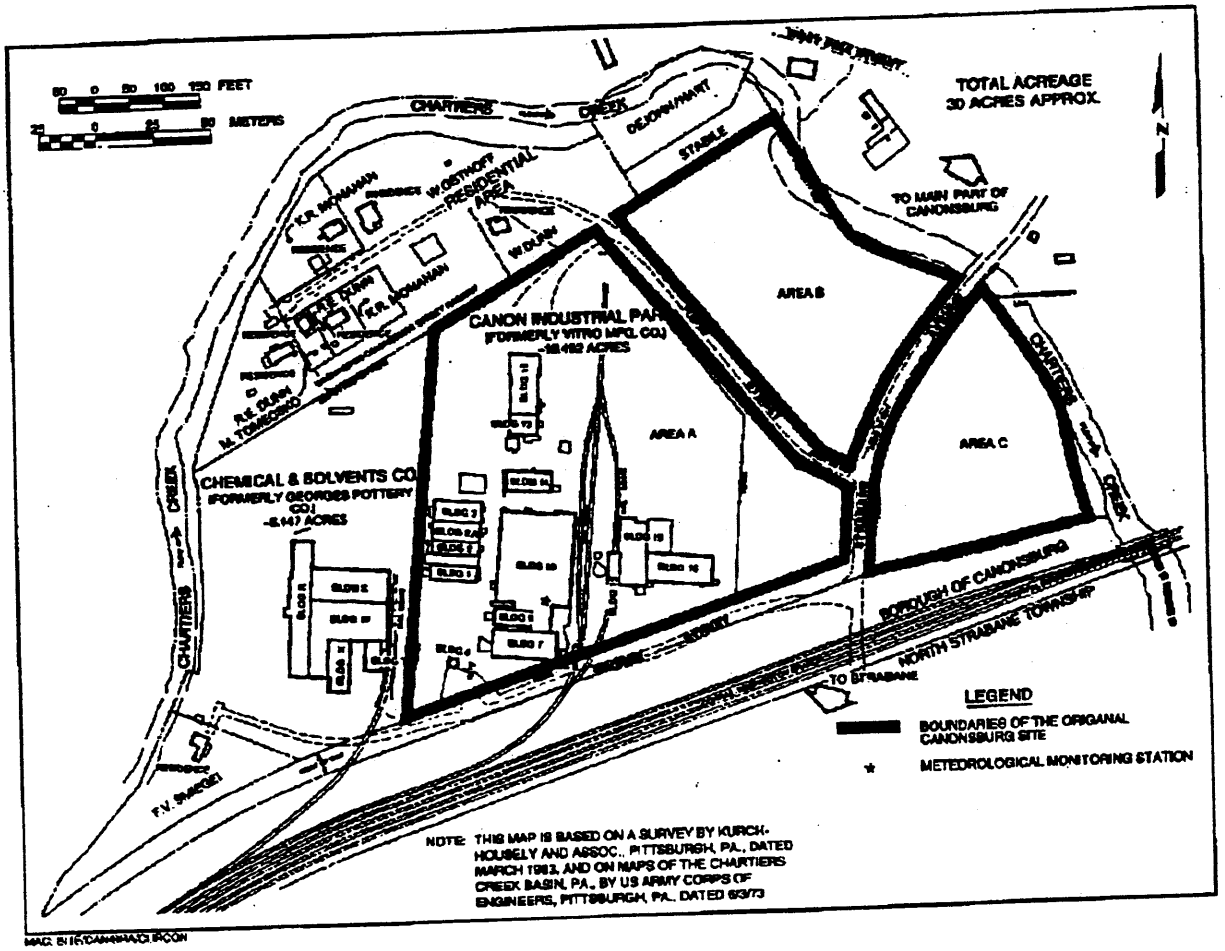


*Figure 1–2. Historical Site Layout for the Canonsburg UMTRA Mill Tailings Facility*

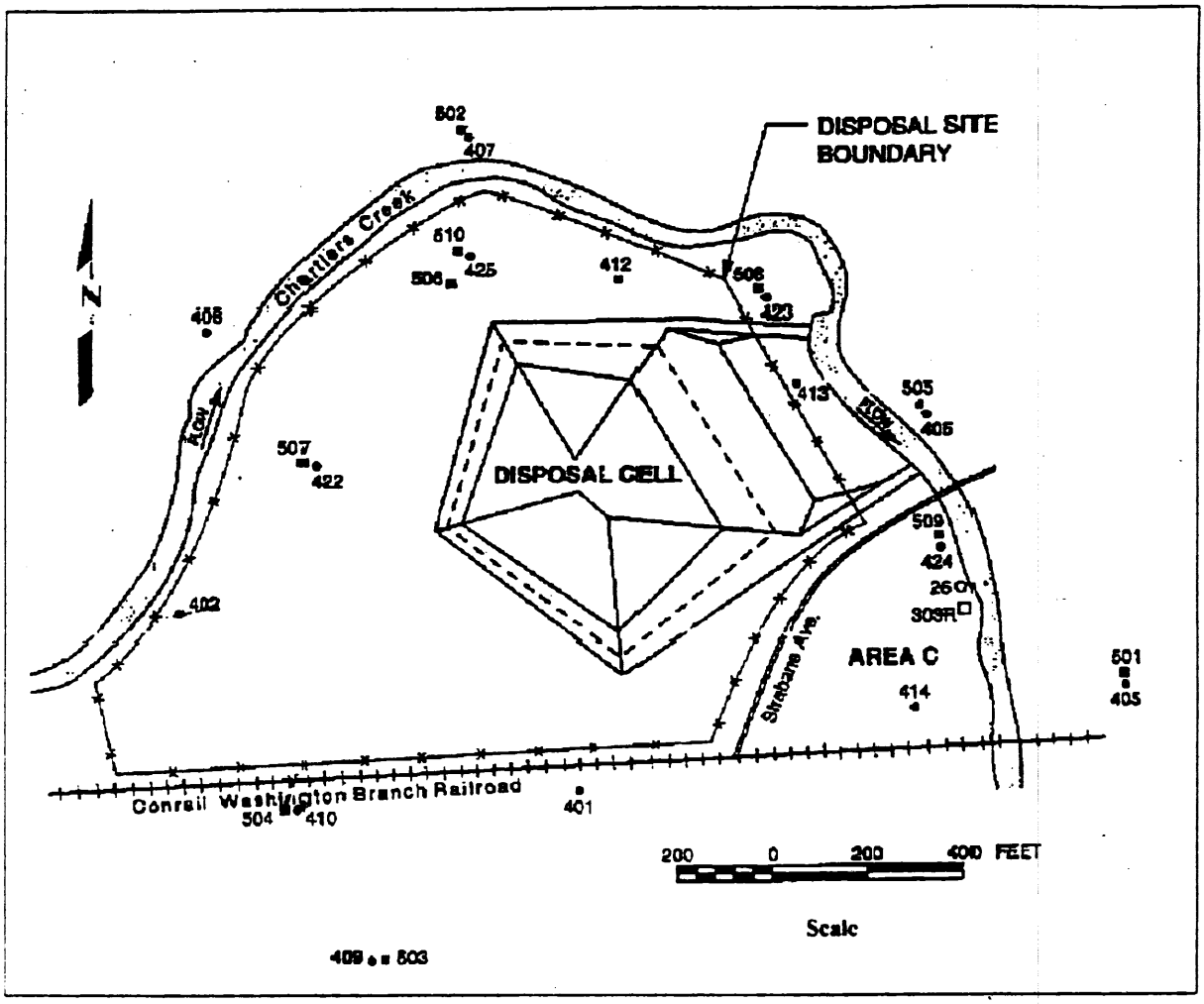


*Figure 1–3. Present Day Site Layout for the Canonsburg UMTRA Mill Tailings Facility*

*Pennsylvania, Disposal Site* (DOE 1995a). After final disposition of the site DOE will retain ownership of Areas A and B, and the Commonwealth of Pennsylvania will own Area C.

### 1.2.2 Climate

The Canonsburg site is in the humid continental climatic region. The average annual temperature is 50 °F (10 °C) (DOE 1995b). Winter temperatures range from –6 to 63 °F (–21 to 17 °C); the average winter temperature is 28 °F (–2 °C). Summer temperatures range from 36 to 95 °F (2 to 35 °C); the average summer temperature is 70 °F (21 °C). According to data from the Pittsburgh International Airport from 1941 to 1980, the average annual precipitation in the area is 38 inches (97 centimeters [cm]). March and June are generally the wettest months, each averaging 3.8 inches (10 cm); February and November are the driest, each averaging 2.4 inches (6 cm). The average annual snowfall in the area is 45 inches (114 cm).

### 1.2.3 Geologic Conditions

The Canonsburg site is in southwestern Pennsylvania where the geologic structural setting consists of subparallel folds with northeastern axis orientation. Landfilling and earth-moving activities have altered the topography of the Canonsburg site, originally a low-lying floodplain. The site lies in the Chartiers Creek basin along the creek's southern bank, approximately 15 miles (24 km) upstream from its confluence with the Ohio River.

The geologic material at the site consists of unconsolidated materials overlying bedrock of the Pennsylvanian Casselman Formation. The unconsolidated materials are composed of sandy loam to silty clay, clay, alluvium, and fill material (e.g., cinders mixed with soil, stones/cobbles, and building rubble), up to 30 feet (ft) (9 meters [m]) thick. These materials are heterogeneous and do not form discrete, continuous units. The permeability is variable because of the types and placement of the materials.

The lithology of the bedrock to a depth of 95 ft (29 m), based on lithologic logs of monitor wells 504 through 506, consists predominantly of gray siltstone and shale, some interbedded limestone, and sparse coal seams. Shale near the bedrock surface is broken and weathered to thin, brittle plates. The bedrock surface generally dips northeast at less than one degree. Fracturing was observed in core samples in the upper 5 to 20 ft (2 to 6 m) of the bedrock beneath the site. The interval of interest for evaluating potential bedrock contamination is the upper 25 ft (7 m) beneath the contact with the unconsolidated material, referred to as the "shallow bedrock." The shallow bedrock has been observed at the surface in the site vicinity.

### 1.2.4 Ground Water Conditions

Ground water is present in the unconsolidated materials and in the shallow bedrock. The two lithologic units are hydraulically connected, and vertical gradient is generally downward from the unconsolidated materials to the shallow bedrock. The dominant boundary condition for ground water movement in the unconsolidated materials and shallow bedrock is Chartiers Creek, which surrounds the site on the west, north, and east and is the normal discharge zone for the water table and shallow bedrock ground water systems. Although Chartiers Creek is principally a gaining stream, minor gradient reversals in ground water flow may occur near the creek during

periods of maximum flow. However, this should not substantially affect potential contaminant migration.

Although ground water is present in the unconsolidated materials and shallow bedrock beneath the site, neither unit is considered a viable aquifer from a water resource perspective, but only in the sense that the zone is capable of discharging to surface water (Appendix A to 10 CFR Part 40). Because the materials are not ideal for aquifer formation and the source of recharge to the shallow units is minimal, sustained yield from a well from these units is limited. However, yield is sufficient that ground water in the unconsolidated material does not meet the definition of a limited use aquifer based on yield, which is less than 150 gallons per day [40 CFR 192.11(e)(3)].

Ground water is unconfined in the unconsolidated materials; depth to ground water ranges from 3 to 14 ft (0.9 to 4.3 m) below ground surface. Ground water is present as a result of precipitation infiltrating the unit and migrating downward toward contact with the shallow bedrock. Water may perch on clay layers within the unit or on the shallow bedrock. Lateral continuity of ground water in this unit has not been definitively determined. Transmissivity, based on aquifer pumping tests in monitor well 26, averaged 300 $ft^2$ per day (3.22 $cm^2$ per second) in the unconsolidated materials (DOE 1983). That value, an estimated saturated thickness of 10 ft (3 m), a porosity of 0.2, and a gradient of 0.027, result in an approximate ground water velocity of 4 ft per day ($1.4 \times 10^{-3}$ cm per second).

Ground water occurs in the underlying shallow bedrock under semiconfined conditions and is a result of water infiltrating from above into zones of secondary porosity where the shale bedrock is weathered or fractured. Some ground water appears to be present in deeper zones in the bedrock and is associated with limestone or more porous zones. Because intervening shale layers act as aquitards, this ground water is probably not related to surface infiltration, but is a result of ground water underflow. Transmissivity, based on aquifer pumping tests in well 303R, ranged from 15.5 to 366 $ft^2$ per day (0.167 to 3.94 $cm^2$ per second) in the shallow bedrock (DOE 1983). That value, an estimated saturated thickness of 20 ft (6 m), a porosity of 0.2, and a gradient of 0.016 result in an approximate ground water velocity range of 0.1 to 3 ft per day ($4.3\times 10^{-5}$ to $1.0 \times 10^{-3}$ cm per second).

### 1.2.5 Surface Water Conditions

The Canonsburg site lies along the southern bank of Chartiers Creek (Figure 1–2), a meandering stream 75 to 100 ft (23 to 30 m) wide and about 10 ft (3 m) deep. Chartiers Creek drains an area of approximately 80 $mi^2$ (200 $km^2$) upstream from the site and drains into the Ohio River 15 mi (24 km) downstream from the site. The average flow of Chartiers Creek past the site is 90 to 130 $ft^3$ per second (2.5 to 3.7 $m^3$ per second). Ground water in the unconsolidated material discharges into Chartiers Creek.

### 1.2.6 Land Use in the Area

A 1-mi (1.6-km) radius around the site encompasses four municipalities: the Borough of Canonsburg, the Borough of Houston, Chartiers Township, and North Strabane Township. The Borough of Houston and North Strabane Township are hydrologically upgradient or

crossgradient of the site. The two other municipalities, the Borough of Canonsburg and Chartiers Township, are on the opposite side of Chartiers Creek relative to the site. Ground water from their location flows toward the site and discharges into the creek. Therefore, these municipalities are not expected to be influenced by ground water flow from the site.

The primary land use near the site is residential. The closest residences are approximately 80 to 100 ft (24 to 30 m) east of the site along Strabane Avenue and adjacent streets in the Borough of Canonsburg. Residences are also directly south of the site in North Strabane Township on Latimer Avenue and west and southwest of the site in the Borough of Houston (Figure 1–2).

North of the site along West Pike Street is a commercial and light industrial area. Businesses in this area include a gas station, car wash, car repair shop, car dealerships, woodcrafting company, and a heating and cooling company. Residences are north of this commercial/industrial area on Pike Street. A light industrial area is also located southwest of the site. Undeveloped areas are primarily northwest of the site in Chartiers Township and south of the site in North Strabane Township. Site visits in 1994 indicated that land uses have changed only slightly with the possible addition of some new residential and commercial areas.

Based on 1990 data (Washington County Planning Commission 1993), the populations of the municipalities in the site vicinity are as follows:

- Borough of Canonsburg: 9,200
- Borough of Houston: 1,445
- Chartiers Township: 7,603
- North Strabane Township: 8,157

The population of Washington County has fluctuated but has remained at more than 200,000 for the past few decades. The 1990 population of the county was 204,584 (Washington County Planning Commission 1993).

The 1992–1993 Industrial Directory for Washington County lists 491 industries and businesses that employ 19,980 persons. Washington County's resident civilian labor force was approximately 95,400 in 1991, when approximately 66,860 persons worked in the county. By categories, the major employers in the county are steel (1,989 employees), electronics (1,789 employees), mining (1,276 employees), and plastics (1,212 employees) (Washington County Board of Commissioners 1993). Manufacturing in Washington County has declined over the years, primarily in steel and glass and their supporting industries. However, employment has increased in the government, wholesale and retail trade, and service industries. The major manufacturing employer in Canonsburg is Cooper Power Systems, which employs approximately 1,080 persons (Washington County Board of Commissioners 1993).

Approximately 1,590 farms are in Washington County; the average size is 137 acres (55 hectares). The main products are milk and dairy products (Washington County Board of Commissioners 1993).

### 1.2.7 Water Use in the Area

Most residents of Canonsburg, Houston, North Strabane, and Chartiers near the site are connected to a municipal water supply system operated by the Pennsylvania-American Water Company. The Monongahela River, located east of the site, supplies the water for the system. There are two water intake stations. The Aldridge plant can treat about 60 million gallons (230 million liters [L]) of water per day, and the Pittsburgh plant can treat 80 million gallons (300 million L) of water per day (Taylor 1994). Washington District residents use approximately 10 million gallons (38 million L) of water daily.

A water use survey was conducted within a 1-mi (1.6-km) radius of the Canonsburg site in April 1994. The purpose of the survey was to verify locations and status of domestic well information listed in previous surveys (DOE 1983), either provided by the Pennsylvania Geologic Survey (PGS 1994) or obtained from personal communications with local residents. From this water use survey, 16 wells were identified within a 1-mi (1.6-km) radius of the site. Of these wells, one was in use, 11 were not in use, and four were abandoned. Seven of these wells are upgradient of the site and would not be affected by any site-related contaminants. The remaining five wells are on the opposite side of Chartiers Creek relative to the site. Of these five wells, only one is in use. This well is approximately 400 ft (122 m) north of the site and is used for washing cars, mixing cement, and watering the garden. Due to the location of this well it is not expected to be influenced by any ground water flow from the site. Ground water from this location flows toward the site and discharges into Chartiers Creek.

The five wells situated immediately outside the 1-mi (1.6-km) radius are used for drinking as well as for all other domestic purposes. Three of these wells are just over 1 mi (1.6 km) south of the site. The municipal water supply does not service houses farther south of this area; thus, individuals residing in this area most likely use well water. These wells are upgradient of the site and would not be affected by contamination migrating from the site. Two additional wells are approximately 1.3 mi (2.1 km) north of the site. Houses farther north of this area also are not serviced by the municipal water supply system, and these residents also most likely use well water. Because of the distance from the site, and the fact that these wells are hydraulically crossgradient (rather than downgradient) of the site, any contamination migrating from the site is not expected to affect ground water in this area.

Chartiers Creek, which flows along the western, northern, and eastern boundaries of the site, is designated by the Commonwealth of Pennsylvania for the maintenance and propagation of fish species and protection of additional flora and fauna indigenous to a warm-water habitat (PADER 1992). Because of its ambient contamination upstream of the site (DOE 1995), the creek is not a potable water resource. Local residents use the creek for fishing, swimming, and wading. Children have also been observed playing in the creek and on its banks. The types of fish found in the creek include carp, catfish, and bluegill (Templeton 1993).

## 1.3 Extent of Ground Water Contamination

Some site-related contamination is in ground water in the uppermost aquifer (unconsolidated materials) downgradient from the disposal cell and adjacent to Chartiers Creek in the area of the

main processing site, as well as in Area C just east of the main site. Uranium is the only COPC that exceeds the MCL in ground water. Characterization information from the past 17 years indicate that concentrations of other constituents in ground water have been relatively stable, and no concentrations have been detected above the MCLs in surface water adjacent to the site.

Source areas for contaminant leaching to ground water existed in Areas A, B, and C of the site. The principal source areas were removed during remedial action from 1984 to 1986. Since that time, residual contamination in the saturated unconsolidated materials has presumably continued its migration toward Chartiers Creek, where the aquifer discharges. Elevated levels of uranium, manganese, selenium, and other constituents, have been identified at the site. With the exception of uranium, constituents that were elevated relative to existing standards or background in years past have decreased to, and remain at, acceptable levels. Distribution of contaminants in the unconsolidated materials is sporadic, and no well-defined contaminant plumes are apparent.

Appendix B contains information from the SEE.UMTRA database on ground water quality data for selected constituents. Uranium concentrations are elevated in monitor wells adjacent to Chartiers Creek along the eastern and southeastern portions of the site. The migration of this contaminant in ground water has been modeled, and results are presented in Section 2.0 of this report. Figure 1–4 shows the nature and extent of uranium contamination in ground water based on water quality data and computer simulation results for November 1997. Even though Chartiers Creek is a discharge point for the contaminated ground water, concentrations of uranium in the river are well below the MCL (0.044 mg/L).

## 1.4 Current Ground Water Protection Standards

The EPA ground water protection standards specify implementation of a ground water monitoring plan to evaluate the effectiveness of the remedial action and to demonstrate compliance with the ground water standards (40 CFR §192.03). The Canonsburg remedial action was completed about the time that the U.S. Court of Appeals remanded the ground water standards in 1985; however, EPA concluded that modification of the existing Canonsburg disposal cell was not warranted to meet the ground water standards, as the disposal cell's design is adequate to provide long-term protection of human health and the environment (60 FR 2863). As a best management practice, DOE has continued Subpart A ground water monitoring in the unconsolidated materials at the Canonsburg site, as well as surface water monitoring to evaluate the potential effects of ground water discharging from the site to Chartiers Creek. This monitoring program for Subpart A is described in Section 4.0 of the Long-Term Surveillance Plan (LTSP) for the Canonsburg disposal site (DOE 1995a).

EPA further concludes that any contaminants that leach from the disposal cell would reach the surface within the site boundary and would be diluted to insignificant levels by water in adjacent Chartiers Creek. Under these circumstances, the Canonsburg site qualifies for an ACL under 40 CFR 192.02(c)(3)(ii) for compliance with Subpart B of the ground water protection standards (60 FR 2863).

## 1.5 Proposed Alternate Concentration Limit

In order to propose ACLs to comply with ground water standards, several factors must be addressed. These include (1) identifying site-specific hazardous constituents, (2) establishing ground water concentration limits (or standards), (3) defining a POC where the concentration limits must be met, and a POE where ground water quality must be maintained at levels that are protective of potential receptors, and (4) determining a time period during which compliance is required.

The spatial relationship between the POC and the POE is critical to the establishment of an ACL. Natural processes such as dilution, dispersion, and sorption may attenuate uranium concentrations between the POC and the POE. Thus, an ACL for uranium established at the POC may be greater than an appropriate health and environmental concentration limit at the POE, and still be protective of human health and the environment.

A POC must be established to provide an indicator that the ground water system is performing as predicted and that safe concentration thresholds are maintained at the POE. Designated POC wells are 412 and 413 downgradient of the disposal cell and 414 in Area C. Each of the POC wells is upgradient of Chartiers Creek. These three wells currently have elevated concentrations of uranium in ground water. Analyses presented in Appendix C provide detail of the modeling of uranium fate and transport, as well as the predicted range of ground water concentrations at these wells that will allow for a safe concentration threshold at the POE. Natural attenuation processes are occurring between the POC and the POE and account for the differences in concentrations at these two compliance points. It is possible that uranium concentrations in the POC wells may increase for some time but that the levels will not cause any adverse effects at the POE. Numerical modeling indicates that concentrations will begin to decline in several years.

ACLs are developed to ensure that if met at the POC, these concentration levels are protective at the POE to both human health and the environment. As described in Section 4.1, an ACL of 1.0 mg/L is proposed for uranium, the COPC.

A POE must be established that is protective of human health and the environment. The designated POE the surface water in Chartiers Creek, where exposures due to recreational activities may occur. Installation of drinking water wells at the site is not likely because DOE owns the site and controls access, and the background ground water is probably not potable. Therefore, water quality in Chartiers Creek should be protective of human health and the environment because of migration and mixing of contaminated ground water into the stream. Currently, contaminant concentrations in Chartiers Creek are within acceptable limits and are therefore protective of human health and the environment. The proposed sampling location for the POE is one that has been used for a number of years for the Long-Term Surveillance and Maintenance program, which is surface water sampling station 602.

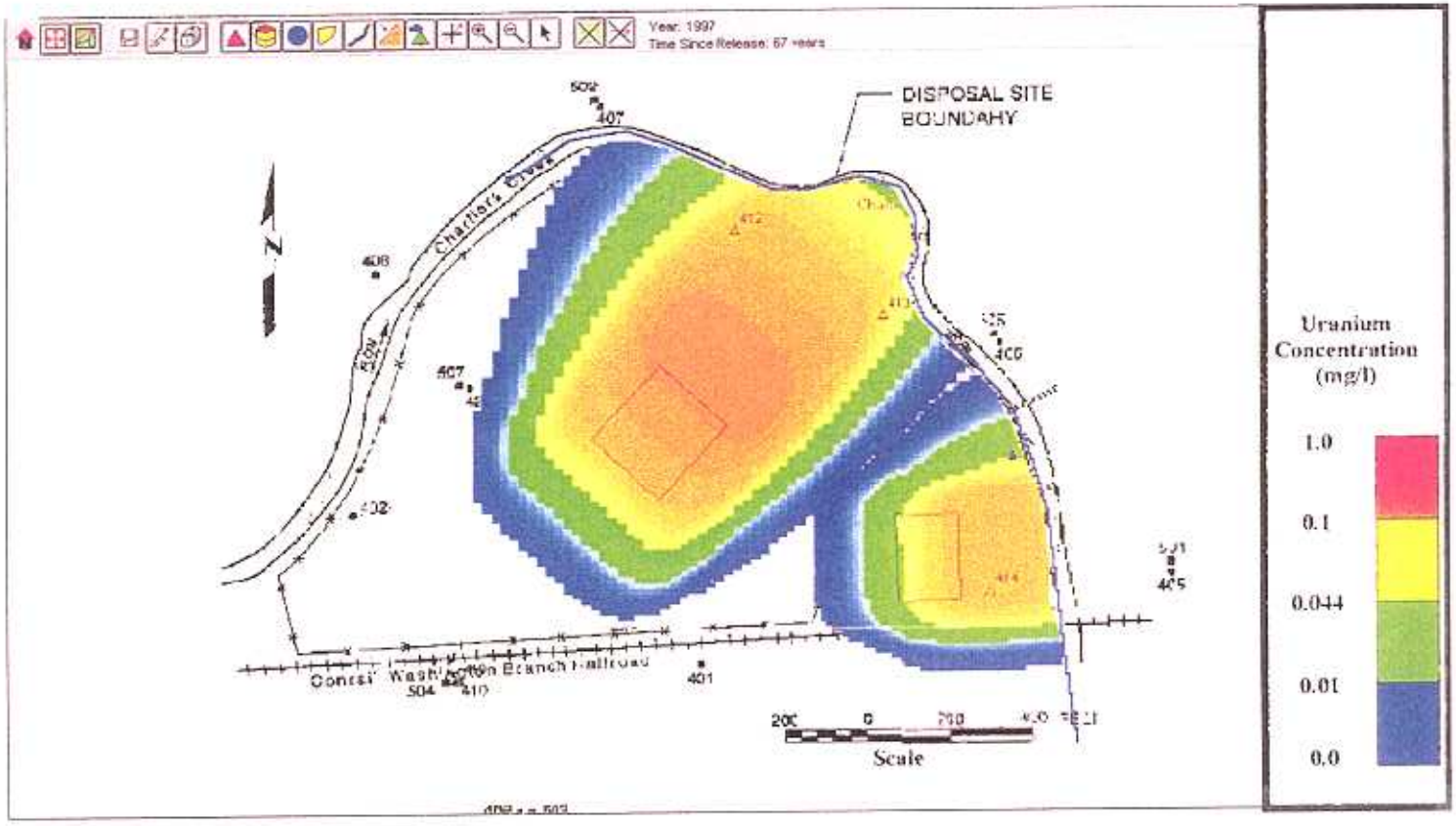


*Figure 1–4. Mean Concentration Distribution for Uranium at Conditioning Time (1997)*

Current water sampling has shown that although concentrations of uranium in ground water in the POC wells exceed the MCL, concentrations have never exceeded the MCL in surface water in Chartiers Creek at the POE. Therefore, the site is already in compliance with Subpart B of the regulations. The establishment of an ACL for uranium at the POC and the incorporation of institutional controls and compliance monitoring at the Canonsburg site is a conservative approach to demonstrate that site-related contamination will not result in future adverse effects on human health and the environment. This conclusion is supported by results of the ground water and surface water modeling (see Appendix C), which indicates that elevated concentrations of uranium in ground water at the POC will be below the MCL within 30 years, and that contaminants will not effect the POE.

This document provides a summary of investigations and analyses performed to evaluate the potential for success of no remediation in conjunction with ACLs as the compliance strategy at the Canonsburg site. The format of this report is based on the NRC guidance document (NRC 1996). Appendix C provides a more detailed discussion of the computer modeling performed for this assessment. The format of Appendix C follows guidelines from the American Society for Testing and Materials "Standard Guide for Documenting a Ground-Water Flow Model Application" (ASTM 1995), with additional sections discussing ground water flow and contaminant transport aspects of the Groundwater Analysis and Network Design Tool (GANDT) methodology.

# 2.0 Hazard Assessment

## 2.1 Source and Contaminant Characterization

The Canonsburg site has had some form of radionuclide processing or containment within its boundaries since 1911. Area A was the main processing facility, Area B contained residual contamination, and Area C was used for liquid effluent disposal. In the early 1960s some surface soil remediation was performed in Area A; the resulting contaminated soils and material were placed in Area C and covered with a relatively impermeable cover material. DOE remediated the site from 1984 to 1986. Contaminated materials were removed from Areas A and C and surrounding areas and placed in an engineered disposal cell (Figure 1–3). The waste/source in the disposal cell is fully encapsulated by a liner and a cover, which isolate the materials and prevent contaminant migration into the subsurface and ground water.

Before the remedial action in the mid-1980s, two distinct source areas had the potential for contaminating ground water: overlapping Areas A and B associated with the main processing activities, and Area C. Although information on contaminant concentrations at these locations is substantial, some uncertainty exists with regard to the source term characteristics. These uncertainties can be addressed in a probabilistic modeling approach through the use of the Monte Carlo method.

Sandia National Laboratories has been developing a probabilistic ground water modeling system to address natural attenuation potential, pump-and-treat evaluations, and ACLs. This approach is more robust than previous attempts to address ground water flow and transport concepts in that it explicitly accounts for uncertainty through the use of Monte Carlo simulation techniques.

Therefore, the likelihood of success of a compliance strategy can be evaluated with this approach. In contrast, conventional deterministic modeling approaches use discrete estimates of contaminant fate and transport behavior, which do not address uncertainty. The methodology and associated computer code developed by Sandia is embodied in the GANDT method. This method was used to perform the ground water analyses presented in this report. To assess the potential effects on surface water in Chartiers Creek, a riverine model published by the NRC (1982) was used.

The main source of information that helps to limit the degree of uncertainty in contaminant behavior is data from monitor wells. Several wells have had elevated concentrations of uranium in the last several years, indicating a potential hazard that needs to be evaluated (see Appendix B for water quality summary). The GANDT method has the ability to impose conditions on these observed data and thereby limit the number of possible outcomes predicted in a modeling study of the site. Given the degree of uncertainty in site conditions, a deterministic approach provides little useful information. The probabilistic approach can predict the outcome of contaminant behavior in terms of probabilities or likelihood of attaining certain standards, such as the likelihood of meeting the MCL for a particular constituent.

Water quality information at the three POC monitor wells suggests that the concentration of uranium has increased slightly over the last several years. Figure 2–1, Figure 2–2, and Figure 2–3 show the observed uranium concentration versus time in wells 412, 413, and 414, respectively. The anomalously high uranium concentration of 0.213 mg/L in well 412 (December 1996) was at a more reasonable value of 0.121 mg/L when resampled. The modeling presented in the following section reflects the nature of this transport behavior.

There is some uncertainty with regard to the conceptual model of the uranium behavior that is not readily addressed through this modeling analysis. The disposal cell constructed on the site during the 1984 to 1986 remediation may have altered the hydrologic system in the area and caused these transient increases in uranium concentrations. The cell was engineered to minimize direct infiltration of precipitation through the cell, to enhance evapotranspiration, and to redirect surface runoff through the toe drain. The unconsolidated aquifer has only about 10 ft (3 m) of saturated materials, which are reported to be heterogeneous and potentially discontinuous in terms of hydraulic connection. The ground water flow direction at the site is essentially radial from the south side of the site to Chartiers Creek. Therefore, one conceptual model could involve a substantial change in the water balance in and around the disposal cell, which could have altered the contaminant behavior in such a way as to cause the increases seen in the monitor wells.

The alternative conceptual model, presented in the next section, assumes that the contaminant pulse has only recently arrived at these downgradient monitor wells. In either case, the modeling presented in the next section should bound the time estimates for contaminants to flush to the river and the likely surface water concentrations predicted with the stream-aquifer modeling.

## 2.2 Transport Assessment

An ACL application requires an evaluation of the concentrations at the POC and the POE. The proposed POE is the surface water in Chartiers Creek. Ground water contaminated from the

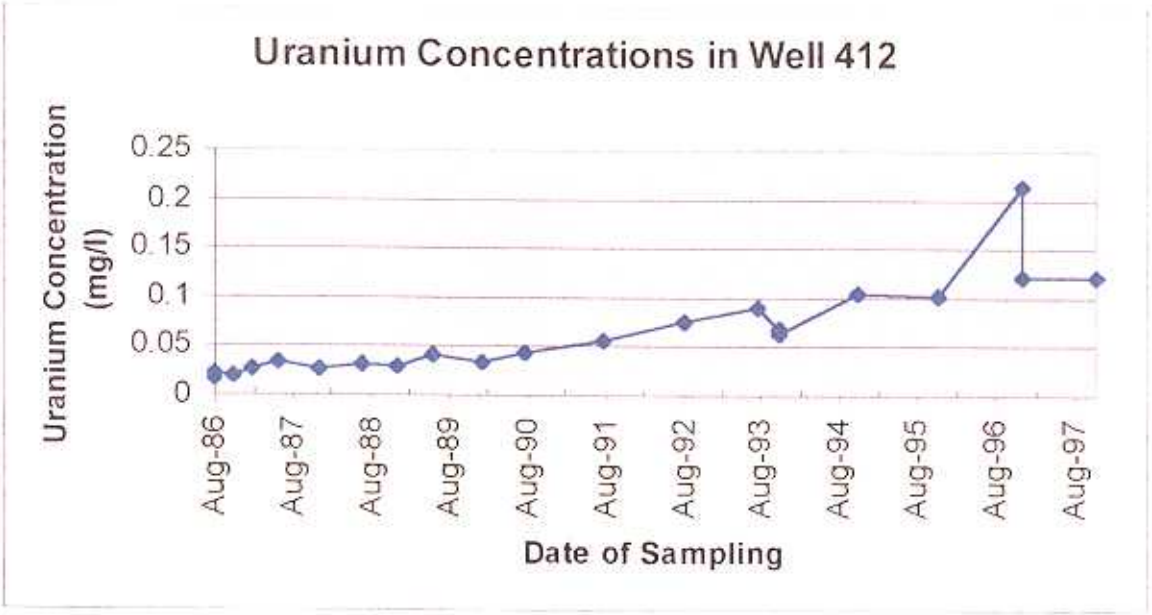


*Figure 2–1. Uranium Concentration Versus Time for Monitor Well 412*

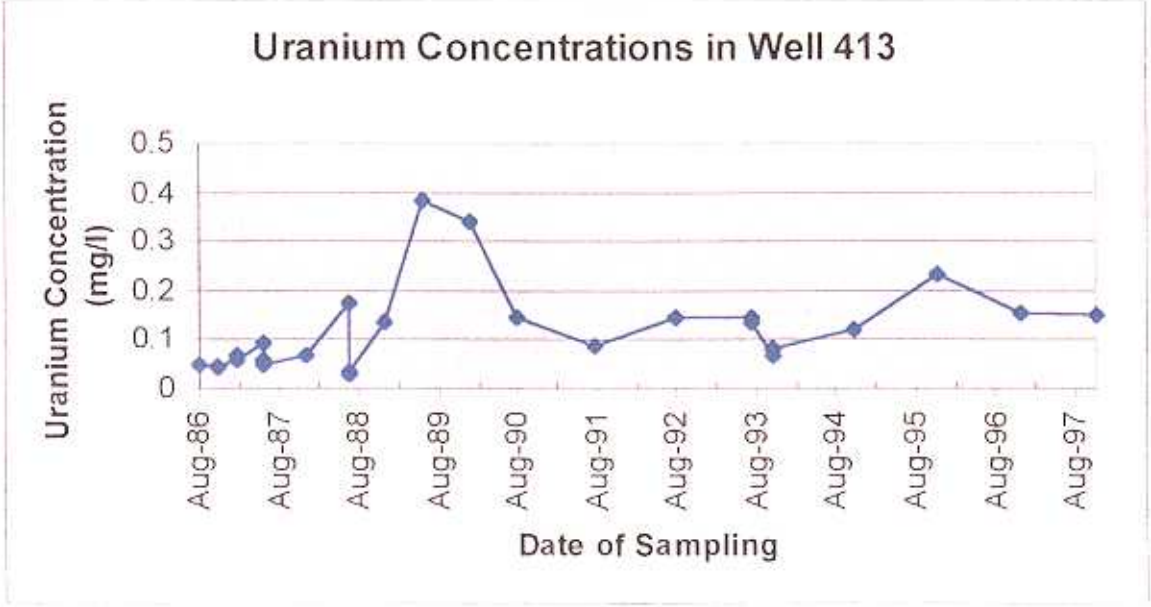


*Figure 2–2. Uranium Concentration Versus Time for Monitor Well 413*

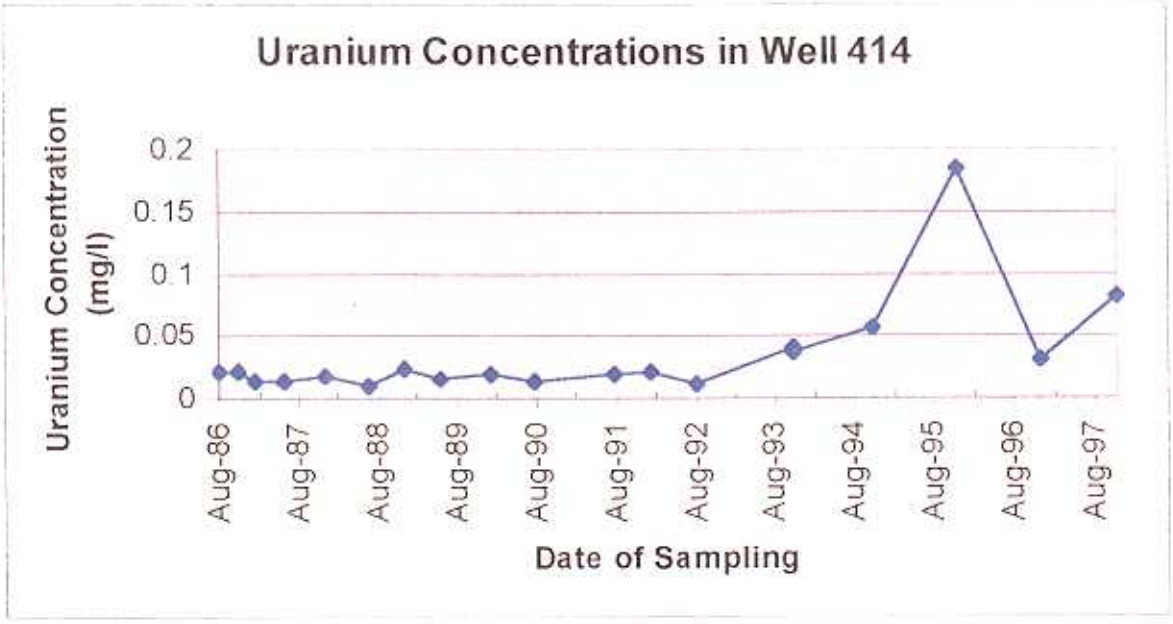


*Figure 2–3. Uranium Concentration Versus Time for Monitor Well 414*

former uranium-processing operation is migrating to, and discharging into, Chartiers Creek. The stream-aquifer interactions should be explicitly analyzed to evaluate whether this proposed ACL is protective of human health and the environment. To accomplish this a combined modeling effort has used the GANDT code to analyze the contaminant flow and transport from the source term, through the unsaturated soils, and through the ground water system, followed by a stream-aquifer model. Model-predicted concentrations in ground water were used as inputs to a riverine model (NRC 1982) to evaluate the potential for dilution and dispersion in Chartiers Creek. Because GANDT does not have the capability to evaluate multiple source terms simultaneously, two modeling efforts were performed—one for the main processing source area and associated plume, and one for the Area C source term and plume. Details of this modeling approach are provided below and in Appendix C.

In the GANDT construct, the source term is modeled as a rectangular area at the top of the unsaturated zone. The size of the source area, as well as the initial concentration of the contaminant in the source area, can be uncertain. Input values to describe the source term are derived from site information, expert judgment, and trial and error with the simulations. The unsaturated zone at the site is approximately 10 ft (3 m) thick. Limited hydrologic characterization information is available regarding the unsaturated materials. The saturated zone of interest is the unconsolidated material. The underlying bedrock formation is not a potential source of potable ground water, given the nature of the fracture system and the background water quality (DOE 1995). In addition, the unconsolidated aquifer discharges to Chartiers Creek, which is the POE. Therefore, flow and transport in the unconsolidated aquifer system is of primary interest. Two sets of simulations were performed—one for the contaminant plume emanating from the former processing area, and one for the source area associated with the contamination in Area C. In both areas of interest the hydrologic characterization information is sparse. Therefore, spatial variability was not explicitly taken into account; only uncertainty was taken into account in the form of assigning a lognormal distribution to the hydraulic conductivity in the Monte Carlo suite. In other words, each simulation in the Monte Carlo suite assumed a homogeneous hydraulic conductivity field, although the value of the hydraulic conductivity was different in each simulation to account for uncertainty.

A summary of the input parameters used in the GANDT simulations for the main tailings source area are shown in Appendix C, Tables C–1, C–2, and C–3 for the source term, unsaturated zone, and saturated zone parameters respectively. Uranium was the only COPC addressed in the modeling. Information sources and justification for selection of the input data in the simulations are also shown in these tables. A more detailed description of the simulation modeling is given in Appendix C. The monitor well data used for conditioning on water quality information included wells 410, 412, 413, and 424. The conditioning time selected was November 1997 (see Appendix B for monitor well analysis results). The conditioning criterion used to match observed with simulated water quality data was the Root Mean Square Error (RMSE) statistic. For this suite of model runs, the value of the RMSE selected was 0.06 mg/L based on expert judgment and trial and error. Results from monitor well 423 were not used because the data were considered anomalous. The concentrations in well 423 are considerably lower than those in 412 and 413 and likely have been influenced either by runoff and dilution from Chartiers Creek or from the toe of the disposal cell.

Results of the modeling analyses are presented with two types of graphical displays. First, the average concentration distribution of all the Monte Carlo runs that passed the conditioning test are displayed as two-dimensional plumes. These plots represent the expected behavior of the plume based on the data and assumptions used in the modeling analyses. Second, a probability plot is used to evaluate the likelihood of attaining the MCL. Therefore, in the case of uranium, a plot is constructed that shows the spatial distribution of the probability that the concentration is less than the MCL, or 0.044 mg/L.

Results of the probabilistic analysis for the plume emanating from the main processing source area suggest that the concentrations of uranium will be elevated above the MCL in ground water for 20 to 25 years. Figure 1–4 and Figure 2–4 show the average concentration distribution predicted for uranium in the years 1997 and 2017, respectively. Appendix C contains graphical displays of several more time periods from the model simulations for a more complete visualization of the transient behavior of the contaminant plume. The corresponding plots of the probability that the uranium concentration is less than the MCL are shown in Figure 2–5 and Figure 2–6, respectively. Appendix C also contains additional probability plots. It can be seen from these plots that after 20 to 25 years the probability becomes greater than 95 percent that the concentration will be below the MCL because of natural attenuation processes (e.g., dilution and dispersion).

A second modeling study was performed to address the elevated concentrations of uranium in Area C, where the liquid from the processing was disposed of. The conceptual model for this area is similar to the one derived for the main processing area plume. Tables C–4, C–5, and C–6 in Appendix C present a summary of the input parameters and assumptions for the source term, unsaturated flow and transport specifications, and the saturated zone flow and transport specifications for the GANDT model runs, respectively. Appendix C provides a more detailed discussion of the model setup and results.

Results of the probabilistic analysis for the plume within Area C suggest that the concentrations of uranium will be elevated above the MCL in ground water for a period of 15 to 20 years. Figure 2–7 and Figure 2–8 show the average concentration distributions predicted for uranium in the years 1997 and 2017, respectively. The corresponding plots of the probability that the uranium concentration is less than the MCL are shown in Figure 2–9 and Figure 2–10, respectively. The years 2022 and 2027 are not displayed because the probability is 100 percent that the concentrations will be less than the MCL by the year 2017. Appendix C contains additional plots of average uranium concentration distributions and probability distributions for a more complete visualization of the transient behavior of the plume. It can be seen from these plots that in 15 to 20 years the probability becomes greater than 95 percent that the concentrations will have diminished below the MCL because of natural attenuation processes (e.g., dilution and dispersion).

A riverine model was employed to assess the potential effects of contaminated ground water on the surface water in Chartiers Creek. The model used was published by the NRC in 1982. The riverine solution is a point source model that accounts for mixing, dilution, and dispersion in a steady-state river-flow system. Two codes documented in the NRC publication were employed: (1) TUBE.FOR was used to estimate the dispersion factor for the river, which in turn is needed

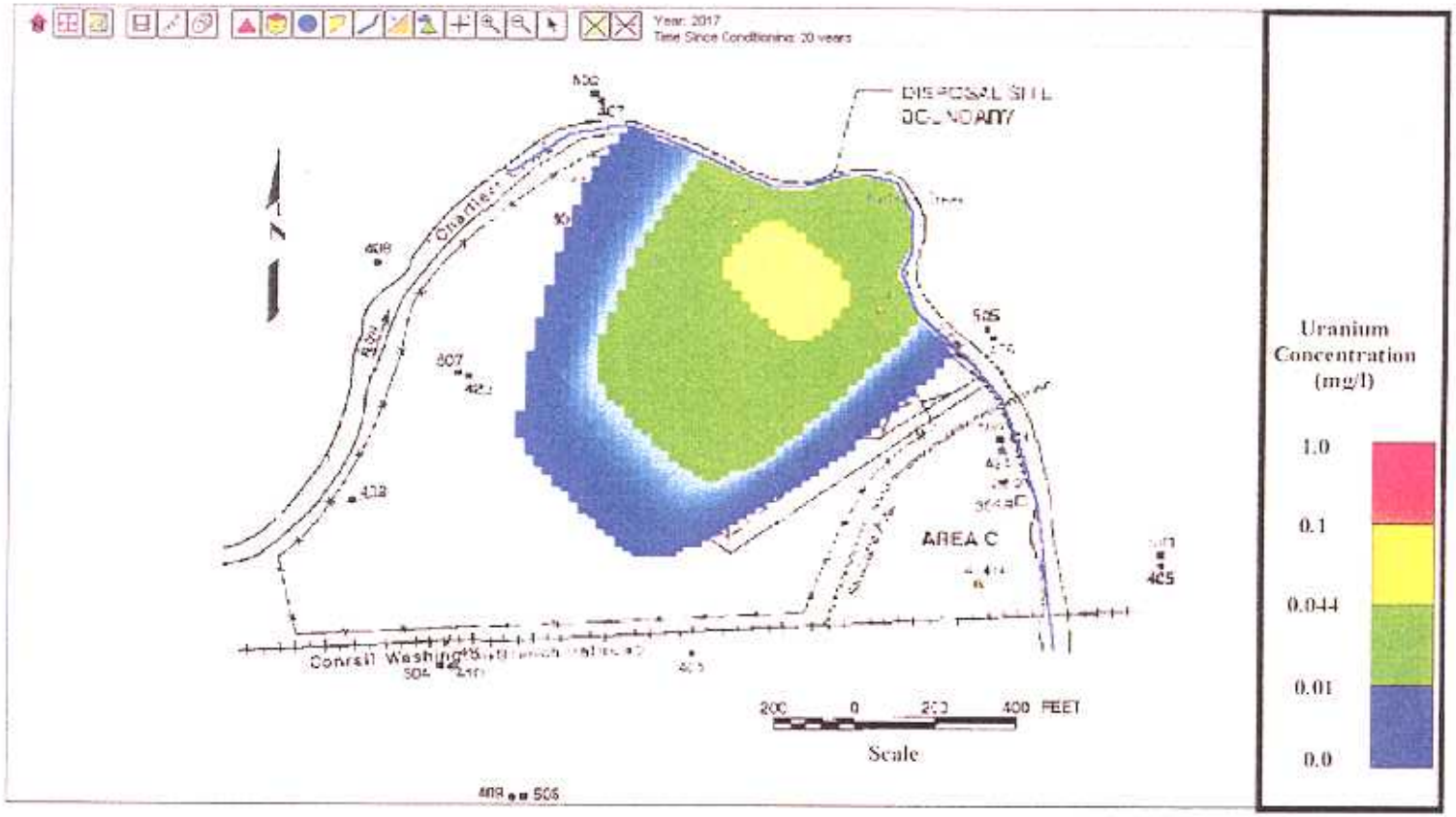


*Figure 2–4. Mean Concentration Distribution for Uranium 20 Years after Conditioning Time (2017)*

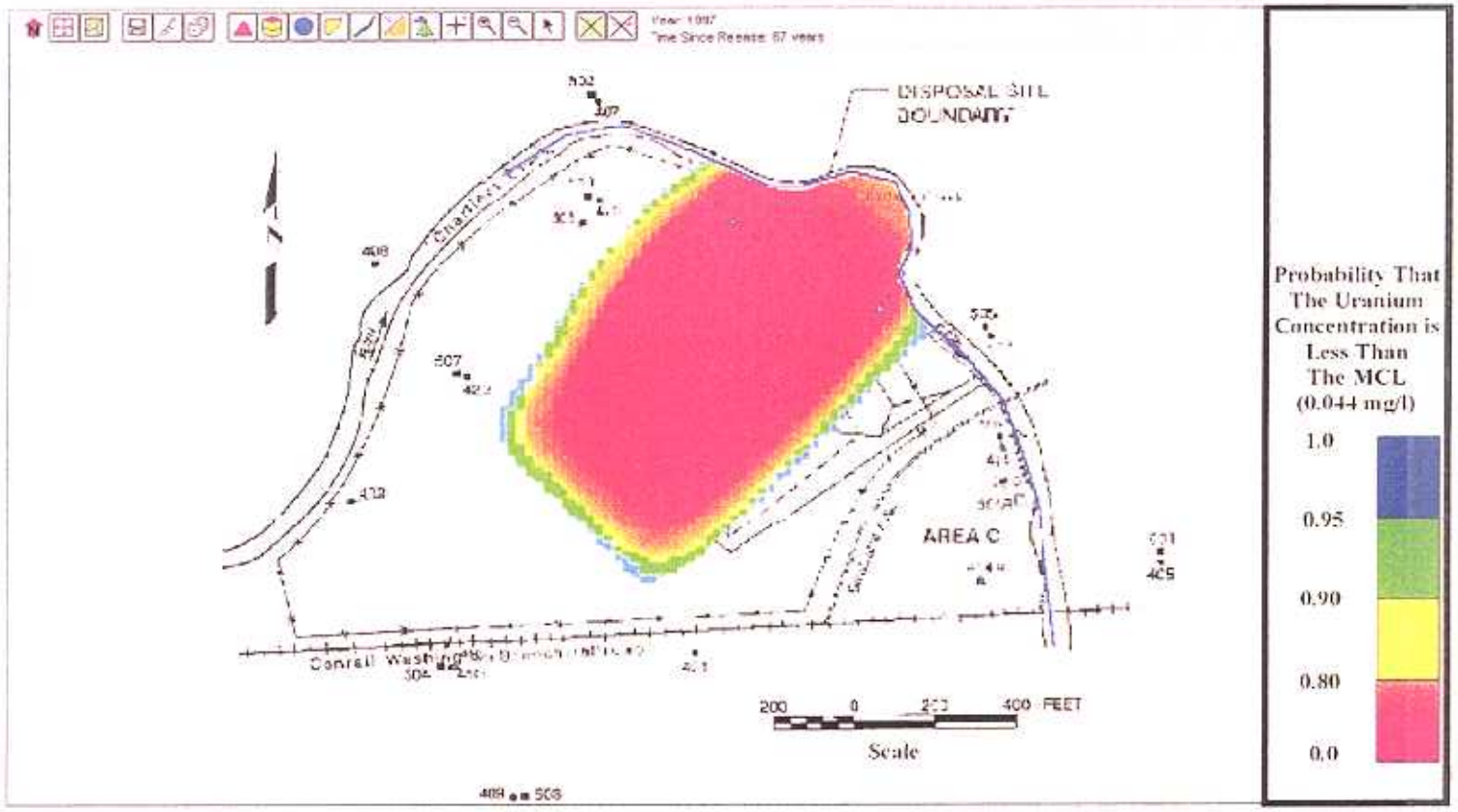


*Figure 2–5. Probability of Concentration Being Less Than the MCL for Uranium at Conditioning Time (1997)*

*Figure 2–6. Probability of Concentration Being Less Than the MCL for Uranium 20 Years after Conditioning Time (2017)*

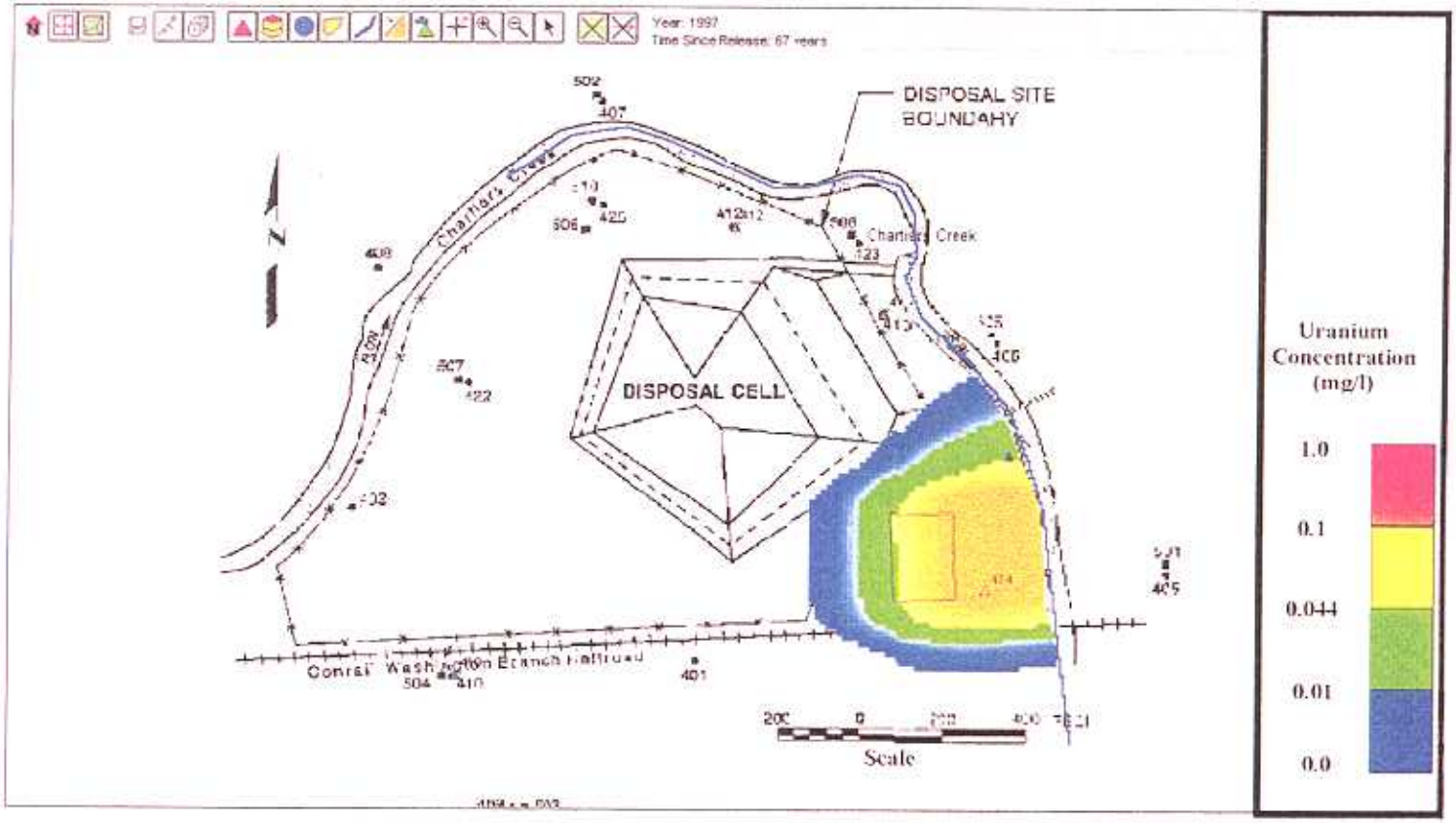


*Figure 2–7. Mean Concentration Distribution for Uranium at Conditioning Time (1997)*

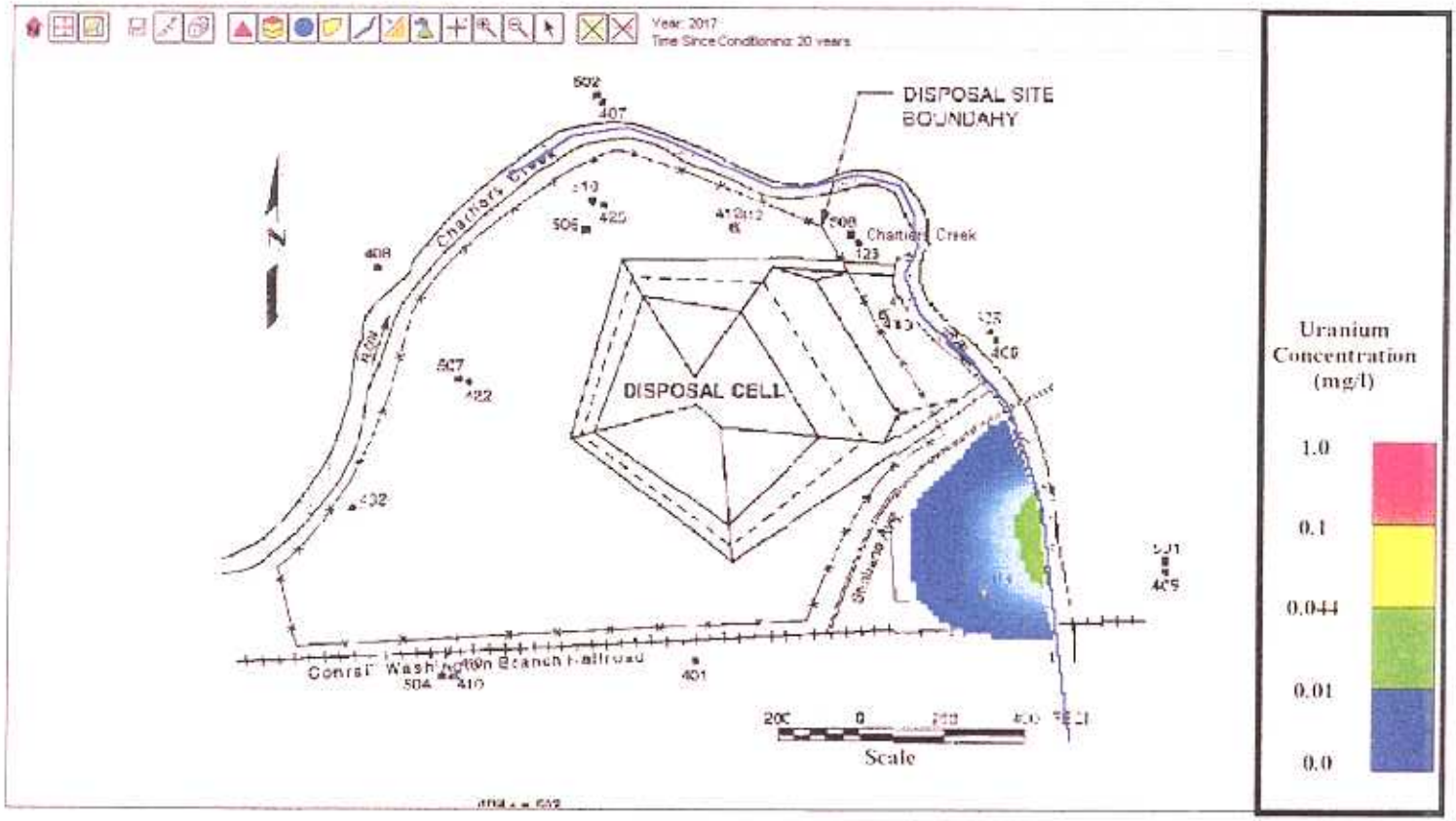


*Figure 2–8. Mean Concentration Distribution for Uranium 20 Years after Conditioning Time (2017)*

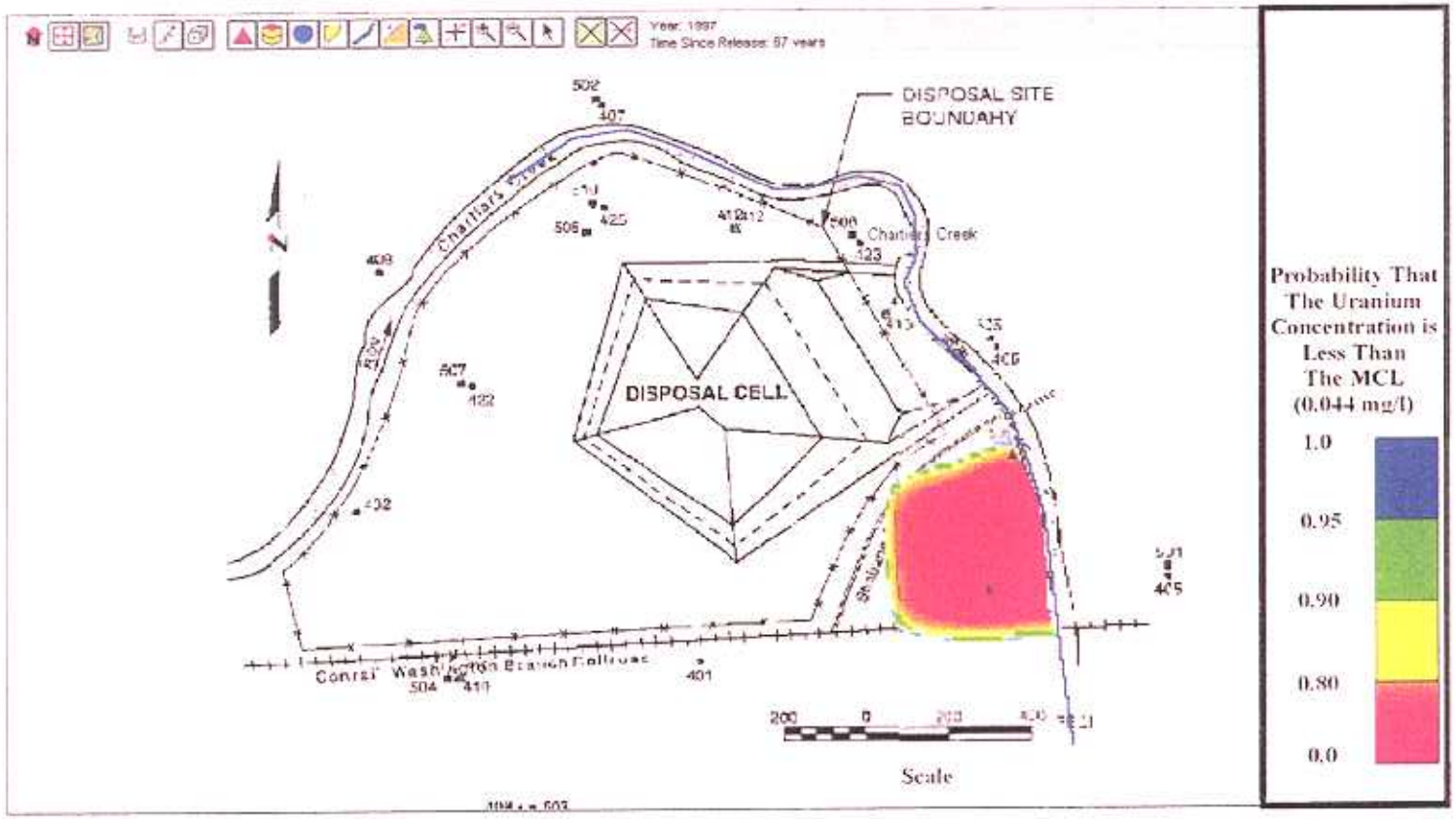


*Figure 2–9. Probability of Concentration Being Less Then the MCL for Uranium at Conditioning Time (1997)*

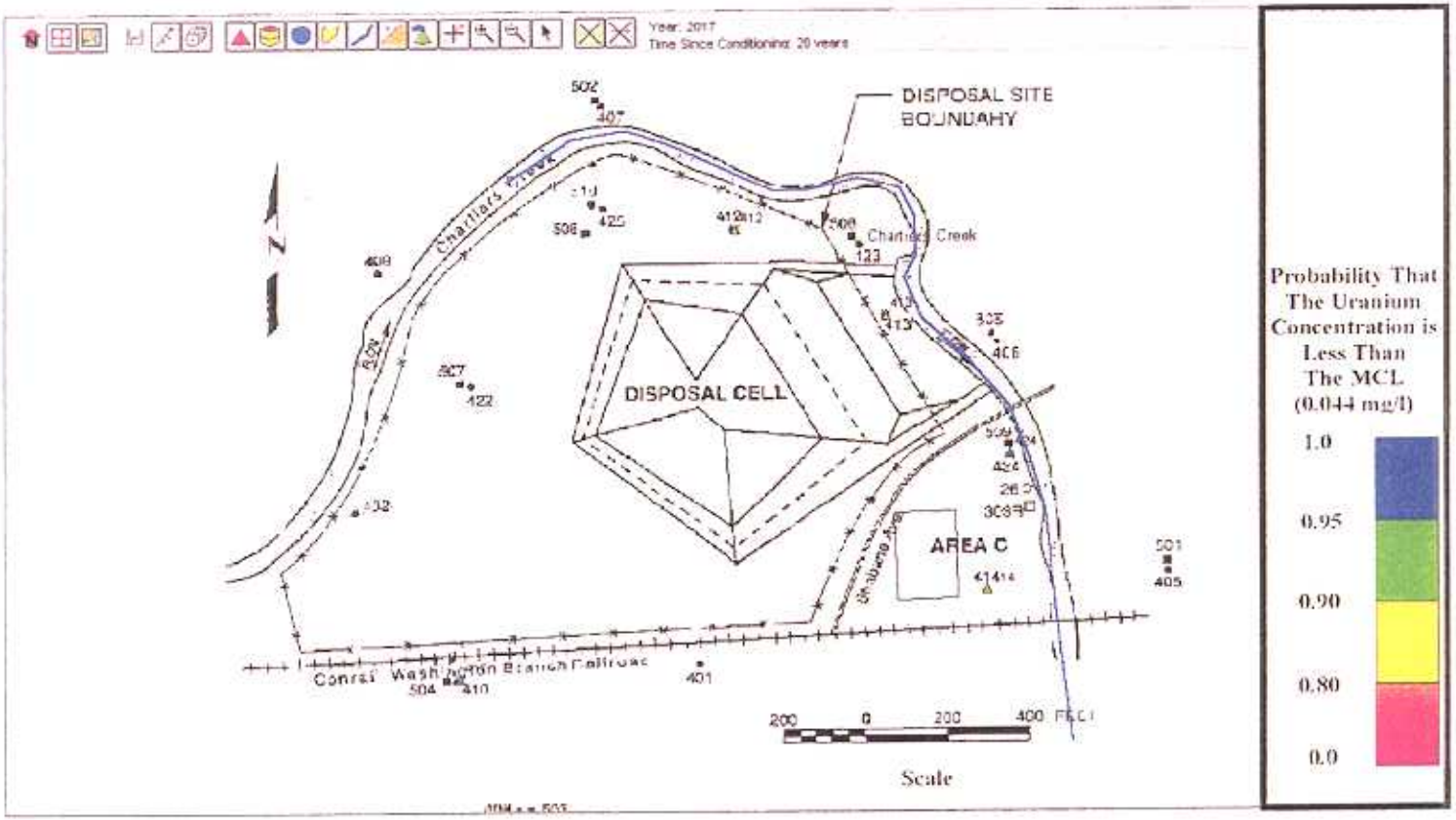


*Figure 2–10. Probability of Concentration Being Less Than the MCL for Uranium 20 Years after Conditioning Time (2017)*

as input to the second code and (2) STTUBE.FOR was used to model the contaminant transport in the river. Contaminant migration from the ground water to the river does not occur as a point source. A common practice to account for a line-source discharge to a river is the use of multiple point sources and a superposition method to integrate the effects (Whelan and McDonald 1996).

The results of the two GANDT modeling simulations were used as input to the riverine model to evaluate the potential effects of the uranium plumes on water quality in Chartiers Creek. Five point source locations were assumed for each of the two plumes (the main processing area plume and the Area C plume), making a total of ten point source discharges into the river to approximate the discharge along the length of Chartiers Creek adjacent to the Canonsburg facility. Maximum simulated groundwater concentrations at the river were used as input concentrations for the point sources. The combined effects of the ten point sources were integrated with a superposition method. The STTUBE code has the ability to differentiate concentrations in the river in multiple stream tubes across the width of the river. However, the results of the analysis for Chartiers Creek suggest that complete mixing does not occur until nearly a half-mile downgradient of the site. Therefore, the stream tube along the closest riverbank was used for estimating water quality in Chartiers Creek. This assumption represents a conservative approach to evaluating water quality in the stream.

Chartiers Creek is approximately 75 to 100 ft (23 to 30 m) wide and 10 ft (3 m) deep in the vicinity of the Canonsburg site (DOE 1995). The flow rate in the creek is between 90 to 130 $ft^3$ per second (2.5 to 3.7 $m^3$ per second). This information was used with the ground water modeling results to predict uranium concentrations in Chartiers Creek. Results of the riverine simulations are shown in Figure 2–11 as uranium concentration versus distance along Chartiers Creek. Also shown in the figure is a composite graphic of the predicted ground water plume concentrations that discharge to the river, as a reference for the surface water concentration profile. These results are important to the evaluation of the site as an ACL candidate because the water quality in Chartiers Creek must be protective of human health and the environment, inasmuch as the stream is designated as the POE for the site.

Because uranium concentrations in Chartiers Creek are generally below detection limits, the actual concentrations of uranium migrating from ground water to the stream cannot be measured. Results of the surface water modeling predict concentrations from the site that are one or two orders of magnitude below detection limits. The uncertainty associated with the ground water concentrations migrating into the river is fairly large, and the stream-aquifer modeling used expected values for ground water concentrations and conservatively low input values for stream discharge characteristics. Even if the ground water uranium concentrations migrating into Chartiers Creek approached the maximum ever detected in a well at the site, the surface water concentrations would still be below detection limits. The processes affecting uranium concentrations are dilution and dispersion in the stream.

## 2.3 Exposure Assessment

For an ACL application to be considered for a site, the contaminants associated with the site must not pose a threat to human health and the environment. The ACL scenario requires the definition of a POE where the judgment of acceptable exposures is made. The site itself is under institutional control and DOE will prohibit the installation of ground water supply wells. Access

to the ground water in the area will be limited. Therefore, the ground water that discharges to Chartiers Creek is the main exposure route of interest. For the Canonsburg site the surface water in Chartiers Creek is considered the POE.

DOE completed a BLRA of potential exposures associated with the site (DOE 1995b). The BLRA evaluated a number of exposure pathways for human and ecological receptors.

### 2.3.1 Human Health Risk Assessment

For human health the following pathways were evaluated:

- Direct ingestion of ground water.
- Dermal absorption of ground water (e.g., through bathing).
- Ingestion of ground-water-irrigated produce.
- Incidental ingestion of surface water through recreational use.
- Dermal contact with surface water through recreational use.
- Incidental ingestion of sediments through recreational use.
- Ingestion of contaminated fish from Chartiers Creek.

The only unacceptable risks posed were through direct ingestion of contaminated ground water. All other pathways, including the use of surface water for recreational purposes, presented negligible risk in terms of human health. The contaminants evaluated in the risk assessment were manganese, molybdenum, and uranium. Of these, only manganese was present in concentrations posing an unacceptable risk.

Contaminant concentrations in the unconsolidated aquifer have changed since the BLRA was completed. Molybdenum concentrations have decreased below the MCL, so it is not considered further in this ACL application. Other constituents are present in ground water at concentrations exceeding established human health and ecological benchmarks for ground water and surface water (Table C–7). These constituents include iron, sulfate, and selenium.

Maximum concentrations of uranium in ground water have increased threefold since the completion of the BLRA and appear to still be rising; samples from several wells exceed the MCL. Selenium, which was present in concentrations near the detection limit in earlier sampling rounds, exceeded the MCL in samples collected from monitor well 413 during the most recent round of sampling (November 1997). Sulfate in ground water has risen to concentrations within the range of EPA guidance values, and iron and manganese exceed risk-based values. However, because access to ground water will be restricted by institutional controls (DOE and the Commonwealth of Pennsylvania ownership of land above affected ground water), use of ground water does not constitute a direct human health risk. Ground water fate and transport modeling

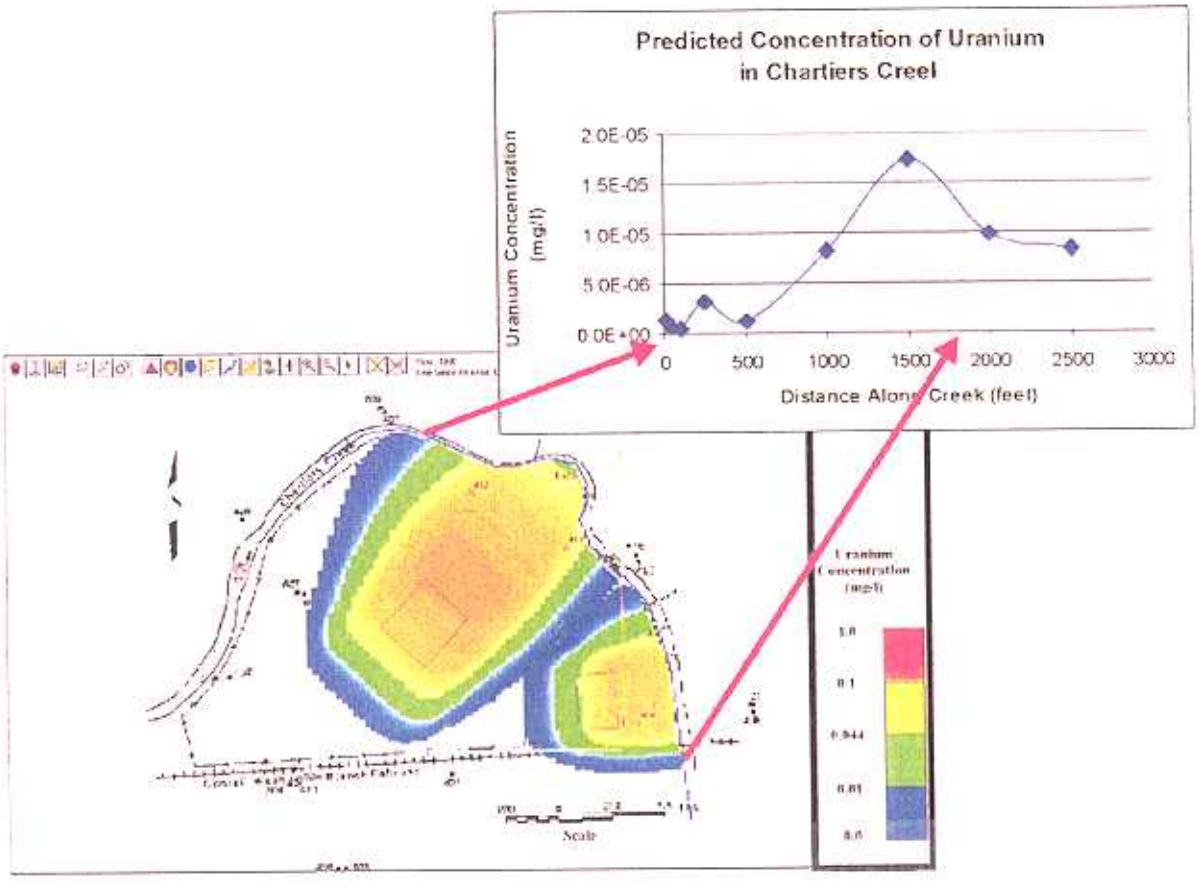


*Figure 2–11. Stream-Aquifer Modeling Results Predicting Surface Water Concentrations of Uranium in Chartiers Creek*

for uranium demonstrated that orders-of-magnitude increases of uranium concentrations in ground water would be required to present a human health risk through contact with surface water. That large an increase in contaminant concentration would probably be required for other contaminants as well and is unrealistic given the current knowledge of site conditions. Risks are low because of the large amount of dilution as ground water enters Chartiers Creek and the limited degree of exposure to surface water that would occur through recreational use. Therefore, the need for an ACL is not driven by human health concerns associated with the use of surface water.

### 2.3.2 Ecological Risk Assessment

The BLRA identified several ecological receptors and pathways. The major receptors of concern are aquatic life living in the water and sediment in Chartiers Creek, and vegetation with roots tapping into contaminated ground water or surface water. Results of the BLRA indicated that manganese concentrations in ground water exceed levels for irrigation water considered to be protective of plants. No adverse effects to vegetation has been observed, however, as documented in the yearly monitoring reports for the site (DOE 1998). Concentrations of iron, manganese, selenium, and uranium in ground water also exceed aquatic benchmarks for surface water, though none of these exceeded benchmark values in surface water itself. Because of the large amount of coal mining and consequent acid mine drainage in the region, iron and manganese cannot be solely attributed to past activities at the Canonsburg site, and ACLs are not proposed for these constituents. However, because uranium contamination is associated with site activities and because the concentrations may still be increasing in ground water, an ACL for uranium is based on the protection of aquatic life.

# 3.0 Corrective Action Assessment

## 3.1 Results of Corrective Action Program

Two phases of remedial action have been performed to mitigate exposure to contaminated soils at the Canonsburg site. In the early 1960s contaminated surface soils were removed from the processing site in Area A and stockpiled in Area C. The contaminated soils were covered with a relatively impermeable cap in 1964. Between 1984 and 1986 contaminated soils and materials were stabilized in an on-site engineered disposal cell by DOE (DOE 1983 and 1995b). The disposal cell was designed to prevent any further migration of contaminated materials and is basically encapsulating the waste in perpetuity. DOE controls access to the site and has no plans for future development of the disposal cell site.

Since completion of remedial action at the Canonsburg site in the mid-1980s, concentrations of uranium in ground water downgradient from the disposal cell have increased through the mid-1990s, and are now generally on a downward trend (with minor anticipated fluctuations) (Figure 3–1). This is consistent with modeling predictions that concentrations will decrease over time. Although concentrations of uranium are still elevated above the MCL in ground water at two of the three POC wells, there is no potential impact to human health and the environment, and the concentrations are significantly below the proposed ACL (Section 4.1). Also, no uranium has ever been detected at the POE in surface water in Chartiers Creek.

## 3.2 Identification of Alternatives

Even though there is currently no potential impact to human health and the environment because of site-related contamination in ground water downgradient from the Canonsburg site, alternative corrective action measures will be considered and evaluated as part of the ACL application. Practicable corrective actions for controlling, reducing, mitigating, or eliminating ground water contamination include conventional pump-and-treat technology or the construction of a permeable reactive treatment (PeRT) wall. The third alternative considered is no remediation in conjunction with ACLs.

### 3.2.1 Pump-and-Treat

A common approach to mitigating ground water contamination is an active ground water withdrawal and ex situ treatment process (commonly referred to as the pump-and-treat method). One or more pumping wells are typically installed to hydraulically capture the contaminant plume, and then the water is pumped through some form of treatment system. Pump-and-treat methods are typically time consuming and costly because of the complex nature of contaminant transport processes in heterogeneous media. Depending on the cleanup criteria, some pump-and-treat operations have not been able to meet their technical objectives because of heterogeneities and sorption characteristics of the aquifer matrix. Despite the potential shortcomings, it is still considered the baseline technology for a comparison of alternatives.

### 3.2.2 PeRT Wall

Another option that was evaluated for use at the Canonsburg site is the construction of a PeRT wall. A PeRT wall is a zone of reactive material that is placed in a contaminated aquifer such that the ground water is remediated as it passes through the wall. To date, over 50 PeRT walls have been used to treat a wide range of contaminants. Most of these walls have been used to treat chlorinated solvents; however, several walls have been used to effectively treat heavy metals or low level radionuclides. These walls have only been in place for the last several years.

### 3.2.3 No Remediation

The third alternative is no remediation in conjunction with an ACL for uranium. Since there is no current or projected risk to human health and the environment because of site-related contamination in ground water or surface water at the Canonsburg site, this alternative would comply with the ground water protection standards. Also, ground water in the uppermost aquifer is not a current or potential source of drinking water, and access to ground water is (and will continue to be) prohibited by institutional controls.

## 3.3 Technical Feasibility

### 3.3.1 Pump-and-Treat

To evaluate a pump-and-treat option for the Canonsburg site, the GANDT model was employed to simulate the flow and transport potential, including withdrawal wells intended to hasten the

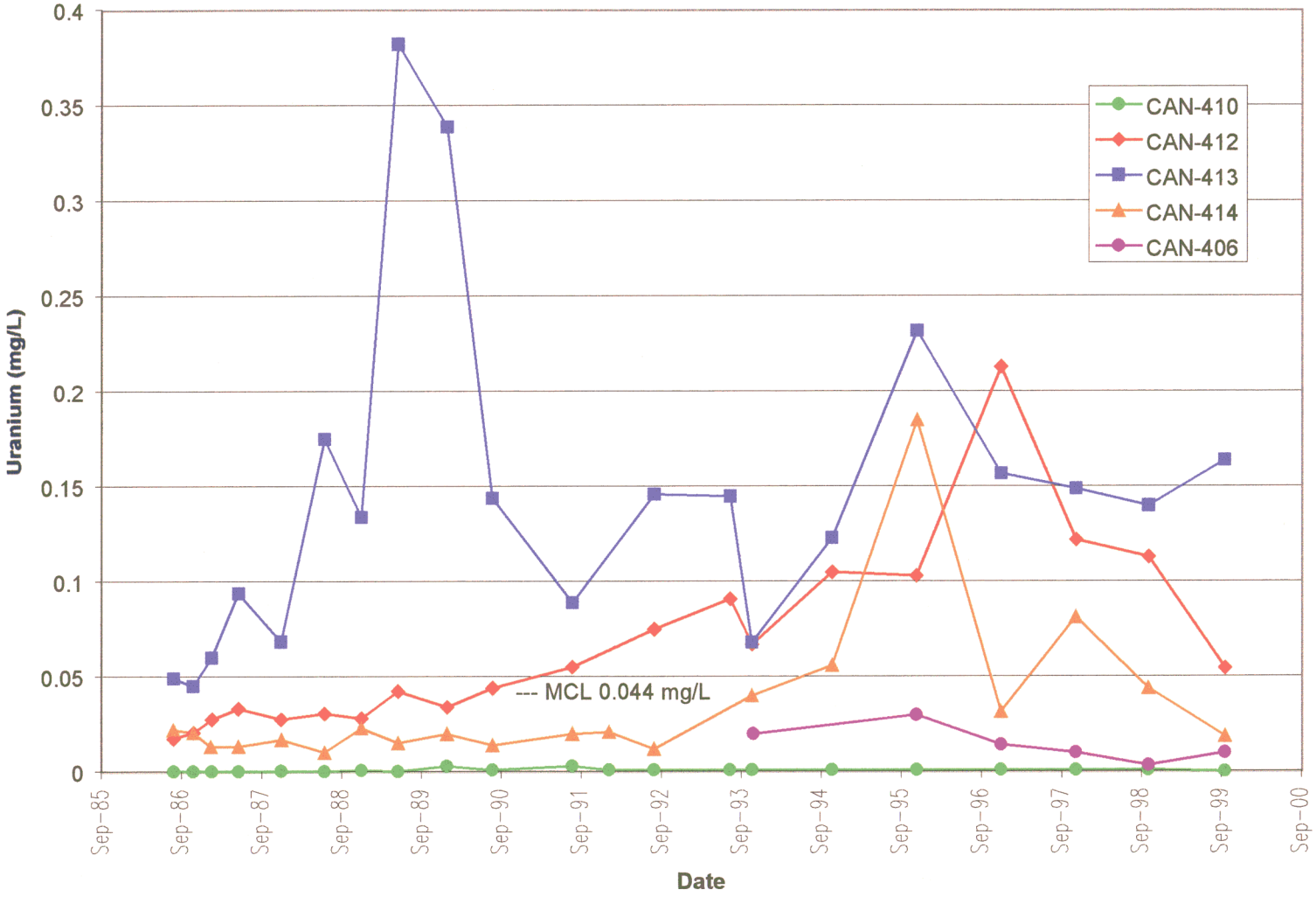


*Figure 3–1. Uranium Concentrations in Ground Water*

cleanup of the aquifer. Any number of configurations could be used to effectively clean up the aquifer in terms of numbers of pumping wells, withdrawal rates, and duration of pumping. Several options were considered for this analysis. The following scenario was used for the feasibility analysis:

- Two pumping wells located downgradient from the disposal cell (the location of the disposal cell next to the creek is an obstacle to effective placement of the wells).
- Pumping rates set at 10 gallons per minute in each well (it is unlikely that the wells could sustain this yield for extended periods of time).
- Duration of the pumping period set to 10 years.

The modeling results suggest that a pump-and-treat scenario will do little to enhance the cleanup of the aquifer in a timely and cost-efficient manner. Figure 3–2 and Figure 3–3 show the average concentration distributions of uranium at the site through time for the pumping scenario discussed above. Figure 3–4 and Figure 3–5 show the probability distributions for the likelihood of concentrations being less than the MCL. Additional time frames are shown in Appendix C for both average concentration distributions and probability distributions in order to visualize the transient effects of a pump-and-treat scenario. From these simulation results it is likely that the pump-and-treat scenario will help clean up the site within 15 to 20 years.

Based on the modeling assessment the proposed practical construction approach for the pump-and-treat process would involve three wells, each pumping at 7 gallons per minute, to capture the plume downstream of the disposal cell (Figure 3–6). It is worth noting that the predicted drawdown at the three pumping wells is on the order of 5 to 6 ft (1.5 to 1.8 m). In the area between the disposal cell and Chartiers Creek, the unconsolidated materials (uppermost aquifer) are approximately 15 ft (4.6 m) thick with a saturated thickness of 10 ft (3 m). In addition, the pumping wells are located close enough to Chartiers Creek to likely induce recharge to the aquifer from the stream. Lower pumping rates would cause less water to emanate from the stream; however, it would have a pronounced effect on the hydraulic control of the plume. The position of the disposal cell next to the creek limits the optimal placement of pumping wells; therefore, the efficiency of a pump-and-treat system is questionable.

Assuming that an adequate stream of contaminated ground water could be extracted from the aquifer, it would be pumped through a collection pipe to the treatment facility. Because of the cold climate the treatment unit would need to be housed instead of being in the open. The most feasible treatment technology would utilize zero valent iron (ZVI) to reduce the uranium concentration in the ground water. The treatment unit would be comprised of ZVI filings inside of a steel tank. The ZVI would remove the uranium in a reaction similar to how the PeRT wall would work. Uranium is removed through reductive precipitation as the contaminated water contacts the ZVI. Because carbonates will precipitate onto the ZVI lowering the iron's hydraulic conductivity, the ZVI filing media will need to be replaced every four months. Conceptually it appears that no other treatment process or chemical additives are required. Although iron and manganese will leach out initially, the levels should drop off to concentrations that are acceptable

and not require further treatment. From the tank the treated water would flow by gravity to a discharge point in Chartiers Creek. Figure 3–6 depicts the conceptual treatment train.

Treated water will meet UMTRA Project ground water standards for heavy metals. Although it may not meet all drinking water standards, it should be clean enough to discharge directly into Chartiers Creek. A National Pollution Discharge Elimination System Permit required for this discharge would stipulate periodic monitoring. If there was a regulatory issue with discharging into the creek, the city sewer-line passing through the site presents another option. Since the discharge would eventually be treated at a Publicly Owned Treatment Works, the pretreatment standards for accepting wastes into the sewer-line are typically not as strict as a direct discharge would be into the creek.

Other treatment technologies such as reverse osmosis and distillation were considered; however, they were considered impractical because they would each create large waste streams that would have to be disposed of. The NRC has verbally stated that the waste byproduct (solids of some form containing uranium) of treating the ground water would be residual radioactive material (RRM) as defined in Public Law 95-604, Uranium Mill Tailings Radiation Control Act. Consequently RRM would have to be disposed of in a licensed disposal cell increasing the costs to the point where these other options appear not feasible.

### 3.3.2 PeRT Wall

If a PeRT wall was constructed at Canonsburg, it would be emplaced between the disposal cell and Chartiers Creek (Figure 3–7). Because ground water flow is relatively low, a funnel and gate PeRT wall would be the most feasible. In this configuration, the gate is the reactive medium and the funnel is an impermeable material such as a bentonite/soil slurry wall. Contaminated water that contacts the impermeable portion is funneled to the reactive gate for passive treatment. Because of the low ground water flows at Canonsburg, only limited mounding is expected directly upgradient of the wall.

Numerous materials have been used in PeRT walls to remove contaminants from ground water. The most commonly used material is ZVI, which creates a strongly reducing environment in ground water. Heavy metals are removed from ground water as it passes through a ZVI barrier from reductive precipitation reactions. The major constituent of concern, uranium, will precipitate as the mineral uraninite (or an amorphous precursor of this mineral) if the oxidation state of an aqueous solution is lowered sufficiently, as occurs with ZVI. Based on analytical results from the PeRT wall constructed in Monticello, Utah, ZVI was found to reduce uranium concentrations in ground water to nondetectable levels. ZVI was also found to be effective in reducing concentrations of molybdenum. However, for the other constituent of concern at Canonsburg, manganese, ZVI may actually increase the concentrations in ground water. This occurs because manganese is a trace contaminant in ZVI. Typical contamination levels of manganese are approximately 0.5 percent. This may limit the practicality of using a PeRT wall at this site.

Based on the monitoring data, the most effective area for the PeRT wall would be between monitor wells 412 and 414 southwest of Chartiers Creek (Figure 3–7). The reactive portion of the wall would be directly downgradient of the encapsulation area. The southern impermeable wall

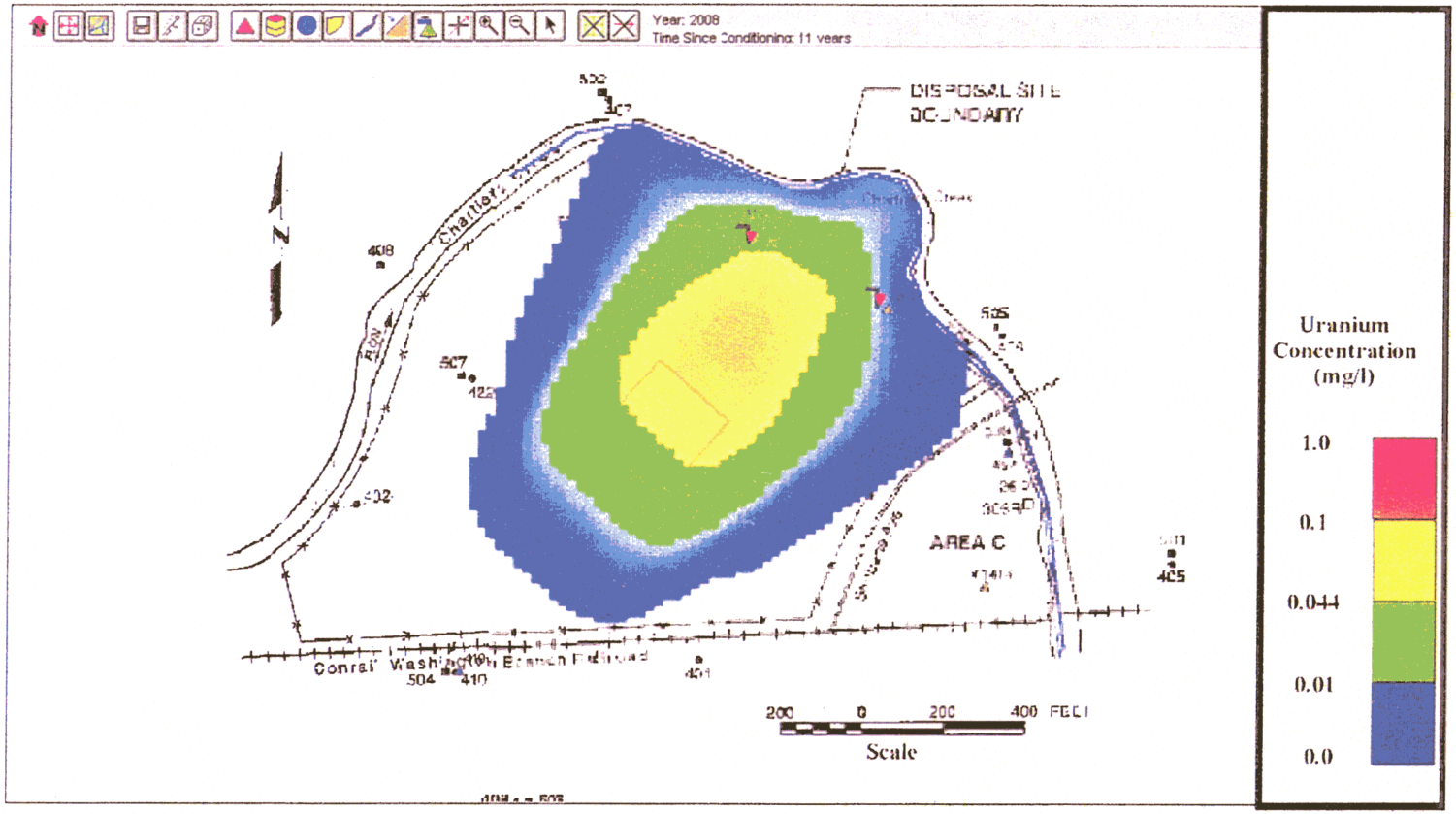


*Figure 3–2. Mean Concentration Distribution for Uranium 10 Years After Start of Pump-and-Treat Scenario (y008)*

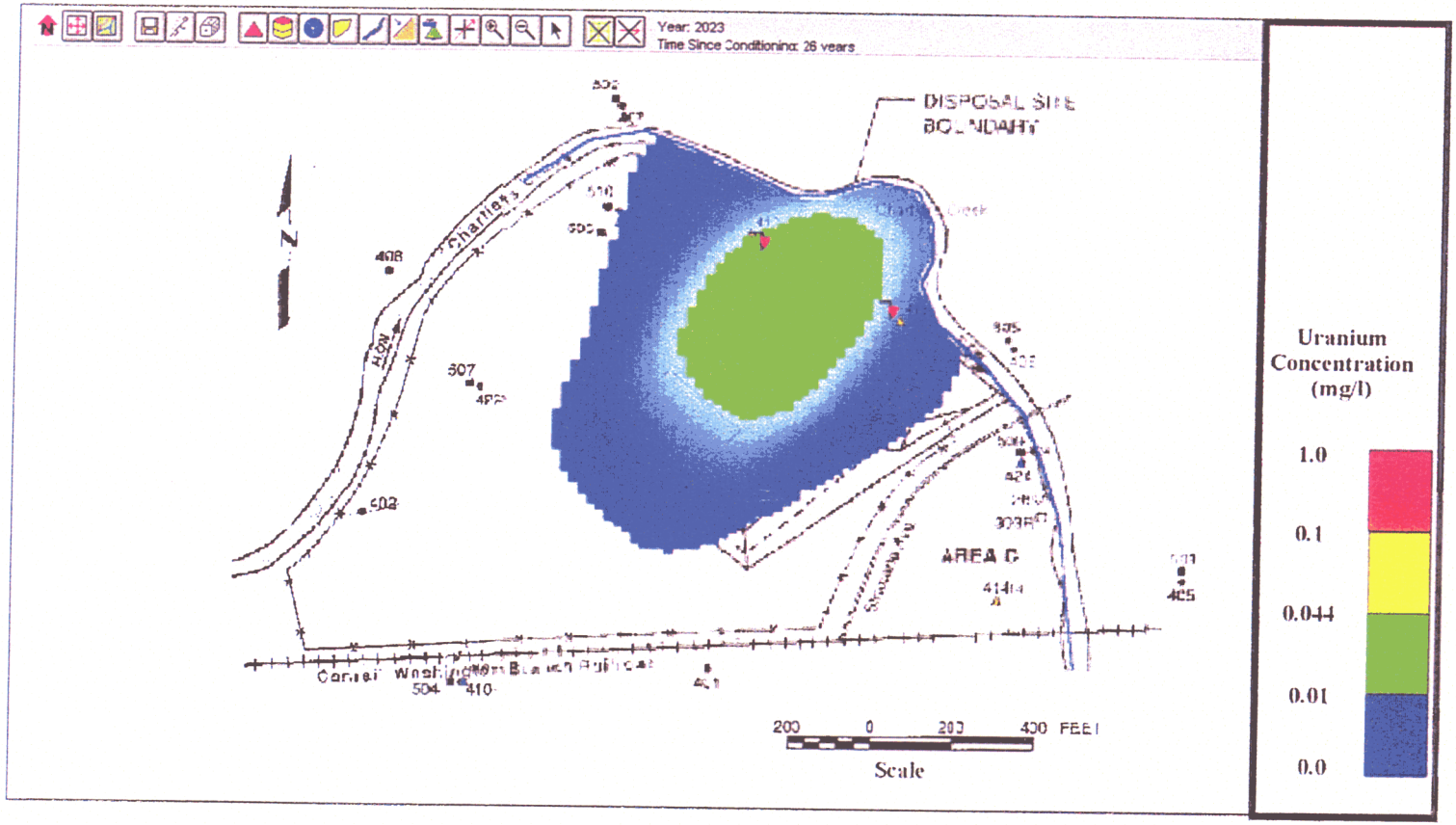


*Figure 3–3. Mean Concentration Distribution for Uranium 15 Years After 10-Year Pump-and-Treat Scenario (2023)*

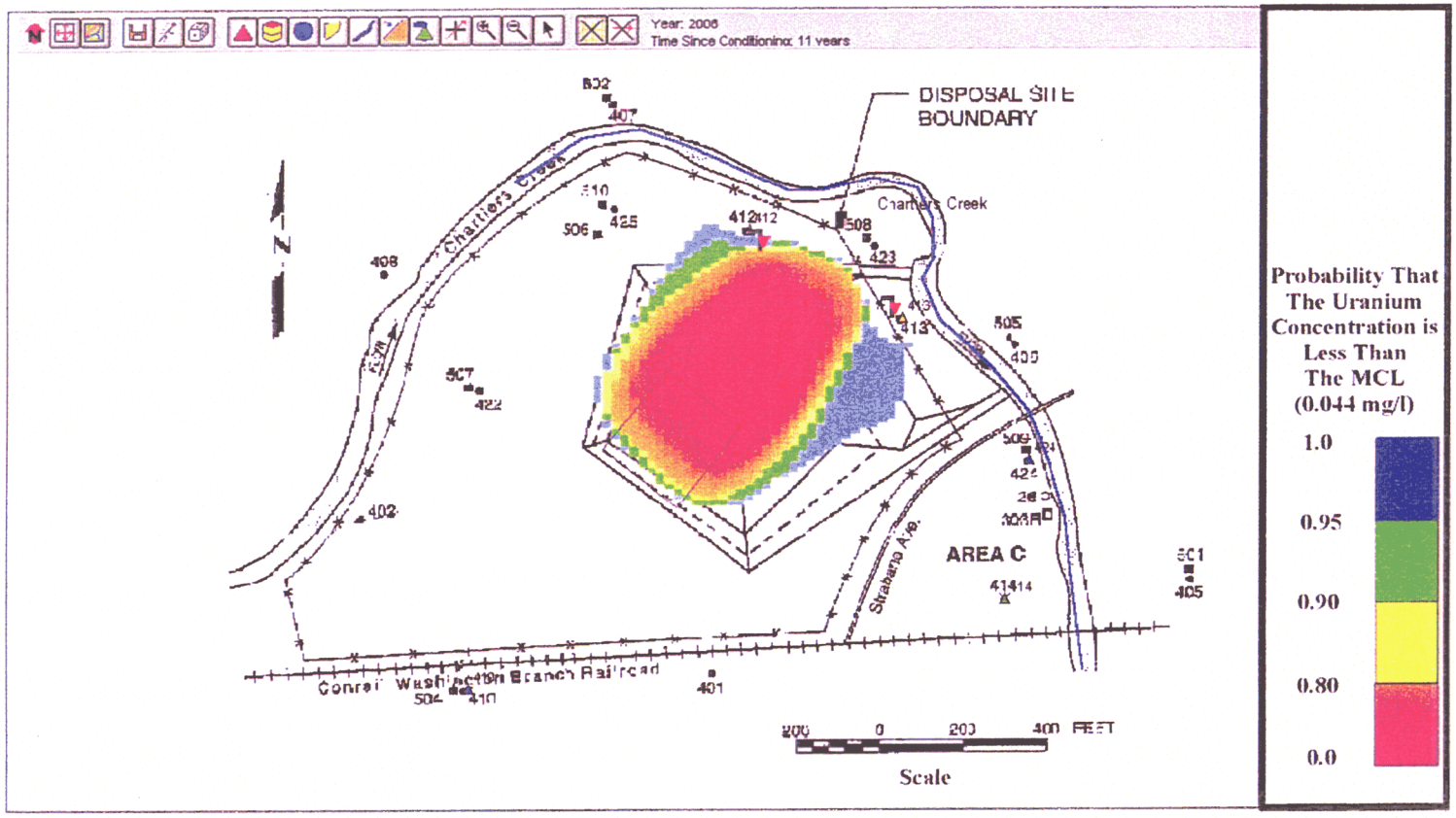


*Figure 3–4. Probability of Concentration Being Less Than the MCL for Uranium 10 Years After Start of Pump-and-Treat Scenario (2008)*

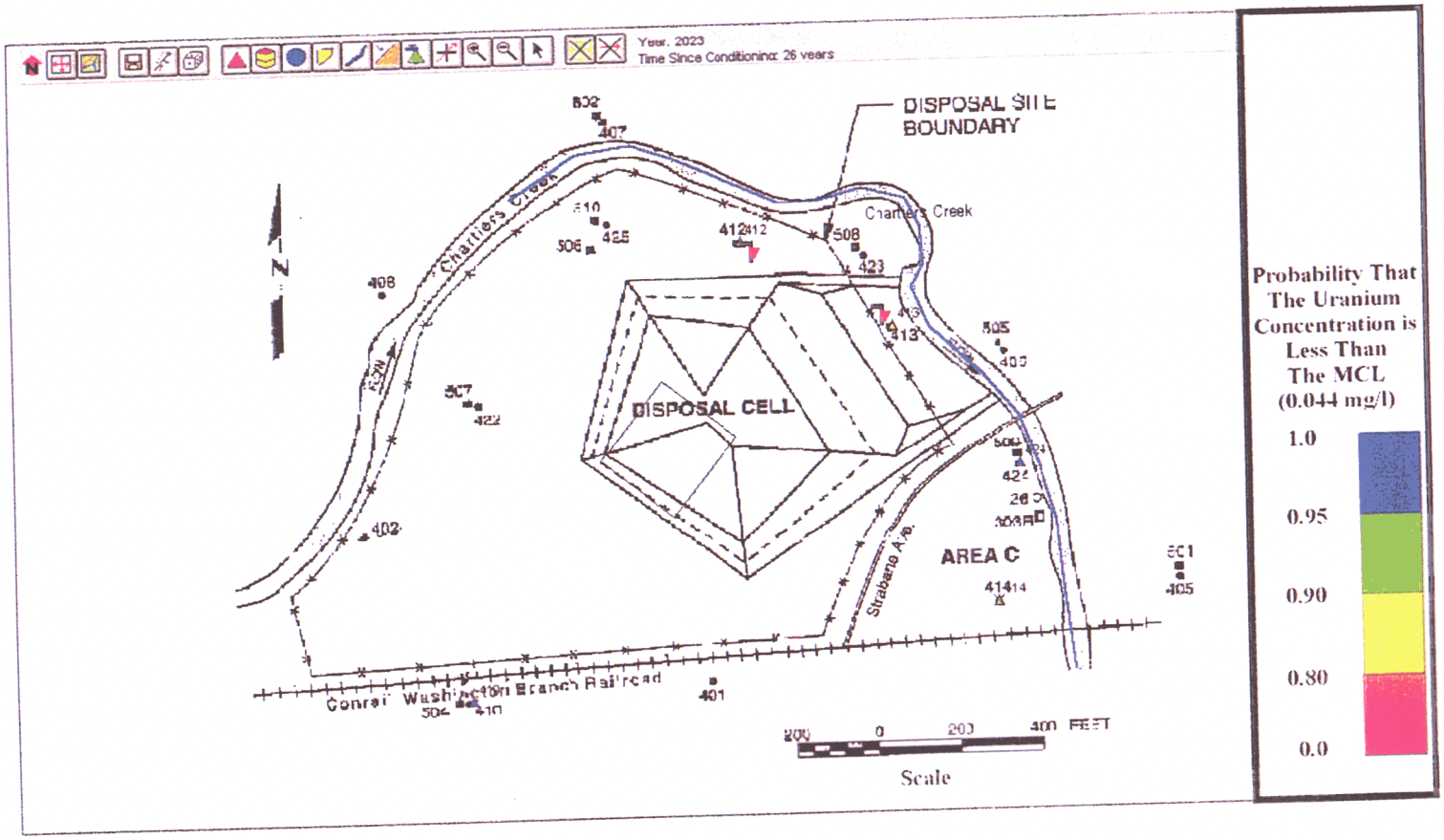


*Figure 3–5. Probability of Concentration Being Less Than the MCL for Uranium 15 Years After 10-Year Pump-and-Treat Scenario (2023)*

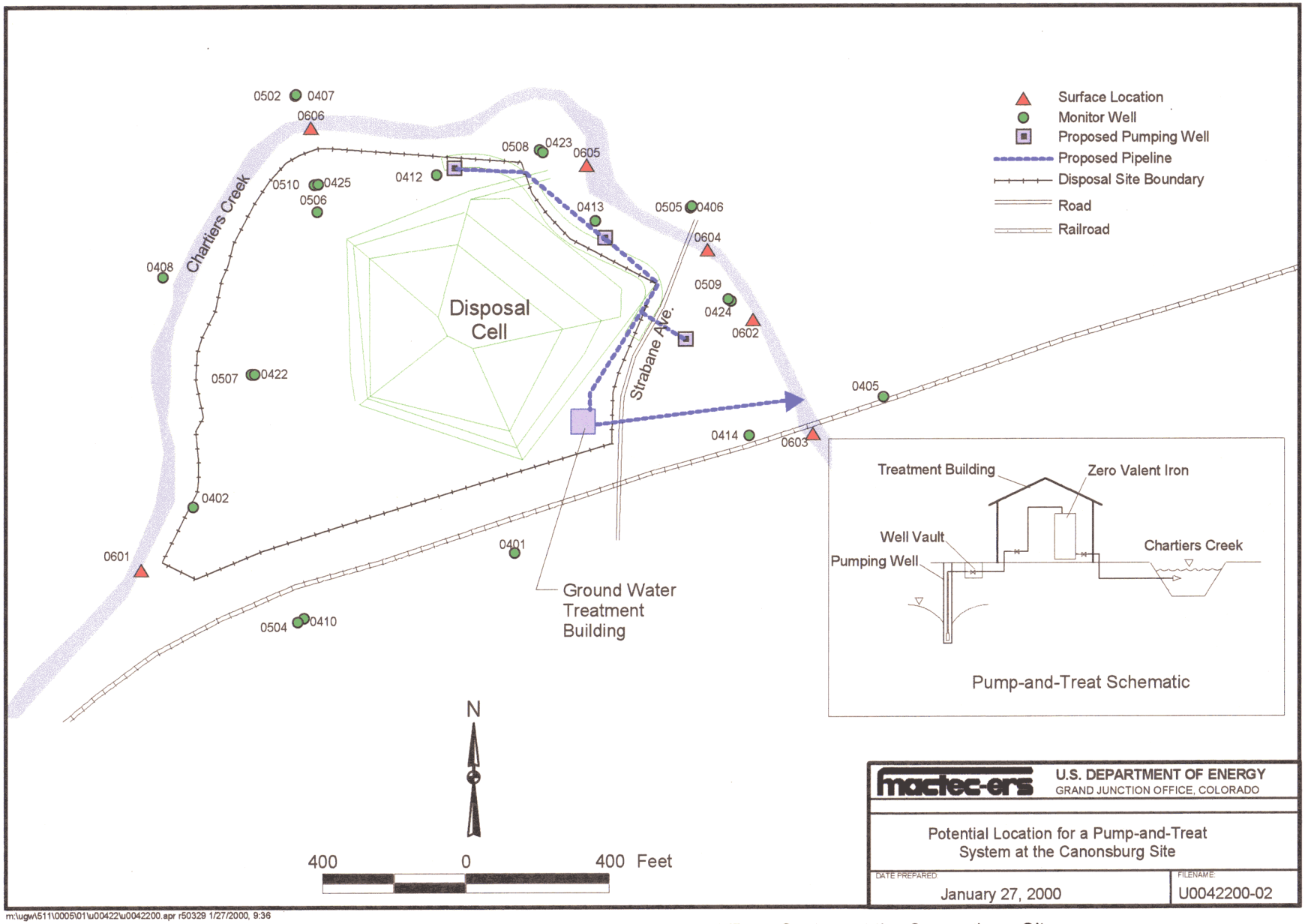


*Figure 3–6. Potential Location for a Pump-and-Treat System at the Canonsburg Site*

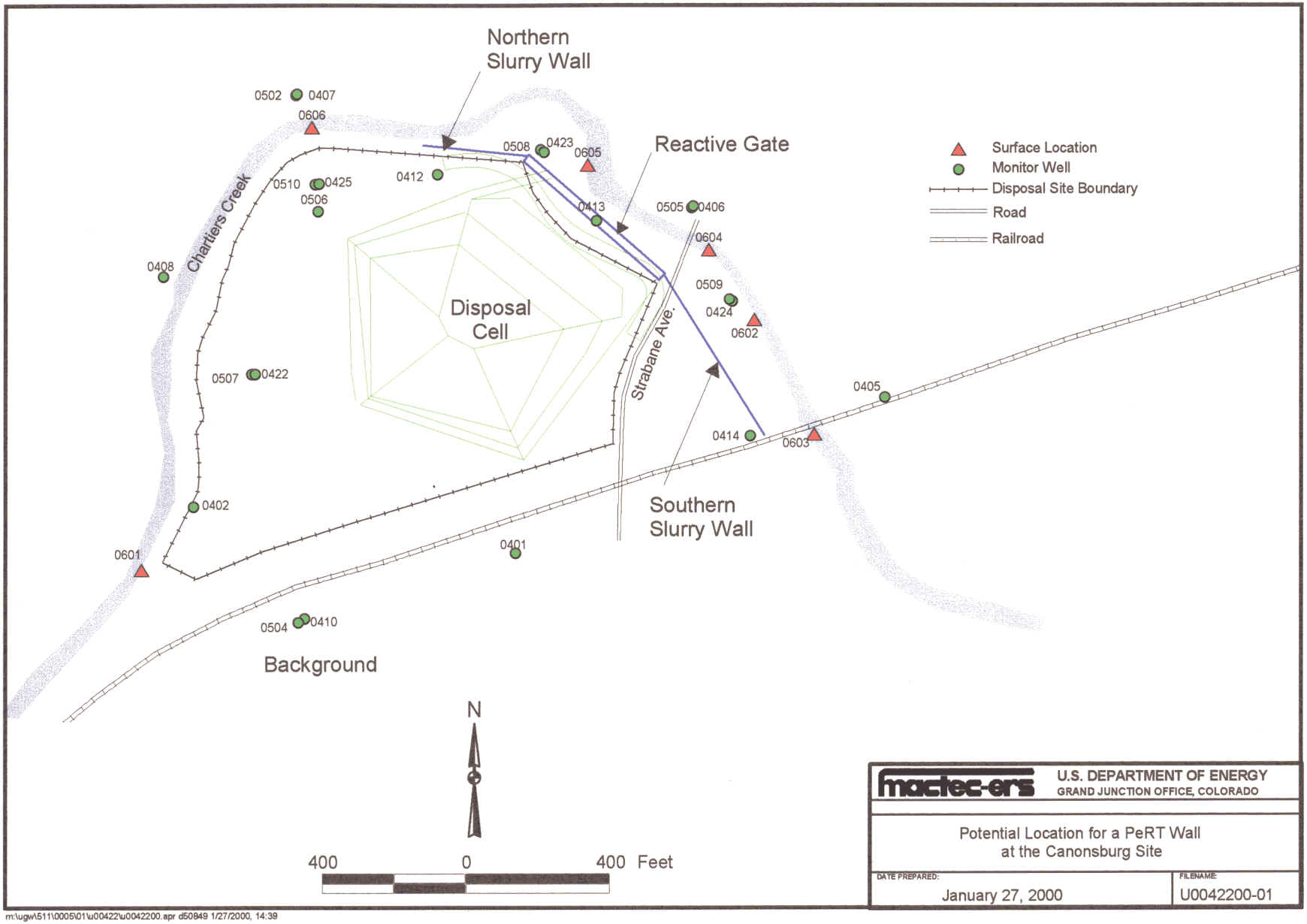


*Figure 3–7. Potential Location for a PeRT Wall at the Canonsburg Site*

would extend from just north of Strabane Avenue to monitor well 414. The northern impermeable wall would be from north of monitor well 412 to just west of monitor well 423. The bottom portion of this wall would be keyed into the bedrock. Based on a depth to ground water of approximately 5 feet below ground surface (bgs) and a depth to competent bedrock of approximately 25 feet bgs (including up to 10 feet of the weathered/fractured zone at the top of the bedrock) the vertical extent of the wall would be 20 feet.

There do not appear to be any engineering constraints for constructing a PeRT wall at this location. The area north and east of the disposal cell is relatively flat with easy access for construction equipment. The estimated construction time is approximately 60 days with 6 to 9 months needed to develop a formal design, procure materials, and arrange for construction equipment. Since this is a passive system, treatment would begin immediately after the wall is installed and continue as long as contaminated ground water passes through the ZVI. Precipitation reactions would eventually reduce the hydraulic conductivity of the ZVI, which would limit its effectiveness. Because this is a relatively new technology and the first PeRT wall has been in operation less than 10 years, the timeframe for when this may occur is unknown. Geochemical modeling on other systems indicates that failure could occur as soon as 10 years to as long as 100 or more years.

### 3.3.3 No Remediation

This alternative would require no additional activities at the site.

## 3.4 Estimated Costs and Benefits

The costs of implementing alternate corrective actions and their benefits must be compared to evaluate the feasibility of an ACL application. Direct and indirect benefits that may be considered include an estimate of the value of pre-contaminated water resources based on water rights, availability of alternative water supplies, water-use demands, and water rates to consumers. Benefits may also include those that result from cleaning up the aquifer and thereby reducing adverse effects to human health from exposure to contaminated ground water. Another consideration may involve the benefits associated with land-value depreciation. This last factor is left out of the evaluation because DOE will retain ownership of the property in perpetuity.

### 3.4.1 Pump-and-Treat

The costs to operate the pump-and-treat system will primarily involve power and labor. Since chemicals are not required to operate the system, only occasional checks on the pumps and meters will be required. The operator will have to change the media 3 times a year and store it until disposal. Sampling of the treated effluent and ground water will be required on a regular basis. Additionally, the hydrology of the system and effectiveness of the treatment system to reduce contaminants in the plume will have to be assessed on a regular basis. The iron filing treatment media, as discussed previously, will need to be managed as RRM. Since the Cheney disposal cell operated by DOE in Grand Junction, Colorado has no disposal fee and can accept RRM, the estimate assumes that the material would be transported to there from Pennsylvania.

The cost estimate for this analysis includes:

- Remedial design/permitting/construction management – includes preparing permits for discharge to creek and installation of wells, developing a hydrologic model of the plume, and construction oversight of subcontractors hired to install the system.

- Well installation and piping – includes well development, vaults, electrical service to each well, and discharge piping from the wells to the treatment facility.

- Treatment facility – includes garage style building, electrical controls, steel tank containing zero valent iron filings, one year supply of iron filings, piping and valves.

- Operation and maintenance costs – utilities for the building, electricity for well pumps, purchase and disposal of zero valent iron filing media, part-time labor to operate system, professional labor to assess plume.

- Monitoring and sampling costs – labor to sample wells and discharge effluent and analytical laboratory costs.

Table 3–1 shows a summary breakdown of the cost estimate for the pump-and-treat option. Operating and monitoring costs are shown as the present worth value of operating the system for ten years. The total cost of the pump-and-treat option is $1,112,000.

*Table 3–1. Cost Estimate for Pump-and-Treat Operation*

| Item | Cost |
|---|---|
| Remedial Design/Permitting/Construction Management | $100,000 |
| Well Installation/Piping | $108,000 |
| Treatment Facility | $73,000 |
| Operation and Maintenance | $435,000 |
| Monitoring/Sampling Costs | $140,000 |
| | |
| **Subtotal** | $856,000 |
| Contingency @ 30% | $256,000 |
| | |
| **Total Cost** | **$1,112,000** |

No households in the area use ground water from the shallow unconfined aquifer as a drinking water source. Residents of the area have a public water distribution system supplied mostly by surface water from some distance away from the site. Therefore, direct impacts or benefits to the surrounding population relative to a degraded water supply are not directly applicable. However, for the sake of justifying a cost-benefit analysis, an estimate of the economic worth of the degraded resource is provided. The GANDT code is capable of estimating the volume of the aquifer contaminated within a specified concentration threshold. From the GANDT model runs, the average volume of contaminated ground water (i.e., water with a concentration greater than or equal to the MCL) is estimated at 42.3 million gallons. A typical rate for water use is 0.0094 cents per gallon. Therefore, the economic worth of the contaminated ground water based on consumptive use rates is approximately $40,000.

From a cost-benefit analysis perspective, the economic and risk-reduction benefits of performing an action should outweigh the cost of implementation. In this particular case, if the pump-and-treat option were invoked it would arguably produce economic benefits on the order of $40,000 (assuming the water resource benefit is $40,000). The estimated cost of implementing the pump-and-treat scenario over a 10-year period (which does not bring concentrations completely down to the MCL but still requires 10 or more years of natural attenuation to achieve the cleanup goal) is approximately $1 million. Concentrations of uranium at the point of exposure are at the low end of EPA's $10^{-4}$ to $10^{-6}$ risk range for carcinogens and are not expected to undergo any significant increase. As such, pump-and-treat would provide no practical risk reduction. Therefore, the cost of implementation far outweighs the economic and risk-reduction benefits, and the pump-and-treat system is not considered an efficient or effective alternative.

### 3.4.2 PeRT Wall

PeRT walls do have high capital costs, in part, because of the high costs of materials. Table 3–2 shows a summary cost estimate for a PeRT wall at the Canonsburg site, based on PeRT wall construction information from the Monticello, Utah project. The capital costs for a PeRT wall are approximately $1,700,000. Since PeRT walls are passive systems, there are no annual operating costs. However, site-monitoring costs will increase because of the additional monitor wells that are needed to evaluate performance.

The cost-benefit analysis and risk-reduction benefits for the PeRT wall follows the same rationale described above for the pump-and-treat system. Since the PeRT wall has a higher cost then the pump-and-treat alternative, it is also not considered an efficient or effective alternative.

### 3.4.3 No Remediation

The only costs associated with the no remediation alternative would be the ongoing monitoring of ground water at the three POC wells and surface water at the POE in Chartiers Creek.

## 3.5 Selection of Preferred Alternative

The three corrective action alternatives under consideration for the Canonsburg site are (1) a conventional pump-and-treat scenario for active cleanup of the aquifer, (2) a PeRT wall to remove uranium from ground water, and (3) no remediation in conjunction with an ACL. If the cost of implementing a corrective action is greater than the benefits of the outcome, then the alternative may be inappropriate or inefficient. The cost for implementing a pump-and-treat system is approximately $1.1 million and the cost for a PeRT wall is approximately $1.7 million. Neither alternative provides any practical risk reduction. Therefore, neither the pump-and-treat or the PeRT wall options would be an appropriate or efficient corrective action alternative.
The Canonsburg site is already in compliance with the proposed ACL, as concentrations of uranium in ground water at the POC wells are already below the ACL, and uranium has never been detected in surface water at the POE in Chartiers Creek. Thus, there is no practicable reason to consider implementing any expensive and intensive corrective action alternative. Also, ground water in the vicinity is not a current or potential source of drinking water, alternative water

*Table 3–2. Cost Estimate for Permeable Reactive Treatment (PeRT) Wall*

| Item | Quantity | Units | Cost/Unit | Total Cost | Notes |
|---|---|---|---|---|---|
| ZVI Cost | 20000 | Cubic Ft | $33.21 | $664,200 | Based on prior quotes for -8/+50 mesh ZVI. This includes shipping. |
| Slurry Wall Installation | 16000 | Square Ft | $15.60 | $249,600 | Unit price based on slurry wall quote for the Monticello PeRT wall. |
| Mob/demob | 1 | Event | $90,000.00 | $90,000 | Based on Monticello |
| Install Sheet Piling | 1004 | Square Ft | $89.00 | $89,356 | Installed for the reactive gate portion. Monticello Quote. |
| Remove Sheet piling | 1000 | Square Ft | $3.80 | $3,800 | Pilings perpendicular to ground water flow are removed after placement of ZVI |
| Excavate Reactive Wall | 741 | Cubic Yd | $72.00 | $53,352 | Removal of native materials before ZVI is placed. Based on Monticello Estimate |
| Place ZVI in the trench | 1 | Activity | 40,000.00 | $40,000 | Placed from Supper Sacks. Rough estimate based on one week of labor and equipment use |
| Temporary Facilities | 2 | Number | $17,000.00 | $34,000 | Unit cost based on Monticello |
| Site prep/Cleanup | 1 | Activity | $25,000.00 | $25,000 | Limited site prep/cleanup is expected. Rough Estimate. |
| Monitoring Well Install. | 30 | Wells | $1,000.00 | $30,000 | Unit Cost based on Monticello costs. Number of wells needed to fully evaluate performance |
| **Subtotal** | | | | $1,279,308 | |
| Construction Oversight | 30 % of subtotal | | | $383,792 | |
| **Total Cost** | | | | **$1,663,100** | |

**PeRT Wall Assumptions:**

Funnel and gate construction
Impermeable portion is a slurry wall
Ground water capture is needed from Well 414 to Well 412
Measured linear feet based on drawing CAN-LTSP-001: 500 feet Southern Slurry, 500 feet reactive gate, 300 feet Northern Slurry
Assumes Reactive gate is directly downgadient of the repository and ground water flow is low enough to minimize mounding
Depth to ground water is approximately 5 feet
Depth to bedrock is 25 feet
Therefore, vertical depth of slurry wall and reactive gate is 20 feet
The reactive material in the gate is Zero valent Iron (ZVI). ZVI is very effective in taking uranium concentrations to nondetect
The thickness of the reactive gate is 2 feet
Assume that gravel packs are not used on the reactive gate
Ten rows (with 3 wells in each row-1 upgradient, 1 in the ZVI, and 1 downgradient) of performance monitoring wells will be installed in the gate

Slurry Wall Size 800 x 20 =16,000 ft2
Reactive Gate Size 500 x 20 x 2=20,000 ft3

supplies are readily available and in use in the area, and there is no problem with potential exposure of contaminated ground water.

Therefore, based on current and predicted conditions at the site and evaluation of the identified alternatives, no remediation in conjunction with an ACL for uranium is the preferred alternative for the compliance strategy to meet ground water protection standards at the Canonsburg site. This alternative is the most cost effective, providing maximum benefit and protection of human health and the environment.

# 4.0 Proposed Alternate Concentration Limit and Implementation Measures

## 4.1 Proposed Alternate Concentration Limit

The purpose of an ACL application is to provide a cost-effective means of dealing with a contaminated site in a manner that is protective of human health and the environment. The analyses presented in Section 2.0 demonstrate that the ACL approach is protective of human health and the environment for the Canonsburg site under the following scenario:

- Chartiers Creek is the POE. Contaminant concentrations in the stream are protective of human health and the environment as a result of dilution of ground water from the site by Chartiers Creek.

- DOE will control access to the disposal site area and will develop institutional controls for Area C to prevent any use of ground water over the next 20 to 30 years.

Section 3.0 provided an analysis of alternative corrective action strategies including (1) a conventional pump-and-treat scenario for active cleanup of the aquifer, (2) a PeRT wall to remove uranium from ground water, and (3) no remediation in conjunction with an ACL. The first and second alternatives are inappropriate from a cost-benefit perspective and do not provide any practical risk reduction. Thus, no remediation in conjunction with an ACL is the preferred alternative.

The proposed ACL was developed on the basis of the potential for ground water to contribute contamination to surface water. The POE is presumed to be Chartiers Creek and receptors would be organisms living in the creek waters and being exposed to surface water and sediment. Aquatic benchmarks compiled by Oak Ridge National Laboratory (ORNL 1996) for uranium in surface water range from 0.0026 to 0.142 mg/L. The BLRA statement that 8 mg/L in surface water is protective to aquatic life is based on a State of Colorado chronic water quality standard (CDPHE 1991). It is proposed that a value of 0.01 mg/L be used at the Canonsburg site at the POE for the purpose of developing an ACL for uranium. This concentration is at the lower end of the benchmark range. Because safety factors are built into the development of benchmark criteria, 0.01 mg/L should be protective at the POE. Ground water modeling using conservative assumptions (e.g., estimating water quality by using only the stream tube closest to the riverbank) indicates that ground water concentrations of uranium are diluted by five orders of

magnitude through discharge to Chartiers Creek. This means that concentrations on the order of 100 mg/L in ground water at the POC would still result in acceptable concentrations at the POE. However, to take into account modeling uncertainties, it is proposed that 1.0 mg/L uranium be established as the ACL at the POC for the Canonsburg site. If monitoring results show that concentrations in ground water exceed this ACL, the compliance strategy for the site will be reevaluated.

The modeling results discussed in Section 2.0 also provide information for predicting appropriate monitoring in the POC wells to determine if the site will remain in compliance with the ACL over time. The probabilistic nature of the modeling analysis allows for the prediction of a suitable range of concentration results to expect through time at each of the POC monitor wells. Figure 4–1, Figure 4–2, and Figure 4–3 show the predicted range of uranium concentrations through time at wells 412, 413, and 414, respectively. These predicted ranges of contaminant concentrations should provide the basis for comparison in a long-term surveillance and maintenance program. If at any time in the future the concentrations detected in these wells are greater than the maximum predicted concentrations, DOE and NRC would reevaluate conditions at the site as they relate to the application of an ACL.

## 4.2 Proposed Implementation Measures

In order for the application of an ACL to be effective the following criteria are proposed:

- DOE will maintain institutional control over the main area of the Canonsburg site (Areas A and B, Figure 1–2) to prevent any future development or access to the site.

- DOE will develop and the Commonwealth of Pennsylvania will implement institutional controls limiting future use of Area C to prevent any ground water use.

- DOE will monitor ground water in the POC wells (412, 413, and 414), monitor well 406, and at the POE (602), to ensure that the ACL for uranium of 1.0 mg/L at the POC and 0.010 mg/L at the POE are not exceeded and that uranium concentrations are decreasing with time (Figure 2 of the GCAP). Ground water samples will be collected and analyzed for uranium, molybdenum, and manganese annually for a period no less than 5 years and up to 30 years. Re-evaluation of site conditions will be conducted after the 5 year period. If the compliance strategy is not proceeding as predicted, the site will be re-evaluated and the strategy will be modified as necessary. Termination of ground water monitoring or modification of the ground water compliance action plan strategy will not be made prior to NRC approval.

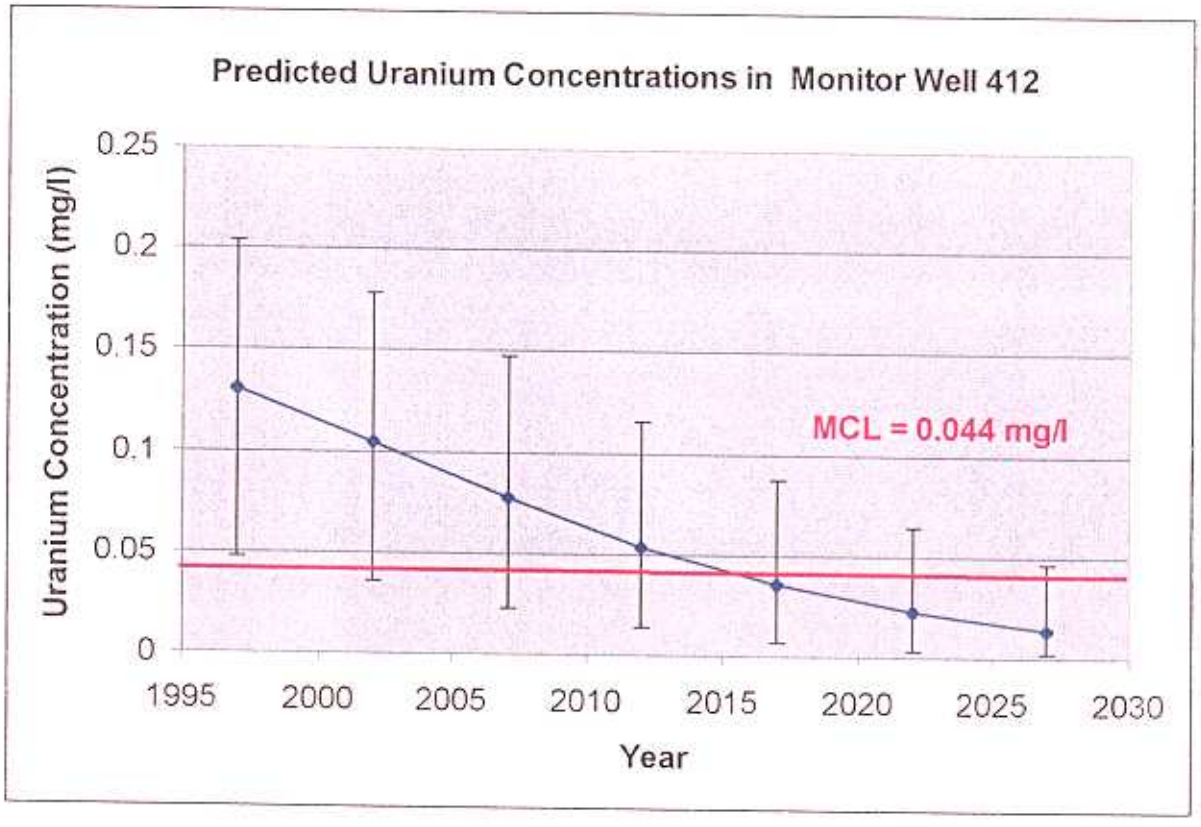


*Figure 4–1. Uranium Concentration Versus Time for Verification Monitoring in Well 412*

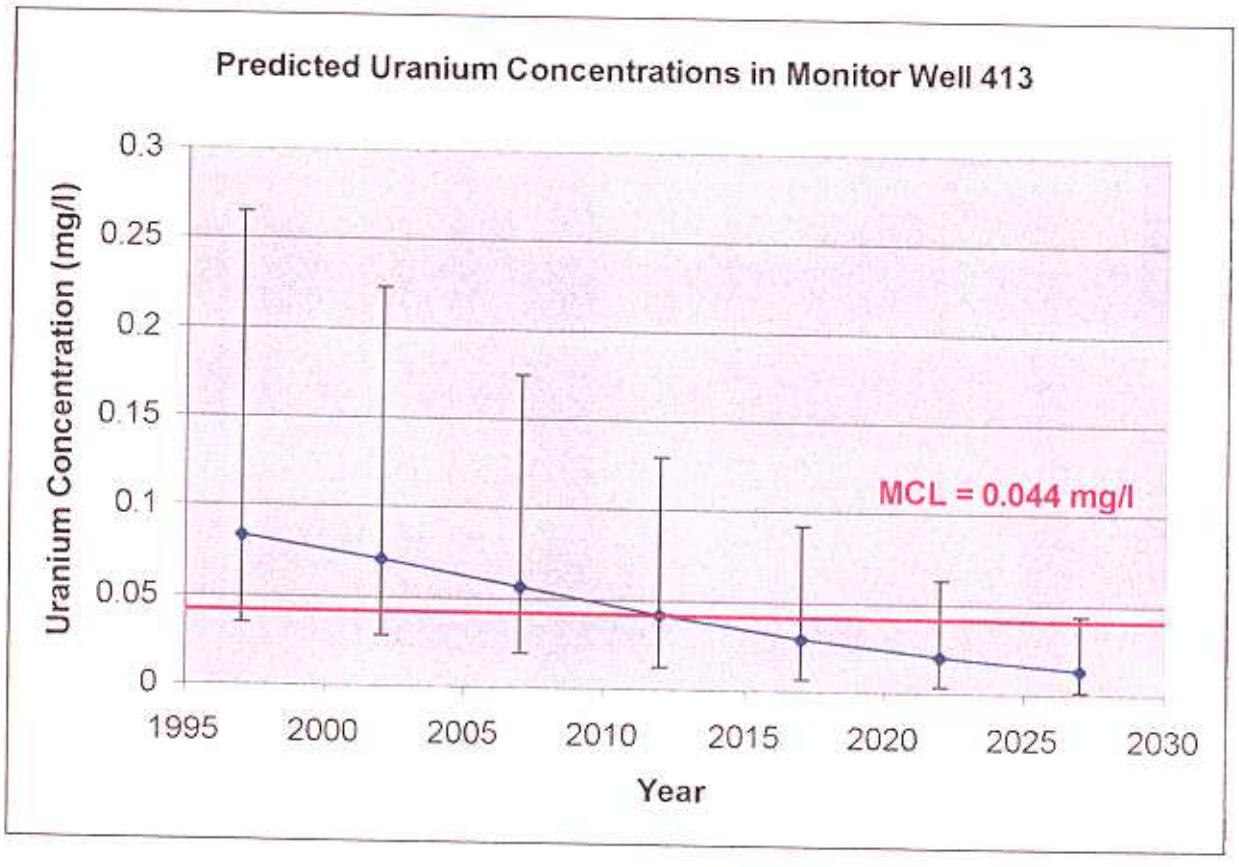


*Figure 4–2. Uranium Concentration Versus Time for Verification Monitoring in Well 413*

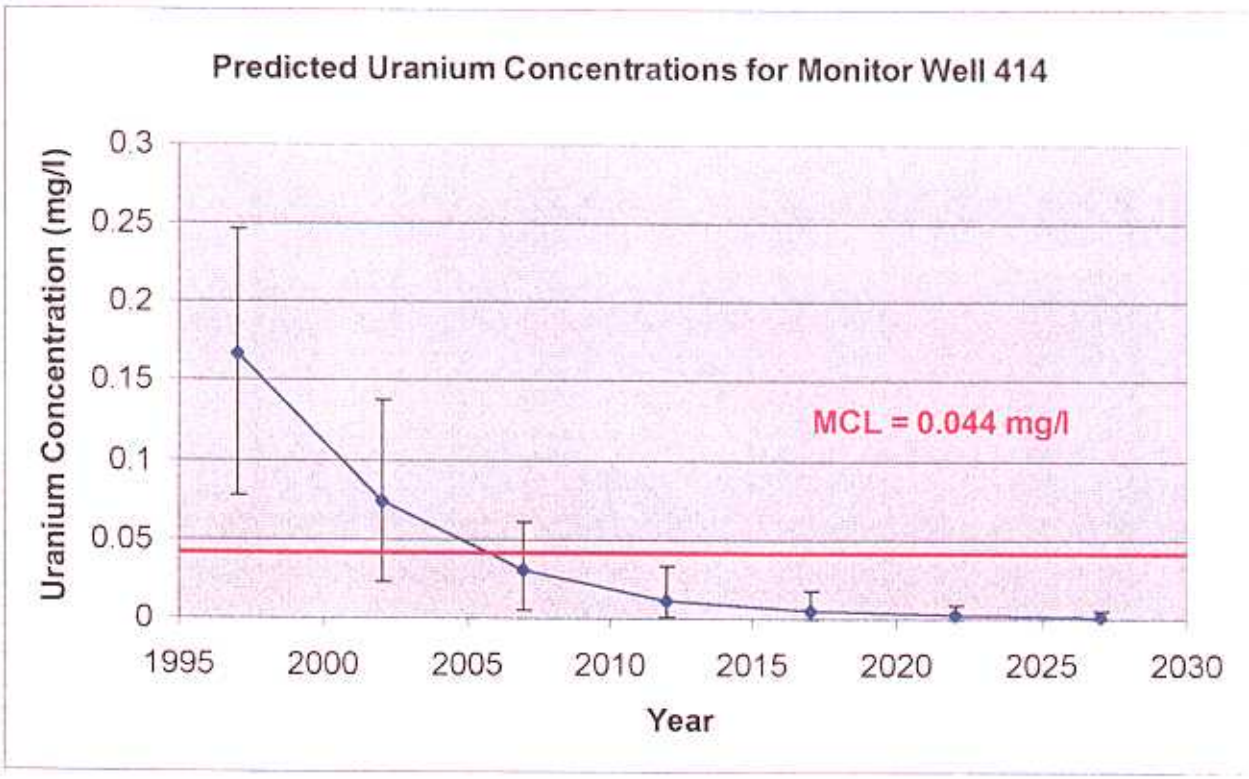


*Figure 4–3. Uranium Concentration Versus Time for Verification Monitoring in Well 414*

# 5.0 Summary and Conclusions

This document presents a proposal for no remediation in conjunction with an ACL for the compliance strategy at the Canonsburg, Pennsylvania, processing site. Remedial action was performed at the site in the mid-1980's to encapsulate contaminated soils and materials in an on-site disposal cell, eliminating the potential for further migration of the source materials. Residual contamination does exist in the ground water system at the site.

Ground water exists in shallow unconsolidated materials as well as in a deeper fractured bedrock unit. The unconsolidated aquifer is the unit of concern. The background ground water in the area is of poor quality and is not suitable as a drinking water source. Nearby residents receive drinking water from a public distribution system that uses surface water sources some distance away. There are no plans to use ground water as a drinking water source. The ground water yield at the site is also limited in terms of use as a public drinking-water source. Contaminant plumes cannot be accurately defined.

Uranium concentrations in the unconsolidated aquifer are above the MCL. Computer simulations suggest that contaminant concentrations will be attenuated by natural processes (e.g., dilution and dispersion), thus lowering concentrations of uranium to acceptable limits within 25 to 30 years. A stream-aquifer model was used to estimate the concentrations of uranium in surface water as a result of ground water discharging to Chartiers Creek. The model results suggest that surface water concentrations should be well below the MCL and ecological indicator limits. The conclusion that contaminated ground water will have a minimal effect on stream concentrations is supported by the surface-water monitoring data from Chartiers Creek.

An ACL application required identification of a POC, which is a monitoring location upgradient of the POE, where ground water concentrations will be monitored to ensure that the site is in compliance with the ACL requirements. Concentrations at the POC may be higher than the MCL as long as natural attenuation mechanisms between the POC and the POE allow for protection at the POE. Monitor wells 412, 413, and 414 are the proposed POC locations. An uncertainty analysis produced concentration ranges through time at each POC location. If future monitoring at these wells indicates that uranium concentrations are above the predicted ranges, the site will be reevaluated. The POE is defined such that human health and the environment are protected where exposures are most likely to occur. For the Canonsburg site, the POE is assumed to be Chartiers Creek. Surface water quality in Chartiers Creek is currently protective of human health and the environment, and modeling of the surface and ground water indicates this will continue.

The Canonsburg site meets the requirements for no remediation in conjunction with ACLs. However, the NRC requires a comparative analysis of the ACL approach with alternative corrective actions. The corrective action alternatives under consideration for the Canonsburg site are (1) a conventional pump-and-treat scenario for active cleanup of the aquifer and (2) a PeRT wall to remove uranium from ground water. If the cost of implementing a corrective action is greater than the benefits of the outcome, then the alternative may be inappropriate or inefficient. The cost for implementing a pump-and-treat system is approximately $1.1 million and the cost for a PeRT wall is approximately $1.7 million. Neither alternative provides any practical risk

reduction. Therefore, neither the pump-and-treat or the PeRT wall options would be an appropriate or efficient corrective action alternative.

## 5.1 Factors to be Considered for ACL Applications

The NRC considers a number of factors when reviewing an ACL application (Table 1 in the STP, NRC 1996). The list of factors below is from the Title I regulations [40 CFR 192.02(c)(3)(ii)(B)(1) and (2)], which differ slightly from those in the NRC Title II STP, and add another factor to the ground water quality list.

### 5.1.1 Potential Adverse Effects on Ground Water Quality

The following factors are from 40 CFR 192.02(c)(3)(ii)(B)(1)(*i* through *x*):

1. ***Physical and chemical characteristics of constituents in the residual radioactive material at the site, including their potential for migration***

   The characteristics of constituents in the residual radioactive material at the Canonsburg processing site have been identified, but some uncertainty exists regarding earlier operations and possible source materials (the last license issued at the site in 1961 was for storage of up to 23 tons of uranium contained in approximately 4,500 tons of material). Contaminated materials have been present at the site since the early part of the century. In the mid-1980s the site was remediated and approximately 172,000 $yd^3$ (132,000 $m^3$) of contaminated material on 30 acres (12 hectares) were placed in an on-site disposal cell, which effectively encapsulated the waste and prevented further leaching to ground water. Ground water is contaminated, however, and a probabilistic modeling analysis was performed to address the potential effects of contaminant migration. Concentrations of uranium, the COPC, are expected to attenuate naturally over the next 20 to 25 years and be within the MCL at that time. Migration to Chartiers Creek was also modeled and contaminant levels in the surface water are below the MCL.

2. ***Hydrogeological characteristics of the site and surrounding land***

   The uppermost aquifer at the Canonsburg site consists of unconsolidated materials overlying bedrock of the Pennsylvanian Casselman Formation. The unconsolidated materials consist of soil, clay, alluvium, and fill material, up to 30 ft (9 m) thick. These materials are heterogeneous and do not form discrete, continuous units. The permeability is variable because of the types and placement of the materials. The bedrock consists predominantly of gray siltstone and shale, with some interbedded limestone, and sparse coal seams. Ground water is present in the unconsolidated materials and in the shallow bedrock; the two lithologic units are hydraulically connected and ground water has a generally downward vertical gradient. Ground water occurs in the unconsolidated materials under unconfined (water table) conditions at depths ranging from 3 to 14 ft (0.9 to 4.3 m) beneath the ground surface.

3. ***Quantity of ground water and the direction of ground water flow***

Although ground water is present in the unconsolidated materials (uppermost aquifer) and shallow bedrock beneath the site, neither unit is considered a viable aquifer from a water resource perspective. Because the materials are not ideal for aquifer formation and the source of recharge to the shallow units is minimal, sustained yield from a well from these units is limited. Ground water in the unconsolidated materials generally flows from the Canonsburg site and discharges to adjacent Chartiers Creek, which is a gaining stream. The ground water velocity in the unconsolidated materials is estimated at approximately 4 ft per day ($1.4 \times 10^{-3}$ cm per second). The estimated volume of contaminated ground water at the Canonsburg site is 5.3 million gallons (20 million L).

4. ***Proximity and withdrawal rates of ground water users***

Ground water use at the site is currently prohibited; DOE and the Commonwealth of Pennsylvania maintain institutional controls to preserve this condition.

5. ***Current and future uses of ground water in the region surrounding the site***

Ground water is not currently used at the site. Use restrictions will continue until contaminant concentrations drop below protective levels, estimated to be between 20 to 25 years. Nearby residents are on a public water distribution system. Ground water wells in the unconfined aquifer within a one-mile radius of the site are used primarily for irrigating lawns or washing vehicles, but not for drinking water.

6. ***Existing quality of ground water, including other sources of contamination and their cumulative impact on ground water quality***

Some site-related contamination is in ground water in the uppermost aquifer (unconsolidated materials) downgradient from the disposal cell and adjacent to Chartiers Creek in the area of the main processing site, as well as in Area C, just east of the main site. The only constituent identified in ground water that is above the MCL is uranium. No other sources of ground water contamination are known to be present.

7. ***Potential for health risks caused by human exposure to constituents***

A baseline risk assessment was performed in 1995 for the Canonsburg site. Several exposure scenarios were analyzed. The only human health pathway of concern is drinking contaminated ground water. The site is under the control of DOE and the Commonwealth of Pennsylvania; those agencies will prohibit any use of ground water during the period of ACL application. The surface water exposures are within acceptable limits.

8. ***Potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to constituents***

The Canonsburg site was remediated during the mid-1980s; and contaminated materials were encapsulated in an on-site disposal cell. All physical structures were removed at that time.

Current potential effects on the ecology are mainly from the discharge of contaminated ground water to Chartiers Creek, where surface exposures may take place. No adverse effects have been observed.

*9. Persistence and permanence of potential adverse effects*

The original source of ground water contamination has been encapsulated in an on-site disposal cell. Existing contamination in the ground water is expected to migrate to nearby Chartiers Creek. Natural attenuation processes (e.g., dispersion and dilution) will probably decrease uranium concentrations to acceptable levels. A computer simulation of the contaminant migration indicates that uranium concentrations will be below the MCL in 20 to 25 years.

*10. Presence of underground sources of drinking water and exempted aquifers identified under 40 CFR 144.7 of this chapter*

There are no underground sources of drinking water and exempted aquifers near the site.

### 5.1.2 Potential Adverse Effects on Hydraulically Connected Surface-Water Quality

The following factors are from 40 CFR 192.02(c)(3)(ii)(B)(2)(*i* through *x*):

*1. Volume and physical and chemical characteristics of the residual radioactive material at the site*

The characteristics of the residual radioactive material at the Canonsburg processing site have been identified. In the mid-1980s the site was remediated; and contaminated materials were placed in an on-site disposal cell. The Canonsburg site is bounded on the west, north, and east sides by Chartiers Creek, which receives inflow from ground water at the site. Analysis of the simulation of potential contaminant migration from the ground water to the surface water indicates that the effect of this discharge is minimal. This is confirmed by results of the surface water sampling, which indicate no elevated levels of contaminants in the stream. Chartiers Creek has a discharge of about 90 to 130 $ft^3$ per second near the site, which is approximately five orders of magnitude greater than the amount of ground water discharge to the stream.

*2. Hydrogeological characteristics of the site and surrounding land*

See Factor 2 in Section 5.1.1.

*3. Quantity and quality of ground water, and the direction of ground water flow*

See Factors 3 and 6 in Section 5.1.1.

4. ***Patterns of rainfall in the region***

The average annual precipitation in the area is 38 inches (97 cm). March and June are generally the wettest months, each averaging 3.8 inches (10 cm); February and November are the driest, each averaging 2.4 inches (6 cm). The average annual snowfall in the area is 45 inches (114 cm).

5. ***Proximity of the site to surface waters***

The Canonsburg site is bounded on the west, north, and east by Chartiers Creek. Ground water in the uppermost aquifer discharges to this stream.

6. ***Current and future uses of surface waters in the region surrounding the site and any water quality standards established for those waters***

Water in Chartiers Creek is not a potable water resource because of its ambient contamination upstream of the site. Local residents use the creek for fishing, swimming, and wading. The types of fish found in the creek include carp, catfish, and bluegill. Aquatic benchmarks compiled by Oak Ridge National Laboratory for uranium in surface water range from 0.0026 to 0.142 mg/L. A statement in the BLRA that 8 mg/L in surface water is protective to aquatic life is based on a State of Colorado chronic water quality standard. It is proposed that a value of 0.01 mg/L be used at the Canonsburg site at the POE for the purpose of developing an ACL for uranium. This concentration is at the lower end of the benchmark range. Because safety factors are built into the development of benchmark criteria, 0.01 mg/L should be protective at the POE.

7. ***Existing quality of surface water, including other sources of contamination and their cumulative impact on surface water quality***

The water quality of Chartiers Creek has not been noticeably affected by the ground water discharging to the stream. The dilution potential approaches five orders of magnitude between ground water and surface water flows. Because of the large amount of coal mining and consequent acid mine drainage in the region, iron and manganese levels in the stream cannot be solely attributed to past activities at the Canonsburg site, and ACLs are not proposed for these constituents. No detrimental effects to human health and the environment have been observed within or along the river.

8. ***Potential for health risks caused by human exposure to constituents***

The baseline risk assessment for the Canonsburg site evaluated potential human exposures to contaminants in Chartiers Creek (DOE 1995b). The scenarios that were evaluated included incidental ingestion of surface water through recreational use, dermal contact with surface water through recreational use, incidental ingestion of sediments through recreational use, and ingestion of contaminated fish from Chartiers Creek. None of these scenarios pose a threat.

9. ***Potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to constituents***

   See Factor 8 in Section 5.1.1.

10. ***Persistence and permanence of the potential adverse effects***

    See Factor 9 in Section 5.1.1.

## 5.2 NRC Review Criteria and Procedures

The NRC has specific areas of review that are evaluated to justify an ACL application. These areas are defined in the NRC STP (NRC 1996).

### 5.2.1 Hazard-Assessment Review

1. ***Distribution and extent of hazardous constituents, as well as the potential for future releases of constituents***

   Contamination at the Canonsburg site is the result of decades of mill tailings activities and subsequent migration of contaminants through soil and ground water. A major restoration effort during the mid-1980s resulted in remediation of contaminated soil and placement of contaminated materials in an engineered disposal cell. The source materials are now isolated and stabilized. However, some residual ground water contamination exists, especially with regard to uranium. A probabilistic model was performed to evaluate the nature and extent of contamination, future concentrations of uranium in ground water, and the potential for ground water discharge into Chartiers Creek. Results of these analyses suggest that within 20 to 25 years natural attenuation will lower the concentration of uranium beneath the appropriate concentration limit set by EPA. During that time DOE and the Commonwealth of Pennsylvania will prohibit access to ground water at the site. Potential exposures in the creek are within acceptable limits.

2. ***Transport of hazardous constituents in ground water and hydraulically connected surface water***

   The probabilistic model performed to evaluate the migration potential of uranium in ground water and surface water at the site predicted that within 20 to 25 years concentrations should drop below the MCL due to natural attenuation processes (e.g., dilution and dispersion). Chartiers Creek has about 5 orders of magnitude greater flow than the shallow ground water system, thereby offering a tremendous potential for dilution. Uranium concentrations are below detection limits in the creek, which is considered the POE.

3. ***Risks associated with exposure of humans and the environment to hazardous constituents***

   The BLRA evaluated potential human exposures to contaminants that could enter Chartiers Creek by inflow of contaminated ground water (DOE 1995b). The scenarios that were

evaluated included incidental ingestion of surface water through recreational use, dermal contact with surface water through recreational use, incidental ingestion of sediments through recreational use, and ingestion of contaminated fish from Chartiers Creek. None of these scenarios pose a human health threat. Current potential effects on the ecology are mainly from the discharge of contaminated ground water to Chartiers Creek, where surface exposures may take place. The potential risks are deemed acceptable.

### 5.2.2 Corrective-Action Review

*1. Identification of alternatives*

Contaminated soils and materials associated with past processing activities at the Canonsburg site were remediated in the mid-1980s and placed in an on-site engineered disposal cell. Uranium concentrations in ground water downgradient from the disposal cell exceed the MCL, but are generally on a downward trend. Uranium has never been detected in surface water in Chartiers Creek. Even though there is currently no potential impact to human health and the environment because of site-related contamination in ground water downgradient from the Canonsburg site, alternative corrective action measures have been considered and evaluated as part of the ACL application. Practicable corrective actions for controlling, reducing, mitigating, or eliminating ground water contamination include (1) a conventional pump-and-treat scenario for active cleanup of the aquifer, (2) a PeRT wall to remove uranium from ground water, and (3) no remediation in conjunction with an ACL.

*2. Technical feasibility*

Efficient capture of contaminated ground water beneath the site may be a problem in a pump-and-treat system because of the restricted area to place pumping wells, the limited saturated thickness of the aquifer, and the close proximity to Chartiers Creek which may induce recharge to the aquifer from the stream. Assuming an adequate stream of contaminated water from the aquifer, treatment would be similar to that of the PeRT wall. Discharge of remediated ground water to Chartiers Creek or the nearby sewer system should not present a problem. There do not appear to be any engineering constraints for construction of a PeRT wall at the site. However, long-term effectiveness of the PeRT wall is uncertain since this is a relatively new technology. The no remediation alternative would require no additional activities at the site.

*3. Estimated costs and benefits*

The estimated cost of a pump-and-treat system at the site would be $1,112,000 and the estimated cost of a PeRT wall would be $1,700,000. From a cost-benefit perspective, the economic and risk-reduction benefits of performing an action should outweigh the cost of implementation. Concentrations of uranium at the point of exposure are at the low end of EPA's 10-4 to 10-6 risk range for carcinogens and are not expected to undergo any significant increase. As such neither the pump-and-treat system or the PeRT wall would provide practical risk reduction. Therefore, the costs of implementing either alternative would far outweigh the economic and risk-reduction benefits and neither would be considered an appropriate or efficient alternative. The only costs associated with the no

remediation alternative would be the ongoing monitoring of ground water and surface water at the site.

4. ***Selection of practicable corrective actions for controlling, reducing, mitigating, or eliminating ground water contamination***

The cost for implementing a pump-and-treat system is approximately $1.1 million and the cost for a PeRT wall is approximately $1.7 million. Neither alternative provides any practical risk reduction. Therefore, neither the pump-and-treat or the PeRT wall options would be an appropriate or efficient corrective action alternative. The Canonsburg site is already in compliance with the proposed ACL, as concentrations of uranium in ground water at the POC wells are already below the ACL, and uranium has never been detected in surface water at the POE in Chartiers Creek. Thus, there is no practicable reason to consider implementing any expensive and intensive corrective action alternative. Also, ground water in the vicinity is not a current or potential source of drinking water, alternative water supplies are readily available and in use in the area, and there is no problem with potential exposure of contaminated ground water. Therefore, based on current and predicted conditions at the site and evaluation of the identified alternatives, no remediation in conjunction with an ACL for uranium is the preferred alternative for the compliance strategy to meet ground water protection standards at the Canonsburg site. This alternative is the most cost effective, providing maximum benefit and protection of human health and the environment.

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End of current text

# Appendix A
# Monitor Well Information

Lithologic logs and well completion records will be included in final report.

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WESTON

## DRILLING LOG

WELL NUMBER: 401 (H-1)
LOCATION: _____
_____
_____
SURFACE ELEVATION: _____
DRILLING COMPANY: Terra Testing
DRILLER: B. Bright
LOG BY: W. Balmer

OWNER: A. Maceyko
ADDRESS: 12 Latimer Avenue
TOTAL DEPTH 12.9
WATER LEVEL: 3.2
DRILLING METHOD: HSA
DATE DRILLED: 12/28/82
HELPER: R. Lawrence

SKETCH MAP

NOTES:
S/SP - Split Spoon
R - Recovery

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| 0 | | 401 | S/SP | 3,3 | Gravelly, sandy clay, CL, light olive-brown, |
| 1 | | 0.0 | R= 13/24 | 2,3 | 2.5Y5/4, dry to slightly moist, stiff, low |
| | | 2.0 | | | plasticity, some limonite staining |
| 3 | | | | | |
| 4 | | | | | |
| 5 | CL | 401 | S/SP | 4,6 | Sandy, silty clay, CL, reddish gray, 5YR5/2, intermixed |
| 6 | | 5.0 | R= 20/24 | 7,9 | with light gray (10YR7/1) CL, clay blebs, stiff, dry to slightly moist, low plasticity, oxidized root fibers |
| 7 | | | | | is this Cover? over Coal lenses |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |

* A.S.T.M. D1586

WESTON

## DRILLING LOG

WELL NUMBER: 401 (H-1) OWNER:
LOCATION: ADDRESS:
TOTAL DEPTH
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: DRILLING METHOD: DATE DRILLED:
DRILLER: HELPER:
LOG BY:

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| 10 | | 401 | S/SP | 2,6 | Gravelly, sandy clay, CL, light brownish-gray (10YR6/2), |
| | | 10.0 | R=17 | 6,7 | soft, moist, plastic, mixed with oxidized root fibers; |
| 11 | | 12.0 | 24 | | at 11.0 CL mixture with lignitic shale fragments exhi- |
| | | | | | biting horizontal partings, regolith |
| 1- | | 401 | S/SP | | Gritty, lignitic shale bedrock, very dark gray, 5YR3/1, |
| | | 12.6 | R=5/5 | 50/0.5 | very hard, auger refusal. |
| | | 12.11 | | | End of boring at 12.9 |

* A.S.T.M. D1586

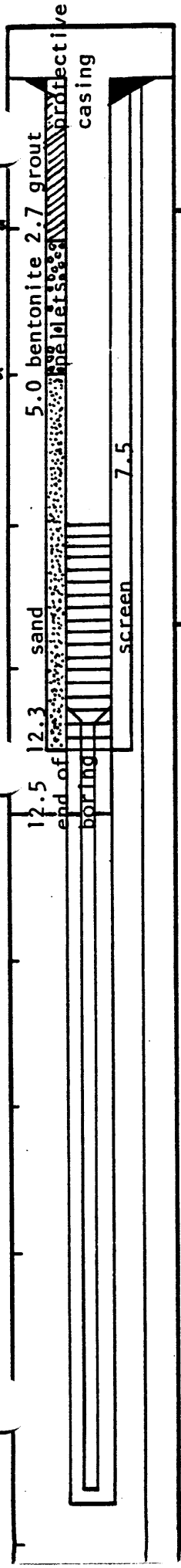
Well 401 (H1)

# Well Construction Summary

Location or Coords: Maceyko property southeast of Area A

Elevation: Ground Level

Top of Casing




Location

Personnel J. Barone/W. Balmer

## Drilling Summary:

Total Depth 12.5 ft

Borehole Diameter 0.5 ft

Driller B. Bright
Terra Testing

Rig CME 55

Bit(s) HSA

Drilling Fluid N/A

Surface Casing 0.5 ft steel

## Well Design:

Basis: Geologic Log XX Geophysical Log

Casing String(s): C=Casing S=Screen

| | | | | | |
|---|---|---|---|---|---|
| +1.1 | 7.5 | C1 | | | |
| 7.5 | 12.2 | S1 | | | |

Casing: C1 4" ABS Sch 40 w/ threaded couplings

C2

Screen: S1 4" ABS Sch 80 w/ threaded couplings; #10 slots

S2

Centralizers N/A

Filter Material #1 sorted sand to 5.0 ft--2.5 ft above the top of the screen

Cement Portland

Other a) bentonite pellets from 5.0 to 2.7 ft; b) grout of bentonite/cement to surface; c) protective casing set in cement at surface

## Construction Time Log:

| Task | Start Date | Start Time | Finish Date | Finish Time |
|---|---|---|---|---|
| Drilling: | 1982 12/28 | 0825 | 12/28 | 0935 |
| Geophys. Logging: | N/A | | N/A | |
| Casing: | 1982 12/28 | 0952 | 12/28 | -- |
| Filter Placement: | " | 1003 | " | -- |
| Cementing: | " | 1037 | " | -- |
| Development: | 1/4/83 | 1442 | 1/4/83 | 1527 |
| Other: | | | | |

## Well Development:

developed by bailing to dryness; total withdrawn = 9 gal

## Comments:

WESTON

WESTON

## DRILLING LOG

WELL NUMBER: 402 (H-2)
LOCATION: End of George Avenue
OWNER: Canonsburg EIS
ADDRESS:
TOTAL DEPTH: 10.5
SURFACE ELEVATION:
WATER LEVEL:
DRILLING COMPANY: Terra Testing
DRILLING METHOD: Auger
DATE DRILLED: 12/28/82
DRILLER: B. Bright
HELPER: B. Lawrence
LOG BY: W. Balmer

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| 0 | CL | 402 | S/SP | 1,2 | Sandy clay, CL, dark brown to yellowish-brown |
| 1 | | 0.0 | R=13/24 | 2,3 | (7.5YR3/2 to 10YR5/6), increasing moisture with depth, soft, low plasticity, limonite staining on shale fragments |
| 3 | | | | | |
| 4 | | | | | |
| 5 | Regolith | 402 | R=9/9 | 50/0.3 | Silty shale, light gray, 10YR7/2 some CL clay, |
| 6 | | 5.0 | | | horizontal partings, limonite coatings on some |
| | | 7.0 | | | shale fragments |
| 7 | | | | | |
| 8 | | | | | |

* ASTM D1586

WESTON

## DRILLING LOG

WELL NUMBER: 402 (H-2)
LOCATION: _____
_____
_____
SURFACE ELEVATION: _____
DRILLING COMPANY: _____
DRILLER: _____
LOG BY: _____

OWNER: _____
ADDRESS: _____
_____
TOTAL DEPTH _____
WATER LEVEL: _____
DRILLING METHOD: _____
DATE DRILLED: _____
HELPER: _____

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| | Bedrock | 401 | S/SP | | Silty shale, gray, bedrock with limonite partings |
| 10.0 | | | R= 6/6 | 50/0.5 | some layers highly coated, auger refusal, bedrock |
| 12.0 | | | | | End of boring at 10.5 |

* A.S.T.M. D1586

Well 402 (H2)

# Well Construction Summary

Location or Coords: Smigiel property southwest of Area A

Elevation: Ground Level

Top of Casing

Personnel J. Barone/W. Balmer

## Drilling Summary:

Total Depth 10.0 ft

Borehole Diameter 0.5 ft

Driller B. Bright, Terra Testing

Rig CME 55

Bit(s) HSA

Drilling Fluid N/A

Surface Casing 0.5 ft steel

## Well Design:

Basis: Geologic Log XX Geophysical Log

Casing String(s): C=Casing S=Screen

| | | | | | |
|---|---|---|---|---|---|
| +1.1 | 3.0 | C1 | | | |
| 3.0 | 10.0 | S1 | | | |

Casing: C1 4" ABS Sch 40 w/ threaded couplings

C2

Screen: S1 4" PVC Sch 80 w/ threaded couplings; #10 slots

S2

Centralizers N/A

Filter Material #1 sorted sand to 2.0 ft--1.0 ft above the top of the screen

Cement Portland

Other a) bentonite pellets from 1.0 to 2.0 ft; b) grout of bentonite/cement to surface; c) protective casing set in cement at surface

## Construction Time Log:

| Task | Start Date | Start Time | Finish Date | Finish Time |
|---|---|---|---|---|
| Drilling: | 1982 12/29 | 0852 | 1982 12/29 | 0926 |
| Geophys. Logging: | N/A | | N/A | |
| Casing: | 1982 12/29 | 1006 | 1982 12/29 | -- |
| Filter Placement: | " | 1006 | " | -- |
| Cementing: | " | -- | " | -- |
| Development: | N/A | | N/A | |
| Other: | | | | |

## Well Development:

no development; well is clear of fluids

## Comments:

WESTON

WESTON

## DRILLING LOG

WELL NUMBER: 405 (H-5) OWNER: Canonsburg EIS
LOCATION: Payne Methodist Church ADDRESS:
TOTAL DEPTH 14.3
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: Terra Testing DRILLING METHOD: Auger DATE DRILLED: 12/30/82
DRILLER: B. Bright HELPER: B. Lawrence
LOG BY: W. Balmer

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| 0 | | 405 0.0 | S/ SP | 2,2 | 0.5 of topsoil dark grayish-brown, 10YR4/2; at 0.5 |
| 1 | | 2.0 | R= 10/ 24 | | sandy clay, CL, yellowish brown to black (10YR5/6 |
| | | | | | to 10YR2/1), dry to slightly moist, stiff, low plas- |
| 2 | | | | | ticity, brick and cinder rubble admixture, fill |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | 405 5.0 | R= 22/ 24 | 9,25 | Carbonaceous shale and coal, black (10YR2.1) semi- |
| 6 | | 7.0 | | 50/ 0.3 | consolidated, lignitic shale, very fractured, dry to |
| | | | | | moist, non-plastic, weathered bedrock |
| 7 | | | | | |
| 9 | | | | | |
| 10 | | | | | |

* A.S.T.M. D1586

WESTON

## DRILLING LOG

405

WELL NUMBER: (H-5) (cont) OWNER: _____

LOCATION: _____ ADDRESS: _____

_____ _____

_____ TOTAL DEPTH _____

SURFACE ELEVATION: _____ WATER LEVEL: _____

DRILLING COMPANY: _____ DRILLING METHOD: _____ DATE DRILLED: _____

DRILLER: _____ HELPER: _____

LOG BY: _____

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| 10 | | 405 10.0 | S/ SP | 23, 30 | Coal and lignitic shale, black, 10YR2/1, very soft |
| | | 12.0 | R= 20/ 24 | 15, 14 | moist, no plasticity, some gray clay as admixture, |
| 11 | | | | | weathered bedrock |
| 12 | | | | | |
| 13 | | | | | |
| 14 | | 405 14.0 | S/ SP | 50/ 0.3 | Sandy, silty shale, gray, 10YR5/1, hard, some |
| | | 16.0 | R= 4/4 | | partings, bedrock, auger refusal |
| | | | | | End of boring at 14.3 |

* A.S.T.M. D1586

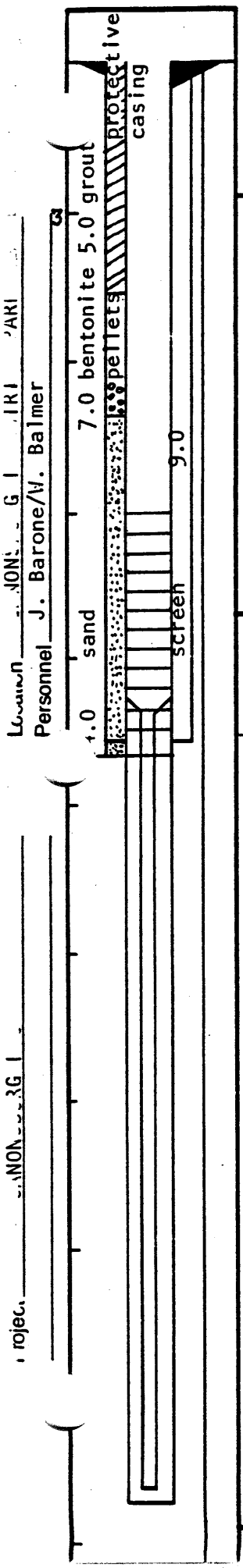
Well 405 (H5)

# Well Construction Summary

Location or Coords: PAME Church cemetery

Elevation: Ground Level

Top of Casing




Location J. Barone/W. Balmer

Personnel

Project

## Drilling Summary:

Total Depth 14.0 ft

Borehole Diameter 0.5 ft

Driller B. Bright
Terra Testing

Rig CME 55

Bit(s) HSA

Drilling Fluid N/A

Surface Casing 0.5 ft steel

## Well Design:

Basis: Geologic Log XX Geophysical Log

Casing String(s): C=Casing S=Screen

| | | | | | |
|---|---|---|---|---|---|
| +0.1 | 9.0 | C1 | | | |
| 9.0 | 14.0 | S1 | | | |

Casing: C1 4" ABS Sch 40 w/ threaded couplings

C2

Screen: S1 4" PVC Sch 80 w/ threaded couplings; #10 slots

S2

Centralizers N/A

Filter Material #1 sorted sand to 7.0 ft--2.0 ft above the top of the screen

Cement Portland

Other a) bentonite pellets from 5.0 to 7.0 ft; b) grout of bentonite/cement to surface; c) protective casing set in cement at surface

## Construction Time Log:

| Task | Start Date | Start Time | Finish Date | Finish Time |
|---|---|---|---|---|
| Drilling: | 1982 12/30 | 1043 | 1982 12/30 | 1156 |
| Geophys. Logging: | N/A | | N/A | |
| Casing: | 1982 12/30 | 1350 | 1982 12/30 | -- |
| Filter Placement: | " | 1350 | " | -- |
| Cementing: | " | 1350 | " | -- |
| Development: | 1/12/83 | -- | 1/12/83 | -- |
| Other: | | • | | |

## Well Development:

developed by bailing to dryness; total withdrawl = 6 gal

## Comments:

WESTON

WESTON

## DRILLING LOG

WELL NUMBER: 406 (H-6) OWNER: Canonsburg EIS

LOCATION: Near Substation off Strabam Road ADDRESS:

TOTAL DEPTH 15.2

SURFACE ELEVATION: WATER LEVEL: 3.6

DRILLING COMPANY: Terra Testing DRILLING METHOD: Auger DATE DRILLED: 12/22/82

DRILLER: B. Bright HELPER: B. Lawrence

LOG BY: W. Balmer

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| 0 | | 406 0.0 | S/SP | 2,2 | Sandy clay fill, CL, dark grayish-brown, 10YR4/2, moist, low plasticity, stiff, admixture of brick and cinder |
| 1 | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| 3 | | | | | |
| | | | | | |
| 4 | | | | | |
| | | | | | |
| 5 | | 406 5.0 | S/SP | 1 | Sandy silty clay, CL, olive gray, 5Y4/2, high plasticity, soft, moist to wet, admixture of red shale fragments and micaceous shale fragments, water level stabilized at 3.5 feet below ground surface |
| | | 7.0 | R= 20/24 | 3 | |
| 6 | | | | 1 | |
| | | | | | |
| 7 | | | | | |
| | | | | | |
| 8 | | | | | |
| | | | | | |
| 9 | | | | | |
| | | | | | |
| 10 | | | | | |

* A.S.T.M. D1586

WESTON

## DRILLING LOG

406

WELL NUMBER: (H-6) (cont)
LOCATION:
OWNER:
ADDRESS:
TOTAL DEPTH
SURFACE ELEVATION:
WATER LEVEL:
DRILLING COMPANY:
DRILLING METHOD:
DATE DRILLED:
DRILLER:
HELPER:
LOG BY:

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| 10 | | 406 10.0 | S/ SP | 1,1 | Silty clay, CL, dark olive gray, 5Y3/2, moist |
| | | 12.0 | R= 24/ 24 | 1 | to wet, very soft, some organic laminae and roots, |
| 11 | | | | 1 | fragments of red shale |
| 12 | | | | | |
| 13 | | | | | |
| 14 | | | | | |
| 15 | | 406 15.0 | S/ SP | 50/ 0.2 | Shale bedrock, very dark gray, 5Y3/1, dry, friable, |
| | | 17.0 | R= 3/3 | | horizontal partings, auger refusal |
| | | | | | End of boring at 15.2 |

* A.S.T.M. D1586

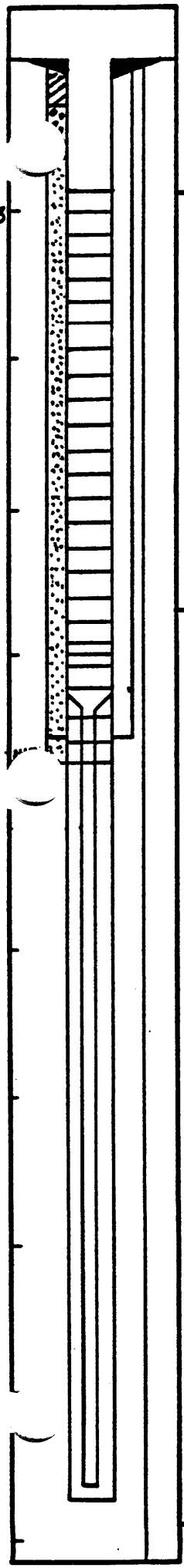
Well 406 (H6)

# Well Construction Summary

Location or Coords: West Penn Power Substation

Elevation: Ground Level

Top of Casing




## Drilling Summary:

Total Depth 14.3 ft
Borehole Diameter 0.5 ft
Driller B. Bright
Terra Testing
Rig CME 55
Bit(s) HSA
Drilling Fluid N/A
Surface Casing 0.5 ft steel

## Well Design:

Basis: Geologic Log XX Geophysical Log

Casing String(s): C=Casing S=Screen

| | | | | | |
|---|---|---|---|---|---|
| +1.3 | 2.7 | C1 | | | |
| 2.7 | 12.0 | S1 | | | |
| 12.0 | 14.3 | S1 | | | |

Casing: C1 4" ABS Sch 40 w/ threaded couplings
C2

Screen: S1 4" PVC Sch 80 w/ threaded couplings and #10 slots
S2

Centralizers N/A

Filter Material #1 sorted sand to 2.0ft--0.7 ft above the top of the screen

Cement Portland

Other a) bentonite pellets from 1.0 to 2.0 ft; b) cement to surface; c) protective casing set in cement at surface

## Construction Time Log:

| Task | Start Date | Start Time | Finish Date | Finish Time |
|---|---|---|---|---|
| Drilling: | 1982 12/22 | 1040 | 1982 12/22 | 1138 |
| Geophys. Logging: | N/A | | N/A | |
| Casing: | 1982 12/22 | -- | 1982 12/22 | -- |
| Filter Placement: | " | -- | " | -- |
| Cementing: | " | 1330 | " | 1445 |
| Development: | 1/5/83 | -- | 1/5/83 | -- |
| Other: | | | | |

## Well Development:

developed by bailing to dryness; total withdrawl = 22 gal

## Comments:

WESTON

WESTON

## DRILLING LOG

WELL NUMBER: 407 (H-7)
OWNER: Canonsburg EIS
LOCATION: Behind Rax, North Side
ADDRESS:
TOTAL DEPTH 19'
SURFACE ELEVATION:
WATER LEVEL:
DRILLING COMPANY: Brooks GeoProbe
DRILLING METHOD: HSA
DATE DRILLED: 12/21/82
DRILLER: J. Pappert
HELPER: F. Mallow
LOG BY: W. Balmer

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| 0 | | 407/ 0.0 | S/ SP | | No sample possible - construction rubble, |
| 1 | | 2.0 | R= 0 | | concrete and parking lot |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | Fill | | | | Sandy silty clay, CL, very dark grayish-brown to |
| 6 | | | | | black, 2.5Y3/2 to 2.5Y2/0, low plasticity, soft, |
| 7 | | | | | low stiffness, moist, mixed with brick and rubble |
| 8 | | | | | fragments, fill |
| 9 | | | | | |

* A.S.T.M. D1586

SHEET ___ OF ___

WESTON

## DRILLING LOG

407

WELL NUMBER: (H-7) (cont) OWNER:

LOCATION: ADDRESS:

TOTAL DEPTH

SURFACE ELEVATION: WATER LEVEL:

DRILLING COMPANY: DRILLING METHOD: DATE DRILLED:

DRILLER: HELPER:

LOG BY:

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| 10 | CL | 407 10.0 | S/ SP | 1,1 | As above, moist to wet, water stabilized |
| | | 12.0 | R= 6/ 24 | 1,2 | in auger to 8.0 |
| 11 | | | | | |
| 13 | | | | | |
| 14 | | | | | |
| 15 | | | | | CL clay as as above, no rubble fragments, very |
| 16 | Regolith | | | | soft, wet, plastic, leaf and root fragments; at 16.5 black to dark greenish-gray shale fragments |
| 17 | | | | | with horizontal partings, regolith |
| 18 | | | | | |
| 19 | | | | | End of boring at 19.0 |

SHEET OF

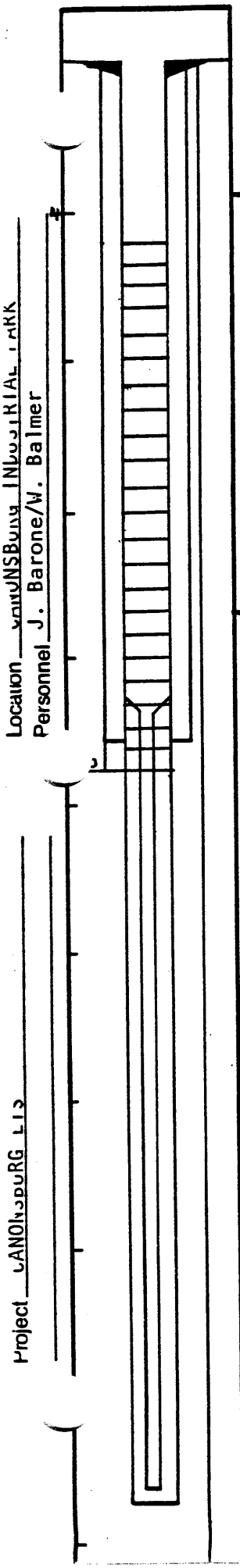
Well 407 (H7)

# Well Construction Summary

Location or Coords: property of the Loyal Order of Moose on W. Pike St.

Elevation: Ground Level _____

Top of Casing _____




## Drilling Summary:

Total Depth 19.0 ft

Borehole Diameter 0.8 ft

Driller J. Pappert
Brooks Geoprobe

Rig Mobile Drill B-80

Bit(s) HSA

Drilling Fluid N/A

Surface Casing 0.5 ft steel

## Well Design:

Basis: Geologic Log XX Geophysical Log ____

Casing String(s): C=Casing S=Screen

| | | | | | |
|---|---|---|---|---|---|
| +2.4 | 4.6 | C1 | | | |
| 4.6 | 9.3 | S1 | | | |
| 9.3 | 19.0 | S1 | | | |

Casing: C1 4" ABS Sch 40 w/ threaded couplings

C2 _____

Screen: S1 4" PVC Sch 80 w/ threaded couplings

S2 _____

Centralizers _____

Filter Material _____

Cement _____

Other _____

## Construction Time Log:

| Task | Start Date | Start Time | Finish Date | Finish Time |
|---|---|---|---|---|
| Drilling: | | | | |
| | | | | |
| | | | | |
| | | | | |
| Geophys. Logging: | | | | |
| Casing: | | | | |
| | | | | |
| | | | | |
| | | | | |
| Filter Placement: | | | | |
| Cementing: | | | | |
| Development: | 1/12/83 | -- | /12/83 | -- |
| Other: | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

## Well Development:

developed by pumping with a surface, centrifugal pump; total withdrawl = 9 gal

## Comments:

WESTON

WESTON

## DRILLING LOG

WELL NUMBER: 408 (H-8)
LOCATION: West Area A
West side Chartiers Creek
Stenger property
SURFACE ELEVATION: _____
DRILLING COMPANY: Terra Testing
DRILLER: B. Bright
LOG BY: J. Barone

OWNER: J. Stenger
ADDRESS: Mobil Station
West Pike Street
TOTAL DEPTH 20
WATER LEVEL: _____
DRILLING METHOD: HSA
HELPER: R. Lawrence
DATE DRILLED: 1/11/83

SKETCH MAP

NOTES:
SS - Split spoon
R - Recovery

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| 0 | ML/CL | H-8 0.0 | SS | 5 | Fine sandy silt; ML/CL |
| | | 2.0 | R= 10/24 | 4 | 10YR4/2, dark grayish-brown |
| 1 | | | | 8 | Non-plastic, stiff and friable |
| | | | | 6 | Mottled, dry, fill |
| | | | | | |
| | | | | | |
| 3 | | | | | |
| | | | | | |
| 4 | | H-8 5.0 | SS | 9 | Gravel-silt-clay, CL |
| | | 7.0 | R= 6/24 | 4 | 10YR5/2, grayish-brown |
| 5 | CL | | | 2 | Non-plastic, stiff and friable to loose |
| | | | | 3 | Mottled, dry, fill |
| 6 | | | | | |
| | | | | | |
| 7 | | | | | |
| | | | | | |
| 8 | | | | | |
| | | | | | |
| 9 | | | | | |
| | | | | | |
| 10 | | | | | |

* A.S.T.M. D1586

WESTON

## DRILLING LOG

408

WELL NUMBER: (H-8) (cont)
LOCATION: _____
_____
_____
SURFACE ELEVATION: _____
DRILLING COMPANY: _____
DRILLER: _____
LOG BY: _____

OWNER: _____
ADDRESS: _____
_____
TOTAL DEPTH _____
WATER LEVEL: _____
DRILLING METHOD: _____
DATE DRILLED: _____
HELPER: _____

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| 10 | | H-8 | SS | 1 | Silty clay, CL |
| | | 10.0 | | 1 | 5Y4/1, dark gray |
| 11 | | 12.0 | | 2 | Moderately plastic, low to moderate stiffness |
| | | | | 3 | Low moisture, mottled, alluvium |
| 12 | | | | | |
| | | | | | |
| 13 | | | | | |
| | | | | | |
| 14 | | | | | |
| | | | | | |
| 15 | | | | | |
| | | 15.0 | SS | 1 | Gravelly, clayey silt, CL |
| | CL | 17.0 | R= 19/24 | 2 | 5Y3/1, very dark grey |
| 16 | | | | 5 | Low plasticity, low stiffness |
| | | | | 5 | Mottled, saturated, alluvium |
| 17 | | | | | |
| | | | | | |
| 18 | | | | | |
| | | | | | |
| 19 | | | | | |
| | | | | | |
| 20 | | | | | |

* A.S.T.M. D1586



KP

WESTON

## DRILLING LOG

408

WELL NUMBER: (H-8) (cont)
LOCATION: _____
_____
_____
SURFACE ELEVATION: _____
DRILLING COMPANY: _____
DRILLER: _____
LOG BY: _____

OWNER: _____
ADDRESS: _____
_____
TOTAL DEPTH _____
WATER LEVEL: _____
DRILLING METHOD: _____
DATE DRILLED: _____
HELPER: _____

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| 20 | Bedrock | H-8 | SS | 50/0.25 | Weathered shale |
| | | 20.0 | R= | | 5Y4/2 olive gray |
| | | 22.0 | 3/3 | | Non-plastic, moderate to high stiffness |
| | | | | | friable, dry |
| | | | | | End of boring at 20 feet below grade |

* A.S.T.M. D1586

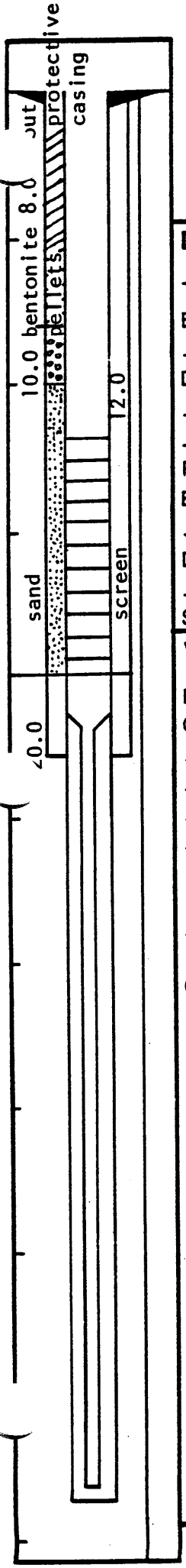
Well 408 (H8)

# Well Construction Summary

Location or Coords: Mobil Station on W. Pike St.; Stenger property

Elevation: Ground Level

Top of Casing




## Drilling Summary:

Total Depth 20.0 ft

Borehole Diameter 0.5 ft

Driller B. Bright, Terra Testing

Rig CME 55

Bit(s) HSA

Drilling Fluid N/A

Surface Casing 0.5 ft steel

## Well Design:

Basis: Geologic Log XX Geophysical Log

Casing String(s): C=Casing S=Screen

| | | | | | |
|---|---|---|---|---|---|
| +1.0 | 3.3 | C1 | | | |
| 3.3 | 12.0 | C1 | | | |
| 12.0 | 20.0 | S1 | | | |

Casing: C1 4" ABS Sch 40 w/ threaded couplings

C2

Screen: S1 4" PVC Sch 80 w/ threaded couplings; #10 slots

S2

Centralizers N/A

Filter Material #1 sorted sand to 10.0 ft - 2.0 ft above top of screen

Cement Portland

Other a) bentonite pellets from 8.0 to 10.0 ft; b) cement/bentonite grout to surface; c) protective casing set in cement at surface

## Construction Time Log:

| Task | Start Date | Start Time | Finish Date | Finish Time |
|---|---|---|---|---|
| Drilling: | 1983 1/11 | 0850 | 1983 1/11 | 1020 |
| Geophys. Logging: | N/A | | N/A | |
| Casing: | 1983 1/11 | 1020 | 1983 1/11 | 1210 |
| Filter Placement: | " | -- | " | -- |
| Cementing: | " | -- | " | 1210 |
| Development: | | | | |
| Other: | | | | |

## Well Development:

## Comments:

1/10

WESTON

WESTON

## DRILLING LOG

WELL NUMBER: 409 (H-9)
LOCATION: Behind the Post Office Near 503
OWNER: S. Twardy
ADDRESS: 160 Alexander Avenue
TOTAL DEPTH: 19
SURFACE ELEVATION:
WATER LEVEL:
DRILLING COMPANY: Brooks GeoProbe
DRILLING METHOD: Air Rotary
DATE DRILLED: 1/27/83
DRILLER: B. Bright
HELPER: F. Mallow
LOG BY: J. Barone

SKETCH MAP

NOTES: SS-Split Spoon, R-Recovery. Overburden description made during drilling of adjacent Boring 503 (S-3)

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| 0 | | S-3 0.0 | SS | 3 | Clayey silt, ML |
| | | 2.0 | R= 24/24 | 3 | 10YR3/3, dark brown |
| 1 | | | | 4 | Low plasticity, low to moderate stiffness |
| | | | | 5 | Low to moderate moisture, mottled, alluvium |
| | | | | | |
| | | | | | |
| 3 | | | | | |
| | | | | | |
| 4 | ML | | | | |
| | | | | | |
| 5 | | | | | |
| | | S-3 | SS | 8 | Clayey silt, ML |
| | | 5.0 | R= 24/24 | 8 | 10YR5/4, yellowish-brown |
| 6 | | 7.0 | | 12 | Low plasticity, low to moderate stiffness |
| | | | | 17 | Low to moderate moisture, mottled, alluvium |
| 7 | | | | | |
| | | | | | |
| 8 | | | | | |
| | | | | | |
| 9 | | | | | |
| | | | | | |
| 10 | | | | | |

* ASTM D1586

WESTON

## DRILLING LOG

409

WELL NUMBER: (H-9) (cont)
LOCATION:
OWNER:
ADDRESS:
TOTAL DEPTH
SURFACE ELEVATION:
WATER LEVEL:
DRILLING COMPANY:
DRILLING METHOD:
DATE DRILLED:
DRILLER:
HELPER:
LOG BY:

SKETCH MAP

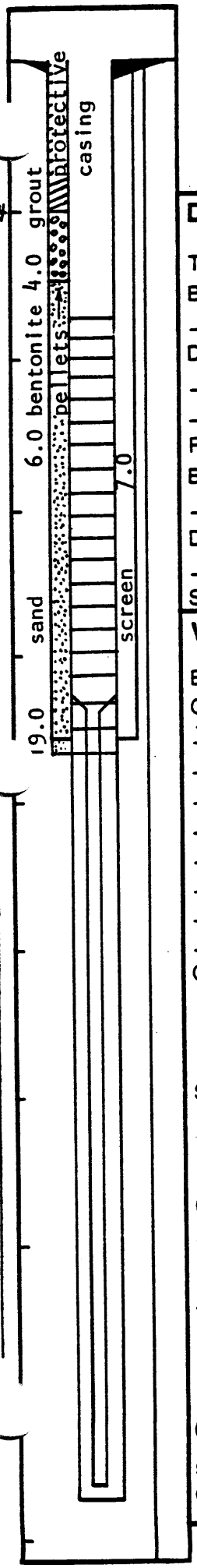
NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| 10 | ML | S-3 10.0 | SS | 10 | Fine, sandy, clayey silt, ML |
| | | 12.0 | R= 24/ 24 | 20 | 10YR5/2, grayish-brown |
| 11 | | | | 20 | Low plasticity, moderate to high stiffness |
| | | | | 19 | Very low moisture, friable |
| | | | | 28 | Fragments of coal-low percentage, alluvium |
| 13 | | | | | |
| 14 | | | | | |
| 15 | | S-3 15.0 | SS | 50/ 3 | Weathered shale |
| | | 17.0 | 6/ 8 | | 10YR1/3, very pale brown |
| 16 | | | | | Dry, friable, iron-stained |
| | | | | | End of boring at 16 |
| 17 | Bedrock | | | | |
| | | | | | Note: 409 completed at 19 feet, 3 feet into rock |
| 18 | | | | | |
| 19 | | | | | |
| 20 | | | | | |

* A.S.T.M. D1586

Well 409 (H9)

# Well Construction Summary




Location or Coords: Twardy property south of Area A

Elevation: Ground Level

Top of Casing

## Drilling Summary:

Total Depth 19.0 ft

Borehole Diameter 0.5 ft

Driller B. Bright
Brooks Geoprobe

Rig Mobile Drill B-80
tri-cone roller

Bit(s)

Drilling Fluid N/A

Surface Casing 0.5 ft steel

## Well Design:

Basis: Geologic Log XX Geophysical Log

Casing String(s): C=Casing S=Screen

| | | | | | |
|---|---|---|---|---|---|
| +1.0 | 7.0 | C1 | | | |
| 7.0 | 16.7 | S1 | | | |
| 16.7 | 19.0 | S1 | | | |

Casing: C1 4" ABS Sch 40 w/ threaded couplings

C2

Screen: S1 4" PVC Sch 40 w/ threaded couplings; #10 slots

S2

Centralizers N/A

Filter Material #1 sorted sand to 6.0 ft--1.0 ft above the top of the screen

Cement Portland

Other a) bentonite pellets from 4.0 to 6.0 ft; b) cement/bentonite grout to surface; c) protective casing set in cement at surface

## Construction Time Log:

| Task | Start Date | Start Time | Finish Date | Finish Time |
|---|---|---|---|---|
| Drilling: | 1983 1/26 | 1405 | 1983 1/26 | 1545 |
| Geophys. Logging: | N/A | | N/A | |
| Casing: | 1983 1/27 | 0930 | 1983 1/27 | -- |
| Filter Placement: | " | -- | " | -- |
| Cementing: | " | -- | " | 1100 |
| Development: | 1/28 | -- | 1/28 | -- |
| Other: | | | | |

## Well Development:

developed by pumping with a surface, centrifugal pump; total withdrawl = 5 gal

## Comments:

WESTON

WESTON

## DRILLING LOG

WELL NUMBER: 410 (H-10)
LOCATION: end of Selwyn Ave South of Site
SURFACE ELEVATION:
DRILLING COMPANY: Tectra Testing
DRILLER: B.Bright
LOG BY: W. T. Balmer

OWNER: Canonsburg EIS
ADDRESS:
TOTAL DEPTH 17.6
WATER LEVEL:
DRILLING METHOD: HSA
HELPER: R. Lawrence
DATE DRILLED: 12/20/83

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| 0 | | 410 0.0 | S/ SP | 1,1 | Sandy clay, CL, very dark grayish brown to black, |
| | | 2.0 | R= 9/ 24 | 3,3 | 2.5Y3/2 to 2.5Y2/0, dry to slightly moist, stiff |
| 1 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | CL | 410 5.0 | S/ SP | 6 | Silty, sandy clay, CL, very stiff, |
| | | 7.0 | R= 18/ 24 | 11 | low plasticity, dry |
| 6 | | | | 15 | |
| | | | | 24 | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |

* A.S.T.M. D1586

WESTON

## DRILLING LOG

WELL NUMBER: 410 (H-10) OWNER: Canonsburg EIS

LOCATION: ADDRESS:

TOTAL DEPTH

SURFACE ELEVATION: WATER LEVEL:

DRILLING COMPANY: DRILLING METHOD: DATE DRILLED:

DRILLER: HELPER:

LOG BY:

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| 10 | CL | 410 10.0 | S/ SP | 3 | 10.0 to 10.3 as above, 10.3 to 11.5 silty |
| | | 12/0 | R= 24/ | 3 | sand, SM/CL saturated,moderate plasticity, |
| 11 | | | 24 | 3 | 2.5Y4/0 dark gray, moderately stiff |
| | | | | 6 | |
| 12 | SM/CL | | | | |
| | | | | | |
| 13 | | | | | |
| | | | | | |
| 14 | | | | | |
| | | | | | |
| 15 | CL | 15'- 15'9 | S/ SP | 30 | Highly weathered siltstone, 2.5Y5/0 gray, |
| | | 410 15.0 | R= 9/9 | 50/ 3" | horizontal parting, friable, dry, no plasticity |
| 16 | REGOLIGH | 15.8 | | | |
| | | | | | |
| 17 | | | | | |
| | | 410 17.0 | S/ SP | 50/ 5.5 | friable, 2.5Y5/0 gray, shale, soft, partially weather- |
| 18 | | 17.5 | R= 4/ | | ed, dry horizontal partings. |
| | | | 24 | | |
| 19 | BEDROCK | | | | |
| | | | | | |
| 20 | | | | | |

* A.S.T.M. D1586

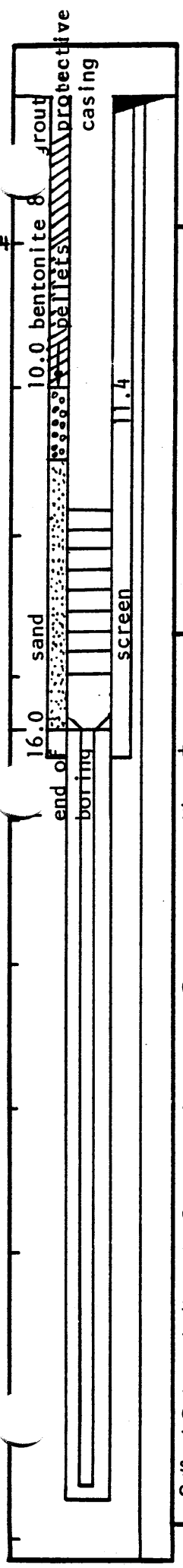
Well 410 (H10)

# Well Construction Summary

Location or Coords: north end of Selwyn St.; south of Area A

Elevation: Ground Level

Top of Casing




Personnel J. Barone/ W. Balmer

## Drilling Summary:

Total Depth 17.0

Borehole Diameter 0.5

Driller B. Bright
Terra Testing

Rig CME 55

Bit(s) HSA

Drilling Fluid N/A

Surface Casing 0.5 ft steel

## Well Design:

Basis: Geologic Log XX Geophysical Log ___

Casing String(s): C=Casing S=Screen

| | | | | | | |
|---|---|---|---|---|---|---|
| +0.8 | 1.6 | C1 | | | | |
| 1.6 | 11.4 | C1 | | | | |
| 11.4 | 16.0 | S1 | | | | |

Casing: C1 4" ABS Sch 40 w/ threaded couplings

C2 ___

Screen: S1 4" PVC Sch 80 w/ threaded couplings; #10 slots

S2 ___

Centralizers N/A

Filter Material #1 sorted sand to 10.0 ft
1.4 ft above the top of the screen

Cement Portland

Other a) bentonite pellets from 8.0 to 10.0 ft; b) cement/bentonite grout to surface; c) protective casing set in cement at surface

## Construction Time Log:

| Task | Start Date | Start Time | Finish Date | Finish Time |
|---|---|---|---|---|
| Drilling: | 1982 12/20 | 1358 | 1982 12/20 | 1455 |
| Geophys. Logging: | N/A | | N/A | |
| Casing: | 1982 12/20 | 1520 | 1982 12/20 | -- |
| Filter Placement: | " | -- | " | -- |
| Cementing: | " | -- | " | 1625 |
| Development: | 1/12/83 | -- | 1/12/83 | -- |
| Other: | | | | |

## Well Development:

developed by bailing to dryness; total withdrawl = 6 gal

## Comments:

WESTON

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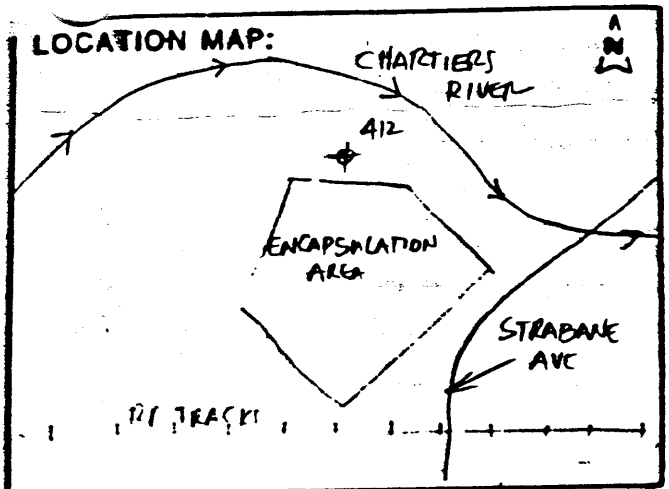
# BOREHOLE LOG (SOIL)



LOCATION MAP:




SITE ID: CAN 01 LOCATION ID: 412
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: AUGER
DRILLING CONTR.: PENNSYLVANIA DRILLING CO
DATE STARTED: 7-14-88
DATE COMPLETED: 7-15-88
FIELD REP.: P.S. DAER

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| 7-15 | 9.30 AM | 12 |
| 7-21-88 | 11:05 AM | 13.1 |
| 7-24-88 | 7:30 AM | 12.3 |

LOCATION DESCRIPTION N. side of Encapsulation area on site.
SITE CONDITION Moderately sloping grass covered

| DEPTH | SAMPLE INTERVAL | SAMPLE RECOVERY | SAMPLE RETAINED | TYPE | ID | BLOWS PER 6 in. | N VALUE | USCS | VISUAL CLASSIFICATION |
|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | | Silty clay low plastic |
| | | | | | | 5-8-12-9 | | CL | ... shale, moist, very stiff, grayish brown mottled w/olive brown, gray, reddish brown & black. FILL |
| | | | | | | 7-11-12-12 | | | |
| 5 | | | | | | 4-5-6-7 | | | |
| | | | | | | 6-7-8-13 | | CL | Silty Clay, low plastic, wet, stiff, ... of red brick and porcelain, ... w/red, light brown, gray, olive and yellow brown. FILL |
| | | | | | | 3-4-6-8 | | | |
| 10 | | | | | | 9-8-7-6 | | | note: becoming wet at 7 FT. and very stiff. |
| | | | | | | 3-4-4-6 | | | |
| | | | | | | 6-4-5-5 | | CL | Silty Clay, low plastic, medium ... stiff, very wet to saturated at 13.5 FT, dark brown to dark olive brown. |
| 15 | | | | | | 1-1-1-1 | | | |
| | | | | | | | | | Alluvium |
| | | | | | | 4-6-12-72 | | | Shale |
| 20 | | | | | | 100/3" | | | |
| | | | | | | | | | stopped sampling at 20.3 FT |
| | | | | | | | | | stopped auger drilling at 21 FT |

COMMENTS: Started drilling at 9:50pm - Stopped drilling at 5:25pm
Started drilling at 7:30am Stopped drilling at 8:45am

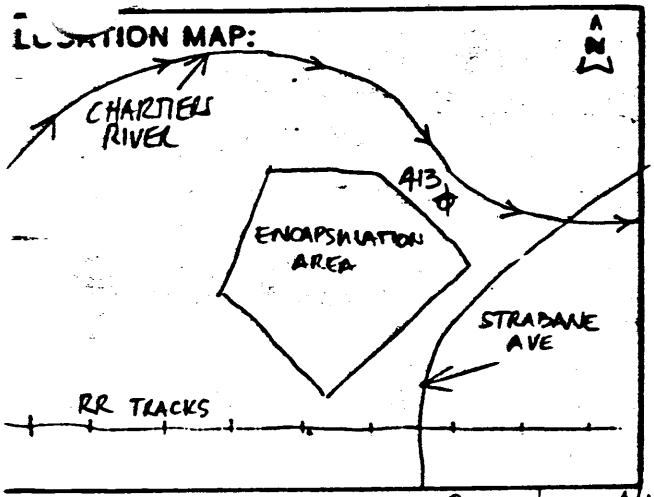
SAMPLE TYPE
A - Auger cuttings
S - 2" O.D 1.38" I.D drive sample
U - 3" O.D 2.42" I.D tube sample
T - 3" O.D thin-walled Shelby tube

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG (SOIL)



LOCATION MAP:




SITE ID: CAN 01 LOCATION ID: 415
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: Auger
DRILLING CONTR.: Pennsylvania Drilling Co.
DATE STARTED: 7-15-86
DATE COMPLETED: 7-15-86
FIELD REP.: P.S Dara

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| 7-15-86 | 3:15 pm | 6.5 |
| 7-22-86 | 7:40 am | 6.0 |
| 7-24-86 | 7:45 am | 6.5 |

LOCATION DESCRIPTION On site NW of encapsulation area.
SITE CONDITION gently sloping grass covered.

| DEPTH | SAMPLE INTERVAL | SAMPLE RECOVERY | SAMPLE RETAINED | TYPE | ID | BLOWS PER 6 in. | N VALUE | USCS | VISUAL CLASSIFICATION |
|---|---|---|---|---|---|---|---|---|---|
| 0 | X | | | | | 2-3-4-17 | | | Silty Clay, low plastic, med. stiff, moist, occasional gravel, olive brown mottled w/ grayish brown. FILL |
| | X | | | | | 6-8-8-11 | | CL | |
| | X | | | | | 11-9-7-6 | | | |
| 4 | X | | | | | 2-3-4-7 | | | NOTE: saturated at 7 FT and becomes dark grayish brown mottled w/ black. |
| | X | | | | | 2-6-5-7 | | | |
| 10 | X | | | | | 1-1-1-2 | | SM | Silty Sand, v.f. to fine, trace clay, very loose, saturated, dark grayish brown ALLUVIUM |
| | X | | | | | 73/6" | | | Shale |
| | | | | | | | | | Stopped sampling at 12.5 FT |
| | | | | | | | | | Stopped drilling at 13.0 FT |

COMMENTS: Start drilling at 2:00 pm Stopped drilling at 2:40 pm

SAMPLE TYPE
A - Auger cuttings
S - 2" O.D 1.38" I.D drive sample
U - 3" O.D 2.42" I.D tube sample
T - 3" O.D thin-walled Shelby tube

JE JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG (SOIL)

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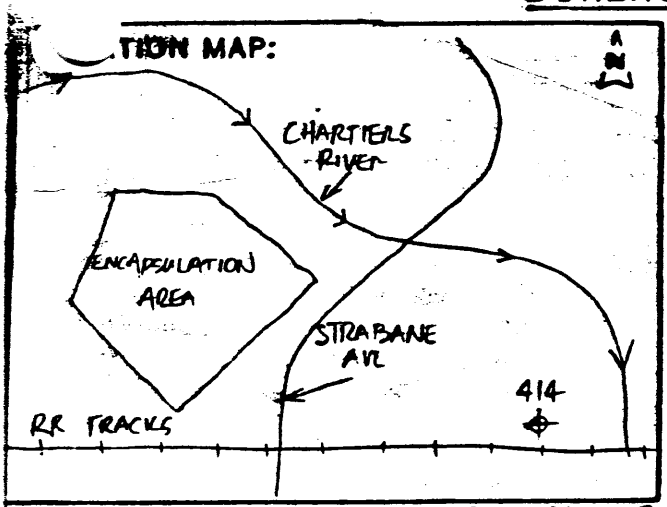


SITE ID: CAN 01 LOCATION ID: 414
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: AUGER
DRILLING CONTR.: PENNSYLVANIA DRILLING Co.
DATE STARTED: 7-15-86
DATE COMPLETED: 7-15-86
FIELD REP.: P.S. DARR

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| 7-15-86 | 12:45 pm | 2.5 |
| 7-24-86 | 8:00 am | 5.4 B.T.O. [illegible] |
| | | |

LOCATION DESCRIPTION On site SE of encapsulation area.
SITE CONDITION near base of slope of RR track grade. Grass covered site.

| DEPTH | SAMPLE INTERVAL | SAMPLE RECOVERY | SAMPLE RETAINED | TYPE | ID | BLOWS PER 6 in. | N VALUE | USCS | VISUAL CLASSIFICATION |
|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | 1-1-2-7 | | CL | Sandy Clay, low to medium plastic, stiff, wet, yellowish brown mottled w/ grayish brown. FILL |
| | | | | | | 9-6-7-8 | | | |
| | | | | | | 3-3-8-7 | | CL | Silty Clay, medium plastic, very stiff to soft, moist to wet, grayish brown mottled w/ yellowish brown and dark yellowish brown. note: saturated at 8.0 FT ALLUVIUM? |
| | | | | | | 4-4-5-9 | | | |
| | | | | | | 1-1-1-3 | | | |
| 10 | | | | | | 3-4-5-6 | | | |
| | | | | | | 2-2-3-5 | | CL | Sandy Clay, low plastic, fine to medium sand, medium stiff, dark yellowish brown mottled w/ reddish brown and grayish brown. ALLUVIUM |
| 15 | | | | | | 4-2-100 | | | |
| | | | | | | | | | Shale. |

Stopped sampling at 15.0 FT
Stopped drilling at 16.0 FT

COMMENTS: Start drilling at 10:30 am Stop drilling at 11:55
Small surface flow of water coming from deep ~200 FT west of borehole along RR track foundation.

SAMPLE TYPE
A - Auger cuttings
S - 3" O.D 1.38" I.D drive sample
U - 3" O.D 2.42" I.D tube sample
T - 3" O.D thin-walled Shelby tube

EG-AL-ENG-2S (4/85)

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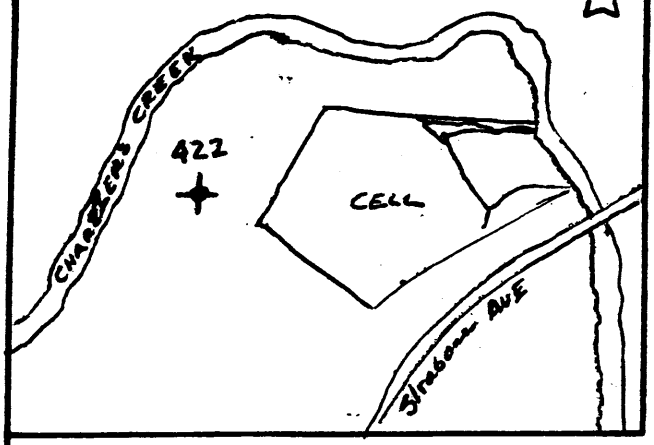
# BOREHOLE LOG

Page 1 of 1

LOCATION MAP:




SITE ID: CAN 01 LOCATION ID: 422
APPROX. SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: 9¼" HSA
DRILLER: Lambert Drilling
DATE STARTED: 10-19-93
DATE COMPLETED: 10-20-93
FIELD REP.: MP Wood

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| | None | |
| | | |
| | | |

LOCATION DESCRIPTION West of Cell
SITE CONDITION Rolling, grass covered Area

| DEPTH (ft.) | SAMPLE INT. | SAMPLE TYPE | SAMPLE ID | UNIFIED SOIL CLASS. | VISUAL CLASS.: DENSITY, COLOR, STRENGTH, PLASTICITY, CONDITION, ETC. |
|---|---|---|---|---|---|
| 8-14-18 | | S | 001 | CL | Fill: Sandy clay, some brick & concrete fragments, medium Plasticity, Tan. |
| 9-10 5 | | S | 002 | CL | Fill: Silty clay, some gravel, med Pl, dark brown |
| 4-10-10 10 | | S | 003 | CL | Sandy clay, low-medium Plasticity light yellow-brown |
| 5-9-12 15 | | S | 004 | | Note: occasional seams of silty clay, medium Plasticity |
| | | | | CL | clayey Sandy clay, considerable gravel, to 1½", low-medium Plasticity light brown |
| 3-8-12 | | S | 005 | | |
| | | | | CL | sandy clay, small amount of fine gravel, medium Plasticity brown |
| 50/4" | | S | 006 | | Cretaceous Shale, soft, gray |
| | | | | | Stopped drilling @ 23½' Sampler Ref @ 23'-10" |

COMMENTS: No free water encountered during drilling.

SAMPLE TYPE
A - Auger cuttings
S - 2" O.D. 1.38" I.D. drive sample
U - 3" O.D. 2.42" I.D. tube sample
T - 3" O.D. thin-walled Shelby tube

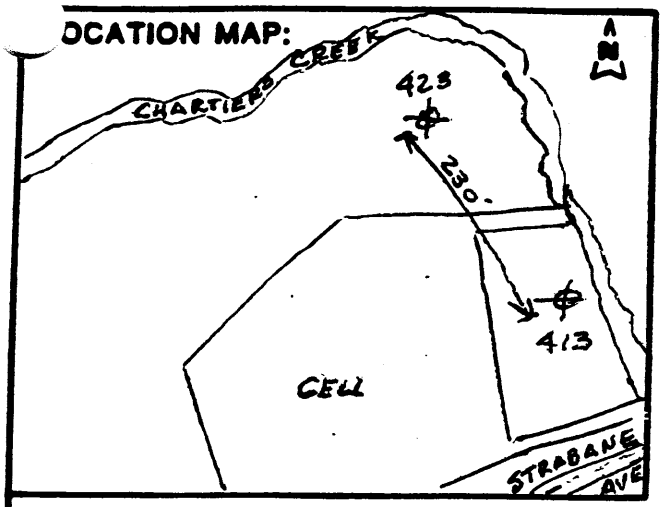
JEG-AL-ENG-2 (3/84)

**JACOBS ENGINEERING GROUP INC.**
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG



LOCATION MAP:




SITE ID: CAN 01 LOCATION ID: 423
APPROX. SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: 9 1/2" HSA
DRILLER: Lambert Drilling
DATE STARTED: 10-22-93
DATE COMPLETED: 10-22-93
FIELD REP.: W. R. Nood

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| 10-22-93 | 3:54 P | 7 |
| | | |
| | | |

LOCATION DESCRIPTION 230 Feet North of #413
SITE CONDITION Grass Covered

| DEPTH (ft.) | SAMPLE INT. | SAMPLE TYPE | SAMPLE ID | UNIFIED SOIL CLASS. | VISUAL CLASS.: DENSITY, COLOR, STRENGTH, PLASTICITY, CONDITION, ETC. |
|---|---|---|---|---|---|
| 0 | 5-7-7 | S | 001 | CL | Sandy Clay, some gravel, medium plasticity, light brown. |
| 5 | | S | 002 | CL | Silty clay, some Sand, medium plasticity, dark brown. |
| | | | | ML | Sandy silt, Low Plasticity, dark brown |
| 10 | | S | 003 | | Castleman Shale, soft, brown |
| 15 | | | | | stopped drilling at 13 feet |

COMMENTS: _____

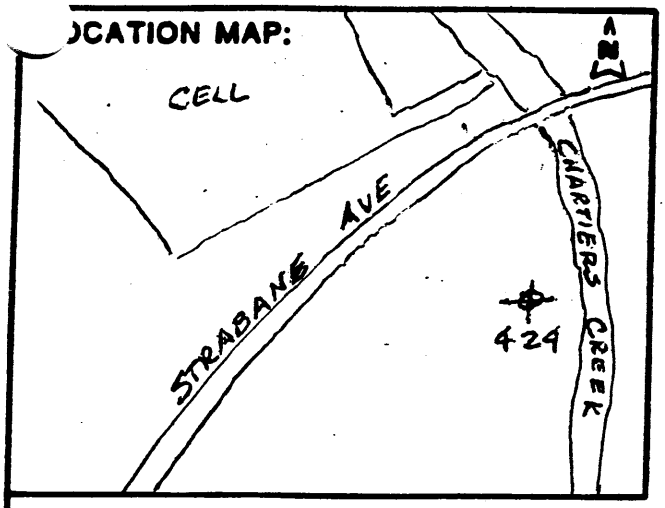
**SAMPLE TYPE**
A - Auger cuttings
S - 2" O.D. 1.38" I.D. drive sample
U - 3" O.D. 2.42" I.D. tube sample
T - 3" O.D. thin-walled Shelby tube

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG



LOCATION MAP:




SITE ID: CAN 01 LOCATION ID: 424
APPROX. SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: 9½" HSA
DRILLER: Lambert Drilling
DATE STARTED: 10-24-93
DATE COMPLETED: 10-24-93
FIELD REP.: W.R. Wood

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| 10-24-93 | 8:51 A | 10' |
| | | |
| | | |

LOCATION DESCRIPTION _____
SITE CONDITION _____

| DEPTH (ft.) | SAMPLE INT. | SAMPLE TYPE | SAMPLE ID | UNIFIED SOIL CLASS. | VISUAL CLASS.: DENSITY, COLOR, STRENGTH, PLASTICITY, CONDITION, ETC. |
|---|---|---|---|---|---|
| 0 | | | | | |
| 2-5-9 | | S | 001 | CL | Silty Clay, some sand, Trace of gravel, Medium Plasticity, light brown |
| 5 | | | | | |
| 4-3-5 | | S | 002 | CL | sandy clay, medium plasticity, dark brown |
| 10 | | | | | Clayey sand, med fine, Low Pl, brown |
| 2-2-2 | | S | 003 | SC | |
| | | | | | Castleman Shale, soft, light gray |
| 15 | | | | | |
| 50/5" | | S | 004 | | |
| | | | | | stopped drilling at 17ft. |

COMMENTS: _____

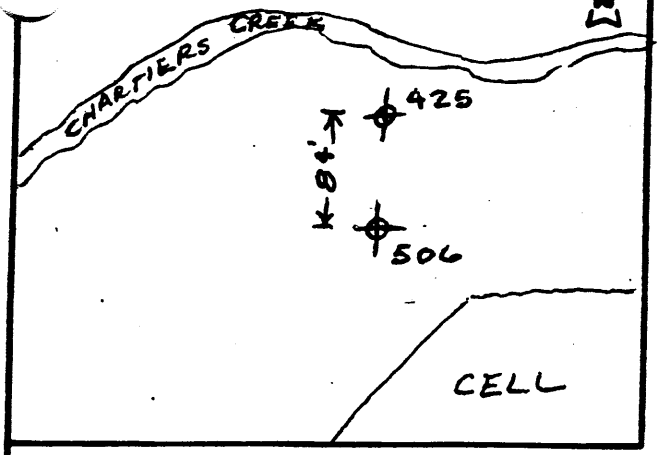
SAMPLE TYPE
A - Auger cuttings
S - 2" O.D. 1.38" I.D. drive sample
U - 3" O.D. 2.42" I.D. tube sample
T - 3" O.D. thin-walled Shelby tube

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG



LOCATION MAP:




SITE ID: CAN 01 LOCATION ID: 425
APPROX. SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: 9½" HSA
DRILLER: Lambert Drilling
DATE STARTED: 10-21-93
DATE COMPLETED: 10-21-93
FIELD REP.: W. R. Weed

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| 10-21-93 | 9:30A | 15' ? |
| | | |
| | | |

LOCATION DESCRIPTION Northwest of cell - near creek
SITE CONDITION Grass covered area

| DEPTH (ft.) | SAMPLE INT. | TYPE | ID | UNIFIED SOIL CLASS. | VISUAL CLASS.: DENSITY, COLOR, STRENGTH, PLASTICITY, CONDITION, ETC. |
|---|---|---|---|---|---|
| 0 | | | | | |
| 3-5-5 | | S | 001 | CL | Sandy clay, trace gravel, occasional coal fragments - low-medium plasticity, yellow-brown |
| 5 | | | | | |
| 6-9-11 | | S | 002 | | |
| | | | | CL | Silty clay, medium plasticity, yellow-brown |
| 10 | | | | | |
| 5-7-8 | | S | 003 | | Note: Trace of gravel |
| 15 | | | | | |
| 8-32-50 | | S | 004 | | Castlemen Shale, soft, light brown to light gray. |
| 20 | | | | | Stopped drilling @ 19' |

COMMENTS: 54' north of #506

SAMPLE TYPE
A - Auger cuttings
S - 2" O.D. 1.38" I.D. drive sample
U - 3" O.D. 2.42" I.D. tube sample
T - 3" O.D. thin-walled Shelby tube

WESTON

## DRILLING LOG

WELL NUMBER: 501
LOCATION: south side of cemetery
OWNER: PAEM Church
ADDRESS: Payne St.
TOTAL DEPTH 119ft
SURFACE ELEVATION:
WATER LEVEL:
DRILLING COMPANY: Brooks Geoprobe
DRILLING METHOD: air rotary
DATE DRILLED: 7-12 Jan 83
DRILLER: J. Pappert
HELPER: F. Mallow
LOG BY: J. Barone

SKETCH MAP

NOTES:
see log for 405 for overburden stratigraphy from 0 to 12.5ft
no foliation--no reaction to dilute HCl--all footages in feet ~~below top of temporary casing~~ at 1ft above grade

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| 12 | | I | core | | 2.5Y5/0 gray carbonaceous shale--thin bedded--preferred parting is along the horizontal beds--12.5 to 13.4 is highly weathered with strong secondary mineralization--16.5 and 16.6 has iron-staining on horizontal fractures--18.1 and 18.2 has secondary mineralization on horizontal fractures--minor compositional banding along bedding--fiability increases downward as carbonization increases--black carbonaceous shale from 22.0 to the end of the core at 21.5 |
| | | | | | Rec 9.2/9.5 = 0.97 (recovery ratio)<br>RQD25 3.4/9.2 0.37 (rock quality data 0.25ft fragments)<br>RQD50 1.1/9.2 0.12 (rock quality data 0.50ft fragments) |
| 21.5 | | II | core | | 2.5Y2/0 black carbonaceous shale from 21.5 to 22.7--10YR4/1 ~~dark gray carbonaceous shale for remainder of core--iron-~~staining on vertical fracture at 26.3 to 26.4 and on ~~horizontal fracture at 26.4--friability decreases as~~ carbonization decreases downward in the black shale--thin ~~bedded-preferred parting is along the horizontal bedding--~~some primary and secondary fractures are healed by ~~carbonization--minor compositional banding--no secondary~~ mineralization other than iron-staining on fracture surfaces--~~primary sedimentary slump structures at 26.5 to 27.1~~ |
| | | | | | Rec 5.9/6.5 = 0.91<br>~~RQD25 3.3/5.9 0.56~~<br>RQD50 2.3/5.9 0.39 |
| | | III | core | | 10YR3/2 very dark grayish brown carbonaceous shale grading to ~~10YR5/1 gray carbonaceous shale at 34.8--thin bedded--~~friable--preferred parting is horizontal along bedding--~~28 to 34.8 has inclusions of brown claystone across bedding~~ with fractures healed with carbonization--no iron-staining |

* A.S.T.M. D1586

WESTON

## DRILLING LOG

WELL NUMBER: 501 OWNER:
LOCATION: ADDRESS:
TOTAL DEPTH
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: DRILLING METHOD: DATE DRILLED:
DRILLER: HELPER:
LOG BY:

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| | | | | | or secondary mineralization on fracture surface other than carbonization--minor compositional banding<br><br>Rec 8.2/10.0 = 0.82<br>RQD25 4.7/8.2 0.57<br>RQD50 1.6/8.2 0.20 |
| 38 | | IV | core | | 10YR4/2 dark grayish brown carbonaceous shale--thin bedded--highly friable from 38 to 41.5 with very weathered shale of high clay content over competent shale with low friability--no iron-staining or secondary mineralization on fracture surfaces--minor compositional banding--fractures commonly healed with carbonization<br><br>Rec 6.5/10.0 = 0.65<br>RQD25 4.9/6.5 0.75<br>RQD50 3.8/6.5 0.58 |
| 48 | | V | core | | 5Y3/2 dark olive gray chloritic shale--occasional carbonization on fracture surfaces--no iron-staining or other secondary mineralization on fracture surfaces except carbonization--no banding--thin bedded--preferred parting is horizontal along bedding--friability slight--inclusions |

* A.S.T.M. D1586

WESTON

## DRILLING LOG

WELL NUMBER: 501 OWNER:

LOCATION: ADDRESS:

TOTAL DEPTH

SURFACE ELEVATION: WATER LEVEL:

DRILLING COMPANY: DRILLING METHOD: DATE DRILLED:

DRILLER: HELPER:

LOG BY:

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| | | | | | of claystone as probable primary structure--no vertical or diagonal fractures |
| | | | | | Rec 8.7/10.0 = 0.87<br>RQD25 8.5/8.7 0.98<br>RQD50 7.5/8.7 0.86 |
| 58 | | VI | core | | 5Y3/2 dark olive gray chloritic shale--highly friable along ~~thin horizontal bedding planes--no iron-staining or secondary~~ mineralization on fracture surfaces--no banding |
| | | | | | Rec 9.9/10.0 = 0.99<br>~~RQD25 9.3/9.9 0.94~~<br>RQD50 4.4/9.9 0.44 |
| | | VII | core | | 5Y3/2 dark olive gray chloritic shale--highly friable along ~~thin horizontal bedding planes no banding no iron staining~~ or secondary mineralization on fracture surfaces |

* ASTM D1586

WESTON

## DRILLING LOG

WELL NUMBER: 501 OWNER:
LOCATION: ADDRESS:
TOTAL DEPTH
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: DRILLING METHOD: DATE DRILLED:
DRILLER: HELPER:
LOG BY:

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| | | | | | Rec 8.1/10.0 = 0.81<br>~~RQD25 2.8/8.1 0.35~~<br>RQD50 1.1/8.1 0.14 |
| 78 | | VIII | core | | 5Y2.5/1 black carbonaceous shale--highly friable--preferred ~~parting is along the thin horizontal bedding planes~~ no iron-staining or secondary mineralization on fracture ~~surfaces - no banding~~<br>~~Rec 6.6/7.0 = 0.94~~<br>RQD25 5.0/6.6 0.76<br>~~RQD50 4.4/6.6 0.67~~ |
| 85 | | | | | TRANSITION TO RED SHALE BETWEEN 85 AND 90 FEET BELOW GROUND ~~LEVEL - NO CORE RECOVERABLE~~ |
| 95 | | | | | red shale to end of boring |

* A.S.T.M. D1586

WESTON

## DRILLING LOG

WELL NUMBER: 501 OWNER: _____

LOCATION: _____ ADDRESS: _____

_____ _____

_____ TOTAL DEPTH _____

SURFACE ELEVATION: _____ WATER LEVEL: _____

DRILLING COMPANY: _____ DRILLING METHOD: _____ DATE DRILLED: _____

DRILLER: _____ HELPER: _____

LOG BY: _____

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| | | | | | red shale--frequent clay seams hamper drilling and recovery of cores |

WESTON

## DRILLING LOG

WELL NUMBER: 501 OWNER:

LOCATION: ADDRESS:

TOTAL DEPTH

SURFACE ELEVATION: WATER LEVEL:

DRILLING COMPANY: DRILLING METHOD: DATE DRILLED:

DRILLER: HELPER:

LOG BY:

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | END OF BORING AT 119 FEET BELOW THE TOP OF THE TEMPORARY |
| 119 | | | | | SURFACE CASING--118 FEET BELOW GRADE |

* A.S.T.M. D1586

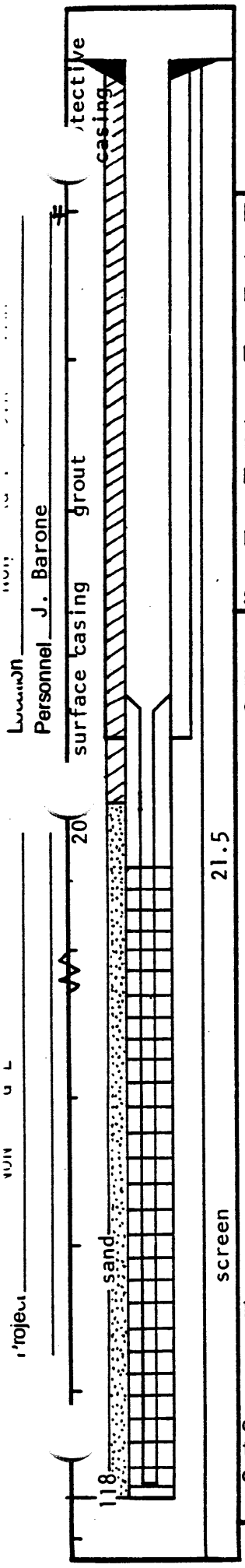
Well 501 (S1)

# Well Construction Summary

Location or Coords: PAEM Church cemetery

Elevation: Ground Level

Top of Casing




## Drilling Summary:

Total Depth: 118 ft

Borehole Diameter: 0.5 ft (surface casing)
0.3 ft (core)

Driller: J. Pappert
Brooks Geoprobe

Rig: Mobile Drill B-80

Bit(s): core: NX diamond; reaming: 0.3ft tri-cone roller; surface: 0.5 ft tri-cone

Drilling Fluid: air

Surface Casing: 4" ABS

## Well Design:

Basis: Geologic Log XX. Geophysical Log ____

Casing String(s): C=Casing S=Screen

| | | | | | |
|---|---|---|---|---|---|
| +1.0 | 20.0 | C1 | | | |
| +1.0 | 21.5 | C2 | | | |
| 21.5 | 118.0 | S1 | | | |

Casing: C1 surface casing: 4" ABS Sch 40 w/ threaded coupling

C2 inner casing: 3" ABS Sch 40 w/ threaded coupling

Screen: S1 3' PVC Sch 80 w/ threaded coupling; #10 slots

S2 ____

Centralizers: N/A

Filter Material: #1 sorted sand to 20.0 ft - 1.5 ft above the top of the screen

Cement: Portland

Other: a) surface casing set in rock in cement; b) bentonite/cement grout from 20.0 to surface; c) protective casing set in cement at surface

## Construction Time Log:

| Task | Start Date | Start Time | Finish Date | Finish Time |
|---|---|---|---|---|
| Drilling: | 1983 1/7 | 0820 | 1983 1/11 | 1700 |
| | | | | |
| | | | | |
| Geophys. Logging: | N/A | | N/A | |
| Casing: | 1983 1/12 | 0900 | 1983 1/12 | -- |
| | | | | |
| | | | | |
| Filter Placement: | " | 1025 | " | -- |
| Cementing: | " | -- | " | 1225 |
| Development: | | | | |
| Other: | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

## Well Development:

## Comments:

Personnel J. Barone

Project

WESTON DESIGNERS CONSULTANTS

WESTON

## DRILLING LOG

WELL NUMBER: 502
LOCATION: north side of Chartiers Creek
OWNER: Loyal Order of Moose
ADDRESS: West Pike St.
TOTAL DEPTH 85ft BTOC
SURFACE ELEVATION: _____
WATER LEVEL: _____
DRILLING COMPANY: Brooks Geoprobe
DRILLING METHOD: air rotary
DATE DRILLED: 21 Dec 82--4 Jan 83
DRILLER: J. Pappert
HELPER: F. Mallow
LOG BY: J. Barone

SKETCH MAP

NOTES: see log for 40' for overburden material--all footages in feet below top of temporary casing at 1ft above grade-- no foliation--no reaction to dilute HCl

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| 19 | | I | core | | 10YR3/1 very dark gray carbonaceous shale--highly friable--preferred parting is along the horizontal bedding planes--thin compositional banding--content of fine grained quartz is greatest from 23.2 to 24.9 with primary sedimentary structures and higher competence--no iron-staining or secondary mineralization other than carbon replacement on fracture surfaces<br><br>Rec 8.4/9.0 = 0.93<br>RQD25 1.7/8.4 0.20<br>RQD50 0.5/8.4 0.06 |
| 28 | | II | core | | 10YR2/1 black carbonaceous shale--highly friable--thinly bedded--preferred parting is along the horizontal bedding--no iron-staining or growth of secondary minerals other than by carbon replacement on fracture surfaces--compositonal banding with fine quartz from 30.7 to 31.1 and 35.0 to 35.4 associated with higher competence--primary sedimentary structures in the layer of higher quartz content include slump structures with borders healed by primary clays and silts<br><br>Rec 10.0/10.0 = 1.00<br>RQD25 1.9/10.0 0.19<br>RQD50 0.0/10.0 0.00 |
| 38 | | III | core | | 10YR2/1 black carbonaceous shale--highly friable--preferred |

* A.S.T.M. D1586

WESTON

## DRILLING LOG

WELL NUMBER: 502 OWNER:
LOCATION: ADDRESS:
TOTAL DEPTH
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: DRILLING METHOD: DATE DRILLED:
DRILLER: HELPER:
LOG BY:

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| | | | | | parting is along thin horizontal bedding planes--no iron-staining or secondary mineralization except carbonization on fracture surfaces--compositional banding with an increased content of fine-grained quartz from 41.5 to 42.9 and 44.5 to 44.7--primary slump structures apparent--fragments of highest content of quartz have the highest competence |
| | | | | | Rec 9.7/10.0 = 0.97<br>RQD25 6.9/9.7 0.71<br>RQD50 2.0/9.7 0.21 |
| 48 | | IV | core | | 10YR2/1 black carbonaceous shale--thin bedded--highly friable--preferred parting is along the horizontal bedding planes--compositonal banding with light-colored, fine-grained quartz layers of higher competence from 48.0 to 48.8 and from 54.6 to 57.3--primary structures in the layers of high quartz content are confused--no iron-staining or secondary mineralization except carbonization on some fracture surfaces |
| | | | | | Rec 10.0/10.0 = 1.00<br>RQD25 8.0/10.0 0.80<br>RQD50 5.6/10.0 0.56 |
| 58 | | V | core | | 10Yr2/1 black carbonaceous shale grading to 5Y4/3 olive |

* A.S.T.M. D1586

WESTON

## DRILLING LOG

WELL NUMBER: 502 OWNER:
LOCATION: ADDRESS:
TOTAL DEPTH
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: DRILLING METHOD: DATE DRILLED:
DRILLER: HELPER:
LOG BY:

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| | | | | | quartzose shale at 62.6 (about 62 ft below grade)--the black shale is thin-bedded and highly friable--preferred parting is along the horizontal bedding--minor compositional banding with fine grains of quartz at 59.0 to 59.2--no iron-staining or growth of secondary minerals except by carbonization on some fracture surfaces — 62 |
| | | | | | the contact between the shales is probably horizontal--the shales are highly friable above and below the contact--possible clay layer at the contact--the clay may be derived from both units |
| | | | | | the chloritic shale is thin-bedded grading to cross-bedded, quartzose, chloritic shale--compositional banding with fine-grained quartz from 65.2 to 67.8 in cross-beds--no iron-staining--growth of secondary (?) clays in slump structures fractures at 55.6, 55.8, 56.1, 66.4 and 66.8--change to massive chloritic shale at 67.5 to 68.0 |
| | | | | | Rec 8.2/10.0 = 0.82 RQD25 4.1/8.2 = 0.50 RQD50 1.6/8.2 = 0.20 |
| 68 | | VI | core | | 5Y3/1 very dark gray chloritic shale overlying 10R3/3 dusky red weathered clayey shale at 72.9 (about 72 ft below grade)-- — 72 |
| | | | | | the chloritic shale is thin-bedded and friable--preferred parting is horizontal along bedding--no banding--no iron-staining or secondary mineralization on fracture surfaces--the contact between shales is confused from 71.2 to 71.9 (about 70 to 71 ft below grade)--highly friable chloritic shale with inclusions of the underlying clayey shale--very soft and porous--badly weathered to clay |
| | | | | | the red shale is badly weathered, clayey, soft and porous--bedding is obscure--no iron-staining or secondary mineralization on fracture surfaces--parting is masked by pervasive fissility and weathering--clay weathering increases downward |
| | | | | | Rec 7.2/8.0 = 0.90<br>RQD25 3.2/7.2 0.44<br>RQD50 1.3/7.2 0.18 |
| 78 | | VII | core | | 10R3/3 dusky red weathered clayey shale--highly porous and |

* A.S.T.M. D1586

WESTON

## DRILLING LOG

WELL NUMBER: 502 OWNER:

LOCATION: ADDRESS:

TOTAL DEPTH

SURFACE ELEVATION: WATER LEVEL:

DRILLING COMPANY: DRILLING METHOD: DATE DRILLED:

DRILLER: HELPER:

LOG BY:

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| | | | | | friable--fractures, parting and bedding are obscured by fissility and weathering--soft--no iron-staining. |
| 80.5 | | | | | Growth of secondary minerals throughout irregular compositional banding |
| | | | | | Rec 0.7/1.5 = 0.47<br>RQD25 0.7/0.7 1.00<br>RQD50 0.0/1.7 0.00 |
| | | | | | END OF BORING AT 85 FEET BELOW THE TOP OF THE TEMPORARY SURFACE CASING--84 FEET BELOW GRADE |

* A.S.T.M. D1586

Well 502 (S2)

# Well Construction Summary

Location or Coords: north side of Chartiers Creek

Elevation: Ground Level

Top of Casing

## Drilling Summary:

Total Depth 84 ft

Borehole Diameter 0.5 ft (surface casing)
0.3 ft (rock)

Driller J. Pappert
Brooks Geoprobe

Rig Mobile Drill B-80

Bit(s) core: NX diamond; reaming: 0.3 ft tri-cone; surface: 0.5 ft tri-cone

Drilling Fluid air

Surface Casing 4" ABS

## Well Design:

Basis: Geologic Log XX Geophysical Log

Casing String(s): C=Casing S=Screen

| | | | | | |
|---|---|---|---|---|---|
| +0.8 | 38.0 | C1 | | | |
| +1.2 | 40.0 | C2 | | | |
| 40.0 | 84.0 | S1 | | | |

Casing: C1 surface casing: 4" ABS Sch 40 w/ threaded coupling

C2 inner casing: 3" ABS Sch 40 w/ threaded coupling

Screen: S1 3" PVC Sch 80 w/ threaded coupling; #10 slots

S2

Centralizers N/A

Filter Material #1 sorted sand to 35.0 ft - 5.0 ft above the top of the screen

Cement Portland

Other a) surface casing set in rock in cement; b) bentonite/cement grout from 0.0 to 35 ft; c) protective casing set in cement at surface

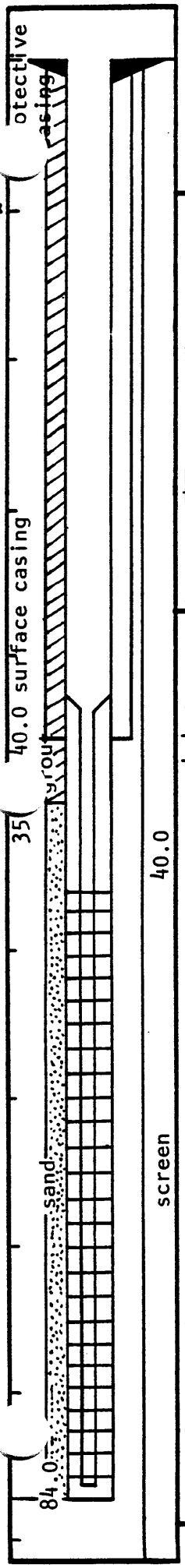
## Construction Time Log:

| Task | Start Date | Start Time | Finish Date | Finish Time |
|---|---|---|---|---|
| Drilling: | 1982 12/20 | 1300 | 1983 1/4 | 1230 |
| | | | | |
| | | | | |
| Geophys. Logging: | N/A | | N/A | |
| Casing: | 1983 1/9 | 0900 | 1983 1/9 | -- |
| | | | | |
| | | | | |
| Filter Placement: | " | -- | " | -- |
| Cementing: | " | -- | " | 1300 |
| Development: | 1/12/83 | -- | 1/12/83 | -- |
| Other: | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

## Well Development:

developed by pumping with a surface centrifugal pump; total withdrawl = 330 gal

## Comments:




KD

WESTON

WESTON

## DRILLING LOG

WELL NUMBER: 503
LOCATION: south of Strabane post office
SURFACE ELEVATION:
DRILLING COMPANY: Brooks Geoprobe
DRILLER: J. Pappert
LOG BY: J. Barone

OWNER: S. Twardy
ADDRESS: alley between Latimer and Alexander Sts.
TOTAL DEPTH 115 BTOC
WATER LEVEL:
DRILLING METHOD: air rotary
DATE DRILLED: 5-26 Jan 83
HELPER: F. Mallow

SKETCH MAP

NOTES: see for gor 409 for overburden material--all footages in feet below top of temporary casing at 1ft above grade-- no foliation--no reaction to dilute HCl

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| 16 | | 1 | core | | 7.5YR4/0 very dark gray carbonaceous shale--thin-bedded--friable--preferred parting is horizontal along bedding planes--minor compositional banding--primary structures confused--heavy iron-staining on vertical and horizontal fractures--carbonization common on fracture surfaces and in healed fractures--friability increases downward |
| | | | | | Rec 6.5/8.0 = 0.81<br>RQD25 1.1/6.5 0.17<br>RQD50 0.5/6.5 0.08 |
| 24 | | 11 | core | | 10YR3/2 very dark grayish brown carbonaceous shale--thin-bedded--low friability with no preferred direction of parting--no banding--very heavy iron-staining on diagonal, vertical and horizontal fracture surfaces--grading to black carbonaceous shale from about 31 to 32-- |
| | | | | | Rec 3.7/10.5 = 0.35<br>RQD25 1.2/3.7 0.32<br>RQD50 0.5/3.7 0.14 |
| 34.5 | | | | | |

* A.S.T.M. D1586

WESTON

## DRILLING LOG

WELL NUMBER: 503 OWNER:
LOCATION: ADDRESS:
TOTAL DEPTH
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: DRILLING METHOD: DATE DRILLED:
DRILLER: HELPER:
LOG BY:

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| | | | | | FROM 34.5 TO 39 FEET, FILLED-IN MINE SHAFT--GRAVEL AND ROCK FRAGMENTS--NO CORE OR SPT SAMPLE RECOVERED |
| 39 | | III | core | | 10YR3/1 very dark gray carbonaceous shale from 39 to 41.8 grading to dark gray downward--thin-bedded--no preferred parting direction from 39 to 43.1--very soft and porous with a high degree of weathering to clay and extreme triaxial fracturing from 36.0 to 37.0 |
| | | | | | Rec 8.1/10.0 = 0.81<br>RQD25 2.4/8.1 0.30<br>RQD50 1.0/8.1 0.12 |
| 49 | | IV | core | | 10YR3/1 very dark gray carbonaceous and lignitic shale--thin-bedded with compositional banding of high and medium carbon content--highly friable--preferred parting is sub-horizontal along bedding--no iron-staining or secondary mineralization on fracture surfaces--diagonal fractures healed with a light-colored mineral from 54.0 to 54.5 and 57.1 to 57.6--carbon content is greatest from 49.0 to 54.0 and from 56.7 to 58.0 |
| | | | | | Rec 7.9/9.0 = 0.88<br>RQD25 2.0/7.9 0.25<br>RQD50 1.1/7.9 0.14 |
| 58 | | | | | |

* A.S.T.M. D1586

WESTON

## DRILLING LOG

WELL NUMBER: 503 OWNER:
LOCATION: ADDRESS:
TOTAL DEPTH
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: DRILLING METHOD: DATE DRILLED:
DRILLER: HELPER:
LOG BY:

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| 58 | | V | core | | 10YR3/1 very dark gray carbonaceous and lignitic shale--thin-bedded--minor compositional banding--large inclusions of high carbon content from 63.2 to 64.2--highly friable--preferred parting is along the sub-horizontal bedding--no iron-staining or secondary mineralization on fracture surfaces except by carbonization--friability increases with an increase in carbonization--carbon content decreases below 61.4<br><br>Rec 9.7/11.0 = 0.88<br>RQD25 7.9/9.7 0.81<br>RQD50 5.2/9.7 0.54 |
| 69 | | VI | core | | 5Y3/2 dark olive gray carbonaceous shale--thin-bedded--no banding--large inclusions of lighter material from 71.6 to 72.1--highly friable--preferred parting is sub-horizontal along bedding--no iron-staining or secondary mineralization on fracture surfaces except by carbonization<br><br>Rec 10.2/9.0 = 1.13<br>RQD25 8.8/10.2 0.86<br>RQD50 6.2/10.2 0.61 |
| 78 | | | | | |

* A.S.T.M. D1586

WESTON

## DRILLING LOG

WELL NUMBER: 503 OWNER:
LOCATION: ADDRESS:
TOTAL DEPTH
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: DRILLING METHOD: DATE DRILLED:
DRILLER: HELPER:
LOG BY:

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| 78 | | VII | core | | 5Y2.5/2 black carbonaceous shale grading to 5Y4/2 olive gray shale at 81.0--thin-bedded--low to moderate friability--large inclusions from 81.0 to 86.9--bedding obscured by these inclusions--no iron-staining or secondary mineralization on fracture surfaces--no regular banding--low to moderate content of chlorite--high degree of weathering to clay and high porosity from 78.8 to 79.9 and 87.0 to 88.0--no preferred direction of parting |
| | | | | | Rec 9.2/10.0 = 0.92<br>RQD25 7.1/9.2 0.77<br>RQD50 4.3/9.2 0.47 |
| 88 | | VIII | core | | confused gradational contact with obscure layering of red and gray shales from 88.0 to 93.0 to 5Y4/2 olive gray chloritic shale--bedding in the contact is obscured--very high friability in three axes--very highly porous and weathered to clay--no iron-staining on fracture surfaces--very soft--the chloritic shale is thin-bedded without banding--primary inclusions of claystone across bedding--no preferred direction of parting--no iron-staining or secondary mineralization on fracture surfaces |
| | | | | | Rec 6.6/7.0 = 0.94<br>RQD25 4.2/6.6 0.64<br>RQD50 1.8/6.6 0.27 |
| | | IX | core | | 5Y3/2 dark olive gray quartzose chloritic shale--thin-bedded--no regular banding--primary inclusions of claystone across bedding--moderate friability--preferred parting is along the horizontal bedding--no iron-staining or secondary mineralization on fracture surfaces--very porous and highly friable from 100.9 to 102.4 with obscure inclusions of |

* A.S.T.M. D1586

WESTON

DRILLING LOG

WELL NUMBER: 503 OWNER:
LOCATION: ADDRESS:
TOTAL DEPTH
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: DRILLING METHOD: DATE DRILLED:
DRILLER: HELPER:
LOG BY:

SKETCH MAP

NOTES:

| DEPTH (FEET) | GRAPHIC LOG | SAMPLE NUMBER | SAMPLE TYPE | SAMPLE BLOWS* | DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES) |
|---|---|---|---|---|---|
| | | | | | red shale |
| | | | | | Rec 10.0/10.0 = 1.00<br>RQD25 8.6/10.0 0.86<br>RQD50 5.8/10.0 0.58 |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| 105 | | X | core | | 5Y3/2 dark olive gray quartzose chloritic shale from 105.0 to 108.8 over 10R3/2 dusky red shale--contact is about 108 ft below grade--the chloritic shale is thin-bedded with no banding--no iron-staining or secondary mineralization on fracture surfaces--friable--preferred parting direction is along horizontal bedding--primary inclusions of claystone across bedding--friability increases from 108.2 to 108.8--light to moderate weathering from 108.2 to 108.8, increasing toward the contact with the red shale--the red shale is highly weathered with obscured bedding--strong secondary mineralization of yellow-green clays--extremely friable in three axes--highly porous--preferred parting is horizontal--no iron-staining on fracture surfaces |
| | | | | | Rec 6.9/10.0 = 0.69<br>RQD25 4.5/6.9 0.65<br>RQD50 3.2/6.9 0.46 |
| | | | | | END OF BORING AT 115 FEET BELOW THE TOP OF THE TEMPORARY CASING--114 FEET BELOW GRADE |
| | | | | | |
| | | | | | |

* A.S.T.M. D1586

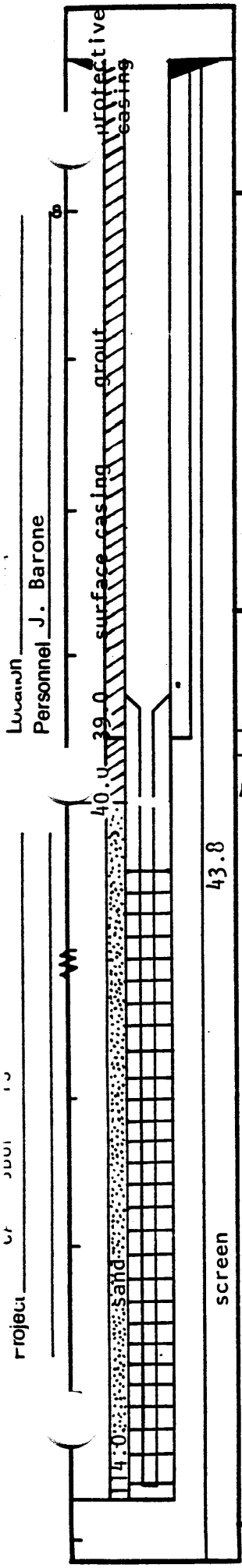
Well 503 (S3)

# Well Construction Summary

Location or Coords: Twardy property south of Strabane Post Office

Elevation: Ground Level

Top of Casing




## Drilling Summary:

Total Depth: 114 ft

Borehole Diameter: 0.5 ft (surface casing)
0.3 ft (rock)

Driller: J. Pappert
Brooks Geoprobe

Rig: Mobile Drill B-80

Bit(s): core: NX diamond; reaming: 0.3 ft
tri-cone roller; surface: 0.5 ft tri-cone

Drilling Fluid: air

Surface Casing: 4" steel

## Well Design:

Basis: Geologic Log XX Geophysical Log

Casing String(s): C=Casing S=Screen

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| +1.0 | - 39.0 | C1 | | | - | | |
| +1.0 | - 43.8 | C2 | | | - | | |
| 43.8 | - 114.0 | S1 | | | - | | |
| | - | | | | - | | |
| | - | | | | - | | |
| | - | | | | - | | |
| | - | | | | - | | |
| | - | | | | - | | |

Casing: C1 surface casing: 4" galvanized steel w/ threaded couplings

C2 inner casing: 3" ABS Sch 40 w/ threaded couplings

Screen: S1 3" PVC Sch 80 w/ threaded couplings; #10 slots

S2

Centralizers: N/A

Filter Material: #1 sorted sand to 40.0 ft - 3.8 ft above the top of the screen

Cement: Portland

Other: a) surface casing set in rock in cement; b) bentonite/cement grout to surface; c) protective casing set in cement at surface

## Construction Time Log:

| Task | Start Date | Start Time | Finish Date | Finish Time |
|---|---|---|---|---|
| Drilling: | 1983 1/5 | 1000 | 1983 1/26 | 1130 |
| Geophys. Logging: | N/A | | N/A | |
| Casing: | 1983 1/26 | 1130 | 1983 1/26 | -- |
| Filter Placement: | " | -- | " | -- |
| Cementing: | " | -- | " | 1405 |
| Development: | 1/28/83 | -- | 1/28/83 | -- |
| Other: | | | | |

## Well Development:

developed by surface centrifugal pump; ~~total withdrawl of 180 gal~~

## Comments:

KD

WESTON

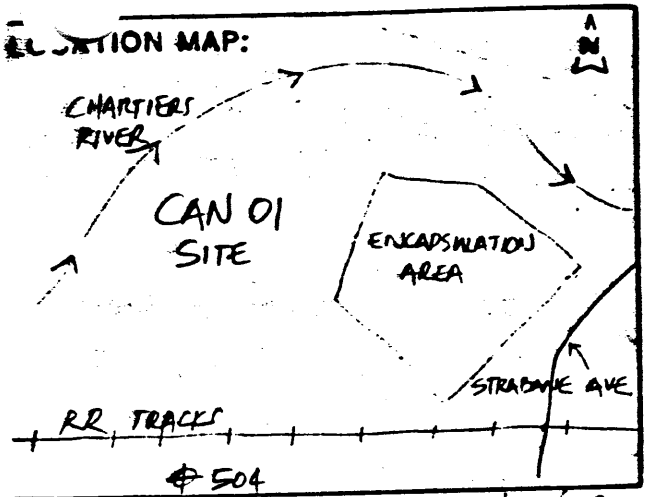
JE JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG (SOIL)

Page 1 of 1

Giant Log 504A

LOCATION MAP:




SITE ID: CAN 01 LOCATION ID: 504
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: AUGER
DRILLING CONTR.: PENNSYLVANIA DRILLING CO.
DATE STARTED: 7-14-86
DATE COMPLETED: 7-15-86
FIELD REP.: P.S. DARR

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| 7-14-86 | 1:00 pm | 15.5 |
| 7-21-86 | 1:00 pm | 11.7 FT. |
| | | |

LOCATION DESCRIPTION End of Saylyr Street S. of site.
SITE CONDITION street embankment drops off sharply.

| DEPTH | SAMPLE INTERVAL | SAMPLE RECOVERY | SAMPLE RETAINED | TYPE | ID | BLOWS PER 6 in. | N VALUE | USCS | VISUAL CLASSIFICATION |
|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | 2-1-1-2 | | CL | Silty Clay, some v.f. to f. sand, low plastic, soft, moist, rootlets and wood chips, brown mottled w/ black, yellowish brown and grayish brown. FILL |
| | | | | | | 3-7-17-27 | | CL | |
| 5 | | | | | | 18-23-74-28 | | | Silty Clay, some v.f. sand, low plastic, moist very stiff, yellowish brown mottled w/ grayish brown, dark yellowish brown and black. ALLUVIUM |
| | | | | | | 6-11-16-15 | | | |
| | | | | | | 18-19-14-15 | | | |
| 10 | | | | | | 16-25-27-36 | | | |
| | | | | | | 76-39-64-54/4" | | SM-CL | Clayey Sand - sandy clay, v.f. sand, low to medium plastic, wet, med. dense-dense to very stiff, dark yellowish brown mottled w/ grayish brown, yellowish brown and black. note: saturated at 10 FT. |
| 15 | | | | | | | | | Shale |
| | | | | | | | | | Stopped sampling at 13.9 FT. Stopped auger drilling at 16.0 FT. Start NX coring at 16.0 FT. |

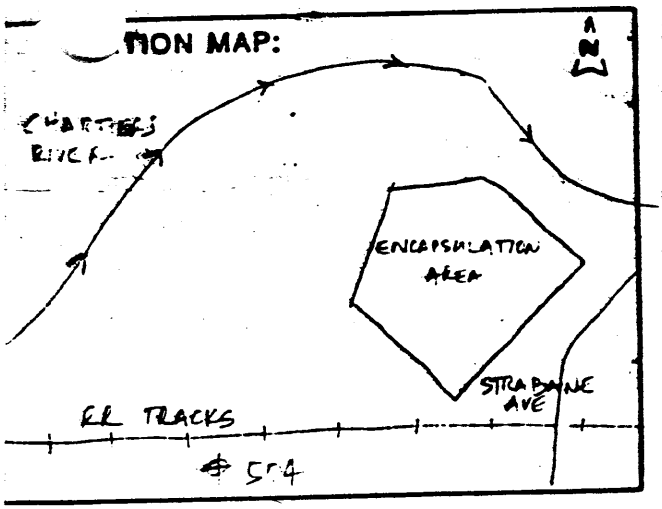
COMMENTS: Start drilling at 10:15 Stop drilling at 11:55

SAMPLE TYPE
A - Auger cuttings
S - 2" OD 1.38" ID drive sample
U - 3" OD 2.42" ID tube sample
T - 3" OD thin-walled Shelby tube

**JE** JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG (ROCK)






SITE ID: CAN 01 LOCATION ID: 504
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: ROTARY - WATER
DRILLING CONTR.: PENNSYLVANIA DRILLING
DATE STARTED: 7-14-86
DATE COMPLETED: 7-18-86
FIELD REP.: D.A. DARR

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| 7-21-86 | 9:[illegible] AM | 4.7 [illegible] |
| | | |
| | | |

LOCATION DESCRIPTION End of Sewlyn Street S. of site.
SITE CONDITION _____

| DEPTH (FT.) | BORING OPERATION | % CORE RECOVERY | % ROCK QUALITY DESIGNATION (RQD) | % DRILLING FLUID RECOVERY | PACKER TEST INTERVAL | SPACING | ORIENTATION | CONDITION | WEATHERING | LITHOLOGY | ROCK TYPE & REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Stopped auger drilling at 16.0 FT. Started rock |
| 15 | | | | | | | | | | | coring at 16.8 FT. |
| | | 100 | 21 | NA | NA | | | | | SH | Shale, clayey, thinly bedded, gray. |
| | | | | | | | | | | | Coal, black |
| 20 | | | | | | | | | | LS | Limestone, thinly to thickly bedded, locally discolored with $FeO_2$, gray mottled with brown and dark yellowish brown. |
| | | 100 | 89 | NA | NA | | | | | | Shale, hard, massive, gray. |
| 25 | | | | | | | | | | | |
| 30 | | | | | | | | | | | |
| | | 100 | 91 | NA | NA | | | | | | |
| 35 | | | | | | | | | | | |
| 40 | | | | | | | | | | | |

ENTS: _____

BORING OPERATION
H - 6 1/2 HOLLOW STEM AUGER
C - 4 1/2 CONTINUOUS FLIGHT AUGER
GB - GEAR BIT
NX - NX ROCK CORING
NQ - NQ WIRELINE ROCK CORING

JEG-AL-ENG-2A (4/85)

JE JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG (ROCK)



ATION MAP: N

SITE ID: CAN C1 LOCATION ID: 504
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: ROTARY - WATER
DRILLING CONTR.: PENNSYLVANIA DRILLING CO.
DATE STARTED: 7-14-86
DATE COMPLETED: 7-18-86
FIELD REP.: P.S. DARE

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| | | |
| | | |
| | | |

LOCATION DESCRIPTION End of Spanish Street E. of Site.
SITE CONDITION _____

| DEPTH (FT.) | BORING OPERATION | % CORE RECOVERY | % ROCK QUALITY DESIGNATION (RQD) | % DRILLING FLUID RECOVERY | PACKER TEST INTERVAL | SPACING | ORIENTATION | CONDITION | WEATHERING | LITHOLOGY | ROCK TYPE & REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 | | | | | | | | | | | |
| | | 96 | 84 | NA | NA | | | | | | |
| 45 | | | | | | | | | | | |
| 50 | | | | | | | | | | | |
| | | 100 | 89 | NA | NA | | | | | | Limestone, thickly bedded, hard, gray. |
| 55 | | | | | | | | | | | |
| | | | | | | | | | | | Shale, clayey, gray. |
| | | | | | | | | | | | Limestone, thinly bedded, hard, gray. |
| 60 | | | | | | | | | | | Shale, clayey, gray w/stringers of dusky red. |
| | | 100 | 69 | NA | NA | | | | | | Shale, clayey, dusky red. |
| | | | | | | | | | | | Shale, gray w/stringers of dusky red. |
| 65 | | | | | | | | | | | |

ENTS: _____

BORING OPERATION
H - 8 1/2 HOLLOW STEM AUGER
C - 4 1/2 CONTINUOUS FLIGHT AUGER
GB - GEAR BIT
NX - NX ROCK CORING
NQ - NQ WIRELINE ROCK CORING

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG (ROCK)



LOCATION MAP:

SITE ID: CAN 01 LOCATION ID: 5-4
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: ROTARY - WATER
DRILLING CONTR.: PENNSYLVANIA DRILLING CO.
DATE STARTED: 7-14-86
DATE COMPLETED: 7-16-86
FIELD REP.: P.S. DARK

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| | | |
| | | |
| | | |

LOCATION DESCRIPTION End of Sewlyn street E. of site.
SITE CONDITION _____

| DEPTH (FT.) | BORING OPERATION | % CORE RECOVERY | % ROCK QUALITY DESIGNATION (RQD) | % DRILLING FLUID RECOVERY | PACKER TEST INTERVAL | SPACING | ORIENTATION | CONDITION | WEATHERING | LITHOLOGY | ROCK TYPE & REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Shale, dusky red mottled w/ gray. |
| 70 | | | | | | | | | | | Shale, massive, hard, gray. Note: fresh slickenside at 77.5 ft. |
| | | 100 | 55 | NA | NA | | | | | | |
| 75 | | | | | | | | | | | |
| 80 | | | | | | | | | | | |
| | | 100 | 47 | NA | NA | | | | | | Shale, sandy, limy, fine to medium grains of limestone in the shale matrix, gray, becoming dusky red. |
| 85 | | | | | | | | | | | |
| 90 | | | | | | | | | | | |

COMMENTS: _____

BORING OPERATION
H - 8 1/2 HOLLOW STEM AUGER
C - 6 1/2 CONTINUOUS FLIGHT AUGER
GB - GEAR BIT
NX - NX ROCK CORING
NO - NO WIRELINE ROCK CORING

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG (ROCK)



LOCATION MAP:

SITE ID: CAN 01 LOCATION ID: 514
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: ROTARY - WATER
DRILLING CONTR.: PENNSYLVANIA [illegible]
DATE STARTED: 7-12-96
DATE COMPLETED: 7-18-96
FIELD REP.: [illegible]

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| | | |
| | | |
| | | |

LOCATION DESCRIPTION End of [illegible]
SITE CONDITION _____

| DEPTH (ft.) | BORING OPERATION | % CORE RECOVERY | % ROCK QUALITY DESIGNATION (RQD) | % DRILLING FLUID RECOVERY | PACKER TEST INTERVAL | SPACING | ORIENTATION | CONDITION | WEATHERING | LITHOLOGY | ROCK TYPE & REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 90 | | | | | | | | | | | |
| 92 | | | | | | | | | | | |
| | | | | | | | | | | | [illegible] casing at 93.0 ft. |

COMMENTS: _____

BORING OPERATION
H - 6 1/2 HOLLOW STEM AUGER
C - 4 1/2 CONTINUOUS FLIGHT AUGER
GB - GEAR BIT
NX - NX ROCK CORING
NO - NO WIRELINE ROCK CORING

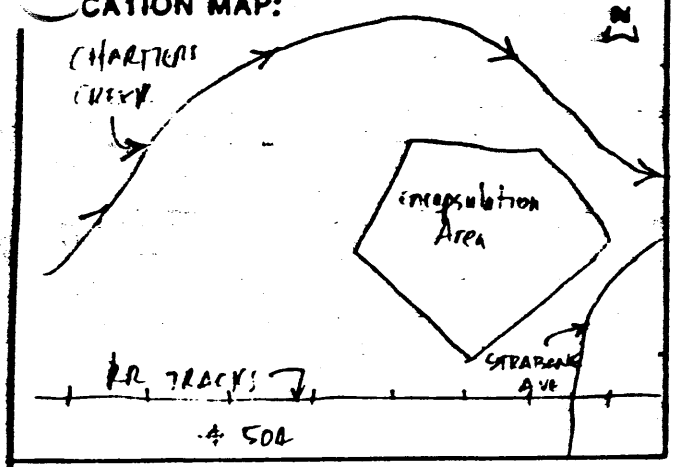
JEG-AL-ENG-2A (4/85)

JE JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG (SOIL)



LOCATION MAP:




SITE ID: CAN 01 LOCATION ID: 504
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: Auger
DRILLING CONTR.: Pennsylvania Drilling Co.
DATE STARTED: 7-23-86
DATE COMPLETED: 7-24-86
FIELD REP.: P.S. DARR

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| 7-25-86 | 7:30 am | 12.3 |
| | | |
| | | |

LOCATION DESCRIPTION _____
SITE CONDITION _____

| DEPTH | SAMPLE INTERVAL | SAMPLE RECOVERY | SAMPLE RETAINED | TYPE | ID | BLOWS PER 6 in. | N VALUE | USCS | VISUAL CLASSIFICATION |
|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | | Alluvium |
| 5 | | | | | | | | | See log of 504 drilled 7-14-86 thru 7-18-86 |
| 10 | | | | | | | | | |
| 14 | | | | | | | | | Shale |
| 16 | | | | | | | | | Stopped auger drilling at 16.0 FT<br>This borehole ± 10 FT from 504 drilled on 7-14-86 and completed on 7-18-86. Original borehole abandoned due to grout contamination. |

COMMENTS: Current borehole location is 18 FT west of 401 and 11 FT west of abandoned 504.

SAMPLE TYPE
A - Auger cuttings
S - 2" O.D 1.38" I.D drive sample
U - 3" O.D 2.42" I.D tube sample
T - 3" O.D thin-walled Shelby tube

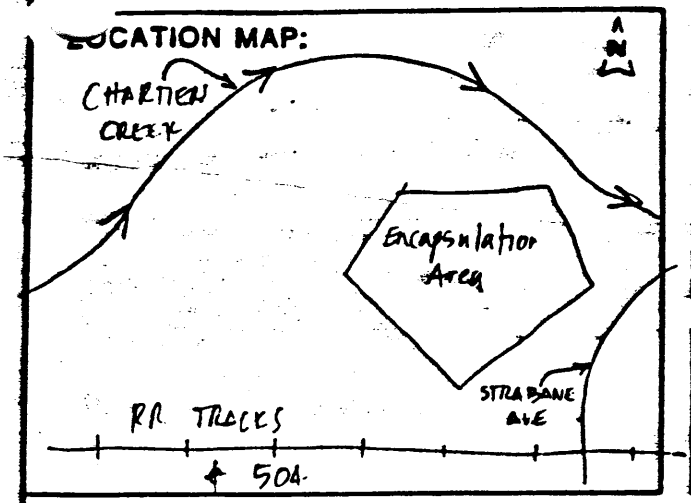
JEG-AL-ENG-2S (4/85)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG (ROCK)



LOCATION MAP:




SITE ID: CAN 01 LOCATION ID: 504
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: Roller Bit
DRILLING CONTR.: Pennsylvania Drilling Co.
DATE STARTED: 7-13-86
DATE COMPLETED: 7-24-86
FIELD REP.: PG. Datt

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| | | |
| | | |
| | | |

LOCATION DESCRIPTION _____
SITE CONDITION _____

| DEPTH (FT.) | BOHING OPERATION | % CORE RECOVERY | % ROCK QUALITY DESIGNATION (RQD) | % DRILLING FLUID RECOVERY | PACKER TEST INTERVAL | SPACING | ORIENTATION | CONDITION | WEATHERING | LITHOLOGY | ROCK TYPE & REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Shale |
| | | | | | | | | | | | Shale See log of 504 drilled 7-14-86 thru 7-15-86. |
| 26.5 | | | | | | | | | | | Stopped roller bit at 26.5 FT, |
| | | | | | | | | | | | This borehole 1 10 FT from 504 drilled on 7-14-86 and completed on 7-18-86. Original borehole abandoned due to grout contamination. |

COMMENTS: _____

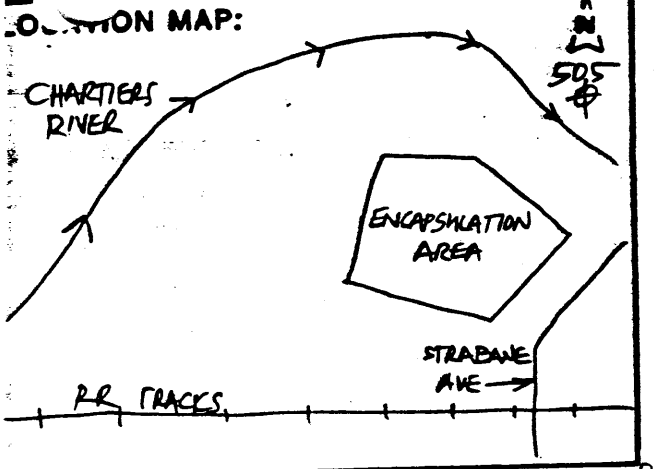
BORING OPERATION
H - 8 1/2 HOLLOW STEM AUGER
C - 4 1/2 CONTINUOUS FLIGHT AUGER
GB - GEAR BIT
NX - NX ROCK CORING
NO - NO WIRELINE ROCK CORING

JE JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

Page 1 of 1

# BOREHOLE LOG (SOIL)

LOCATION MAP:




SITE ID: CAN 01 LOCATION ID: 505
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: AUGER
DRILLING CONTR.: PENNSYLVANIA DRILLING CO.
DATE STARTED: 7-14-86
DATE COMPLETED: 7-17-86
FIELD REP.: P.S. DARR

GROUNDWATER LEVELS

| DATE | TIME | DEPTH (ft.) |
|---|---|---|
| 7-14-86 | 8:30 am | 2.5 |
| 7-21-86 | 9:35 am | 7.2 B.T.O.S.C. |
| 7-22-86 | 9:25 am | 6.4 B.T.O. PVC C. |

LOCATION DESCRIPTION West Penn Power Canonsburg Substation N. of site.
SITE CONDITION Flat parking area.

| DEPTH | SAMPLE INTERVAL | SAMPLE RECOVERY | SAMPLE RETAINED | TYPE | ID | BLOWS PER 6 in. | N VALUE | USCS | VISUAL CLASSIFICATION |
|---|---|---|---|---|---|---|---|---|---|
| 0 | X | | | | | 8-15-10-7 | | CL | Silty Clay, med. plastic, some fine sand, chips of gravel and fragments of red shale and coal, rootlets, moist, stiff, grayish to yellowish brown. |
| | X | | | | | 15-7-8-7 | | | note: considerable fragments of red brick from 2-3 FT. |
| | X | | | | | 4-3-4-4 | | CL-ML | FILL |
| 5 | X | | | | | 2-1-1-1 | | | Silty Clay, some fine sand, low plastic, micaceous, moist to wet, rootlets, olive gray mottled with dark brown, olive and black, |
| | X | | | | | 1-2-1-1 | | | note: saturated at 8 FT |
| | X | | | | | 1-1-2-2 | | | ALLUVIUM |
| 10 | X | | | | | 1-1-1-17 | | | Shale |
| | X | | | | | 65/6" | | | Stopped sampling at 14.5 FT |
| | X | | | | | | | | stopped auger drilling at 16.0 FT |
| 15 | | | | | | | | | Start NX coring at 17.2 FT |

COMMENTS: Start drilling @ 7:25 am stopped drilling @ 9:15 am
W.L. @ 7.25 B.T.O. PVC pk. 7-24 @ 8:40 am

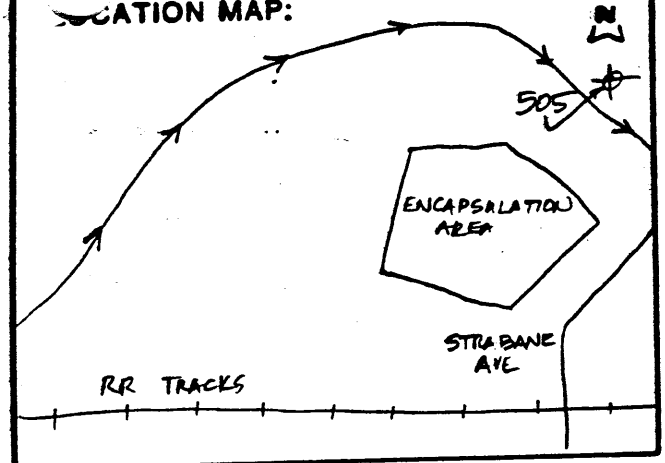
SAMPLE TYPE
A - Auger cuttings
S - 2" O.D. 1.38" I.D. drive sample
U - 3" O.D. 2.42" I.D. tube sample
T - 3" O.D. thin-walled Shelby tube

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG (ROCK)



LOCATION MAP:




SITE ID: CAN 01 LOCATION ID: 505
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: NX CORING
DRILLING CONTR.: PENNSYLVANIA DRILLING CO.
DATE STARTED: 7-14-86
DATE COMPLETED: 7-17-86
FIELD REP.: P.S. DARR

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| 7-21-86 | 9:35 am | 7.2 B.T.C. S.C. |
| 7-22-86 | 9:25 am | 6.4 B.T.C. PVC C. |
| | | |

LOCATION DESCRIPTION WEST PENN POWER CANONSBURG SUBSTATION N. OF SITE.
SITE CONDITION Flat graveled lot.

| DEPTH (FT.) | BORING OPERATION | % CORE RECOVERY | % ROCK QUALITY DESIGNATION (RQD) | % DRILLING FLUID RECOVERY | PACKER TEST INTERVAL | SPACING | ORIENTATION | CONDITION | WEATHERING | LITHOLOGY | ROCK TYPE & REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Auger drilled to 16.0 FT. See Borehole Log (SOIL) For lithologic description to 16.0 FT. |
| 19.2 | | 100 | 54 | NA | NA | | | | FR | SH | Shale, massive, fresh, hard, competent, becoming clayey at 29 FT. Predominately gray with dusky red stringers at 28-30 FT. |
| 20 | | | | | | | | | | | |
| 25 | | 75 | 0 | NA | NA | | | | FR | | |
| 30 | | 50 | 0 | NA | NA | | | | FR | | |
| 32.5 | | 100 | 0 | NA | NA | | | | SLW FR | LS SH | Limestone, thinnly bedded, slightly weathered w/iron staining shale directly atop this stringer, brown. |
| 35 | | 100 | 0 | NA | NA | | | | | | Shale, massive fresh, hard, competent, predominately gray with dusky red stringers at 42.0-42.5 FT. |
| | | 100 | 56 | NA | NA | | | | | | |
| 40 | | | | | | | | | | | |

COMMENTS: _____

BORING OPERATION
H - 6 1/2 HOLLOW STEM AUGER
C - 4 1/2 CONTINUOUS FLIGHT AUGER
GB - GEAR BIT
NX - NX ROCK CORING
NO - NO WIRELINE ROCK CORING

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG (ROCK)



LOCATION MAP:

SITE ID: CAN 01 LOCATION ID: 505
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: NX CORING
DRILLING CONTR.: PENNSYLVANIA DRILLING CO.
DATE STARTED: 7-14-86
DATE COMPLETED: 7-17-86
FIELD REP.: P.S. DARR

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| | | |
| | | |
| | | |

LOCATION DESCRIPTION West Penn Power Connellsburg Substation N. of site.
SITE CONDITION Flat graveled lot.

| DEPTH (FT.) | JOINING OPERATION | % CORE RECOVERY | % ROCK QUALITY DESIGNATION (RQD) | % DRILLING FLUID RECOVERY | PACKER TEST INTERVAL | SPACING | ORIENTATION | CONDITION | WEATHERING | LITHOLOGY | ROCK TYPE & REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | SH | |
| 45 | X | 20 | 0 | NA | NA | | | | | | |
| 45.5 | | | | | | | | | FR | LS | LIMESTONE, thinnly bedded, fresh, hard, competent, brown. |
| 46 | | 41 | 21 | | | | | | | | |
| 46 | | | | | | | | | | SH | Shale, clayey, fresh, thickly bedded to massive, dusky red. |
| 50 | | | | | | | | | | | |
| 55 | | | | | | | | | FR | LS | LIMESTONE, occasional limy shale stringers, hard thickly bedded, gray. |
| 59.5 | | 100 | 21 | NA | NA | | | | | | Shale, massive, core recovery very broken-up, occasional slickensides that shows no discoloration limy shale stringer at 59.5-60.0 FT, gray. |
| 60 | | | | | | | | | | | |
| | | | | | | | | | FR | SH | Shale, thinnly bedded, broken up core recovery dusky red. |

COMMENTS: _____

BORING OPERATION
H - 6 1/2 HOLLOW STEM AUGER
C - 4 1/2 CONTINUOUS FLIGHT AUGER
GB - GEAR BIT
NX - NX ROCK CORING
NQ - NQ WIRELINE ROCK CORING

JE JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG (ROCK)



LOCATION MAP:

SITE ID: CAN 01 LOCATION ID: 505
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: NX CORING
DRILLING CONTR.: PENNSYLVANIA DRILLING CO.
DATE STARTED: 7-14-86
DATE COMPLETED: 7-17-86
FIELD REP.: P.S. DARR

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| | | |
| | | |
| | | |

LOCATION DESCRIPTION West Penn Power Substation N. of site
SITE CONDITION Flat graveled lot.

| DEPTH (FT.) | JOINING OPERATION | % CORE RECOVERY | % ROCK QUALITY DESIGNATION (ROD) | % DRILLING FLUID RECOVERY | PACKER TEST INTERVAL | SPACING | ORIENTATION | CONDITION | WEATHERING | LITHOLOGY | ROCK TYPE & REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 100 | 89 | NA | NA | | | | | SH | SHALE, DUSKY RED. |
| | | | | | | | | | | SH | SHALE, massive, fresh, gray. |
| 70 | | | | | | | | | | | Dusky red shale 74.5-75.0 FT<br>Dusky red colored stringers to 76.5 FT. |
| 75 | | 100 | 80 | NA | NA | | | | | | |
| 80 | | | | | | | | | | | |
| | | | | | | | | | | SH | Shale, sandy, limy, fine to coarse fragments of limestone, massive, fresh, occasional fresh slickensides, dusky red. |
| 85 | | 100 | 0 | NA | NA | | | | | | Becoming less sandy and limy below 85 FT. |

COMMENTS: _____

BORING OPERATION
H - 8 1/2 HOLLOW STEM AUGER
C - 4 1/2 CONTINUOUS FLIGHT AUGER
GB - GEAR BIT
NX - NX ROCK CORING
NQ - NQ WIRELINE ROCK CORING

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG (ROCK)



LOCATION MAP:

SITE ID: CAN 01 LOCATION ID: 505
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: NX CORING
DRILLING CONTR.: PENNSYLVANIA DRILLING CO.
DATE STARTED: 7-14-86
DATE COMPLETED: 7-17-86
FIELD REP.: P.S. DARK

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| | | |
| | | |
| | | |

LOCATION DESCRIPTION West Penn Power Canonsburg Substation N. of site.
SITE CONDITION flat, graveled lot.

| DEPTH (FT.) | BOHING OPERATION | % CORE RECOVERY | % ROCK QUALITY DESIGNATION (RQD) | % DRILLING FLUID RECOVERY | PACKER TEST INTERVAL | SPACING | ORIENTATION | CONDITION | WEATHERING | LITHOLOGY | ROCK TYPE & REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | SH | SHALE, dusky red mottled with gray and yellowish brown, |
| 95 | | | | | | | | | | | Stopped coring at 95.0 FT. |

COMMENTS: _____

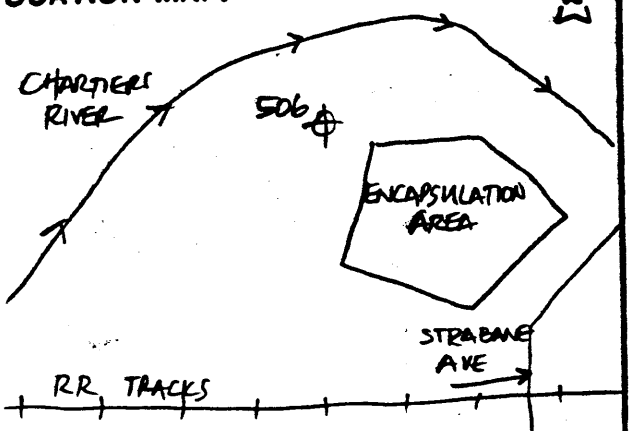
BORING OPERATION
H - 6 1/2 HOLLOW STEM AUGER
C - 4 1/2 CONTINUOUS FLIGHT AUGER
GB - GEAR BIT
NX - NX ROCK CORING
NQ - NQ WIRELINE ROCK CORING

JE JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG (SOIL)



LOCATION MAP:




SITE ID: CAN 01 LOCATION ID: 506
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: AUGER
DRILLING CONTR.: PENNSYLVANIA DRILLING CO.
DATE STARTED: 7-14-86
DATE COMPLETED: 7-18-86
FIELD REP.: P.S. DARR

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| 7-14-86 | 3:35 | DRY |
| 7-21-86 | 9:32 am | 17.6 B.T.O.S.C. |
| | | |

LOCATION DESCRIPTION On site NW of Encapsulation area.
SITE CONDITION Flat grass covered

| DEPTH | SAMPLE INTERVAL | SAMPLE RECOVERY | SAMPLE RETAINED | TYPE | ID | BLOWS PER 6 in. | N VALUE | USCS | VISUAL CLASSIFICATION |
|---|---|---|---|---|---|---|---|---|---|
| 0 | X | | | | | 4-12-16-16 | | CL | Silty Clay, low plastic, some f-med sand, moist, hard, yellowish brown mottled w/ grayish brown. FILL |
| | X | | | | | 26-39-64 | | | |
| | X | | | | | | | Note | Asphalt layer @ 3.5 FT. |
| 5 | X | | | | | 13-13-14-17 | | | |
| | X | | | | | 20-22-17-22 | | CL | Sandy Clay, low plastic, v.f. to f. sand, hard, wet, yellowish brown mottled w/ grayish brown and black. |
| | X | | | | | 10-10-9-14 | | | |
| 10 | X | | | | | 26-32-33-36 | | SC | Clayey sand, v.f. to f. sand, moist, medium dense, yellowish brown mottled w/ grayish brown. |
| | X | | | | | 73/6" | | | |
| | | | | | | | | | Shale |
| | | | | | | | | | Stopped sampling at 12.5 FT |
| | | | | | | | | | Stopped drilling at 15.0 FT |
| | | | | | | | | | Start NX coring at 15.0 FT |

COMMENTS: start drilling @ 2:05 Stopped drilling at 3:15

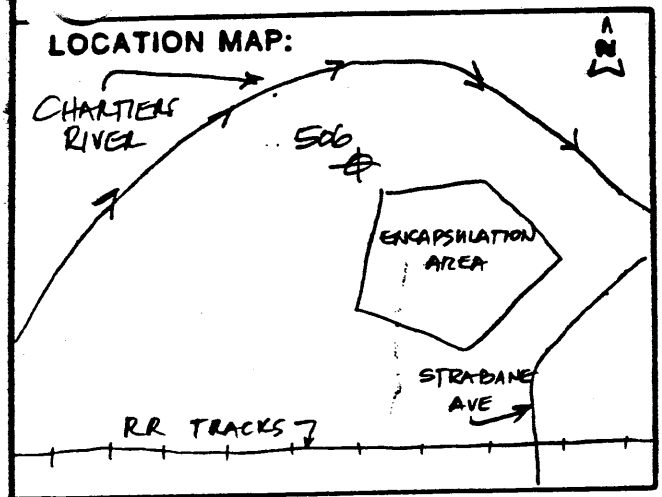
SAMPLE TYPE
A - Auger cuttings
S - 2" O.D. 1.38" I.D. drive sample
U - 3" O.D. 2.42" I.D. tube sample
T - 3" O.D. thin-walled Shelby tube

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG (ROCK)



LOCATION MAP:




SITE ID: CAN 01 LOCATION ID: 506
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: AIR ROTARY
DRILLING CONTR.: PENNSYLVANIA DRILLING CO.
DATE STARTED: 7-14-86
DATE COMPLETED: 7-18-86
FIELD REP.: P.S. DARR

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| 7-21-86 | 9:32 AM | 17.6 B.T.O.S.C. |
| 7-24-86 | 8:50 AM | 13.7 B.T.O. PVC C. |
| | | |

LOCATION DESCRIPTION On site NW of Encapsulation area.
SITE CONDITION Flat grass covered

| DEPTH (FT.) | BORING OPERATION | % CORE RECOVERY | % ROCK QUALITY DESIGNATION (ROD) | % DRILLING FLUID RECOVERY | PACKER TEST INTERVAL | SPACING | ORIENTATION | CONDITION | WEATHERING | LITHOLOGY | ROCK TYPE & REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Augered borehole to 15 FT. SET SURFACE CASING (6 in. steel) to 15 FT. |
| 15 | | 100 | 40 | NA | NA | | | | | | |
| 16.5 | | | | | | | | | | | Shale, v. fractured, v. weathered, fractures stained w/ $FeO_2$, hard, thickly bedded, water at 20 FT, yellowish brown mottled w/ gray. |
| 20 | | 100 | 19 | NA | NA | | | | | | |
| 23 | | | | | | | | | | | Shale, massive, fresh, gray. |
| 25 | | | | | | | | | | | |
| 30 | | 116 | 13 | NA | NA | | | | | | note: $FeO_2$ coated fracture at 33.7 FT. |

COMMENTS: _____

BORING OPERATION
H - 6 1/2 HOLLOW STEM AUGER
C - 4 1/2 CONTINUOUS FLIGHT AUGER
GB - GEAR BIT
NX - NX ROCK CORING
NO - NO WIRELINE ROCK CORING

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG (ROCK)



LOCATION MAP:

SITE ID: CAN 01 LOCATION ID: 506
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: AIR ROTARY
DRILLING CONTR.: PENNSYLVANIA DRILLING CO.
DATE STARTED: 7-14-86
DATE COMPLETED: 7-16-86
FIELD REP.: P.S. DARR

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| | | |
| | | |
| | | |

LOCATION DESCRIPTION On site NW of Encapsulation area.
SITE CONDITION _____

| DEPTH (FT.) | BORING OPERATION | % CORE RECOVERY | % ROCK QUALITY DESIGNATION (RQD) | % DRILLING FLUID RECOVERY | PACKER TEST INTERVAL | SPACING | ORIENTATION | CONDITION | WEATHERING | LITHOLOGY | ROCK TYPE & REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 | | 100 | 18 | NA | NA | | | | | | Shale, massive, hard, gray, note: $FeO_2$ coated fracture at 42.7 FT. and 48.5 FT. |
| 45 | | | | | | | | | | | |
| 50 | | 56 | 18 | NA | NA | | | | | | note: no core recovery 50-53 FT. |
| 54 | | | | | | | | | | | Shale, massive, sandy, limy, hard, v.f. sand, gray |
| 56.5 | | | | | | | | | | | Shale, massive, hard, gray |

COMMENTS: _____

BORING OPERATION
H - 6 1/2 HOLLOW STEM AUGER
C - 4 1/2 CONTINUOUS FLIGHT AUGER
GB - GEAR BIT
NX - NX ROCK CORING
NQ - NQ WIRELINE ROCK CORING

JE JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG (ROCK)



LOCATION MAP:

SITE ID: CAN 01 LOCATION ID: 506
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: AIR ROTARY
DRILLING CONTR.: PENNSYLVANIA DRILLING CO.
DATE STARTED: 7-14-86
DATE COMPLETED: 7-18-86
FIELD REP.: P.S. DARR

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| | | |
| | | |
| | | |

LOCATION DESCRIPTION On site NW of Encapsulation site
SITE CONDITION _____

| DEPTH (FT.) | BORING OPERATION | % CORE RECOVERY | % ROCK QUALITY DESIGNATION (RQD) | % DRILLING FLUID RECOVERY | PACKER TEST INTERVAL | SPACING | ORIENTATION | CONDITION | WEATHERING | LITHOLOGY | ROCK TYPE & REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 63 | 0 | NA | NA | | | | | | note: no recovery 60 – 63 FT. |
| 65 | | | | | | | | | | | |
| 70 | | 32 | 19 | NA | NA | | | | | | |
| 74 | | | | | | | | | | | Shale, clayey, gray. |
| 75 | | | | | | | | | | | note: no recovery 72 – 80 FT. |
| 77 | | | | | | | | | | | Shale, clayey, red |
| 80 | | 100 | 29 | NA | NA | | | | | | |

COMMENTS: _____

BORING OPERATION
H – 8 1/2 HOLLOW STEM AUGER
C – 4 1/2 CONTINUOUS FLIGHT AUGER
GB – GEAR BIT
NX – NX ROCK CORING
NQ – NQ WIRELINE ROCK CORING

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG (ROCK)



LOCATION MAP: N

SITE ID: CAN 01 LOCATION ID: 506
SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: AIR ROTARY
DRILLING CONTR.: PENNSYLVANIA DRILLING CO.
DATE STARTED: 7-14-86
DATE COMPLETED: 7-18-86
FIELD REP.: P.S. BARR

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| | | |
| | | |
| | | |

LOCATION DESCRIPTION On site NW of Encapsulation area.
SITE CONDITION _____

| DEPTH (FT.) | BORING OPERATION | % CORE RECOVERY | % ROCK QUALITY DESIGNATION (RQD) | % DRILLING FLUID RECOVERY | PACKER TEST INTERVAL | SPACING | ORIENTATION | CONDITION | WEATHERING | LITHOLOGY | ROCK TYPE & REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Shale, sandy with occasional fine to medium grains of limestone, silty, dusky red. |
| 90 | | | | | | | | | | | Stopped coring at 90 FT. |

COMMENTS: _____

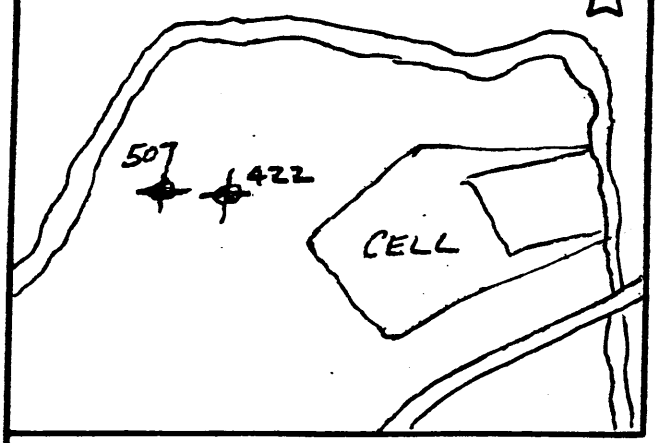
BORING OPERATION
H - 8 1/2 HOLLOW STEM AUGER
C - 4 1/2 CONTINUOUS FLIGHT AUGER
GB - GEAR BIT
NX - NX ROCK CORING
NO - NO WIRELINE ROCK CORING

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG



LOCATION MAP:




SITE ID: CAN 01 LOCATION ID: 507
APPROX. SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: 9½" HSA
DRILLER: Lambert Drilling
DATE STARTED: 10-20-93
DATE COMPLETED: 10-20-93
FIELD REP.: W R Wood

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| 10-20-93 | 12:38P | 38 |
| | | |
| | | |

LOCATION DESCRIPTION 10' west of #422
SITE CONDITION Rolling, grass Covered Area

| DEPTH (ft.) | SAMPLE INT. | SAMPLE TYPE | SAMPLE ID | UNIFIED SOIL CLASS. | VISUAL CLASS.: DENSITY, COLOR, STRENGTH, PLASTICITY, CONDITION, ETC. |
|---|---|---|---|---|---|
| | | | | CL | Fill: Silty Clay, considerable gravel, med Pl, light tan |
| 5 | | | | CL | Fill: Silty Clay, considerable fine gravel, some sand, med Pl, dark brown |
| | | | | | Note: some pottery shards. |
| | | | | CL | Fill: Sandy Clay, Low-med Pl, brown |
| 10 | | | | CL | Silty Clay, some sand, med Plasticity light brown |
| 15 | | | | CL | Sandy Clay, Considerable gravel, Low-med Pl, tan |
| 20 | | | | CL | Silty Clay, med Plasticity, light brown |
| | | | | | Cootleman Shale, soft, gray |
| 25 | | A | 001 | | |
| 0 | | | | | |

COMMENTS: _____

SAMPLE TYPE
A - Auger cuttings
S - 2" O.D. 1.38" I.D. drive sample
U - 3" O.D. 2.42" I.D. tube sample
T - 3" O.D. thin-walled Shelby tube

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG



LOCATION MAP: N

SITE ID: CAN 01 LOCATION ID: 507
APPROX. SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: 9¼" HSA
DRILLER: Lambert Drilling
DATE STARTED: 10-20-93
DATE COMPLETED: 10-20-93
FIELD REP.: W. R. Wood

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| 10-20-93 | 12:38 P | 38' |
| | | |
| | | |

LOCATION DESCRIPTION _____
SITE CONDITION _____

| DEPTH (ft.) | SAMPLE INT. | SAMPLE TYPE | SAMPLE ID | UNIFIED SOIL CLASS. | VISUAL CLASS.: DENSITY, COLOR, STRENGTH, PLASTICITY, CONDITION, ETC. |
|---|---|---|---|---|---|
| | | A | 002 | | Castleman Shale, soft, gray. |
| 5 | | | | | Note: becoming hard at 33½' |
| | | A | 003 | | occasional fine coal seam. |
| 40 | | | | | |
| | | | | | stopped drilling @ 42' |

COMMENTS: _____

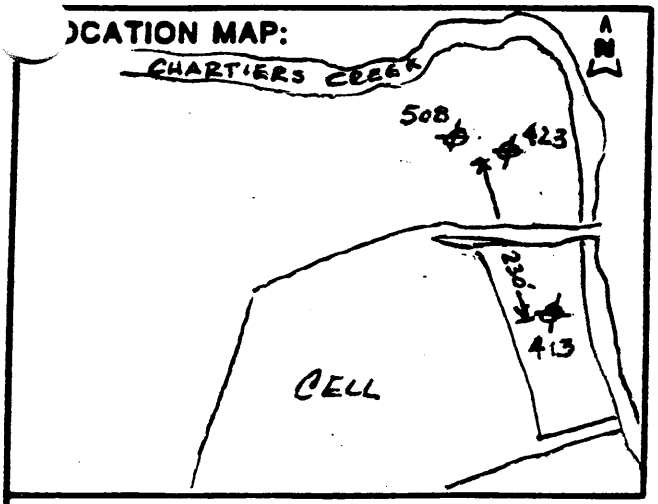
SAMPLE TYPE
A - Auger cuttings
S - 2" O.D. 1.38" I.D. drive sample
U - 3" O.D. 2.42" I.D. tube sample
T - 3" O.D. thin-walled Shelby tube

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG



LOCATION MAP:




SITE ID: CAN 01 LOCATION ID: 508
APPROX. SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: 9¼" HSA
DRILLER: Lambert Drilling
DATE STARTED: 10-23-93
DATE COMPLETED: 10-23-93
FIELD REP.: W. R. Wood

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| 10-23-93 | 9:30 A | 7 |
| 10-23-93 | 9:55 A | 27 |
| | | |

LOCATION DESCRIPTION _____
SITE CONDITION _____

| DEPTH (ft.) | SAMPLE INT. | SAMPLE TYPE | SAMPLE ID | UNIFIED SOIL CLASS. | VISUAL CLASS.: DENSITY, COLOR, STRENGTH, PLASTICITY, CONDITION, ETC. |
|---|---|---|---|---|---|
| 0 | | | | CL | Sandy clay, considerable gravel, medium plasticity, light brown. |
| 5 | | | | CL | silty clay, medium plasticity dark brown. |
| 10 | | | | ML | sandy silt, some clay, low plasticity, dark brown. |
| 15 | | | | | Cretaceous shale, soft to moderately hard, brown to gray. |
| 20 | | A | 001 | | |
| 25 | | A | 002 | | |
| 30 | | A | 003 | | |

COMMENTS: _____

SAMPLE TYPE
A - Auger cuttings
S - 2" O.D. 1.38" I.D. drive sample
U - 3" O.D. 2.42" I.D. tube sample
T - 3" O.D. thin-walled Shelby tube

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG



LOCATION MAP: N

SITE ID: CAN 01 LOCATION ID: 508
APPROX. SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: 9½" HSA
DRILLER: Lambert Drilling
DATE STARTED: 10-23-93
DATE COMPLETED: 10-23-93
FIELD REP.: W. R Wood

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| | | |
| | | |
| | | |

LOCATION DESCRIPTION _____
SITE CONDITION _____

| DEPTH (ft.) | SAMPLE INT. | SAMPLE TYPE | SAMPLE ID | UNIFIED SOIL CLASS. | VISUAL CLASS.: DENSITY, COLOR, STRENGTH, PLASTICITY, CONDITION, ETC. |
|---|---|---|---|---|---|
| 30 | | | | | Castleman Shale, moderately Hard, gray |
| 32 | | | | | Stopped drilling at 32 feet |

COMMENTS: 230 ft to 413 from 423

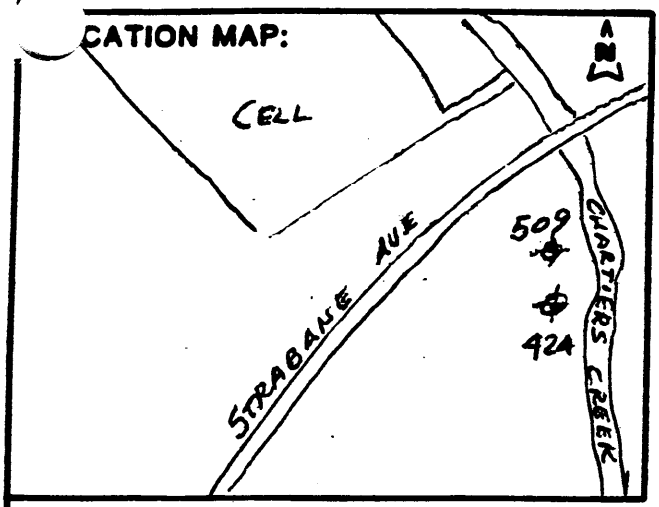
SAMPLE TYPE
A - Auger cuttings
S - 2" O.D. 1.38" I.D. drive sample
U - 3" O.D. 2.42" I.D. tube sample
T - 3" O.D. thin-walled Shelby tube

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG



LOCATION MAP:




SITE ID: CAN 01 LOCATION ID: 509
APPROX. SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: 9½" HSA
DRILLER: Lambert Drilling
DATE STARTED: 10-24-93
DATE COMPLETED: 10-24-93
FIELD REP.: W. R. Wood

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| 10-24-93 | 10:40A | 13'? |
| | | |
| | | |

LOCATION DESCRIPTION _____
SITE CONDITION _____

| DEPTH (ft.) | SAMPLE INT. | SAMPLE TYPE | SAMPLE ID | UNIFIED SOIL CLASS. | VISUAL CLASS.: DENSITY, COLOR, STRENGTH, PLASTICITY, CONDITION, ETC. |
|---|---|---|---|---|---|
| 0 | | | | CL | Silty Clay some fine gravel, medium plasticity, brown<br>Note: some cobbles from 3' to 4' |
| | | | | CL | Sandy clay, medium Plasticity, dark brown. |
| 10 | | | | SC | Clayey sand, predominantly fine, low Plasticity, dark brown |
| 15 | | | | | Castleman Shale, soft to moderately hard, light gray. |
| 20 | | A | 001 | | |
| 25 | | A | 002 | | |

COMMENTS: _____

SAMPLE TYPE
A - Auger cuttings
S - 2" O.D. 1.38" I.D. drive sample
U - 3" O.D. 2.42" I.D. tube sample
T - 3" O.D. thin-walled Shelby tube

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG



LOCATION MAP: A N

SITE ID: CAN 01 LOCATION ID: 509
APPROX. SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: 8¼" HSA
DRILLER: Lambert Drilling
DATE STARTED: 10-24-93
DATE COMPLETED: 10-24-93
FIELD REP.: W. R. Wood

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| | | |
| | | |
| | | |

LOCATION DESCRIPTION _____
SITE CONDITION _____

| DEPTH (ft.) | SAMPLE INT. | SAMPLE TYPE | SAMPLE ID | UNIFIED SOIL CLASS. | VISUAL CLASS.: DENSITY, COLOR, STRENGTH, PLASTICITY, CONDITION, ETC. |
|---|---|---|---|---|---|
| 30 | | A | 003 | | Castlemon Shale, hard, gray. |
| | | | | | Stopped drilling at 39½' |
| 40 | | | | | |

COMMENTS: _____

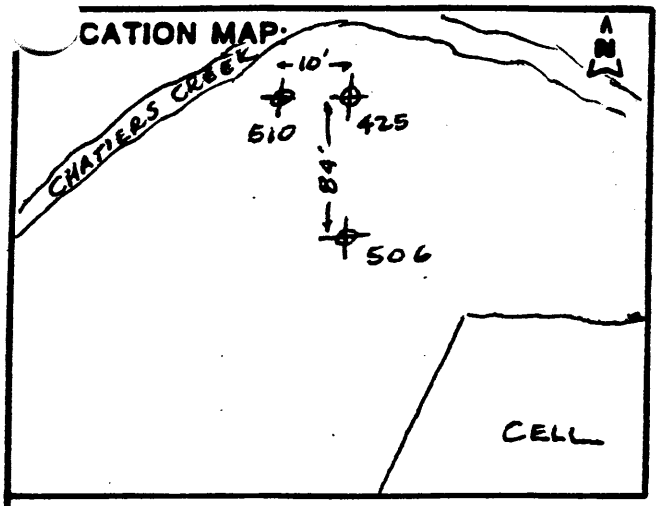
SAMPLE TYPE
A - Auger cuttings
S - 2" O.D. 1.38" I.D. drive sample
U - 3" O.D. 2.42" I.D. tube sample
T - 3" O.D. thin-walled Shelby tube

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG



LOCATION MAP:




SITE ID: CAN 01 LOCATION ID: 510
APPROX. SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: 2½" Auger - 7⅞" Air Rotary
DRILLER: _____
DATE STARTED: 10-21-93
DATE COMPLETED: 10-22-93
FIELD REP.: W R Wood

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| | | |
| | | |
| | | |

LOCATION DESCRIPTION _____
SITE CONDITION _____

| DEPTH (ft.) | SAMPLE INT. | SAMPLE TYPE | SAMPLE ID | UNIFIED SOIL CLASS. | VISUAL CLASS.: DENSITY, COLOR, STRENGTH, PLASTICITY, CONDITION, ETC. |
|---|---|---|---|---|---|
| 0 | | | | CL | Sandy clay, low-medium Plasticity<br>Yellow-brown<br>Note: Trace of gravel. |
| 5 | | | | CL | Silty clay, medium Plasticity<br>yellow-brown |
| | | | | CL | Sandy clay, some fine gravel,<br>medium Plasticity, brown |
| | | | | CL | sandy clay, med Pl, dark brown. |
| 10 | | A | 001 | | Castleman Shale, soft, light<br>tan to gray.<br>Becoming harder @ 22½' |
| 15 | | | | | Sandstone, fine, hard, brown |
| | | A | 002 | | Shale, soft to med hard, gray |
| 20 | | | | | |

COMMENTS: _____

SAMPLE TYPE
A - Auger cuttings
S - 2" O.D. 1.38" I.D. drive sample
U - 3" O.D. 2.42" I.D. tube sample
T - 3" O.D. thin-walled Shelby tube

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE LOG



OCATION MAP: N

SITE ID: CAN 01 LOCATION ID: 510
APPROX. SITE COORDINATES (ft.):
N _____ E _____
GROUND ELEVATION (ft. MSL): _____
DRILLING METHOD: 9½" HSA - 7⅞ Rotary
DRILLER: Lambert Drilling
DATE STARTED: 10-21-93
DATE COMPLETED: 10-22-93
FIELD REP.: W L Wood

| GROUNDWATER LEVELS | | |
|---|---|---|
| DATE | TIME | DEPTH (ft.) |
| 10-22-93 | 10:15 P | 15' ± |
| | | |
| | | |

LOCATION DESCRIPTION _____
SITE CONDITION _____

| DEPTH (ft.) | SAMPLE INT. | SAMPLE TYPE | SAMPLE ID | UNIFIED SOIL CLASS. | VISUAL CLASS.: DENSITY, COLOR, STRENGTH, PLASTICITY, CONDITION, ETC. |
|---|---|---|---|---|---|
| 20 | | A | 003 | | Shale, soft to moderately hard, gray |
| 25 | | | | | |
| 30 | | | | | Stopped drilling @ 38' |

COMMENTS: _____

SAMPLE TYPE
A - Auger cuttings
S - 2" O.D. 1.38" I.D. drive sample
U - 3" O.D. 2.42" I.D. tube sample
T - 3" O.D. thin-walled Shelby tube

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# WELL COMPLETION RECORD

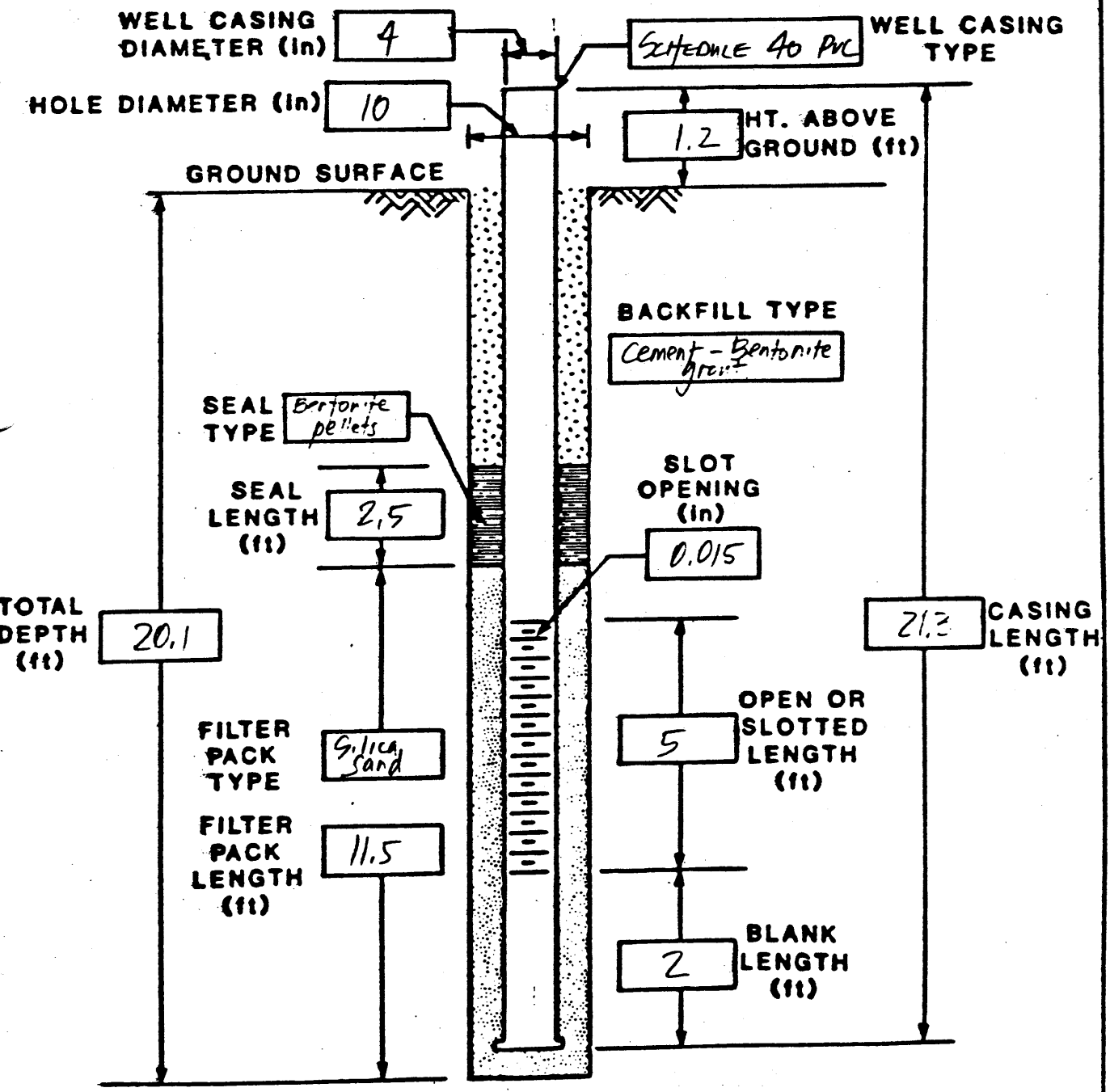
SITE ID: CAN 01 LOCATION ID: 412 DATE INSTALLED: 7-15-85

APPROX. SITE COORDINATES: (FT.) N _____ E _____

OPEN AREA PER LINEAL FT. ($IN^2/FT.$) _____

FORMATION OF COMPLETION: ALLUVIUM

FIELD REP.: P.S. DARR DRILLER: PENNSYLVANIA DRILLING CO.




COMMENTS: _____

JEG-AL-ENG-3 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# WELL COMPLETION RECORD

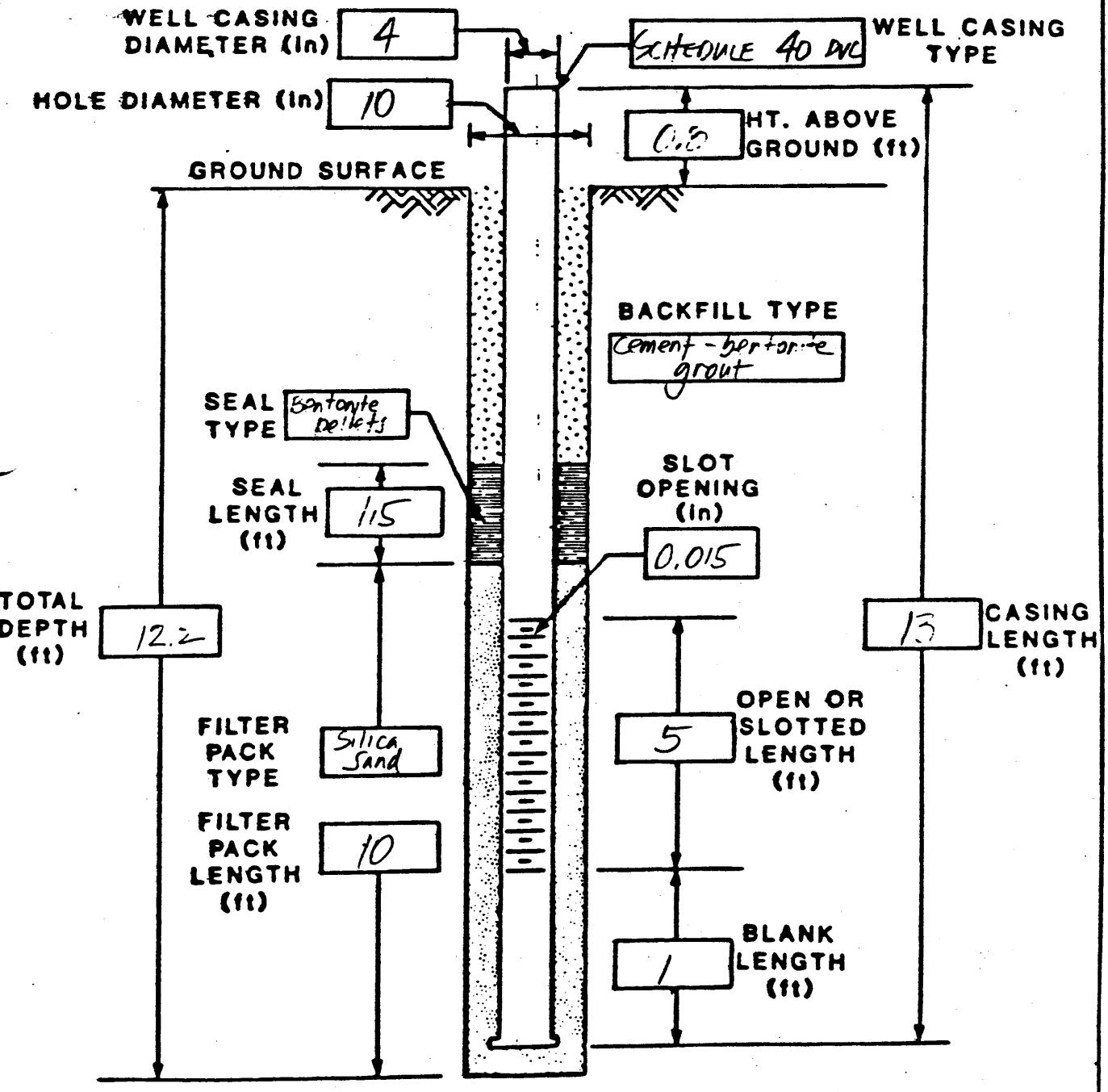
SITE ID: CAN 0' LOCATION ID: 413 DATE INSTALLED: 7-15-86

APPROX. SITE COORDINATES: (FT.) N _____ E _____

OPEN AREA PER LINEAL FT. ($IN^2/FT.$) _____

FORMATION OF COMPLETION: Alluvium

FIELD REP.: P.S. Davis DRILLER: Pennsylvania Drilling Co.




COMMENTS: _____

JEG-AL-ENG-3 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# WELL COMPLETION RECORD

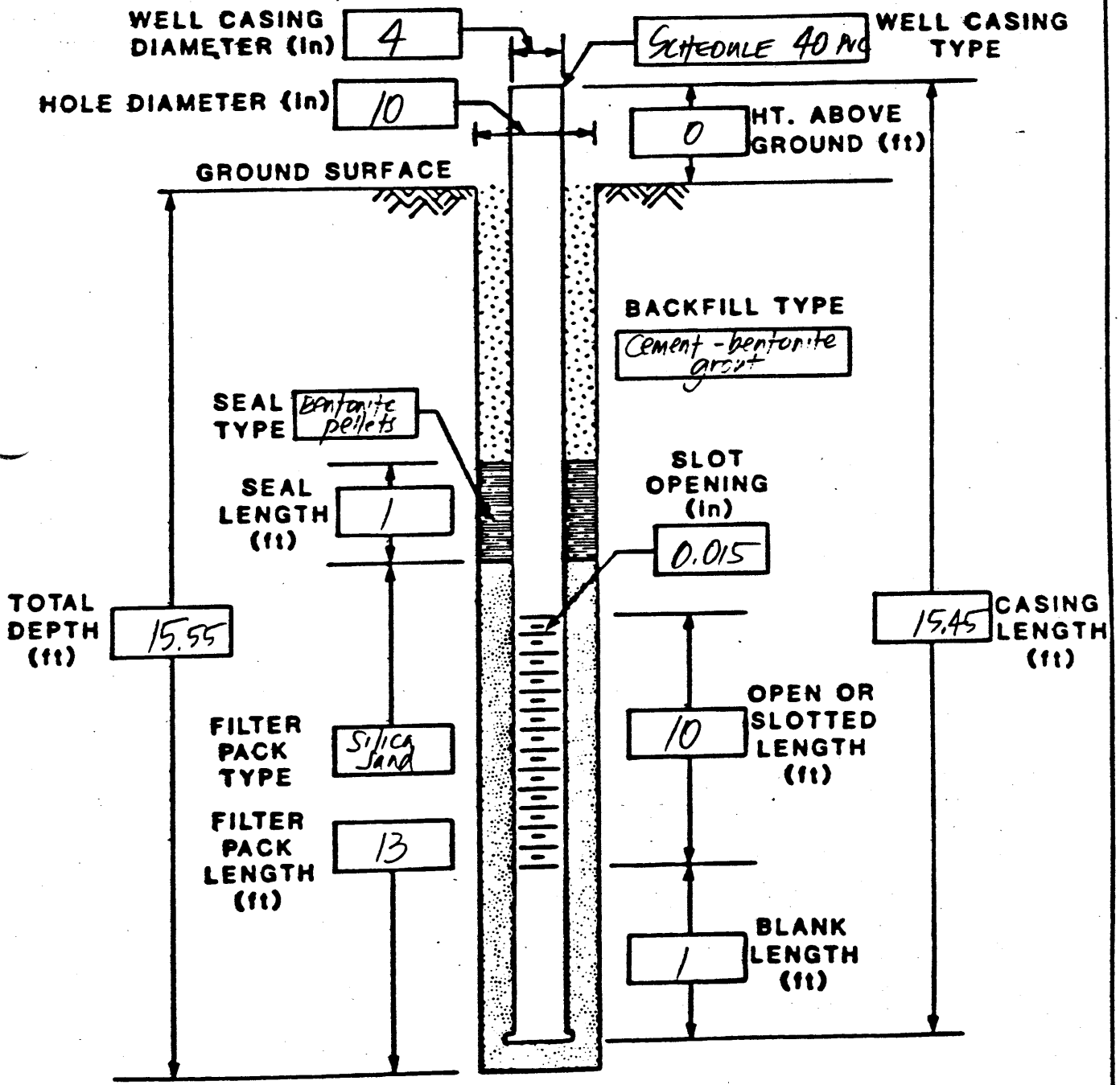
SITE ID: CAN 01 LOCATION JD: 414 DATE INSTALLED: 7-15-86

APPROX. SITE COORDINATES: (FT.) N _____ E _____

OPEN AREA PER LINEAL FT. ($IN^2/FT.$) _____

FORMATION OF COMPLETION: Alluvium

FIELD REP.: P.S. DARR DRILLER: Pennsylvania Drilling Co.




COMMENTS: _____

JEG-AL-ENG-3 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# WELL COMPLETION RECORD

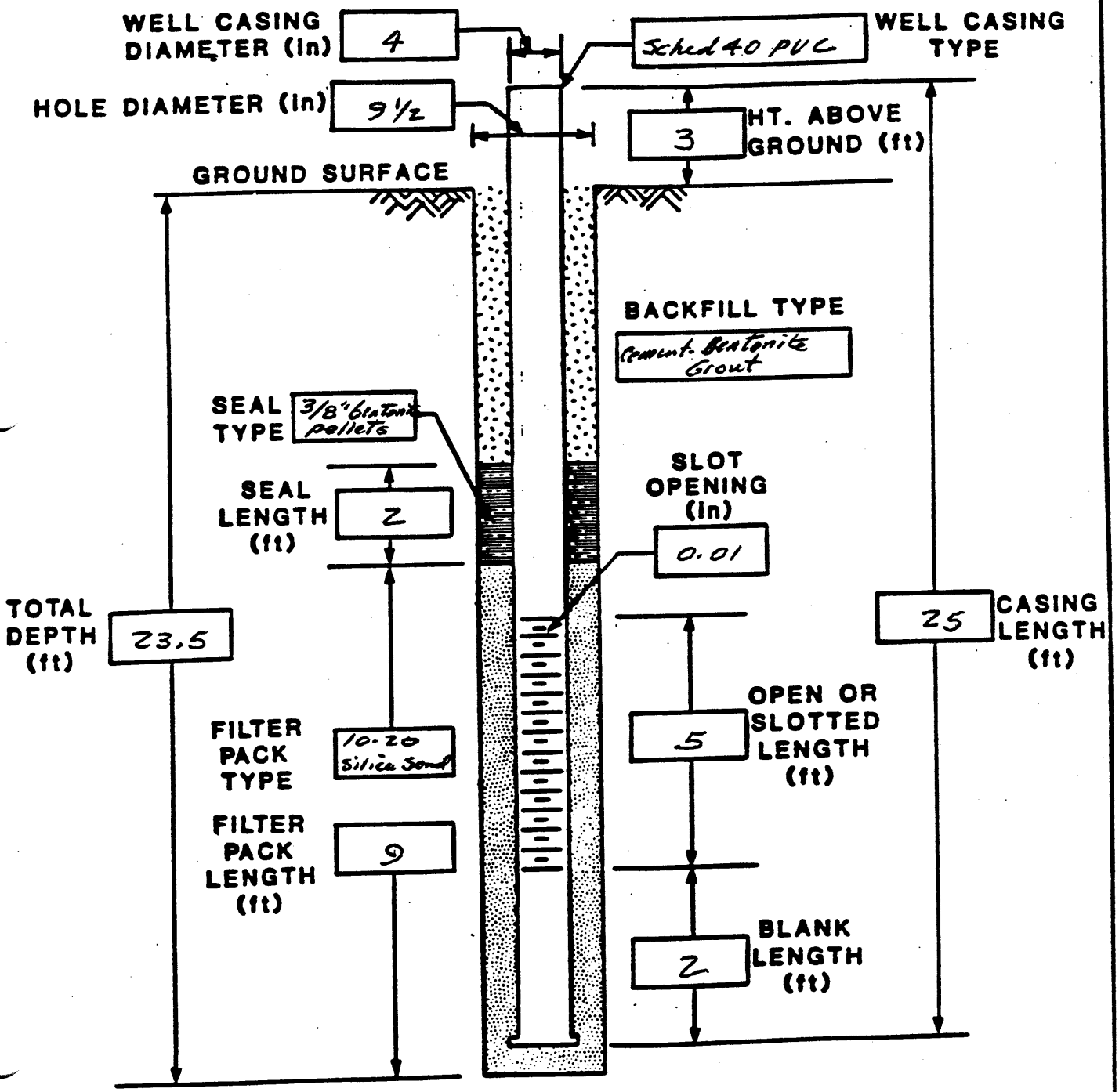
SITE ID: CAN 01 LOCATION ID: 422 DATE INSTALLED: 10-20-93

APPROX. SITE COORDINATES: (FT.) N _____ E _____

OPEN AREA PER LINEAL FT. ($IN^2/FT.$) _____

FORMATION OF COMPLETION: Alluvium (sandy clay)

FIELD REP.: M. R. Wood DRILLER: Lambert Drilling




COMMENTS: Installed well in dry hole

JEG-AI-ENG-3 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# WELL COMPLETION RECORD

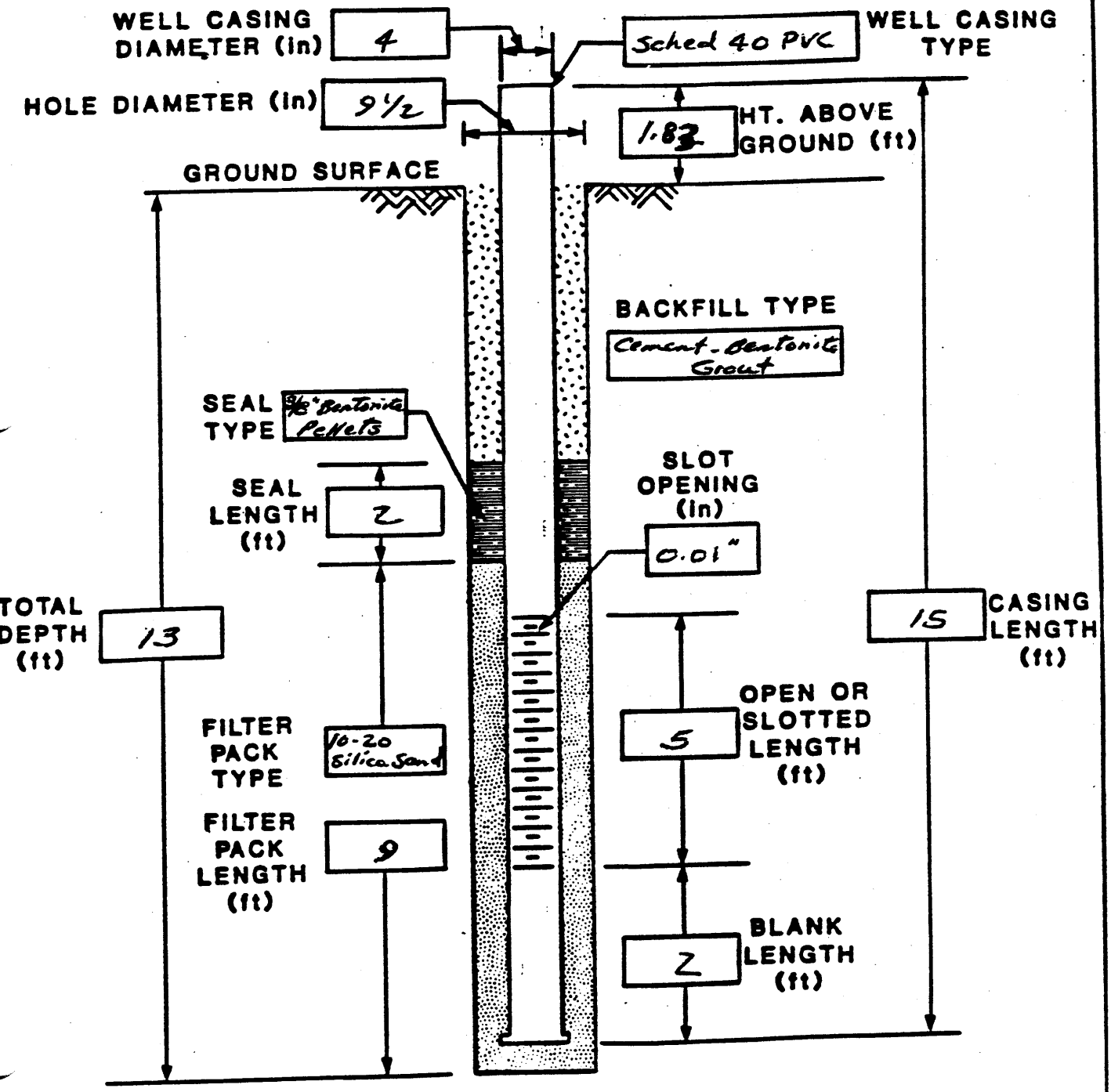
SITE ID: CAN 01 LOCATION ID: 423 DATE INSTALLED: 10-22-93

APPROX. SITE COORDINATES: (FT.) N _____ E _____

OPEN AREA PER LINEAL FT. ($IN^2/FT.$) _____

FORMATION OF COMPLETION: Alluvium (clay & silt)

FIELD REP.: W. R. Wood DRILLER: Lambert Drilling




COMMENTS: Shallow water

JEG-AL-ENG-3 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# WELL COMPLETION RECORD

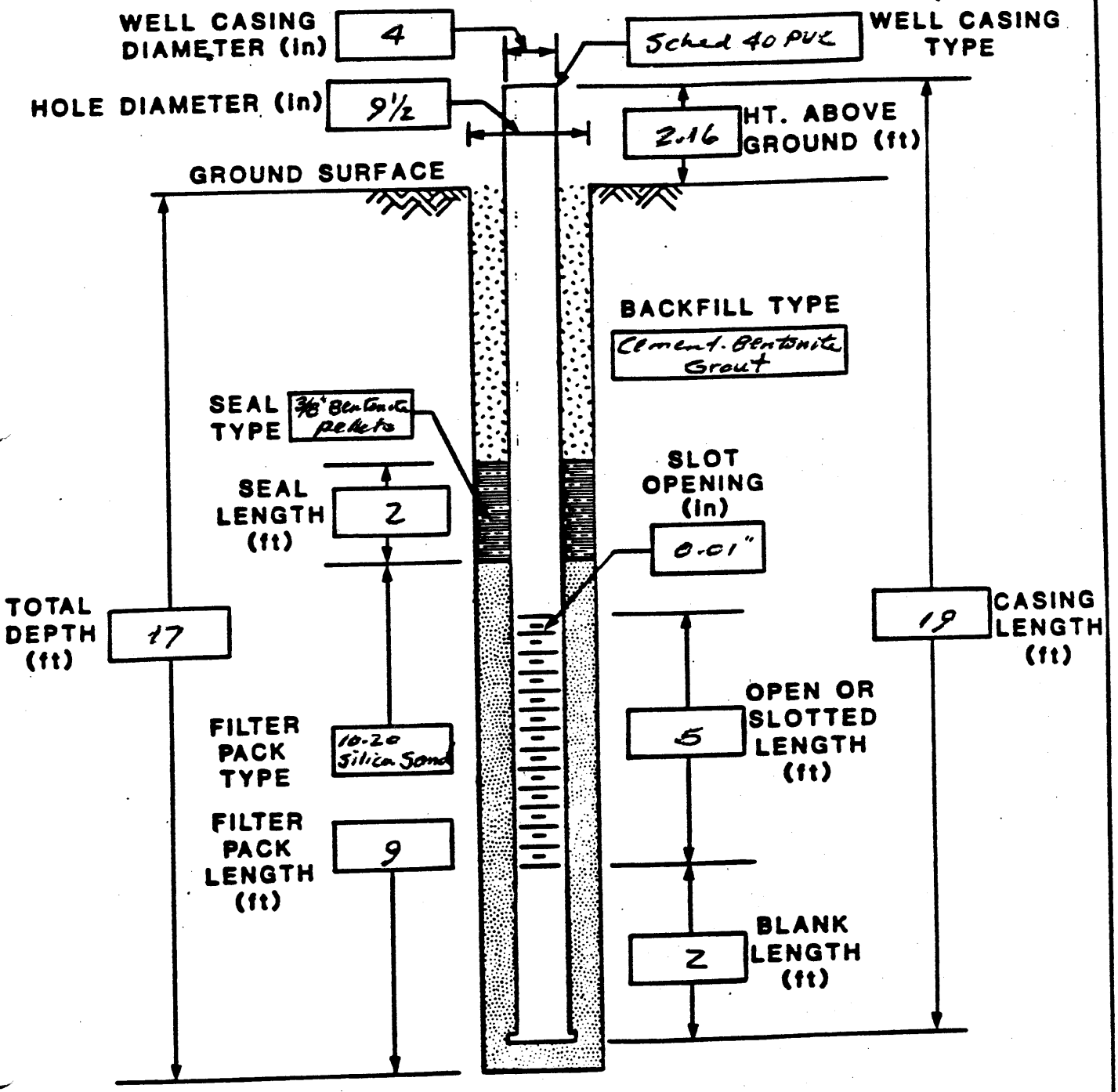
SITE ID: CAN 01 LOCATION ID: 424 DATE INSTALLED: 10-24-23

APPROX. SITE COORDINATES: (FT.) N _____ E _____

OPEN AREA PER LINEAL FT. ($IN^2/FT.$) _____

FORMATION OF COMPLETION: Alluvium (clayey sand)

FIELD REP.: W.R. Wood DRILLER: Lambert Drilling




COMMENTS: _____

JEG-AL-ENG-3 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# WELL COMPLETION RECORD

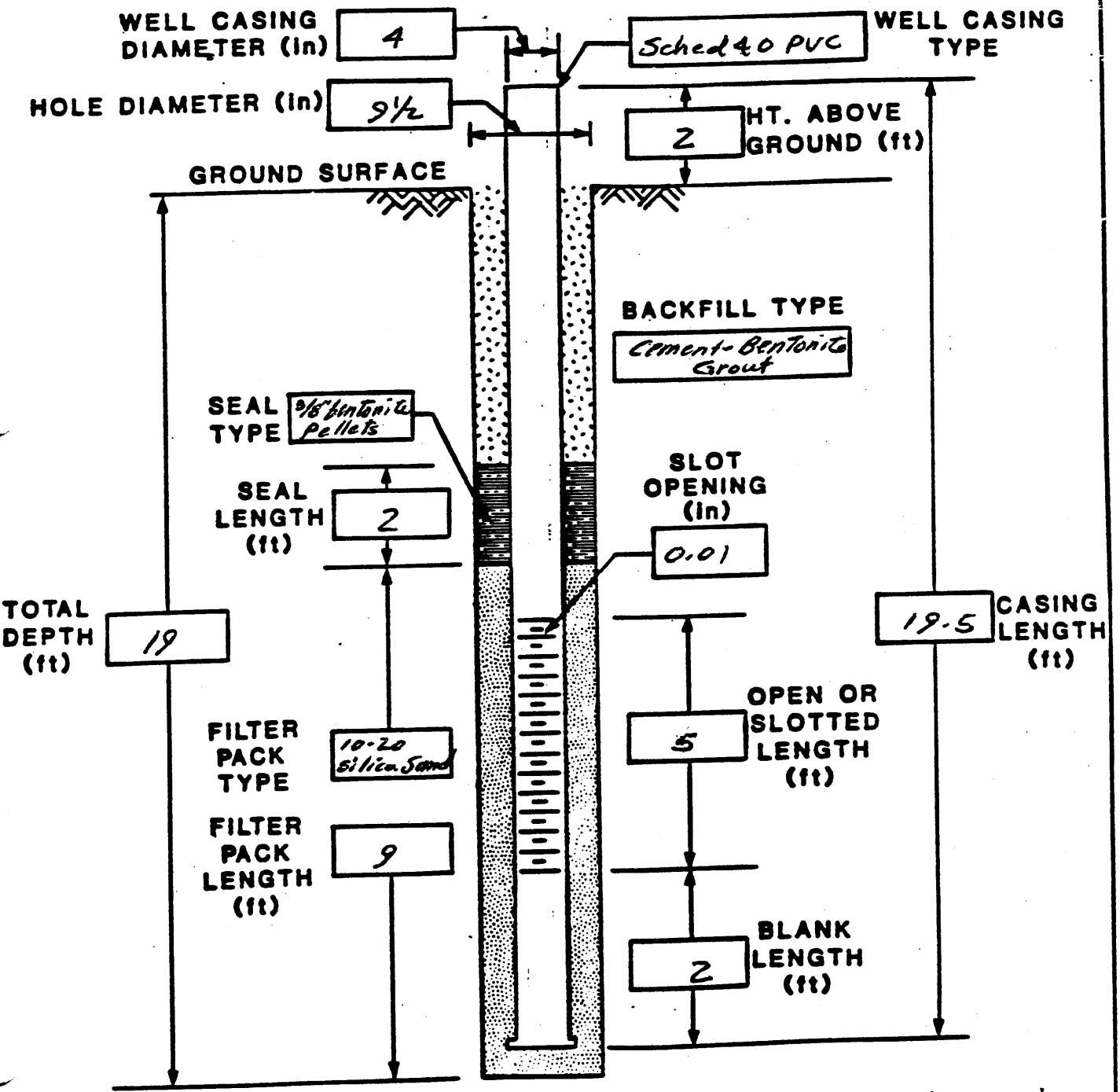
SITE ID: CAN 01 LOCATION ID: 425 DATE INSTALLED: 10-21-93

APPROX. SITE COORDINATES: (FT.) N _____ E _____

OPEN AREA PER LINEAL FT. ($IN^2/FT.$) _____

FORMATION OF COMPLETION: Alluvium (clay)

FIELD REP.: W. R. Wood DRILLER: Lambert Drilling




COMMENTS: 3" seam of very moist clayey sand above bedrock
Hole dry at time of installation

JEG-AL-ENG-3 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# WELL COMPLETION RECORD

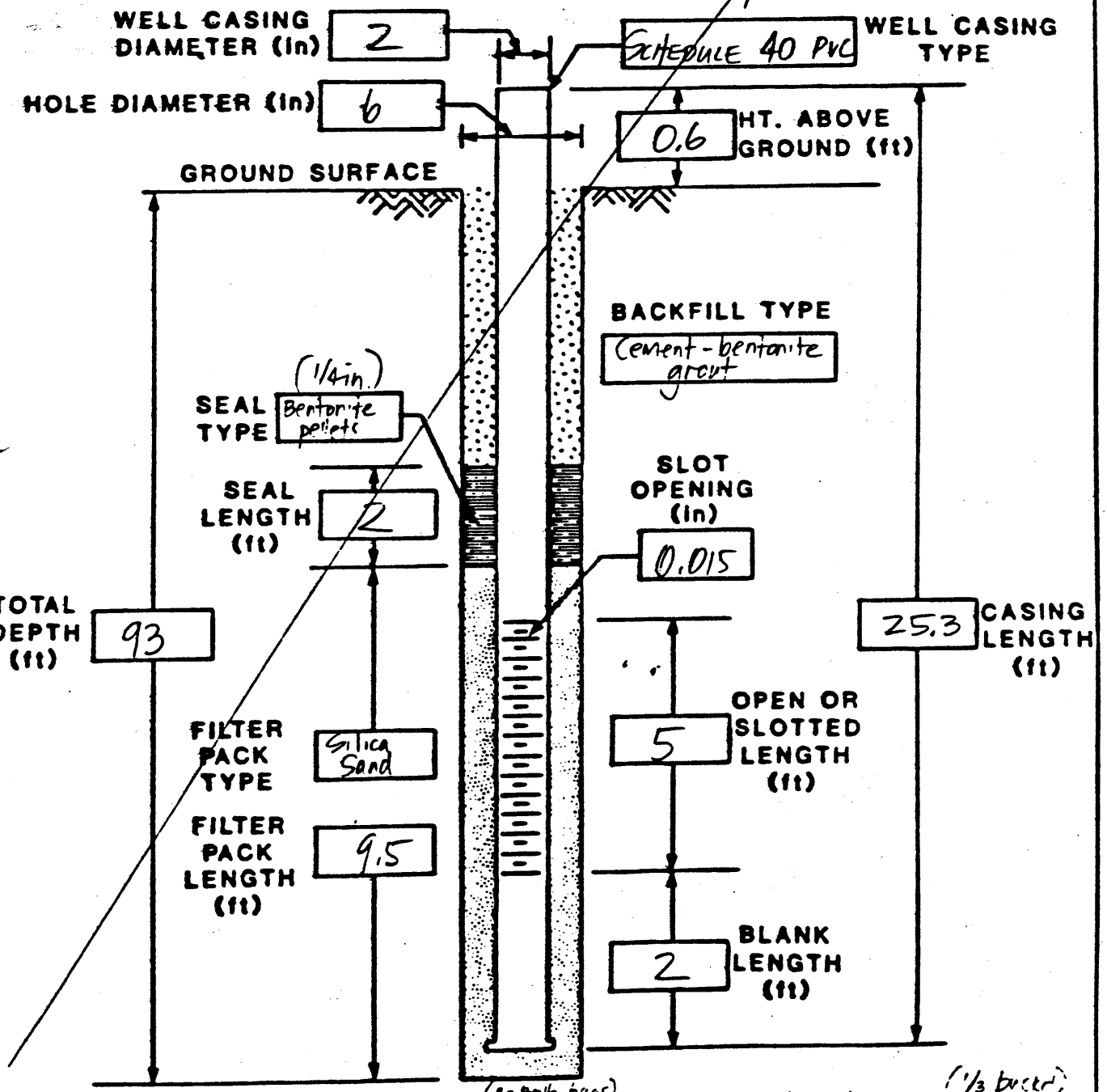
SITE ID: CAN 01 LOCATION ID: 504 DATE INSTALLED: 7-21-86

APPROX. SITE COORDINATES:(FT.) N _____ E _____

OPEN AREA PER LINEAL FT. ($IN^2$/FT.) _____

FORMATION OF COMPLETION: First water producing zone in bedrock

FIELD REP.: P.S. Darr DRILLER: Pennsylvania DRILLING Co.




COMMENTS: Backfilled borehole to 27 FT (8-Bolb bags) w/Silica sand and to (1/3 bucket) FT w/ Bentonite pellets.

JEG-AL-ENG-3 (3/84)

JE JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# WELL COMPLETION RECORD

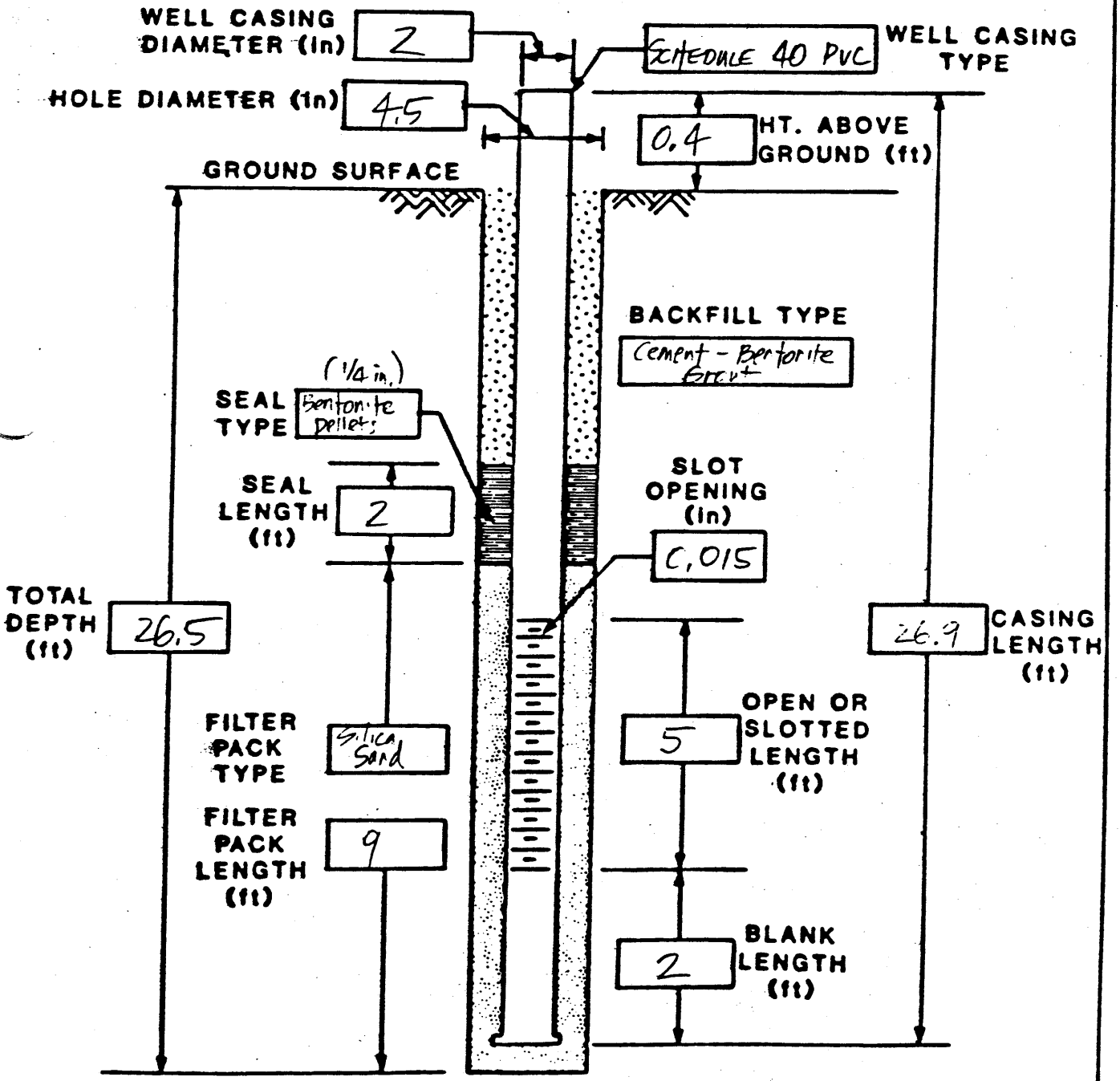
SITE ID: CAN 01 LOCATION ID: 504 DATE INSTALLED: 7-24-[illegible]

APPROX. SITE COORDINATES: (FT.) N _____ E _____

OPEN AREA PER LINEAL FT. ($IN^2$/FT.) _____

FORMATION OF COMPLETION: Alluvium

FIELD REP.: P.S. DARR DRILLER: PENNSYLVANIA DRILLING CO.




COMMENTS: _____

JEG-AL-ENG-3 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# WELL COMPLETION RECORD

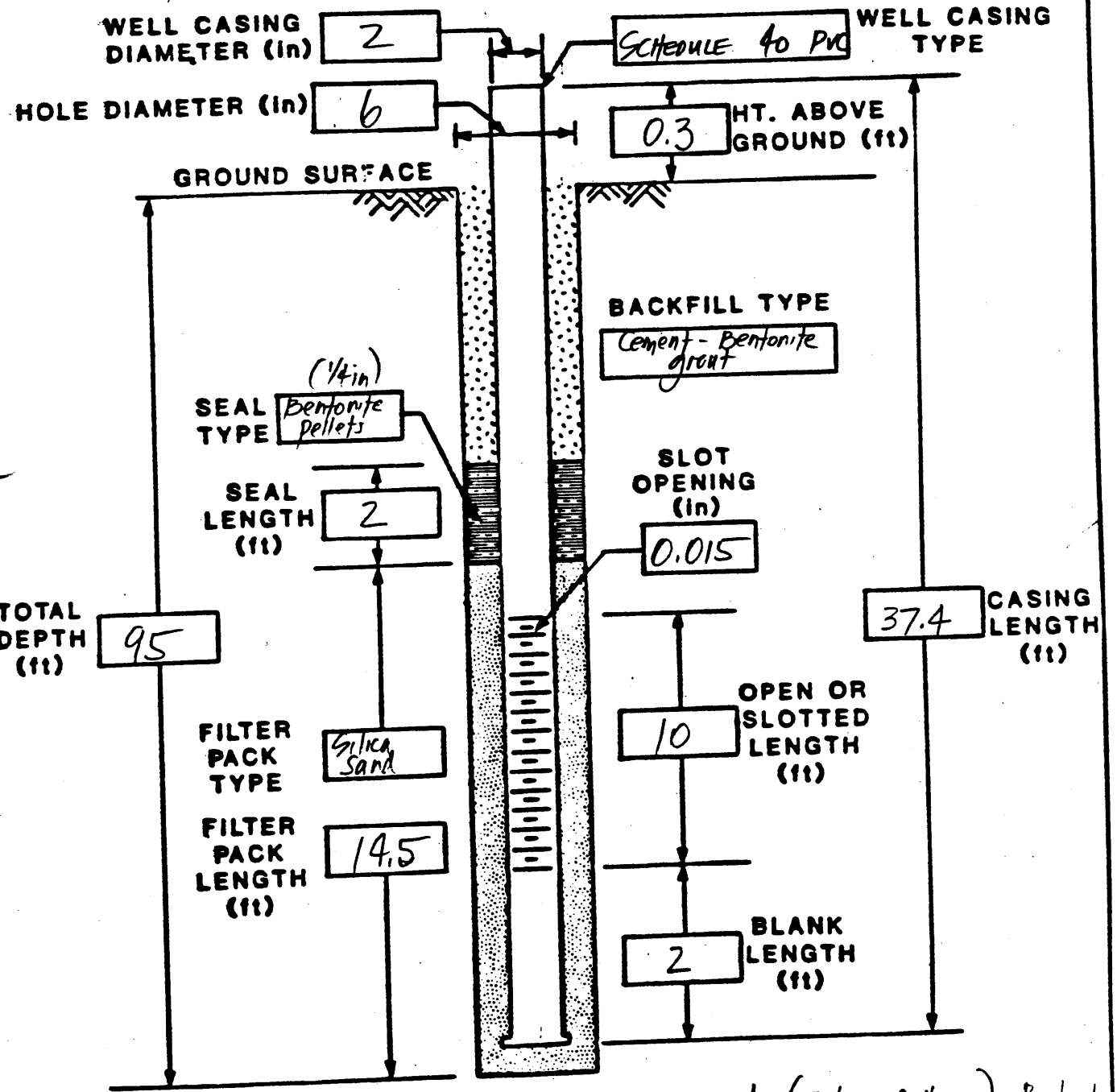
SITE ID: CAN 01 LOCATION ID: 505 DATE INSTALLED: 7-21-86

APPROX. SITE COORDINATES: (FT.) N _____ E _____

OPEN AREA PER LINEAL FT. ($IN^2/FT.$) _____

FORMATION OF COMPLETION: First water producing zone in bedrock.

FIELD REP.: P.S. DARR DRILLER: PENNSYLVANIA DRILLING CO.




COMMENTS: Backfilled borehole to 40 FT w/ Silica sand (7 bags - 80 lb ea.). Bentorite pellets to 38 FT (1/2 bucket).

JEG-AL-ENG-3 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# WELL COMPLETION RECORD

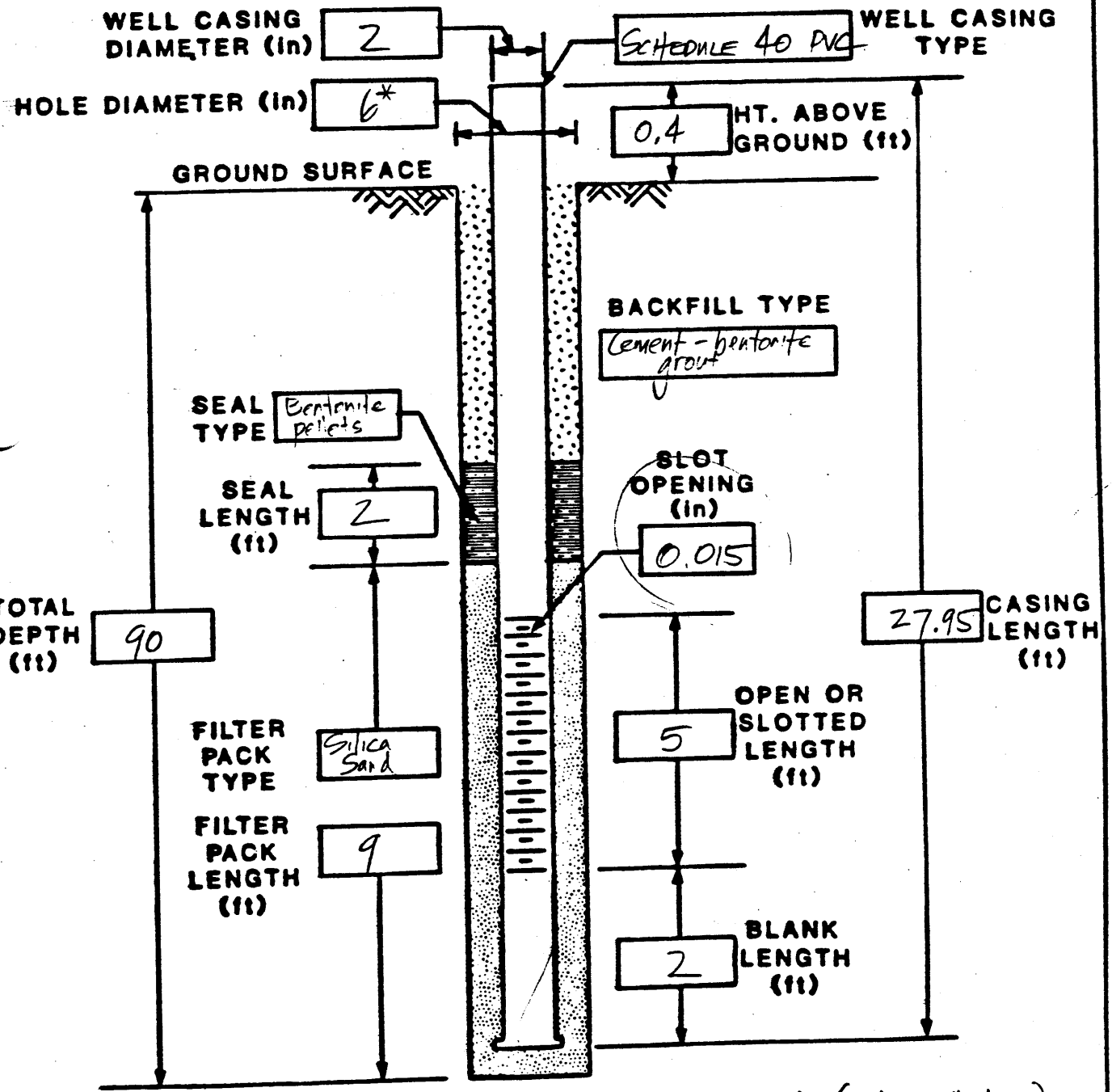
SITE ID: CAN 01 LOCATION ID: 506 DATE INSTALLED: 7-21-86

APPROX. SITE COORDINATES: (FT.) N _____ E _____

OPEN AREA PER LINEAL FT. ($IN^2/FT.$) _____

FORMATION OF COMPLETION: First water producing zone in bedrock,

FIELD REP.: P.S. DARR DRILLER: PENNSYLVANIA DRILLING CO.




COMMENTS: Backfilled borehole to 28 FT w/ silica sand (7½-80 lb bags) and 1 FT Bentonite pellets (¾ bucket), ✗ 6 in. to , 4½ in. to .

JEG-AL-ENG-3 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# WELL COMPLETION RECORD

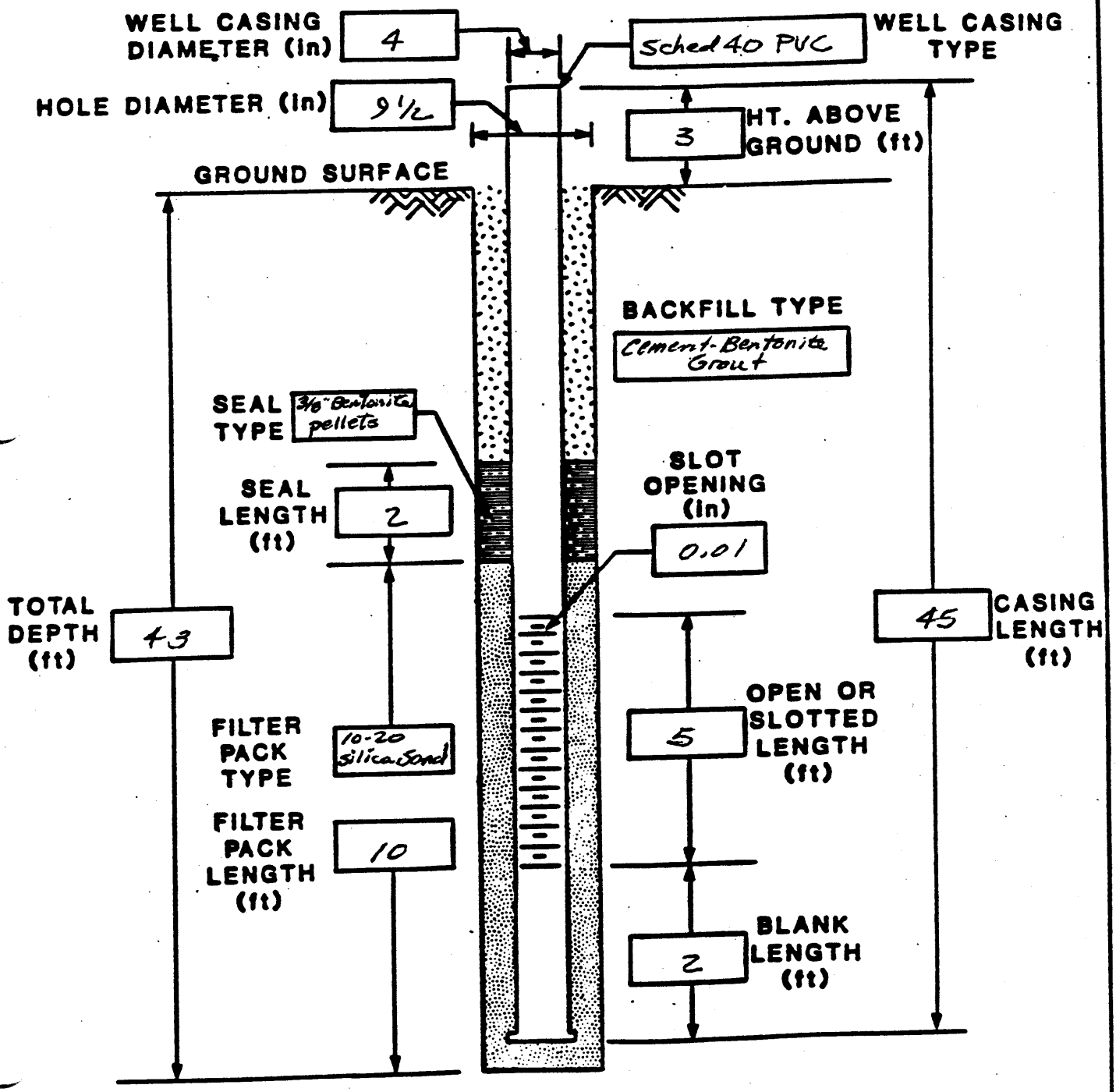
SITE ID: CAN 01 LOCATION ID: 507 DATE INSTALLED: 10-20-93

APPROX. SITE COORDINATES: (FT.) N _____ E _____

OPEN AREA PER LINEAL FT. ($IN^2/FT.$) _____

FORMATION OF COMPLETION: Castleman Shale

FIELD REP.: W. R Wood DRILLER: Lambert Drilling




COMMENTS: Water encountered @ 38 ft.

JEG-AL-ENG-3 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# WELL COMPLETION RECORD

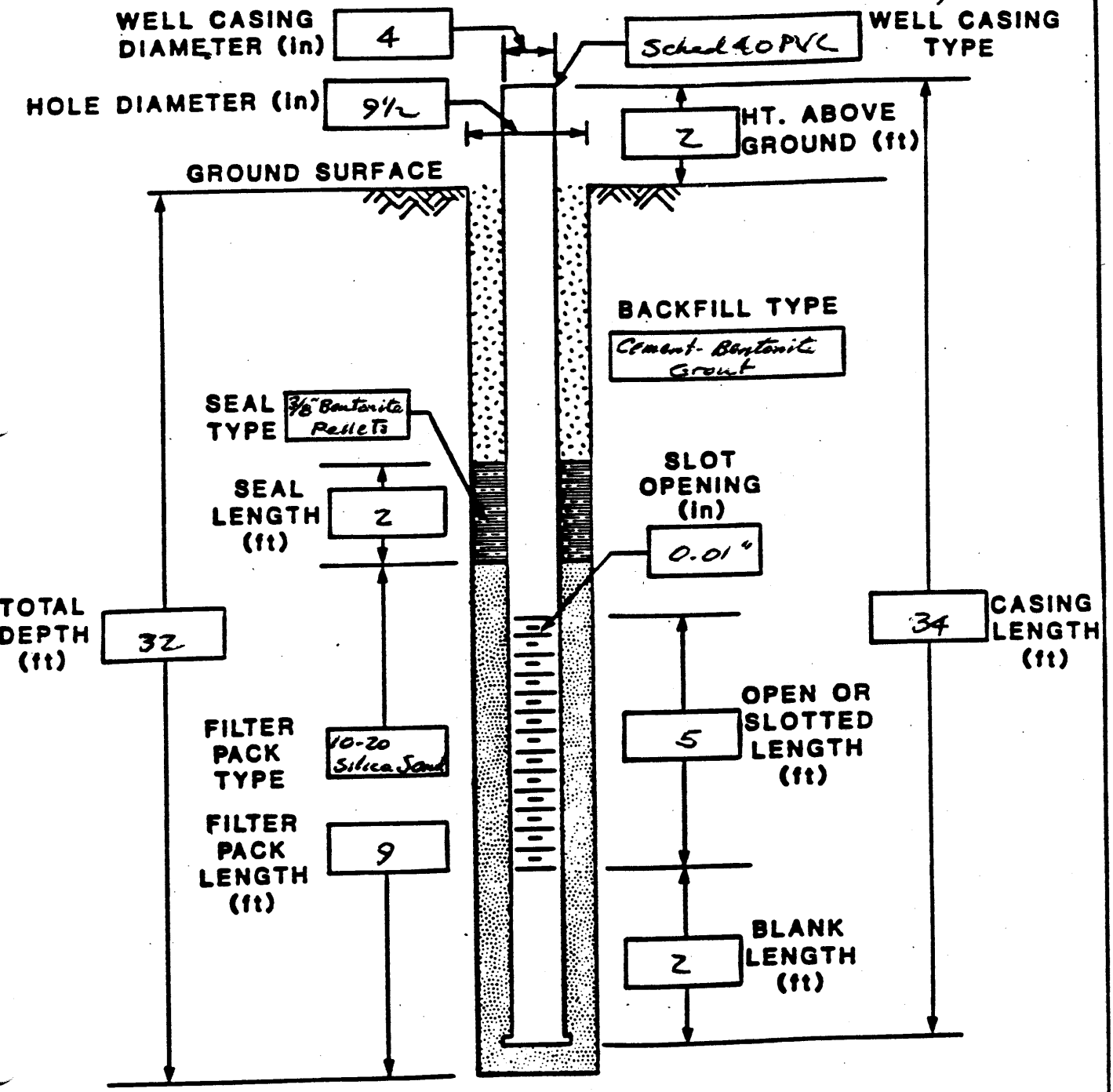
SITE ID: CAN 01 LOCATION ID: 508 DATE INSTALLED: 10-23-83

APPROX. SITE COORDINATES: (FT.) N _____ E _____

OPEN AREA PER LINEAL FT. ($IN^2/FT.$) _____

FORMATION OF COMPLETION: Castleman Shale

FIELD REP.: W. R. Wood DRILLER: Lambert Drilling




COMMENTS: _____

JEG-AL-ENG-3 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# WELL COMPLETION RECORD

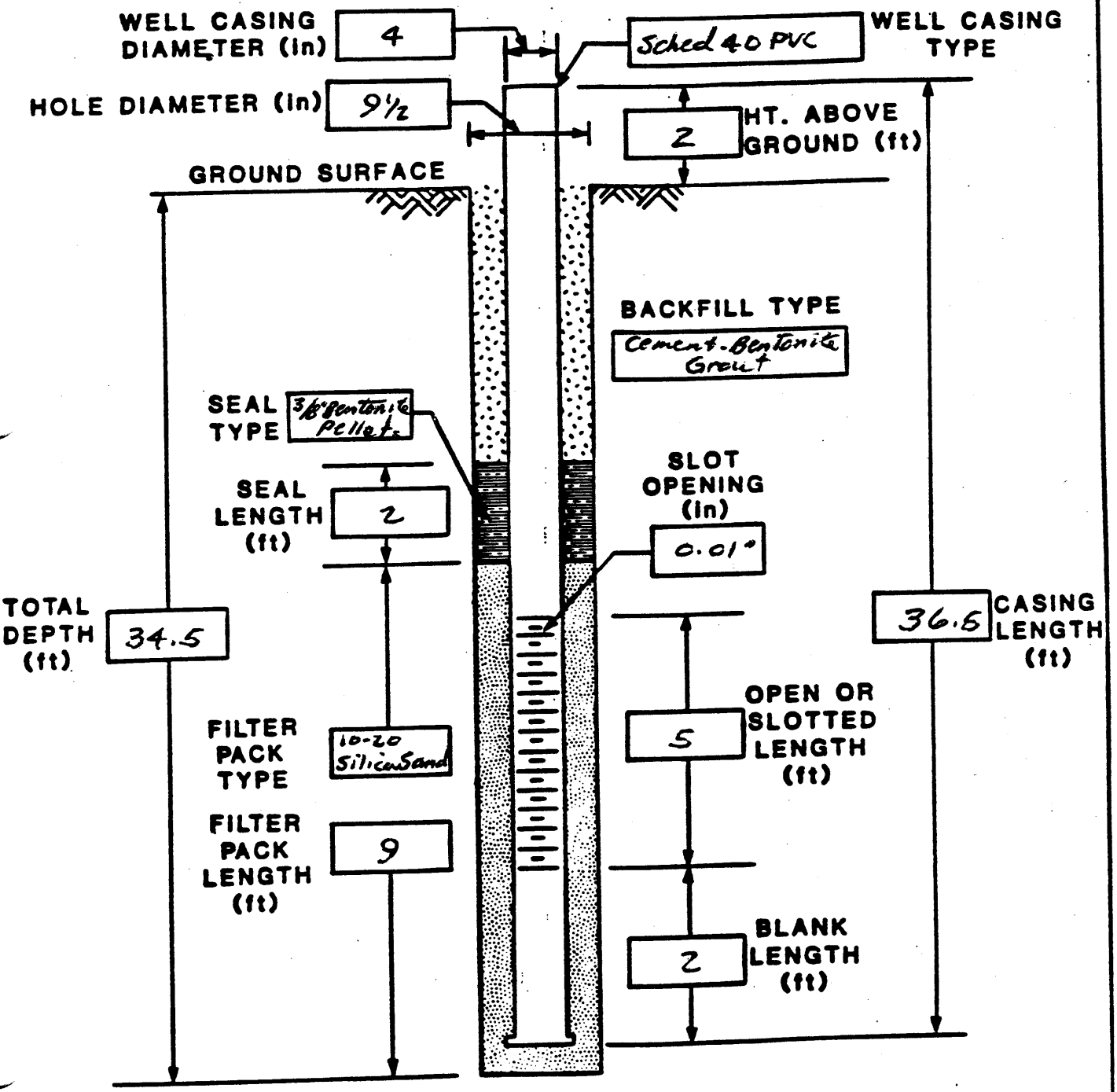
SITE ID: CAN 01 LOCATION ID: 509 DATE INSTALLED: 10-24-93

APPROX. SITE COORDINATES: (FT.) N _____ E _____

OPEN AREA PER LINEAL FT. ($IN^2/FT.$) _____

FORMATION OF COMPLETION: Castleman Shale

FIELD REP.: W. R. Wood DRILLER: Lambert Drilling




COMMENTS: _____

JEG-AL-ENG-3 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# WELL COMPLETION RECORD

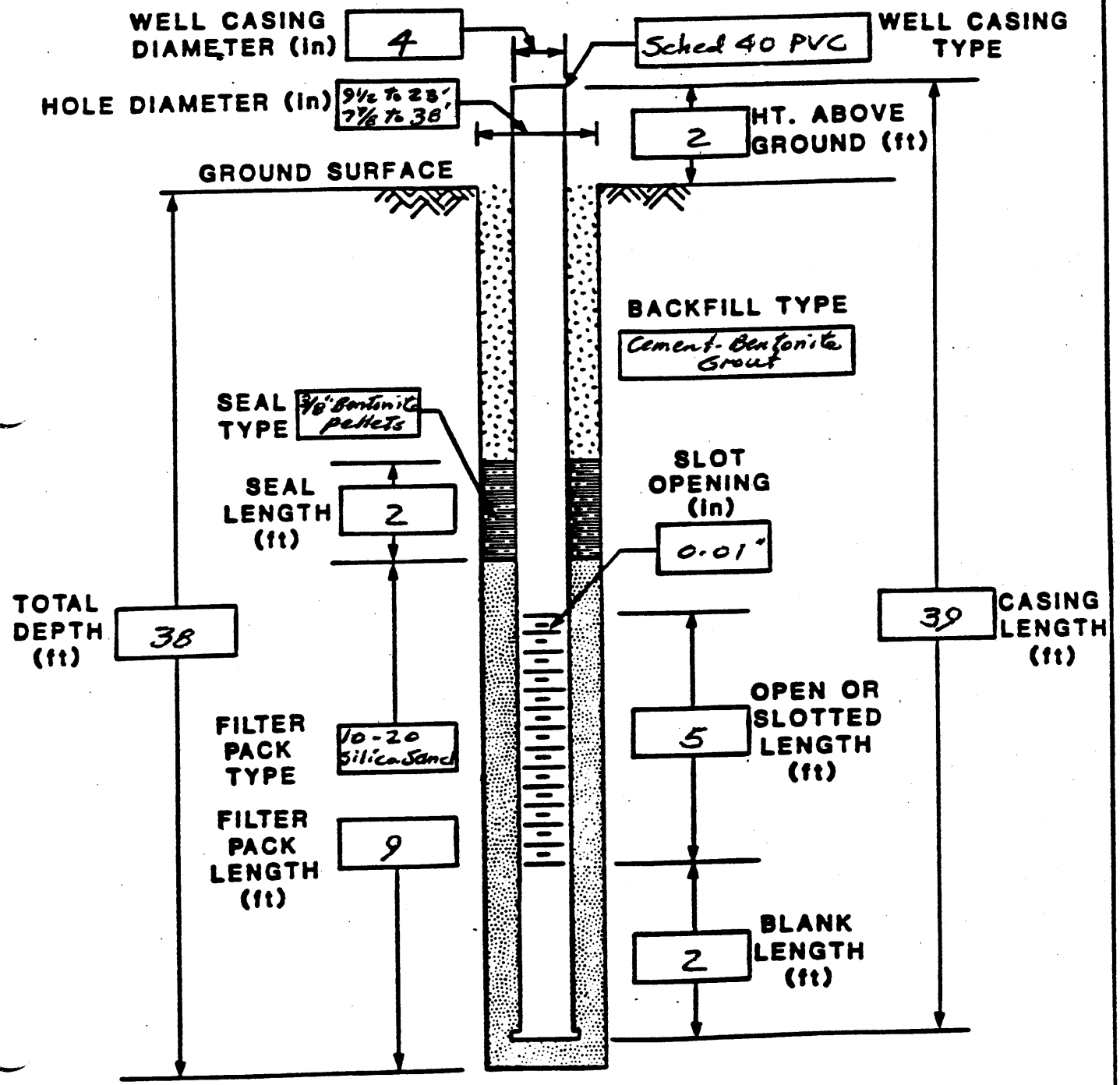
SITE ID: CAN 01 LOCATION ID: 510 DATE INSTALLED: 10-22-93

APPROX. SITE COORDINATES: (FT.) N _____ E _____

OPEN AREA PER LINEAL FT. ($IN^2/FT.$) _____

FORMATION OF COMPLETION: Castleman Shale

FIELD REP.: W. R. Wood DRILLER: Lambert Drilling




COMMENTS: _____

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE/WELL CONSTRUCTION LOG

SITE ID: CAN 01 LOCATION ID: 4-2 FIELD REP: P.S. DARE

APPROX. SITE COORDINATES (FT.): N _____ E _____

GROUND ELEVATION (FT. MSL): _____ COMPLETION DATE: 7-15-86

## BOREHOLE SUMMARY

DRILLER: PENNSYLVANIA DRILLING CO.

RIG TYPE: ACKER

| BIT TYPE | HOLE DIA.* (in.) | END DEPTH● (ft.) | FLUID TYPE |
|---|---|---|---|
| Auger | 10 | 21.0 | NONE |
| | | | |
| | | | |
| | | | |

## CASING SUMMARY

| CASING TYPE* | DESCRIPTION | DIA. (in.) | END✚ DEPTH (ft.) |
|---|---|---|---|
| P | GALVANIZED STEEL | 10 | 5 |
| | SCHEDULE 40 PVC | 4 | 15 |
| S | SCHEDULE 40 PVC | 4 | 20 |
| B | SCHEDULE 40 PVC | 4 | 22 |
| | | | |
| | | | |
| | | | |
| | | | |

* P-Protective S-Screen B-Blank O-Open N-None

✚ Depth from Top of Casing

## WELL CONSTRUCTION

| TYPE CODE* | DESCRIPTION | END● DEPTH (ft.) |
|---|---|---|
| B | Cement-Bentonite grout | 6 |
| S | Bentonite Pellets (1/4 in.) | 10.5 |
| F | Silica Sand | 21 |
| | | |
| | | |
| | | |
| | | |
| | | |

* B - Backfill S - Seal F - Filter Pack

● Depth from Ground Surface

## CONSTRUCTION TIME LOG

| ACTIVITY | START DATE | START TIME | END TIME |
|---|---|---|---|
| DRILLING | 7-14-86 | 4:50 | 5:25 |
| | 7-15-86 | 7:30 | 8:45 |
| CASING | 7-15-86 | 9:00 | 9:15 |
| FILTER PACK | 7-15-86 | 9:20 | 9:35 |
| SEAL | 7-15-86 | 9:35 | 9:40 |
| BACKFILL | 7-23-86 | 1:30 | 2:10 |
| DEVELOPMENT | 7-21-86 | 11:00 | 2:30 |
| | 7-22-86 | 8:15 | 3:15 |
| OTHER | | | |

## WELL DEVELOPMENT

air lifted water column standing in well for 3.5 hr.

| EC (umhos) | pH | T°C | |
|---|---|---|---|
| 1400 | 7 | 18 | 11:00 |
| 1350 | 7 | 18 | 2:30 |
| 1400 | 7 | 20 | 4:00 7-22 |
| 1150 | 6 | 15 | 7:30 7-23 |

COMMENTS: Used 4 bags sand (Bob) 1.5 bucket bentonite pellets. Considerable fines in development water.

JEG-AL-ENG-1 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE/WELL CONSTRUCTION LOG

ID: CAN 01 LOCATION ID: 413 FIELD REP: P.S. DARR

APPROX. SITE COORDINATES (FT.): N _____ E _____

GROUND ELEVATION (FT. MSL): _____ COMPLETION DATE: 7-21-86

## BOREHOLE SUMMARY

DRILLER: PENNSYLVANIA DRILLING CO.

RIG TYPE: ACKER

| BIT TYPE | HOLE DIA.* (In.) | END DEPTH● (ft.) | FLUID TYPE |
|---|---|---|---|
| AUGER | 10 | 13 | NONE |
| | | | |
| | | | |
| | | | |

## CASING SUMMARY

| CASING TYPE* | DESCRIPTION | DIA. (In.) | END◆ DEPTH (ft.) |
|---|---|---|---|
| P | Galvanized Steel | 10 | 1.75 |
| | Schedule 40 PVC | 4 | 8 |
| | Schedule 40 PVC | 4 | 13 |
| B | Schedule 40 PVC | 4 | 14 |
| | | | |
| | | | |
| | | | |
| | | | |

* P-Protective S-Screen B-Blank O-Open N-None

◆ Depth from Top of Casing

## WELL CONSTRUCTION

| TYPE CODE* | DESCRIPTION | END● DEPTH (ft.) |
|---|---|---|
| B | Cement-bentonite grout | 2.5 |
| S | Bentonite pellets (1/4 in.) | 4 |
| F | Silica Sand | 14 |
| | | |
| | | |
| | | |
| | | |
| | | |

* B - Backfill S - Seal F - Filter Pack

● Depth from Ground Surface

## CONSTRUCTION TIME LOG

| ACTIVITY | START DATE | START TIME | END TIME |
|---|---|---|---|
| DRILLING | 7-15-86 | 2:00 | 2:40 |
| CASING | 7-15-86 | 3:05 | 3:15 |
| FILTER PACK | 7-15-86 | 3:20 | 3:35 |
| SEAL | 7-15-86 | 3:35 | 3:40 |
| BACKFILL | 7-23-86 | 1:00 | 1:20 |
| DEVELOPMENT | 7-21-86 | 4:25 | 5:10 |
| | 7-22-86 | 7:40 | 8:45 |
| OTHER | | | |

## WELL DEVELOPMENT

| Ec (umhos) | pH | T°C | |
|---|---|---|---|
| 1100 | 7 | 19 | 4:25pm 7-21 |
| 1250 | 6 | 16 | 7:40am 7-22 |
| 1300 | 6 | 16 | 8:45am 7-22 |
| 1250 | 7 | 17 | 7:45pm 7-22 |

airlifted water column standing in well for 2.5 hr.

COMMENTS: used 3 bags sand
1 bucket bentonite pellets.
Considerable fines in development water.

JEG-AL-ENG-1 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE/WELL CONSTRUCTION LOG

E ID: CAN 01 LOCATION ID: 414 FIELD REP: P.S. DARR

APPROX. SITE COORDINATES (FT.): N _____ E _____

GROUND ELEVATION (FT. MSL): _____ COMPLETION DATE: 7-15-86

## BOREHOLE SUMMARY

DRILLER: PENNSYLVANIA DRILLING CO.

RIG TYPE: ACKER

| BIT TYPE | HOLE DIA.* (in.) | END DEPTH● (ft.) | FLUID TYPE |
|---|---|---|---|
| Auger | 10 | 16 | NONE |
| | | | |
| | | | |
| | | | |

## CASING SUMMARY

| CASING TYPE* | DESCRIPTION | DIA. (in.) | END DEPTH◆ (ft.) |
|---|---|---|---|
| P | GALVANIZED STEEL | 10 | 1.6 |
| | SCHEDULE 40 PVC | 4 | 6 |
| S | SCHEDULE 40 PVC | 4 | 16 |
| B | SCHEDULE 40 PVC | 4 | 17 |
| | | | |
| | | | |
| | | | |
| | | | |

* P-Protective S-Screen B-Blank O-Open N-None

◆ Depth from Top of Casing

## CONSTRUCTION TIME LOG

| ACTIVITY | START DATE | START TIME | END TIME |
|---|---|---|---|
| DRILLING | 7-15-86 | 10:30 | 11:55 |
| CASING | 7-15-86 | 12:50 | 1:00 |
| FILTER PACK | 7-15-86 | 1:05 | 1:15 |
| SEAL | 7-15-86 | 1:15 | 1:20 |
| BACKFILL | 7-23-86 | 3:20 | 3:50 |
| DEVELOPMENT | 7-24-86 | 2:45 | 9:20 |
| OTHER | | | |

## WELL CONSTRUCTION

| TYPE CODE* | DESCRIPTION | END● DEPTH (ft.) |
|---|---|---|
| B | Cement-bentonite grout | 2 |
| S | Bentonite pellets | 3 |
| F | Filter pack | 16 |
| | | |
| | | |
| | | |
| | | |
| | | |

* B - Backfill S - Seal F - Filter Pack

● Depth from Ground Surface

## WELL DEVELOPMENT

| Ec (μmhos) | pH | T°C | |
|---|---|---|---|
| 700 | 7 | 20 | 2:45 |
| 700 | 7 | 20 | 4:20 |
| 600 | 7 | 16 | 8:00 7-24 |

airlifted water column standing in 1½" for 1.75 hr.

COMMENTS: Used 4 bags sand
1 bucket bentonite pellets.
Considerable fines in developing water.

JEG-AL-ENG-1 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE/WELL CONSTRUCTION LOG

E ID: CAN 01 LOCATION ID: 422 FIELD REP: W.R. Wood

APROX. SITE COORDINATES (FT.): N _____ E _____

GROUND ELEVATION (FT. MSL): _____ COMPLETION DATE: 10-20-93

## BOREHOLE SUMMARY

DRILLER: Lambert Drilling Co, Inc.

RIG TYPE: Diedrich-120

| BIT TYPE | HOLE DIA.* (in.) | END DEPTH● (ft.) | FLUID TYPE |
|---|---|---|---|
| HSA | 9 1/2 | 23.5 | — |
| | | | |
| | | | |
| | | | |

## CASING SUMMARY

| CASING TYPE* | DESCRIPTION | DIA. (in.) | END✚ DEPTH (ft.) |
|---|---|---|---|
| P | Steel Casing | 8 | 6 |
| | Sched 40 PVC | 4 | 18 |
| S | 0.01" Slotted PVC | 4 | 23 |
| B | Sched 40 PVC Sump | 4 | 25 |
| | | | |
| | | | |
| | | | |
| | | | |

* P-Protective S-Screen B-Blank O-Open N-None

✚ Depth from Top of Casing

## WELL CONSTRUCTION

| TYPE CODE* | DESCRIPTION | END● DEPTH (ft.) |
|---|---|---|
| B | Cement-Bentonite Grout | 11 |
| S | 3/8" Bentonite Pellets | 13 |
| F | 10-20 Silica Sand | 23.5 |
| | | |
| | | |
| | | |
| | | |
| | | |

* B - Backfill S - Seal F - Filter Pack

● Depth from Ground Surface

## CONSTRUCTION TIME LOG

| ACTIVITY | START DATE | START TIME | END TIME |
|---|---|---|---|
| DRILLING | 10-19-93 | 3:40 P | 5:45 P |
| | 10-20-93 | 8:00 A | 8:25 A |
| CASING | 10-20-93 | 8:35 A | 8:40 A |
| FILTER PACK | 10-20-93 | 8:40 A | 8:50 A |
| SEAL | 10-20-93 | 8:50 A | 8:54 A |
| BACKFILL | 10-20-93 | 4:15 P | 4:34 P |
| DEVELOPMENT | Dry well | | |
| OTHER | | | |

## WELL DEVELOPMENT

COMMENTS: Hole dry at time of installation

JEG-AL-ENG-1 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE/WELL CONSTRUCTION LOG

E ID: CAN 01 LOCATION ID: 423 FIELD REP: W. R. Wood

APROX. SITE COORDINATES (FT.): N _____ E _____

GROUND ELEVATION (FT. MSL): _____ COMPLETION DATE: 10- -93

## BOREHOLE SUMMARY

DRILLER: Lambert Drilling Co., Inc.

RIG TYPE: Diedrich-120

| BIT TYPE | HOLE DIA.* (in.) | END DEPTH● (ft.) | FLUID TYPE |
|---|---|---|---|
| HSA | 9½ | 13 | — |
| | | | |
| | | | |
| | | | |

## CASING SUMMARY

| CASING TYPE* | DESCRIPTION | DIA. (in.) | END DEPTH◆ (ft.) |
|---|---|---|---|
| P | steel Casing | 8 | 6 |
| | Sched 40 PVC | 4 | 8 |
| S | 0.01" slotted PVC | 4 | 13 |
| B | Sched 40 PVC Sump | 4 | 15 |
| | | | |
| | | | |
| | | | |
| | | | |

* P-Protective S-Screen B-Blank O-Open N-None

◆ Depth from Top of Casing

## WELL CONSTRUCTION

| TYPE CODE* | DESCRIPTION | END DEPTH● (ft.) |
|---|---|---|
| B | Cement-Bentonite Grout | 2 |
| S | 3/8" Bentonite Pellets | 4 |
| F | 10-20 Silica Sand | 13 |
| | | |
| | | |
| | | |
| | | |
| | | |

* B - Backfill S - Seal F - Filter Pack

● Depth from Ground Surface

## CONSTRUCTION TIME LOG

| ACTIVITY | START DATE | START TIME | END TIME |
|---|---|---|---|
| DRILLING | 10-22-93 | 3:28 P | 4:18 P |
| CASING | 10-22-93 | 4:19 P | 4:25 P |
| FILTER PACK | 10-22-93 | 4:25 P | 4:30 P |
| SEAL | 10-22-93 | 4:30 P | 4:35 P |
| BACKFILL | 10-23-93 | 2:15 P | 2:20 P |
| DEVELOPMENT | 10-26-93 | 1:40 P | 5:00 P |
| OTHER | | | |

## WELL DEVELOPMENT

COMMENTS: _____

JEG-AL-ENG-1 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE/WELL CONSTRUCTION LOG

ID: CAN 01 LOCATION ID: 424 FIELD REP: W.R. Wood

APPROX. SITE COORDINATES (FT.): N _____ E _____

GROUND ELEVATION (FT. MSL): _____ COMPLETION DATE: 10-24-93

## BOREHOLE SUMMARY

DRILLER: Lambert Drilling Co., Inc.

RIG TYPE: Diedrich-120

| BIT TYPE | HOLE DIA.* (in.) | END DEPTH● (ft.) | FLUID TYPE |
|---|---|---|---|
| HSA | 9 1/2 | 17 | — |
| | | | |
| | | | |
| | | | |

## CASING SUMMARY

| CASING TYPE● | DESCRIPTION | DIA. (in.) | END DEPTH✚ (ft.) |
|---|---|---|---|
| P | steel casing | 8 | 6 |
| | Sched 40 PVC Blank | 4 | 12 |
| S | 0.01" slotted PVC | 4 | 17 |
| B | Sched 40 PVC Sump | 4 | 19 |
| | | | |
| | | | |
| | | | |
| | | | |

● P-Protective S-Screen B-Blank O-Open N-None

✚ Depth from Top of Casing

## WELL CONSTRUCTION

| TYPE CODE● | DESCRIPTION | END DEPTH● (ft.) |
|---|---|---|
| B | Cement-Bentonite Grout | 6 |
| S | 3/8" Bentonite Pellets | 8 |
| F | 10-20 Silica Sand | 17 |
| | | |
| | | |
| | | |
| | | |
| | | |

● B - Backfill S - Seal F - Filter Pack

● Depth from Ground Surface

## CONSTRUCTION TIME LOG

| ACTIVITY | START DATE | START TIME | END TIME |
|---|---|---|---|
| DRILLING | 10-24-93 | 8:14 A | 9:25 A |
| CASING | 10-24-93 | 9:25 A | 9:31 A |
| FILTER PACK | 10-24-93 | 9:31 A | 9:38 A |
| SEAL | 10-24-93 | 9:38 A | 9:40 A |
| BACKFILL | 10-24-93 | 2:26 P | 2:37 P |
| DEVELOPMENT | 10-26-93 | 11:43 A | 1:20 P |
| | 10-27-93 | 10:30 A | 11:00 A |
| OTHER | | | |

## WELL DEVELOPMENT

COMMENTS: _____

JEG-AL-ENG-1 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE/WELL CONSTRUCTION LOG

E ID: Can 01 LOCATION ID: 425 FIELD REP: W. R. Wood

PROX. SITE COORDINATES (FT.): N _____ E _____

GROUND ELEVATION (FT. MSL): _____ COMPLETION DATE: 10-22-93

## BOREHOLE SUMMARY

DRILLER: Lambert Drilling Co., Inc.

RIG TYPE: Diedrich-120

| BIT TYPE | HOLE DIA.* (in.) | END DEPTH● (ft.) | FLUID TYPE |
|---|---|---|---|
| HSA | 9 1/2 | 19 | — |
| | | | |
| | | | |
| | | | |

## CASING SUMMARY

| CASING TYPE* | DESCRIPTION | DIA. (in.) | END DEPTH✤ (ft.) |
|---|---|---|---|
| P | Steel Casing | 8 | 6 |
| | Sched 40 PVC | 4 | 12.5 |
| S | 0.01" slotted PVC | 4 | 17.5 |
| B | Sched 40 PVC Sump | 4 | 19.5 |
| | | | |
| | | | |
| | | | |
| | | | |

* P-Protective S-Screen B-Blank O-Open N-None

✤ Depth from Top of Casing

## WELL CONSTRUCTION

| TYPE CODE* | DESCRIPTION | END DEPTH● (ft.) |
|---|---|---|
| B | Cement-Bentonite Grout | 6.5 |
| S | 3/8" Bentonite Pellets | 8.5 |
| F | 10-20 Silica Sand | 19 |
| | | |
| | | |
| | | |
| | | |
| | | |

* B - Backfill S - Seal F - Filter Pack

● Depth from Ground Surface

## CONSTRUCTION TIME LOG

| ACTIVITY | START DATE | START TIME | END TIME |
|---|---|---|---|
| DRILLING | 10-21-93 | 8:15 A | 9:47 A |
| CASING | 10-21-93 | 9:47 A | 9:50 A |
| FILTER PACK | 10-21-93 | 9:50 A | 10:05 A |
| SEAL | 10-21-93 | 10:05 A | 10:07 A |
| BACKFILL | 10-22-93 | 1:13 P | 1:15 P |
| DEVELOPMENT | Dry well | | |
| OTHER | | | |

## WELL DEVELOPMENT

COMMENTS: _____

JEG-AL-ENG-1 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE/WELL CONSTRUCTION LOG

SITE ID: CAN 01 LOCATION ID: 504 FIELD REP: P.S. DARR

APPROX. SITE COORDINATES (FT.): N _____ E _____

GROUND ELEVATION (FT. MSL): _____ COMPLETION DATE: 7-21-86

## BOREHOLE SUMMARY

DRILLER: PENNSYLVANIA DRILLING CO.

RIG TYPE: MOBILE DRILL B-57

| BIT TYPE | HOLE DIA.* (in.) | END DEPTH● (ft.) | FLUID TYPE |
|---|---|---|---|
| Auger | 10 | 16 | NONE |
| NX Core | 2.5 | 93 | water |
| Roller bit | 4.5 | 93 | water |
| | | | |

## CASING SUMMARY

| CASING TYPE* | DESCRIPTION | DIA. (in.) | END DEPTH✦ (ft.) |
|---|---|---|---|
| P | Galvanized steel * | 6 | 16 |
| | Schedule 40 PVC | 2 | 17.7 |
| S | Schedule 40 PVC | 2 | 22.7 |
| B | Schedule 40 PVC | 2 | 24.7 |
| | | | |
| | * set as permanent | | |
| | surface casing | | |
| | | | |

* P-Protective S-Screen B-Blank O-Open N-None

✦ Depth from Top of Casing

## WELL CONSTRUCTION

| TYPE CODE* | DESCRIPTION | END DEPTH● (ft.) |
|---|---|---|
| B | Cement-bentonite grout | 13.5 |
| S | Bentonite pellets (1/4 in.) | 15.5 |
| F | Silica Sand | 25 |
| S | Bentonite pellets (1/4 in.) | 27 |
| B | Silica sand | 93 |
| | | |
| | | |
| | | |

* B - Backfill S - Seal F - Filter Pack

● Depth from Ground Surface

## CONSTRUCTION TIME LOG

| ACTIVITY | START DATE | START TIME | END TIME |
|---|---|---|---|
| DRILLING | 7-14-86 | 10:15 | 11:55 |
| | 7-17-86 | 11:05 | 5:20 |
| | 7-18-86 | 7:30 | 2:45 |
| CASING | 7-21-86 | 3:00 | 3:05 |
| FILTER PACK | 7-21-86 | 3:05 | 3:15 |
| SEAL | 7-21-86 | 2:50 | 2:55 |
| | | 3:15 | 3:20 |
| BACKFILL (Sand) | 7-21-86 | 2:30 | 2:50 |
| DEVELOPMENT | 7-22-86 | 7:00 | 5:15 |
| OTHER | | | |

## WELL DEVELOPMENT

| Ec (umhos) | pH | T°C |
|---|---|---|
| 900 | 12 | 23 |
| 800 | 12 | 21.5 |

COMMENTS: This well abandoned and redrilled 11 FT away.

JEG-AL-ENG-1 (8/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE/WELL CONSTRUCTION LOG

SITE ID: CAN 01 LOCATION ID: 504 FIELD REP: P.S. DARR

APPROX. SITE COORDINATES (FT.): N _____ E _____

GROUND ELEVATION (FT. MSL): _____ COMPLETION DATE: 7-24-86

## BOREHOLE SUMMARY

DRILLER: PENNSYLVANIA DRILLING CO.

RIG TYPE: MOBILE DRILL B-57

| BIT TYPE | HOLE DIA.* (in.) | END ● DEPTH (ft.) | FLUID TYPE |
|---|---|---|---|
| Auger | 10 | 16 | NONE |
| ROLLER BIT | 4.5 | 26.5 | water |
| | | | |
| | | | |

## CASING SUMMARY

| CASING TYPE* | DESCRIPTION | DIA. (in.) | END✚ DEPTH (ft.) |
|---|---|---|---|
| P | Galvanized steel * | 6 | 16 |
| | Schedule 40 PVC | 2 | 19.5 |
| S | Schedule 40 PVC | 2 | 24.5 |
| B | Schedule 40 PVC | 2 | 26.5 |
| | | | |
| | *Set as permanent | | |
| | surface casing. | | |
| | | | |

* P-Protective S-Screen B-Blank O-Open N-None

✚ Depth from Top of Casing

## WELL CONSTRUCTION

| TYPE CODE* | DESCRIPTION | END● DEPTH (ft.) |
|---|---|---|
| B | Cement-Bentonite Grout | 15.5 |
| S | Bentonite pellets | 17.5 |
| F | Silica Sand | 26.5 |
| | | |
| | | |
| | | |
| | | |
| | | |

● B - Backfill S - Seal F - Filter Pack

● Depth from Ground Surface

## CONSTRUCTION TIME LOG

| ACTIVITY | START DATE | START TIME | END TIME |
|---|---|---|---|
| DRILLING | 7-23-86 | 1:10 | 1:45 |
| | 7-24-86 | 8:05 | 9:10 |
| CASING | 7-24-86 | 9:15 | 9:20 |
| FILTER PACK | 7-24-86 | 9:20 | 9:25 |
| SEAL | 7-24-86 | 9:25 | 9:30 |
| BACKFILL | 7-24-86 | 10:30 | 10:55 |
| DEVELOPMENT (actual depth) | 7-25-86 | 7:30 | 10:20 |
| OTHER | | | |

## WELL DEVELOPMENT

| Ec (umhos) | pH | T°C | |
|---|---|---|---|
| 1800 | 10-11 | 19 | |
| 1100 | 7-8 | 19 | 9:00 AM |
| 1100 | 7 | 21 | 9:45 AM |
| 1100 | 7 | 21 | 10:20 AM |

COMMENTS: used 3/4 bag (80lb) of sand & 1/3 bucket bentonite pellets.

JEG-AL-ENG-1 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE/WELL CONSTRUCTION LOG

SITE ID: CAN 01 LOCATION ID: 505 FIELD REP: P.S. DARR

APPROX. SITE COORDINATES (FT.): N _____ E _____

GROUND ELEVATION (FT. MSL): _____ COMPLETION DATE: 7-21-86

## BOREHOLE SUMMARY

DRILLER: PENNSYLVANIA DRILLING CO.

RIG TYPE: ACKER

| BIT TYPE | HOLE DIA.* (in.) | END DEPTH● (ft.) | FLUID TYPE |
|---|---|---|---|
| Auger | 10 | 16 | NONE |
| NX CORE | 2.5 | 95 | water |
| Roller bit | 4.5 | 95 | water |
| | | | |

## CASING SUMMARY

| CASING TYPE* | DESCRIPTION | DIA. (in.) | END✚ DEPTH (ft.) |
|---|---|---|---|
| P | Galvanized steel* | 6 | 16 |
| B | Schedule 40 PVC | 2 | 25.5 |
| S | Schedule 40 PVC | 2 | 35.5 |
| B | Schedule 40 PVC | 2 | 37.5 |
| | | | |
| | *set as permanent | | |
| | surface casing | | |
| | | | |

* P-Protective S-Screen B-Blank O-Open N-None

✚ Depth from Top of Casing

## WELL CONSTRUCTION

| TYPE CODE* | DESCRIPTION | END● DEPTH (ft.) |
|---|---|---|
| B | Cement-Bentonite grout | 21.5 |
| S | Bentonite pellets (1/4 in.) | 23.5 |
| F | Silica sand | 38 |
| S | Bentonite pellets (1/4 in.) | 40 |
| B | Silica Sand | 95 |
| | | |
| | | |
| | | |

* B - Backfill S - Seal F - Filter Pack

● Depth from Ground Surface

## CONSTRUCTION TIME LOG

| ACTIVITY | START DATE | START TIME | END TIME |
|---|---|---|---|
| DRILLING | 7-14-86 | 7:25 | 9:15 |
| | 7-17-86 | 7:20 | 5:30 |
| CASING | 7-21-86 | 1:30 | 1:40 |
| FILTER PACK | 7-21-86 | 1:40 | 1:50 |
| SEAL | 7-21-86 | 1:20 | 1:30 |
| | 7-21-86 | 1:50 | 2:00 |
| BACKFILL (sand) 35.2 / 37.2 | 7-21-86 | 1:00 | 1:20 |
| grout | 7-23-86 | 3:25 | 4:15 |
| DEVELOPMENT | 7-22-86 | 9:05 | 11:30 |
| | 7-23-86 | 7:45 | 10:45 |
| OTHER | | | |

## WELL DEVELOPMENT

| Ec (umhos) | pH | T°C | |
|---|---|---|---|
| 2050 | 7 | 19 | 9:05 |
| 1900 | 7 | 18 | 11:30 |
| 2250 | 10* | 22 | 7:45 |
| 1850 | 7 | 15 | 9:30 |
| 1900 | 7 | 21 | 10:45 |

airlifted water column standing in well for 2.5 hr.

COMMENTS: developing water relatively fines free. *Appears a trace amount of grout leaked into the well from around the threads atop the threaded screen cap.

JEG-AL-ENG-1 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE/WELL CONSTRUCTION LOG

SITE ID: CAN 01 LOCATION ID: 506 FIELD REP: P.S. DARR

APPROX. SITE COORDINATES (FT.): N _____ E _____

GROUND ELEVATION (FT. MSL): _____ COMPLETION DATE: 7-21-86

## BOREHOLE SUMMARY

DRILLER: PENNSYLVANIA DRILLING CO.

RIG TYPE: ACKER

| BIT TYPE | HOLE DIA.* (in.) | END DEPTH● (ft.) | FLUID TYPE |
|---|---|---|---|
| Auger | 10 | 15 | NONE |
| NX CORE | 2.5 | 90 | air & water |
| Roller Bit | 4.5 | 90 | NONE |
| | | | |

## CASING SUMMARY

| CASING TYPE* | DESCRIPTION | DIA. (in.) | END✚ DEPTH (ft.) |
|---|---|---|---|
| ~~P~~ | Galvanized steel* | 6 | 15 |
| ~~S~~ | Schedule 40 PVC | 2 | 20 |
| S | Schedule 40 PVC | 2 | 25 |
| B | Schedule 40 PVC | 2 | 27 |
| | | | |
| | *set as permanent | | |
| | surface casing. | | |
| | | | |

* P-Protective S-Screen B-Blank O-Open N-None

✚ Depth from Top of Casing

## CONSTRUCTION TIME LOG

| ACTIVITY | START DATE | START TIME | END TIME |
|---|---|---|---|
| DRILLING | 7-14-86 | 2:05 | 3:15 |
| | 7-17-86 | 2:45 | 5:10 |
| | 7-18-86 | 7:35 | 11:40 |
| CASING | 7-21-86 | 10:45 | 10:55 |
| FILTER PACK | 7-21-86 | 11:00 | 11:10 |
| SEAL 15.5 20 | 7-21-86 | 10:10 | 10:35 |
| BACKFILL (sand) 25.5 27.5 | 7-21-86 | 10:35 | 10:45 |
| | 7-21-86 | 11:15 | 11:30 |
| DEVELOPMENT | 7-22-86 | 11:45 | 2:30 |
| | 7-23-86* | 11:15 | 2:45 |

OTHER

| Ec (umhos) | pH | T°C | |
|---|---|---|---|
| 4100 | 9 | 24 | 11:15 (7-23) |
| 3900 | 7 | 24 | 12:45 " |
| 3950 | 7 | 25 | 2:45 " |

## WELL CONSTRUCTION

| TYPE CODE* | DESCRIPTION | END● DEPTH (ft.) |
|---|---|---|
| B | Cement-Bentonite grout | 16 |
| S | Bentonite pellets (1/4 in.) | 18 |
| F | Silica Sand | 27 |
| S | Bentonite pellets (1/4 in.) | 29 |
| B | Silica sand | 90 |
| | | |
| | | |
| | | |

* B - Backfill S - Seal F - Filter Pack

● Depth from Ground Surface

## WELL DEVELOPMENT

| Ec (umhos) | pH | T°C | |
|---|---|---|---|
| 2950 | 7 | 22 | 11:45 |
| 3700 | 7 | 23 | 1:40 |
| 3800 | 7-8 | 26 | 2:30 7-22 |

airlifted water column standing in well for

COMMENTS: * trace of grout in upper portion of monitor well. Re-developed well to purge whatever

JEG-AL-ENG-1 (8/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE/WELL CONSTRUCTION LOG

E ID: CAN 01 LOCATION ID: 507 FIELD REP: W. R. Wood

APPROX. SITE COORDINATES (FT.): N _____ E _____

GROUND ELEVATION (FT. MSL): _____ COMPLETION DATE: 10-20-93

## BOREHOLE SUMMARY

DRILLER: Lambert Drilling Co., Inc.

RIG TYPE: Diedrich - 120

| BIT TYPE | HOLE DIA.* (in.) | END DEPTH● (ft.) | FLUID TYPE |
|---|---|---|---|
| HSA | 9 1/2 | 43 | — |
| | | | |
| | | | |
| | | | |

## CASING SUMMARY

| CASING TYPE* | DESCRIPTION | DIA. (in.) | END DEPTH✣ (ft.) |
|---|---|---|---|
| P | | | |
| | Sched 40 PVC | 4 | |
| S | 0.01" Slotted PVC | 4 | 43 |
| B | Sched 40 PVC Sump | 4 | 45 |
| | | | |
| | | | |
| | | | |
| | | | |

* P-Protective S-Screen B-Blank O-Open N-None

✣ Depth from Top of Casing

## WELL CONSTRUCTION

| TYPE CODE* | DESCRIPTION | END DEPTH● (ft.) |
|---|---|---|
| B | Cement-Bentonite Grout | 30 |
| S | 3/8" Bentonite Pellets | 32 |
| F | 10-20 Silica Sand. | 43 |
| | | |
| | | |
| | | |
| | | |
| | | |

* B - Backfill S - Seal F - Filter Pack

● Depth from Ground Surface

## CONSTRUCTION TIME LOG

| ACTIVITY | START DATE | START TIME | END TIME |
|---|---|---|---|
| DRILLING | 10-20-93 | 11:05 A | 1:30 P |
| CASING | 10-20-93 | 1:32 P | 1:36 P |
| FILTER PACK | 10-20-93 | 1:36 P | 2:40 P |
| SEAL | 10-20-93 | 2:40 P | 2:48 P |
| BACKFILL | 10-20-93 | 3:49 P | 4:15 P |
| DEVELOPMENT | 10-25-93 | 11:45 A | 3:00 P |
| | 10-26-93 | 8:00 A | 10:24 A |
| OTHER | | | |

## WELL DEVELOPMENT

COMMENTS: _____

JEG-AL-ENG-1 (3/84)

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE/WELL CONSTRUCTION LOG

ID: CAN 01 LOCATION ID: 508 FIELD REP: W.R. Wood

APPROX. SITE COORDINATES (FT.): N _____ E _____

GROUND ELEVATION (FT. MSL): _____ COMPLETION DATE: 10-23-93

## BOREHOLE SUMMARY

DRILLER: Lambert Drilling Co., Inc.

RIG TYPE: Diedrich-120

| BIT TYPE | HOLE DIA.• (in.) | END DEPTH● (ft.) | FLUID TYPE |
|---|---|---|---|
| HSA | 91 | 32 | — |
| | | | |
| | | | |
| | | | |

## CASING SUMMARY

| CASING TYPE● | DESCRIPTION | DIA. (in.) | END DEPTH◆ (ft.) |
|---|---|---|---|
| P | steel Casing | 8 | 6 |
| | Sched 40 PVC | 4 | 27 |
| S | 0.01" slotted PVC | 4 | 32 |
| B | Sched 40 PVC Sump | 4 | 34 |
| | | | |
| | | | |
| | | | |
| | | | |

● P-Protective S-Screen B-Blank O-Open N-None

◆ Depth from Top of Casing

## WELL CONSTRUCTION

| TYPE CODE● | DESCRIPTION | END DEPTH● (ft.) |
|---|---|---|
| B | Cement-Bentonite Grout | 21 |
| S | 3/8" Bentonite pellets | 23 |
| F | 10-20 Silica Sand | 32 |
| | | |
| | | |
| | | |
| | | |
| | | |

● B - Backfill S - Seal F - Filter Pack

● Depth from Ground Surface

## CONSTRUCTION TIME LOG

| ACTIVITY | START DATE | START TIME | END TIME |
|---|---|---|---|
| DRILLING | 10-23-93 | 9:20A | 11:12A |
| CASING | 10-23-93 | 11:18A | 11:20A |
| FILTER PACK | 10-23-93 | 11:20A | 11:39A |
| SEAL | 10-23-93 | 11:39A | 11:43A |
| BACKFILL | 10-23-93 | 1:50P | 2:20P |
| DEVELOPMENT | 10-26-93 | 1:40P | 5:02P |
| | 10-27-93 | 8:00A | 10:40A |
| OTHER | | | |

## WELL DEVELOPMENT

COMMENTS: _____

JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

# BOREHOLE/WELL CONSTRUCTION LOG

ID: CAN 01 LOCATION ID: 509 FIELD REP: W. R. Wood

APPROX. SITE COORDINATES (FT.): N _____ E _____

GROUND ELEVATION (FT. MSL): _____ COMPLETION DATE: 10-24-93

## BOREHOLE SUMMARY

DRILLER: Lambert Dilling Co., Inc.

RIG TYPE: Diedrich-120

| BIT TYPE | HOLE DIA.* (in.) | END DEPTH● (ft.) | FLUID TYPE |
|---|---|---|---|
| HSA | 9½ | 34½ | — |
| | | | |
| | | | |
| | | | |

## CASING SUMMARY

| CASING TYPE● | DESCRIPTION | DIA. (in.) | END DEPTH◆ (ft.) |
|---|---|---|---|
| P | Steel Casing | 8 | 6 |
| | Sched 40 PVC | 4 | 29.5 |
| S | 0.01" slotted PVC | 4 | 34.5 |
| B | Sched 40 PVC Sump | 4 | 36.5 |
| | | | |
| | | | |
| | | | |
| | | | |

● P-Protective S-Screen B-Blank O-Open N-None

◆ Depth from Top of Casing

## WELL CONSTRUCTION

| TYPE CODE● | DESCRIPTION | END DEPTH● (ft.) |
|---|---|---|
| B | Cement-Bentonite Grout | 23.5 |
| S | 3/8" Bentonite Pellets | 25.5 |
| F | 10-20 Silica Sand | 34.5 |
| | | |
| | | |
| | | |
| | | |
| | | |

● B - Backfill S - Seal F - Filter Pack

● Depth from Ground Surface

## CONSTRUCTION TIME LOG

| ACTIVITY | START DATE | START TIME | END TIME |
|---|---|---|---|
| DRILLING | 10-24-93 | 10:22A | 12:35P |
| CASING | 10-24-93 | 12:35P | 12:42P |
| FILTER PACK | 10-24-93 | 12:42P | 1:04P |
| SEAL | 10-24-93 | 1:04P | 1:07P |
| BACKFILL | 10-24-93 | 2:37P | 2:58P |
| DEVELOPMENT | 10-26-93 | 12:35P | 1:00P |
| | 10-27-93 | 10:30A | 5:00P |
| OTHER | | | |

## WELL DEVELOPMENT

COMMENTS: _____

JEG-AL-ENG-1 (3/84)

# JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

## BOREHOLE/WELL CONSTRUCTION LOG

SITE ID: CAN 01 LOCATION ID: 510 FIELD REP: W. R Wood

APPROX. SITE COORDINATES (FT.): N _____ E _____

GROUND ELEVATION (FT. MSL): _____ COMPLETION DATE: 10-22-93

### BOREHOLE SUMMARY

DRILLER: Lambert Drilling Co., Inc.

RIG TYPE: Diedrich-120

| BIT TYPE | HOLE DIA.* (In.) | END DEPTH● (ft.) | FLUID TYPE |
|---|---|---|---|
| HSA | 9½" | 23 | — |
| Tricone | 7⅞" | 38 | Air |
| | | | |
| | | | |

### CASING SUMMARY

| CASING TYPE* | DESCRIPTION | DIA. (In.) | END DEPTH✚ (ft.) |
|---|---|---|---|
| P | Steel Casing | 8 | 6 |
| S | Sched 40 PVC | 4 | 32 |
| S | 0.01" slotted PVC | 4 | 37 |
| B | Sched 40 PVC Sump | 4 | 39 |
| | | | |
| | | | |
| | | | |
| | | | |

* P-Protective S-Screen B-Blank O-Open N-None

✚ Depth from Top of Casing

### CONSTRUCTION TIME LOG

| ACTIVITY | START DATE | START TIME | END TIME |
|---|---|---|---|
| DRILLING | 10-21-93 | 12:35P | 2:00P |
| | 10-22-93 | 10:06A | 11:21A |
| CASING | 10-22-93 | 11:21A | 11:28A |
| FILTER PACK | 10-22-93 | 11:28A | 11:56A |
| SEAL | 10-22-93 | 11:56A | 12:15P |
| BACKFILL | 10-22-93 | 1:15P | 1:45P |
| DEVELOPMENT | 10-25-93 | 3:00P | 3:30P |
| | 10-26-93 | 10:00A | 11:08A |
| OTHER | | | |

### WELL CONSTRUCTION

| TYPE CODE* | DESCRIPTION | END DEPTH● (ft.) |
|---|---|---|
| B | Cement-Bentonite Grout | 26 |
| S | 3/8" Bentonite Pellets | 28 |
| F | 10-20 Silica Sand | 38 |
| | | |
| | | |
| | | |
| | | |
| | | |

* B - Backfill S - Seal F - Filter Pack

● Depth from Ground Surface

### WELL DEVELOPMENT

COMMENTS: _____

JEG-AL-ENG-1 (3/84)

# Appendix B

# Water Quality Data

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Monitor Well Data for Selected Constituents from the SEE.UMTRA Database

| RESULT (mg/l) | ANALYTE | LOCATION CODE | LAB QUALIFIERS | DATE SAMPLED | SAMPLE ID | DATA VALIDATION QUALIFIERS |
|---|---|---|---|---|---|---|
| 0.17 | Manganese | 0401 | | 07-Aug-86 | 0001 | F |
| 0.11 | Manganese | 0401 | | 31-Oct-93 | 0001 | |
| 0.05 | Manganese | 0405 | | 30-Oct-93 | 0001 | F |
| 5.04 | Manganese | 0406 | | 02-Nov-93 | 0001 | |
| 2.35 | Manganese | 0406 | | 16-Nov-95 | 0001 | F |
| 7.81 | Manganese | 0406 | | 05-Dec-96 | 0001 | |
| 6.87 | Manganese | 0406 | | 11-Nov-97 | 0001 | L |
| 0.12 | Manganese | 0407 | | 30-Oct-93 | 0001 | F |
| 4.05 | Manganese | 0408 | | 31-Oct-93 | 0001 | |
| 0.05 | Manganese | 0409 | | 02-Nov-93 | 0001 | |
| 3.32 | Manganese | 0410 | | 07-Aug-86 | 0001 | F |
| 2.9 | Manganese | 0410 | | 05-Nov-86 | 0001 | F |
| 3.08 | Manganese | 0410 | | 28-Jan-87 | 0001 | F |
| 3.42 | Manganese | 0410 | | 29-May-87 | 0001 | F |
| 2.91 | Manganese | 0410 | | 09-Dec-87 | 0001 | F |
| 1.47 | Manganese | 0410 | | 22-Jun-88 | 0001 | F |
| 3.12 | Manganese | 0410 | | 08-Dec-88 | 0001 | |
| 4.05 | Manganese | 0410 | | 25-May-89 | 0001 | F |
| 3.38 | Manganese | 0410 | | 04-Jan-90 | 0001 | F |
| 3.2 | Manganese | 0410 | | 31-Jul-90 | 0001 | F |
| 3.11 | Manganese | 0410 | | 07-Feb-91 | 0001 | F |
| 2.95 | Manganese | 0410 | | 01-Aug-91 | 0001 | F |
| 3.36 | Manganese | 0410 | | 15-Jan-92 | 0001 | F |
| 3.3 | Manganese | 0410 | | 06-Aug-92 | 0001 | F |
| 2.82 | Manganese | 0410 | | 20-Jul-93 | 0001 | F |
| 2.66 | Manganese | 0410 | | 30-Oct-93 | 0001 | F |
| 3.2 | Manganese | 0410 | | 28-Oct-94 | 0001 | F |
| 3 | Manganese | 0410 | | 28-Oct-94 | N001 | F |
| 2.75 | Manganese | 0410 | | 17-Nov-95 | 0001 | F |
| 3.07 | Manganese | 0410 | | 05-Dec-96 | 0001 | |
| 2.88 | Manganese | 0410 | | 12-Nov-97 | 0001 | L |
| 9.4 | Manganese | 0412 | | 06-Aug-86 | 0001 | |
| 9.41 | Manganese | 0412 | | 06-Aug-86 | 0002 | |
| 9.41 | Manganese | 0412 | | 06-Aug-86 | 0003 | |
| 9.4 | Manganese | 0412 | | 06-Aug-86 | 0004 | |
| 9.4 | Manganese | 0412 | | 06-Aug-86 | 0005 | |
| 4.05 | Manganese | 0412 | | 06-Nov-86 | 0001 | |
| 9.71 | Manganese | 0412 | | 29-Jan-87 | 0001 | |
| 10.4 | Manganese | 0412 | | 29-May-87 | 0001 | |
| 9.76 | Manganese | 0412 | | 08-Dec-87 | 0001 | |
| 10.5 | Manganese | 0412 | | 22-Jun-88 | 0001 | |
| 10.8 | Manganese | 0412 | | 08-Dec-88 | 0001 | |
| 12.3 | Manganese | 0412 | | 25-May-89 | 0001 | |
| 11.9 | Manganese | 0412 | | 05-Jan-90 | 0001 | |
| 14.6 | Manganese | 0412 | | 01-Aug-90 | 0001 | F |
| 15 | Manganese | 0412 | | 07-Feb-91 | 0001 | |
| 15.8 | Manganese | 0412 | | 01-Aug-91 | 0001 | |
| 18 | Manganese | 0412 | | 07-Aug-92 | 0001 | |
| 17.9 | Manganese | 0412 | | 20-Jul-93 | 0001 | |
| 17.6 | Manganese | 0412 | | 29-Oct-93 | 0001 | |
| 23 | Manganese | 0412 | | 28-Oct-94 | 0001 | F |
| 22 | Manganese | 0412 | | 16-Nov-95 | 0001 | |
| 26.6 | Manganese | 0412 | | 04-Dec-96 | 0001 | |
| 23.8 | Manganese | 0412 | | 04-Dec-96 | 0002 | |
| 20.2 | Manganese | 0412 | | 12-Nov-97 | 0001 | |
| 7.47 | Manganese | 0413 | | 07-Aug-86 | 0001 | F |
| 6.03 | Manganese | 0413 | | 04-Nov-86 | 0001 | F |
| 6.54 | Manganese | 0413 | | 27-Jan-87 | 0001 | F |

Monitor Well Data for Selected Constituents from the SEE.UMTRA Database

| | | | | | | |
|---|---|---|---|---|---|---|
| 6.68 | Manganese | 0413 | | 27-Jan-87 | 0002 | F |
| 6.68 | Manganese | 0413 | | 27-Jan-87 | 0003 | F |
| 6.69 | Manganese | 0413 | | 27-Jan-87 | 0004 | F |
| 6.68 | Manganese | 0413 | | 27-Jan-87 | 0005 | F |
| 6.85 | Manganese | 0413 | | 29-May-87 | 0001 | F |
| 6.82 | Manganese | 0413 | | 29-May-87 | 0002 | F |
| 6.84 | Manganese | 0413 | | 29-May-87 | 0003 | F |
| 6.85 | Manganese | 0413 | | 29-May-87 | 0004 | F |
| 6.83 | Manganese | 0413 | | 29-May-87 | 0005 | F |
| 5.91 | Manganese | 0413 | | 08-Dec-87 | 0001 | F |
| 5.32 | Manganese | 0413 | | 23-Jun-88 | 0001 | F |
| 10.3 | Manganese | 0413 | | 23-Jun-88 | 0002 | F |
| 10.1 | Manganese | 0413 | | 23-Jun-88 | 0003 | F |
| 10.6 | Manganese | 0413 | | 23-Jun-88 | 0004 | F |
| 10.6 | Manganese | 0413 | | 23-Jun-88 | 0005 | F |
| 5.37 | Manganese | 0413 | | 08-Dec-88 | 0001 | F |
| 3.91 | Manganese | 0413 | | 25-May-89 | 0001 | F |
| 1.4 | Manganese | 0413 | | 04-Jan-90 | 0001 | F |
| 4.18 | Manganese | 0413 | | 31-Jul-90 | 0001 | F |
| 4.33 | Manganese | 0413 | | 07-Feb-91 | 0001 | F |
| 5.07 | Manganese | 0413 | | 02-Aug-91 | 0001 | F |
| 3.8 | Manganese | 0413 | | 07-Aug-92 | 0001 | F |
| 4.29 | Manganese | 0413 | | 20-Jul-93 | 0001 | F |
| 3.97 | Manganese | 0413 | | 20-Jul-93 | 0002 | F |
| 4 | Manganese | 0413 | | 28-Oct-93 | 0001 | F |
| 3.8 | Manganese | 0413 | | 29-Oct-94 | 0001 | F |
| 2.14 | Manganese | 0413 | | 18-Nov-95 | 0001 | F |
| 1.49 | Manganese | 0413 | | 04-Dec-96 | 0001 | |
| 1.3 | Manganese | 0413 | | 12-Nov-97 | 0001 | L |
| 10.9 | Manganese | 0414 | | 05-Aug-86 | 0001 | |
| 11.5 | Manganese | 0414 | | 05-Nov-86 | 0001 | F |
| 7.91 | Manganese | 0414 | | 23-Jan-87 | 0001 | F |
| 9.15 | Manganese | 0414 | | 29-May-87 | 0001 | |
| 12.1 | Manganese | 0414 | | 09-Dec-87 | 0001 | |
| 7.11 | Manganese | 0414 | | 23-Jun-88 | 0001 | F |
| 11.2 | Manganese | 0414 | | 08-Dec-88 | 0001 | |
| 4.97 | Manganese | 0414 | | 25-May-89 | 0001 | F |
| 8.26 | Manganese | 0414 | | 04-Jan-90 | 0001 | F |
| 5.92 | Manganese | 0414 | | 01-Aug-90 | 0001 | F |
| 4.85 | Manganese | 0414 | | 07-Feb-91 | 0001 | F |
| 7.56 | Manganese | 0414 | | 01-Aug-91 | 0001 | F |
| 8.47 | Manganese | 0414 | | 15-Jan-92 | 0001 | F |
| 4.5 | Manganese | 0414 | | 06-Aug-92 | 0001 | F |
| 5.84 | Manganese | 0414 | | 28-Oct-93 | 0001 | |
| 5.2 | Manganese | 0414 | | 29-Oct-94 | 0001 | |
| 4.9 | Manganese | 0414 | | 29-Oct-94 | 0002 | |
| 0.46 | Manganese | 0414 | | 18-Nov-95 | 0001 | F |
| 2.36 | Manganese | 0414 | | 05-Dec-96 | 0001 | |
| 1.67 | Manganese | 0414 | | 11-Nov-97 | 0001 | L |
| 2.18 | Manganese | 0423 | | 04-Nov-93 | 0001 | |
| 2.3 | Manganese | 0423 | | 30-Oct-94 | 0001 | |
| 2.16 | Manganese | 0423 | | 04-Dec-96 | 0001 | |
| 6.43 | Manganese | 0424 | | 04-Nov-93 | 0001 | |
| 6.9 | Manganese | 0424 | | 29-Oct-94 | 0001 | |
| 6.9 | Manganese | 0424 | | 29-Oct-94 | N001 | |
| 6.39 | Manganese | 0424 | | 18-Nov-95 | 0001 | |
| 6.46 | Manganese | 0424 | | 18-Nov-95 | 0002 | |
| 6.72 | Manganese | 0424 | | 06-Dec-96 | 0001 | |
| 6.12 | Manganese | 0424 | | 11-Nov-97 | 0001 | |
| 6.42 | Manganese | 0424 | | 11-Nov-97 | 0002 | |
| 0.15 | Manganese | 0425 | | 03-Nov-93 | 0001 | |
| 0.12 | Manganese | 0425 | | 28-Oct-94 | 0001 | |

Monitor Well Data for Selected Constituents from the SEE.UMTRA Database

| | | | | | | |
|---|---|---|---|---|---|---|
| 0.24 | Manganese | 0502 | | 05-Nov-93 | 0001 | |
| 0.24 | Manganese | 0502 | | 05-Nov-93 | 0002 | |
| 0.29 | Manganese | 0502 | | 31-Oct-94 | 0001 | |
| 0.07 | Manganese | 0503 | | 01-Nov-93 | 0001 | |
| 0.07 | Manganese | 0503 | | 01-Nov-93 | 0002 | |
| 0:83 | Manganese | 0504 | | 06-Aug-86 | 0001 | |
| 0.69 | Manganese | 0504 | | 04-Nov-86 | 0001 | |
| 0.73 | Manganese | 0504 | | 28-Jan-87 | 0001 | |
| 0.95 | Manganese | 0504 | | 29-May-87 | 0001 | |
| 0.89 | Manganese | 0504 | | 08-Dec-87 | 0001 | |
| 0.88 | Manganese | 0504 | | 08-Dec-87 | 0002 | |
| 0.87 | Manganese | 0504 | | 08-Dec-87 | 0003 | |
| 0.86 | Manganese | 0504 | | 08-Dec-87 | 0004 | |
| 0.88 | Manganese | 0504 | | 08-Dec-87 | 0005 | |
| 0.97 | Manganese | 0504 | | 22-Jun-88 | 0001 | |
| 0.88 | Manganese | 0504 | | 08-Dec-88 | 0001 | |
| 0.96 | Manganese | 0504 | | 25-May-89 | 0001 | F |
| 0.89 | Manganese | 0504 | | 04-Jan-90 | 0001 | |
| 0.91 | Manganese | 0504 | | 04-Jan-90 | 0002 | |
| 0.88 | Manganese | 0504 | | 04-Jan-90 | 0003 | |
| 0.91 | Manganese | 0504 | | 04-Jan-90 | 0004 | |
| 0.97 | Manganese | 0504 | | 04-Jan-90 | 0005 | |
| 0.98 | Manganese | 0504 | | 31-Jul-90 | 0001 | |
| 0.95 | Manganese | 0504 | | 07-Feb-91 | 0001 | |
| 1.05 | Manganese | 0504 | | 01-Aug-91 | 0001 | F |
| 1.08 | Manganese | 0504 | | 15-Jan-92 | 0001 | F |
| 1.1 | Manganese | 0504 | | 06-Aug-92 | 0001 | |
| 1.07 | Manganese | 0504 | | 20-Jul-93 | 0001 | |
| 1.07 | Manganese | 0504 | | 02-Nov-93 | 0001 | |
| 1.1 | Manganese | 0504 | | 29-Oct-94 | 0001 | |
| 0.02 | Manganese | 0505 | | 05-Aug-86 | 0001 | |
| 0.01 | Manganese | 0505 | | 03-Nov-86 | 0001 | |
| 0.01 | Manganese | 0505 | | 03-Nov-86 | 0002 | |
| 0.41 | Manganese | 0505 | | 03-Nov-86 | 0003 | |
| 0.01 | Manganese | 0505 | | 03-Nov-86 | 0004 | |
| 0.01 | Manganese | 0505 | | 03-Nov-86 | 0005 | |
| 0.02 | Manganese | 0505 | | 27-Jan-87 | 0001 | |
| 0.01 | Manganese | 0505 | U | 29-May-87 | 0001 | |
| 0.01 | Manganese | 0505 | | 08-Dec-87 | 0001 | F |
| 0.01 | Manganese | 0505 | | 22-Jun-88 | 0001 | |
| 0.01 | Manganese | 0505 | | 08-Dec-88 | 0001 | |
| 0.02 | Manganese | 0505 | | 08-Dec-88 | 0002 | |
| 0.01 | Manganese | 0505 | | 08-Dec-88 | 0003 | |
| 0.01 | Manganese | 0505 | | 08-Dec-88 | 0004 | |
| 0.01 | Manganese | 0505 | | 08-Dec-88 | 0005 | |
| 0.01 | Manganese | 0505 | | 25-May-89 | 0001 | |
| 0.02 | Manganese | 0505 | | 25-May-89 | 0002 | |
| 0.02 | Manganese | 0505 | | 25-May-89 | 0003 | |
| 0.02 | Manganese | 0505 | | 25-May-89 | 0004 | |
| 0.01 | Manganese | 0505 | | 25-May-89 | 0005 | |
| 0.01 | Manganese | 0505 | U | 04-Jan-90 | 0001 | |
| 0.01 | Manganese | 0505 | U | 31-Jul-90 | 0001 | |
| 0.01 | Manganese | 0505 | | 07-Feb-91 | 0001 | |
| 0.01 | Manganese | 0505 | U | 02-Aug-91 | 0001 | F |
| 0.01 | Manganese | 0505 | U | 15-Jan-92 | 0001 | |
| 0.008 | Manganese | 0505 | | 06-Aug-92 | 0001 | |
| 0.01 | Manganese | 0505 | U | 20-Jul-93 | 0001 | |
| 0.01 | Manganese | 0505 | U | 02-Nov-93 | 0001 | |
| 0.01 | Manganese | 0505 | U | 30-Oct-94 | 0001 | |
| 0.04 | Manganese | 0506 | | 06-Aug-86 | 0001 | |
| 0.04 | Manganese | 0506 | | 06-Nov-86 | 0001 | |
| 0.08 | Manganese | 0506 | | 29-Jan-87 | 0001 | |

Monitor Well Data for Selected Constituents from the SEE.UMTRA Database

| | | | | | | |
|---|---|---|---|---|---|---|
| 0.08 | Manganese | 0506 | | 29-May-87 | 0001 | |
| 0.1 | Manganese | 0506 | | 08-Dec-87 | 0001 | |
| 0.11 | Manganese | 0506 | | 22-Jun-88 | 0001 | |
| 0.12 | Manganese | 0506 | | 08-Dec-88 | 0001 | |
| 0.11 | Manganese | 0506 | | 25-May-89 | 0001 | |
| 0.14 | Manganese | 0506 | | 05-Jan-90 | 0001 | |
| 0.15 | Manganese | 0506 | | 01-Aug-90 | 0001 | F |
| 0.18 | Manganese | 0506 | | 07-Feb-91 | 0001 | |
| 0.32 | Manganese | 0506 | | 02-Aug-91 | 0001 | |
| 0.46 | Manganese | 0506 | | 07-Aug-92 | 0001 | |
| 0.63 | Manganese | 0506 | | 20-Jul-93 | 0001 | |
| 0.45 | Manganese | 0506 | | 03-Nov-93 | 0001 | |
| 0.894 | Manganese | 0506 | | 04-Dec-96 | 0001 | |
| 0.815 | Manganese | 0506 | | 12-Nov-97 | 0001 | |
| 0.57 | Manganese | 0507 | | 04-Nov-93 | 0001 | |
| 0.66 | Manganese | 0507 | | 31-Oct-94 | 0001 | |
| 0.46 | Manganese | 0508 | | 04-Nov-93 | 0001 | |
| 0.41 | Manganese | 0508 | | 30-Oct-94 | 0001 | |
| 0.42 | Manganese | 0509 | | 05-Nov-93 | 0001 | F |
| 0.38 | Manganese | 0509 | | 29-Oct-94 | 0001 | |
| 0.18 | Manganese | 0510 | | 03-Nov-93 | 0001 | |
| 0.23 | Manganese | 0510 | | 31-Oct-94 | 0001 | |
| 0.27 | Molybdenum | 0401 | | 07-Aug-86 | 0001 | F |
| 0.01 | Molybdenum | 0401 | U | 31-Oct-93 | 0001 | |
| 0.01 | Molybdenum | 0405 | U | 30-Oct-93 | 0001 | F |
| 0.01 | Molybdenum | 0406 | U | 02-Nov-93 | 0001 | |
| 0.01 | Molybdenum | 0406 | U | 16-Nov-95 | 0001 | F |
| 0.0039 | Molybdenum | 0406 | B | 05-Dec-96 | 0001 | |
| 0.0043 | Molybdenum | 0406 | B | 11-Nov-97 | 0001 | L |
| 0.01 | Molybdenum | 0407 | U | 30-Oct-93 | 0001 | F |
| 0.01 | Molybdenum | 0408 | U | 31-Oct-93 | 0001 | |
| 0.01 | Molybdenum | 0409 | U | 02-Nov-93 | 0001 | |
| 0.2 | Molybdenum | 0410 | | 07-Aug-86 | 0001 | F |
| 0.1 | Molybdenum | 0410 | U | 05-Nov-86 | 0001 | F |
| 0.1 | Molybdenum | 0410 | U | 28-Jan-87 | 0001 | F |
| 0.01 | Molybdenum | 0410 | U | 29-May-87 | 0001 | F |
| 0.01 | Molybdenum | 0410 | U | 09-Dec-87 | 0001 | F |
| 0.01 | Molybdenum | 0410 | U | 22-Jun-88 | 0001 | F |
| 0.02 | Molybdenum | 0410 | | 08-Dec-88 | 0001 | |
| 0.01 | Molybdenum | 0410 | U | 25-May-89 | 0001 | F |
| 0.01 | Molybdenum | 0410 | U | 04-Jan-90 | 0001 | F |
| 0.01 | Molybdenum | 0410 | U | 31-Jul-90 | 0001 | F |
| 0.01 | Molybdenum | 0410 | U | 07-Feb-91 | 0001 | F |
| 0.01 | Molybdenum | 0410 | U | 01-Aug-91 | 0001 | F |
| 0.01 | Molybdenum | 0410 | U | 15-Jan-92 | 0001 | F |
| 0.0049 | Molybdenum | 0410 | U | 06-Aug-92 | 0001 | F |
| 0.01 | Molybdenum | 0410 | U | 20-Jul-93 | 0001 | F |
| 0.01 | Molybdenum | 0410 | U | 30-Oct-93 | 0001 | F |
| 0.01 | Molybdenum | 0410 | U | 28-Oct-94 | 0001 | F |
| 0.01 | Molybdenum | 0410 | U | 17-Nov-95 | 0001 | F |
| 0.001 | Molybdenum | 0410 | U | 05-Dec-96 | 0001 | |
| 0.001 | Molybdenum | 0410 | U | 12-Nov-97 | 0001 | L |
| 0.2 | Molybdenum | 0412 | | 06-Aug-86 | 0001 | |
| 0.19 | Molybdenum | 0412 | | 06-Aug-86 | 0002 | |
| 0.19 | Molybdenum | 0412 | | 06-Aug-86 | 0003 | |
| 0.19 | Molybdenum | 0412 | | 06-Aug-86 | 0004 | |
| 0.19 | Molybdenum | 0412 | | 06-Aug-86 | 0005 | |
| 0.1 | Molybdenum | 0412 | U | 06-Nov-86 | 0001 | |
| 0.1 | Molybdenum | 0412 | U | 29-Jan-87 | 0001 | |
| 0.02 | Molybdenum | 0412 | | 29-May-87 | 0001 | |
| 0.02 | Molybdenum | 0412 | | 08-Dec-87 | 0001 | |
| 0.02 | Molybdenum | 0412 | | 22-Jun-88 | 0001 | |

Monitor Well Data for Selected Constituents from the SEE.UMTRA Database

| | | | | | | |
|---|---|---|---|---|---|---|
| 0.04 | Molybdenum | 0412 | | 08-Dec-88 | 0001 | |
| 0.01 | Molybdenum | 0412 | | 25-May-89 | 0001 | |
| 0.01 | Molybdenum | 0412 | U | 05-Jan-90 | 0001 | |
| 0.01 | Molybdenum | 0412 | U | 01-Aug-90 | 0001 | F |
| 0.03 | Molybdenum | 0412 | | 07-Feb-91 | 0001 | |
| 0.01 | Molybdenum | 0412 | U | 01-Aug-91 | 0001 | |
| 0.005 | Molybdenum | 0412 | | 07-Aug-92 | 0001 | |
| 0.01 | Molybdenum | 0412 | U | 20-Jul-93 | 0001 | |
| 0.01 | Molybdenum | 0412 | U | 29-Oct-93 | 0001 | |
| 0.01 | Molybdenum | 0412 | U | 28-Oct-94 | 0001 | F |
| 0.01 | Molybdenum | 0412 | U | 16-Nov-95 | 0001 | |
| 0.001 | Molybdenum | 0412 | U | 04-Dec-96 | 0001 | |
| 0.001 | Molybdenum | 0412 | U | 04-Dec-96 | 0002 | |
| 0.001 | Molybdenum | 0412 | U | 12-Nov-97 | 0001 | |
| 0.19 | Molybdenum | 0413 | | 07-Aug-86 | 0001 | F |
| 0.1 | Molybdenum | 0413 | U | 04-Nov-86 | 0001 | F |
| 0.1 | Molybdenum | 0413 | U | 27-Jan-87 | 0001 | F |
| 0.1 | Molybdenum | 0413 | U | 27-Jan-87 | 0002 | F |
| 0.1 | Molybdenum | 0413 | U | 27-Jan-87 | 0003 | F |
| 0.1 | Molybdenum | 0413 | U | 27-Jan-87 | 0004 | F |
| 0.1 | Molybdenum | 0413 | U | 27-Jan-87 | 0005 | F |
| 0.02 | Molybdenum | 0413 | | 29-May-87 | 0001 | F |
| 0.02 | Molybdenum | 0413 | | 29-May-87 | 0002 | F |
| 0.02 | Molybdenum | 0413 | | 29-May-87 | 0003 | F |
| 0.02 | Molybdenum | 0413 | | 29-May-87 | 0004 | F |
| 0.02 | Molybdenum | 0413 | | 29-May-87 | 0005 | F |
| 0.03 | Molybdenum | 0413 | | 08-Dec-87 | 0001 | F |
| 0.02 | Molybdenum | 0413 | | 23-Jun-88 | 0001 | F |
| 0.02 | Molybdenum | 0413 | | 23-Jun-88 | 0002 | F |
| 0.02 | Molybdenum | 0413 | | 23-Jun-88 | 0003 | F |
| 0.02 | Molybdenum | 0413 | | 23-Jun-88 | 0004 | F |
| 0.02 | Molybdenum | 0413 | | 23-Jun-88 | 0005 | F |
| 0.02 | Molybdenum | 0413 | | 08-Dec-88 | 0001 | F |
| 0.02 | Molybdenum | 0413 | | 25-May-89 | 0001 | F |
| 0.01 | Molybdenum | 0413 | U | 04-Jan-90 | 0001 | F |
| 0.01 | Molybdenum | 0413 | | 31-Jul-90 | 0001 | F |
| 0.01 | Molybdenum | 0413 | | 07-Feb-91 | 0001 | F |
| 0.01 | Molybdenum | 0413 | U | 02-Aug-91 | 0001 | F |
| 0.0049 | Molybdenum | 0413 | U | 07-Aug-92 | 0001 | F |
| 0.01 | Molybdenum | 0413 | U | 20-Jul-93 | 0001 | F |
| 0.01 | Molybdenum | 0413 | U | 20-Jul-93 | 0002 | F |
| 0.01 | Molybdenum | 0413 | U | 28-Oct-93 | 0001 | F |
| 0.01 | Molybdenum | 0413 | U | 29-Oct-94 | 0001 | F |
| 0.01 | Molybdenum | 0413 | U | 18-Nov-95 | 0001 | F |
| 0.0027 | Molybdenum | 0413 | B | 04-Dec-96 | 0001 | |
| 0.0024 | Molybdenum | 0413 | B | 12-Nov-97 | 0001 | L |
| 0.18 | Molybdenum | 0414 | | 05-Aug-86 | 0001 | |
| 0.1 | Molybdenum | 0414 | U | 05-Nov-86 | 0001 | F |
| 0.1 | Molybdenum | 0414 | U | 23-Jan-87 | 0001 | F |
| 0.03 | Molybdenum | 0414 | | 29-May-87 | 0001 | |
| 0.02 | Molybdenum | 0414 | | 09-Dec-87 | 0001 | |
| 0.02 | Molybdenum | 0414 | | 23-Jun-88 | 0001 | F |
| 0.03 | Molybdenum | 0414 | | 08-Dec-88 | 0001 | |
| 0.02 | Molybdenum | 0414 | | 25-May-89 | 0001 | F |
| 0.01 | Molybdenum | 0414 | U | 04-Jan-90 | 0001 | F |
| 0.02 | Molybdenum | 0414 | | 01-Aug-90 | 0001 | F |
| 0.01 | Molybdenum | 0414 | U | 07-Feb-91 | 0001 | F |
| 0.01 | Molybdenum | 0414 | U | 01-Aug-91 | 0001 | F |
| 0.01 | Molybdenum | 0414 | U | 15-Jan-92 | 0001 | F |
| 0.009 | Molybdenum | 0414 | | 06-Aug-92 | 0001 | F |
| 0.01 | Molybdenum | 0414 | U | 28-Oct-93 | 0001 | |
| 0.02 | Molybdenum | 0414 | | 29-Oct-94 | 0001 | |

Monitor Well Data for Selected Constituents from the SEE.UMTRA Database

| | | | | | | |
|---|---|---|---|---|---|---|
| 0.02 | Molybdenum | 0414 | | 29-Oct-94 | 0002 | |
| 0.03 | Molybdenum | 0414 | | 18-Nov-95 | 0001 | F |
| 0.0085 | Molybdenum | 0414 | B | 05-Dec-96 | 0001 | |
| 0.0127 | Molybdenum | 0414 | | 11-Nov-97 | 0001 | L |
| 0.09 | Molybdenum | 0423 | | 04-Nov-93 | 0001 | |
| 0.1 | Molybdenum | 0423 | | 30-Oct-94 | 0001 | |
| 0.0906 | Molybdenum | 0423 | | 04-Dec-96 | 0001 | |
| 0.01 | Molybdenum | 0424 | U | 04-Nov-93 | 0001 | |
| 0.01 | Molybdenum | 0424 | U | 29-Oct-94 | 0001 | |
| 0.01 | Molybdenum | 0424 | U | 18-Nov-95 | 0001 | |
| 0.01 | Molybdenum | 0424 | U | 18-Nov-95 | 0002 | |
| 0.001 | Molybdenum | 0424 | U | 06-Dec-96 | 0001 | |
| 0.0011 | Molybdenum | 0424 | B | 11-Nov-97 | 0001 | |
| 0.0011 | Molybdenum | 0424 | B | 11-Nov-97 | 0002 | |
| 0.01 | Molybdenum | 0425 | U | 03-Nov-93 | 0001 | |
| 0.01 | Molybdenum | 0425 | U | 28-Oct-94 | 0001 | |
| 0.01 | Molybdenum | 0502 | U | 05-Nov-93 | 0001 | |
| 0.01 | Molybdenum | 0502 | U | 05-Nov-93 | 0002 | |
| 0.01 | Molybdenum | 0502 | U | 31-Oct-94 | 0001 | |
| 0.01 | Molybdenum | 0503 | U | 01-Nov-93 | 0001 | |
| 0.01 | Molybdenum | 0503 | U | 01-Nov-93 | 0002 | |
| 0.13 | Molybdenum | 0504 | | 06-Aug-86 | 0001 | |
| 0.1 | Molybdenum | 0504 | U | 04-Nov-86 | 0001 | |
| 0.1 | Molybdenum | 0504 | U | 28-Jan-87 | 0001 | |
| 0.01 | Molybdenum | 0504 | U | 29-May-87 | 0001 | |
| 0.01 | Molybdenum | 0504 | | 08-Dec-87 | 0001 | |
| 0.01 | Molybdenum | 0504 | | 08-Dec-87 | 0002 | |
| 0.01 | Molybdenum | 0504 | | 08-Dec-87 | 0003 | |
| 0.02 | Molybdenum | 0504 | | 08-Dec-87 | 0004 | |
| 0.01 | Molybdenum | 0504 | | 08-Dec-87 | 0005 | |
| 0.01 | Molybdenum | 0504 | U | 22-Jun-88 | 0001 | |
| 0.02 | Molybdenum | 0504 | | 08-Dec-88 | 0001 | |
| 0.01 | Molybdenum | 0504 | | 25-May-89 | 0001 | F |
| 0.01 | Molybdenum | 0504 | U | 04-Jan-90 | 0001 | |
| 0.01 | Molybdenum | 0504 | U | 04-Jan-90 | 0002 | |
| 0.01 | Molybdenum | 0504 | U | 04-Jan-90 | 0003 | |
| 0.01 | Molybdenum | 0504 | U | 04-Jan-90 | 0004 | |
| 0.01 | Molybdenum | 0504 | U | 04-Jan-90 | 0005 | |
| 0.01 | Molybdenum | 0504 | U | 31-Jul-90 | 0001 | |
| 0.01 | Molybdenum | 0504 | U | 07-Feb-91 | 0001 | |
| 0.01 | Molybdenum | 0504 | U | 01-Aug-91 | 0001 | F |
| 0.01 | Molybdenum | 0504 | U | 15-Jan-92 | 0001 | F |
| 0.0049 | Molybdenum | 0504 | U | 06-Aug-92 | 0001 | |
| 0.01 | Molybdenum | 0504 | U | 20-Jul-93 | 0001 | |
| 0.01 | Molybdenum | 0504 | U | 02-Nov-93 | 0001 | |
| 0.01 | Molybdenum | 0504 | U | 29-Oct-94 | 0001 | |
| 0.12 | Molybdenum | 0505 | | 05-Aug-86 | 0001 | |
| 0.1 | Molybdenum | 0505 | U | 03-Nov-86 | 0001 | |
| 0.1 | Molybdenum | 0505 | U | 03-Nov-86 | 0002 | |
| 0.1 | Molybdenum | 0505 | U | 03-Nov-86 | 0003 | |
| 0.1 | Molybdenum | 0505 | U | 03-Nov-86 | 0004 | |
| 0.1 | Molybdenum | 0505 | U | 03-Nov-86 | 0005 | |
| 0.1 | Molybdenum | 0505 | U | 27-Jan-87 | 0001 | |
| 0.01 | Molybdenum | 0505 | U | 29-May-87 | 0001 | |
| 0.02 | Molybdenum | 0505 | | 08-Dec-87 | 0001 | F |
| 0.01 | Molybdenum | 0505 | U | 22-Jun-88 | 0001 | |
| 0.01 | Molybdenum | 0505 | | 08-Dec-88 | 0001 | |
| 0.01 | Molybdenum | 0505 | | 08-Dec-88 | 0002 | |
| 0.02 | Molybdenum | 0505 | | 08-Dec-88 | 0003 | |
| 0.01 | Molybdenum | 0505 | | 08-Dec-88 | 0004 | |
| 0.01 | Molybdenum | 0505 | | 08-Dec-88 | 0005 | |
| 0.01 | Molybdenum | 0505 | | 25-May-89 | 0001 | |

Monitor Well Data for Selected Constituents from the SEE.UMTRA Database

| | | | | | | |
|---|---|---|---|---|---|---|
| 0.01 | Molybdenum | 0505 | | 25-May-89 | 0002 | |
| 0.01 | Molybdenum | 0505 | | 25-May-89 | 0003 | |
| 0.01 | Molybdenum | 0505 | | 25-May-89 | 0004 | |
| 0.01 | Molybdenum | 0505 | | 25-May-89 | 0005 | |
| 0.01 | Molybdenum | 0505 | U | 04-Jan-90 | 0001 | |
| 0.01 | Molybdenum | 0505 | U | 31-Jul-90 | 0001 | |
| 0.01 | Molybdenum | 0505 | U | 07-Feb-91 | 0001 | |
| 0.01 | Molybdenum | 0505 | U | 02-Aug-91 | 0001 | F |
| 0.01 | Molybdenum | 0505 | U | 15-Jan-92 | 0001 | |
| 0.008 | Molybdenum | 0505 | | 06-Aug-92 | 0001 | |
| 0.01 | Molybdenum | 0505 | U | 20-Jul-93 | 0001 | |
| 0.01 | Molybdenum | 0505 | U | 02-Nov-93 | 0001 | |
| 0.01 | Molybdenum | 0505 | U | 30-Oct-94 | 0001 | |
| 0.18 | Molybdenum | 0506 | | 06-Aug-86 | 0001 | |
| 0.1 | Molybdenum | 0506 | U | 06-Nov-86 | 0001 | |
| 0.1 | Molybdenum | 0506 | U | 29-Jan-87 | 0001 | |
| 0.03 | Molybdenum | 0506 | | 29-May-87 | 0001 | |
| 0.03 | Molybdenum | 0506 | | 08-Dec-87 | 0001 | |
| 0.02 | Molybdenum | 0506 | | 22-Jun-88 | 0001 | |
| 0.03 | Molybdenum | 0506 | | 08-Dec-88 | 0001 | |
| 0.01 | Molybdenum | 0506 | U | 25-May-89 | 0001 | |
| 0.01 | Molybdenum | 0506 | U | 05-Jan-90 | 0001 | |
| 0.01 | Molybdenum | 0506 | U | 01-Aug-90 | 0001 | F |
| 0.01 | Molybdenum | 0506 | U | 07-Feb-91 | 0001 | |
| 0.01 | Molybdenum | 0506 | U | 02-Aug-91 | 0001 | |
| 0.0049 | Molybdenum | 0506 | U | 07-Aug-92 | 0001 | |
| 0.01 | Molybdenum | 0506 | U | 20-Jul-93 | 0001 | |
| 0.01 | Molybdenum | 0506 | U | 03-Nov-93 | 0001 | |
| 0.001 | Molybdenum | 0506 | U | 04-Dec-96 | 0001 | |
| 0.0012 | Molybdenum | 0506 | B | 12-Nov-97 | 0001 | |
| 0.01 | Molybdenum | 0507 | U | 04-Nov-93 | 0001 | |
| 0.01 | Molybdenum | 0507 | U | 31-Oct-94 | 0001 | |
| 0.01 | Molybdenum | 0508 | U | 04-Nov-93 | 0001 | |
| 0.01 | Molybdenum | 0508 | U | 30-Oct-94 | 0001 | |
| 0.02 | Molybdenum | 0509 | | 05-Nov-93 | 0001 | F |
| 0.04 | Molybdenum | 0509 | | 29-Oct-94 | 0001 | |
| 0.01 | Molybdenum | 0510 | U | 03-Nov-93 | 0001 | |
| 0.01 | Molybdenum | 0510 | U | 31-Oct-94 | 0001 | |
| 0.0003 | Uranium | 0401 | U | 07-Aug-86 | 0001 | FJ |
| 0.001 | Uranium | 0401 | | 30-Oct-93 | 0001 | F |
| 0.001 | Uranium | 0401 | | 30-Oct-93 | N001 | F |
| 0.001 | Uranium | 0405 | U | 30-Oct-93 | 0001 | F |
| 0.001 | Uranium | 0405 | U | 31-Oct-93 | N001 | |
| 0.02 | Uranium | 0406 | | 02-Nov-93 | 0001 | |
| 0.023 | Uranium | 0406 | | 02-Nov-93 | N001 | |
| 0.03 | Uranium | 0406 | | 16-Nov-95 | 0001 | F |
| 0.0142 | Uranium | 0406 | | 05-Dec-96 | 0001 | |
| 0.0101 | Uranium | 0406 | | 11-Nov-97 | 0001 | L |
| 0.002 | Uranium | 0407 | | 30-Oct-93 | 0001 | F |
| 0.003 | Uranium | 0407 | | 30-Oct-93 | N001 | F |
| 0.001 | Uranium | 0408 | U | 30-Oct-93 | 0001 | F |
| 0.001 | Uranium | 0408 | U | 30-Oct-93 | N001 | F |
| 0.001 | Uranium | 0409 | U | 02-Nov-93 | 0001 | |
| 0.001 | Uranium | 0409 | U | 02-Nov-93 | N001 | |
| 0.0003 | Uranium | 0410 | U | 07-Aug-86 | 0001 | FJ |
| 0.0003 | Uranium | 0410 | U | 05-Nov-86 | 0001 | FJ |
| 0.0003 | Uranium | 0410 | U | 28-Jan-87 | 0001 | FJ |
| 0.0003 | Uranium | 0410 | U | 29-May-87 | 0001 | FJ |
| 0.0006 | Uranium | 0410 | | 09-Dec-87 | 0001 | FJ |
| 0.0003 | Uranium | 0410 | U | 22-Jun-88 | 0001 | FJ |
| 0.0009 | Uranium | 0410 | | 08-Dec-88 | 0001 | J |
| 0.0003 | Uranium | 0410 | U | 25-May-89 | 0001 | FJ |

Monitor Well Data for Selected Constituents from the SEE.UMTRA Database

| | | | | | | |
|---|---|---|---|---|---|---|
| 0.003 | Uranium | 0410 | U | 04-Jan-90 | 0001 | F |
| 0.001 | Uranium | 0410 | U | 31-Jul-90 | 0001 | F |
| 0.003 | Uranium | 0410 | | 01-Aug-91 | 0001 | F |
| 0.001 | Uranium | 0410 | U | 15-Jan-92 | 0001 | F |
| 0.001 | Uranium | 0410 | UH | 06-Aug-92 | 0001 | F |
| 0.001 | Uranium | 0410 | U | 19-Jul-93 | 0001 | F |
| 0.001 | Uranium | 0410 | U | 29-Oct-93 | 0001 | F |
| 0.001 | Uranium | 0410 | U | 29-Oct-93 | N001 | F |
| 0.001 | Uranium | 0410 | U | 28-Oct-94 | 0001 | F |
| 0.001 | Uranium | 0410 | U | 28-Oct-94 | N001 | F |
| 0.001 | Uranium | 0410 | U | 17-Nov-95 | 0001 | F |
| 0.001 | Uranium | 0410 | U | 05-Dec-96 | 0001 | |
| 0.001 | Uranium | 0410 | U | 12-Nov-97 | 0001 | L |
| 0.0176 | Uranium | 0412 | | 06-Aug-86 | 0001 | |
| 0.0222 | Uranium | 0412 | | 06-Aug-86 | 0002 | |
| 0.0223 | Uranium | 0412 | | 06-Aug-86 | 0003 | |
| 0.0223 | Uranium | 0412 | | 06-Aug-86 | 0004 | |
| 0.0221 | Uranium | 0412 | | 06-Aug-86 | 0005 | |
| 0.0206 | Uranium | 0412 | | 06-Nov-86 | 0001 | |
| 0.0276 | Uranium | 0412 | | 29-Jan-87 | 0001 | |
| 0.0332 | Uranium | 0412 | | 29-May-87 | 0001 | |
| 0.0276 | Uranium | 0412 | | 08-Dec-87 | 0001 | |
| 0.0306 | Uranium | 0412 | | 22-Jun-88 | 0001 | |
| 0.0281 | Uranium | 0412 | | 08-Dec-88 | 0001 | |
| 0.0424 | Uranium | 0412 | | 25-May-89 | 0001 | |
| 0.034 | Uranium | 0412 | | 05-Jan-90 | 0001 | |
| 0.044 | Uranium | 0412 | | 01-Aug-90 | 0001 | F |
| 0.055 | Uranium | 0412 | | 01-Aug-91 | 0001 | |
| 0.075 | Uranium | 0412 | H | 07-Aug-92 | 0001 | |
| 0.091 | Uranium | 0412 | | 20-Jul-93 | 0001 | |
| 0.067 | Uranium | 0412 | | 29-Oct-93 | 0001 | |
| 0.063 | Uranium | 0412 | | 29-Oct-93 | N001 | |
| 0.105 | Uranium | 0412 | | 28-Oct-94 | 0001 | F |
| 0.103 | Uranium | 0412 | | 16-Nov-95 | 0001 | |
| 0.213 | Uranium | 0412 | | 04-Dec-96 | 0001 | |
| 0.121 | Uranium | 0412 | | 04-Dec-96 | 0002 | |
| 0.122 | Uranium | 0412 | | 12-Nov-97 | 0001 | |
| 0.0492 | Uranium | 0413 | | 07-Aug-86 | 0001 | F |
| 0.045 | Uranium | 0413 | | 04-Nov-86 | 0001 | F |
| 0.0601 | Uranium | 0413 | | 27-Jan-87 | 0001 | F |
| 0.0689 | Uranium | 0413 | | 27-Jan-87 | 0002 | F |
| 0.0583 | Uranium | 0413 | | 27-Jan-87 | 0003 | F |
| 0.0586 | Uranium | 0413 | | 27-Jan-87 | 0004 | F |
| 0.0583 | Uranium | 0413 | | 27-Jan-87 | 0005 | F |
| 0.094 | Uranium | 0413 | | 29-May-87 | 0001 | F |
| 0.0604 | Uranium | 0413 | | 29-May-87 | 0002 | F |
| 0.0527 | Uranium | 0413 | | 29-May-87 | 0003 | F |
| 0.0485 | Uranium | 0413 | | 29-May-87 | 0004 | F |
| 0.0474 | Uranium | 0413 | | 29-May-87 | 0005 | F |
| 0.0684 | Uranium | 0413 | | 08-Dec-87 | 0001 | F |
| 0.175 | Uranium | 0413 | | 23-Jun-88 | 0001 | F |
| 0.0305 | Uranium | 0413 | | 23-Jun-88 | 0002 | F |
| 0.0294 | Uranium | 0413 | | 23-Jun-88 | 0003 | F |
| 0.029 | Uranium | 0413 | | 23-Jun-88 | 0004 | F |
| 0.0334 | Uranium | 0413 | | 23-Jun-88 | 0005 | F |
| 0.134 | Uranium | 0413 | | 08-Dec-88 | 0001 | F |
| 0.382 | Uranium | 0413 | | 25-May-89 | 0001 | F |
| 0.339 | Uranium | 0413 | | 04-Jan-90 | 0001 | F |
| 0.144 | Uranium | 0413 | | 31-Jul-90 | 0001 | F |
| 0.089 | Uranium | 0413 | | 02-Aug-91 | 0001 | F |
| 0.146 | Uranium | 0413 | | 07-Aug-92 | 0001 | F |
| 0.145 | Uranium | 0413 | | 20-Jul-93 | 0001 | F |

Monitor Well Data for Selected Constituents from the SEE.UMTRA Database

| | | | | | | |
|---|---|---|---|---|---|---|
| 0.137 | Uranium | 0413 | | 20-Jul-93 | 0002 | F |
| 0.068 | Uranium | 0413 | | 28-Oct-93 | 0001 | F |
| 0.082 | Uranium | 0413 | | 29-Oct-93 | N001 | F |
| 0.123 | Uranium | 0413 | | 29-Oct-94 | 0001 | F |
| 0.232 | Uranium | 0413 | | 18-Nov-95 | 0001 | F |
| 0.157 | Uranium | 0413 | | 04-Dec-96 | 0001 | |
| 0.149 | Uranium | 0413 | | 12-Nov-97 | 0001 | L |
| 0.0221 | Uranium | 0414 | | 05-Aug-86 | 0001 | |
| 0.0206 | Uranium | 0414 | | 05-Nov-86 | 0001 | F |
| 0.0133 | Uranium | 0414 | | 23-Jan-87 | 0001 | F |
| 0.0134 | Uranium | 0414 | | 29-May-87 | 0001 | |
| 0.017 | Uranium | 0414 | | 09-Dec-87 | 0001 | |
| 0.0103 | Uranium | 0414 | | 23-Jun-88 | 0001 | F |
| 0.023 | Uranium | 0414 | | 08-Dec-88 | 0001 | |
| 0.0153 | Uranium | 0414 | | 25-May-89 | 0001 | F |
| 0.02 | Uranium | 0414 | | 04-Jan-90 | 0001 | F |
| 0.014 | Uranium | 0414 | | 01-Aug-90 | 0001 | F |
| 0.02 | Uranium | 0414 | | 01-Aug-91 | 0001 | F |
| 0.021 | Uranium | 0414 | | 15-Jan-92 | 0001 | F |
| 0.012 | Uranium | 0414 | | 06-Aug-92 | 0001 | F |
| 0.04 | Uranium | 0414 | | 28-Oct-93 | 0001 | |
| 0.036 | Uranium | 0414 | | 28-Oct-93 | N001 | |
| 0.056 | Uranium | 0414 | | 29-Oct-94 | 0001 | |
| 0.056 | Uranium | 0414 | | 29-Oct-94 | 0002 | |
| 0.185 | Uranium | 0414 | | 18-Nov-95 | 0001 | F |
| 0.0317 | Uranium | 0414 | | 05-Dec-96 | 0001 | |
| 0.0814 | Uranium | 0414 | | 11-Nov-97 | 0001 | L |
| 0.018 | Uranium | 0423 | | 04-Nov-93 | 0001 | |
| 0.02 | Uranium | 0423 | | 04-Nov-93 | N001 | |
| 0.018 | Uranium | 0423 | | 30-Oct-94 | 0001 | |
| 0.0193 | Uranium | 0423 | | 04-Dec-96 | 0001 | |
| 0.001 | Uranium | 0424 | U | 04-Nov-93 | 0001 | |
| 0.001 | Uranium | 0424 | U | 04-Nov-93 | N001 | |
| 0.001 | Uranium | 0424 | U | 29-Oct-94 | 0001 | |
| 0.001 | Uranium | 0424 | U | 29-Oct-94 | N001 | |
| 0.001 | Uranium | 0424 | U | 18-Nov-95 | 0001 | |
| 0.001 | Uranium | 0424 | U | 18-Nov-95 | 0002 | |
| 0.001 | Uranium | 0424 | U | 06-Dec-96 | 0001 | |
| 0.001 | Uranium | 0424 | U | 11-Nov-97 | 0001 | |
| 0.001 | Uranium | 0424 | U | 11-Nov-97 | 0002 | |
| 0.007 | Uranium | 0425 | | 03-Nov-93 | 0001 | |
| 0.006 | Uranium | 0425 | | 03-Nov-93 | N001 | |
| 0.002 | Uranium | 0425 | | 28-Oct-94 | 0001 | |
| 0.001 | Uranium | 0502 | | 05-Nov-93 | 0001 | |
| 0.001 | Uranium | 0502 | U | 05-Nov-93 | 0002 | |
| 0.001 | Uranium | 0502 | U | 05-Nov-93 | N001 | |
| 0.001 | Uranium | 0502 | U | 05-Nov-93 | N002 | |
| 0.001 | Uranium | 0502 | U | 31-Oct-94 | 0001 | |
| 0.001 | Uranium | 0503 | | 01-Nov-93 | 0001 | |
| 0.002 | Uranium | 0503 | | 01-Nov-93 | 0002 | |
| 0.001 | Uranium | 0503 | U | 01-Nov-93 | N001 | |
| 0.001 | Uranium | 0503 | U | 01-Nov-93 | N002 | |
| 0.0014 | Uranium | 0504 | | 06-Aug-86 | 0001 | J |
| 0.0047 | Uranium | 0504 | | 04-Nov-86 | 0001 | |
| 0.0031 | Uranium | 0504 | | 28-Jan-87 | 0001 | |
| 0.0025 | Uranium | 0504 | | 29-May-87 | 0001 | J |
| 0.0046 | Uranium | 0504 | | 08-Dec-87 | 0001 | |
| 0.0044 | Uranium | 0504 | | 08-Dec-87 | 0002 | |
| 0.0046 | Uranium | 0504 | | 08-Dec-87 | 0003 | |
| 0.0047 | Uranium | 0504 | | 08-Dec-87 | 0004 | |
| 0.0044 | Uranium | 0504 | | 08-Dec-87 | 0005 | |
| 0.0031 | Uranium | 0504 | | 22-Jun-88 | 0001 | |

Monitor Well Data for Selected Constituents from the SEE.UMTRA Database

| | | | | | | |
|---|---|---|---|---|---|---|
| 0.0021 | Uranium | 0504 | | 08-Dec-88 | 0001 | |
| 0.0019 | Uranium | 0504 | | 25-May-89 | 0001 | FJ |
| 0.004 | Uranium | 0504 | | 04-Jan-90 | 0001 | |
| 0.003 | Uranium | 0504 | U | 04-Jan-90 | 0002 | |
| 0.005 | Uranium | 0504 | | 04-Jan-90 | 0003 | |
| 0.005 | Uranium | 0504 | | 04-Jan-90 | 0004 | |
| 0.003 | Uranium | 0504 | | 04-Jan-90 | 0005 | |
| 0.001 | Uranium | 0504 | U | 31-Jul-90 | 0001 | |
| 0.006 | Uranium | 0504 | | 01-Aug-91 | 0001 | F |
| 0.002 | Uranium | 0504 | | 15-Jan-92 | 0001 | F |
| 0.007 | Uranium | 0504 | | 06-Aug-92 | 0001 | |
| 0.008 | Uranium | 0504 | | 20-Jul-93 | 0001 | |
| 0.023 | Uranium | 0504 | | 02-Nov-93 | 0001 | |
| 0.021 | Uranium | 0504 | | 02-Nov-93 | N001 | |
| 0.01 | Uranium | 0504 | | 29-Oct-94 | 0001 | |
| 0.0003 | Uranium | 0505 | U | 05-Aug-86 | 0001 | J |
| 0.0003 | Uranium | 0505 | | 03-Nov-86 | 0001 | J |
| 0.0004 | Uranium | 0505 | | 03-Nov-86 | 0002 | J |
| 0.0003 | Uranium | 0505 | | 03-Nov-86 | 0003 | J |
| 0.0005 | Uranium | 0505 | | 03-Nov-86 | 0004 | J |
| 0.0003 | Uranium | 0505 | | 03-Nov-86 | 0005 | J |
| 0.0003 | Uranium | 0505 | U | 27-Jan-87 | 0001 | J |
| 0.0003 | Uranium | 0505 | U | 29-May-87 | 0001 | J |
| 0.0003 | Uranium | 0505 | U | 08-Dec-87 | 0001 | FJ |
| 0.0003 | Uranium | 0505 | U | 22-Jun-88 | 0001 | J |
| 0.0003 | Uranium | 0505 | U | 08-Dec-88 | 0001 | J |
| 0.0003 | Uranium | 0505 | U | 08-Dec-88 | 0002 | J |
| 0.0003 | Uranium | 0505 | U | 08-Dec-88 | 0003 | J |
| 0.0003 | Uranium | 0505 | U | 08-Dec-88 | 0004 | J |
| 0.0003 | Uranium | 0505 | U | 08-Dec-88 | 0005 | J |
| 0.0003 | Uranium | 0505 | U | 25-May-89 | 0001 | J |
| 0.003 | Uranium | 0505 | U | 25-May-89 | 0002 | |
| 0.0003 | Uranium | 0505 | U | 25-May-89 | 0003 | J |
| 0.0003 | Uranium | 0505 | U | 25-May-89 | 0004 | J |
| 0.0011 | Uranium | 0505 | | 25-May-89 | 0005 | J |
| 0.003 | Uranium | 0505 | U | 04-Jan-90 | 0001 | |
| 0.001 | Uranium | 0505 | U | 31-Jul-90 | 0001 | |
| 0.003 | Uranium | 0505 | | 02-Aug-91 | 0001 | F |
| 0.001 | Uranium | 0505 | | 15-Jan-92 | 0001 | |
| 0.001 | Uranium | 0505 | U | 06-Aug-92 | 0001 | |
| 0.001 | Uranium | 0505 | U | 20-Jul-93 | 0001 | |
| 0.002 | Uranium | 0505 | | 02-Nov-93 | 0001 | |
| 0.001 | Uranium | 0505 | U | 02-Nov-93 | N001 | |
| 0.001 | Uranium | 0505 | U | 30-Oct-94 | 0001 | |
| 0.927 | Uranium | 0506 | | 06-Aug-86 | 0001 | |
| 0.865 | Uranium | 0506 | | 06-Nov-86 | 0001 | |
| 0.822 | Uranium | 0506 | | 29-Jan-87 | 0001 | |
| 0.797 | Uranium | 0506 | | 29-May-87 | 0001 | |
| 0.819 | Uranium | 0506 | | 08-Dec-87 | 0001 | |
| 0.848 | Uranium | 0506 | | 22-Jun-88 | 0001 | |
| 0.814 | Uranium | 0506 | | 08-Dec-88 | 0001 | |
| 0.229 | Uranium | 0506 | | 25-May-89 | 0001 | |
| 0.664 | Uranium | 0506 | | 05-Jan-90 | 0001 | |
| 0.347 | Uranium | 0506 | | 01-Aug-90 | 0001 | F |
| 0.465 | Uranium | 0506 | | 02-Aug-91 | 0001 | |
| 0.238 | Uranium | 0506 | | 07-Aug-92 | 0001 | |
| 0.446 | Uranium | 0506 | | 20-Jul-93 | 0001 | |
| 0.5 | Uranium | 0506 | | 03-Nov-93 | 0001 | |
| 0.4 | Uranium | 0506 | | 03-Nov-93 | N001 | |
| 0.0721 | Uranium | 0506 | | 04-Dec-96 | 0001 | |
| 0.126 | Uranium | 0506 | | 12-Nov-97 | 0001 | |
| 0.002 | Uranium | 0507 | | 04-Nov-93 | 0001 | |

Monitor Well Data for Selected Constituents from the SEE.UMTRA Database

| | | | | | | |
|---|---|---|---|---|---|---|
| 0.001 | Uranium | 0507 | U | 04-Nov-93 | N001 | |
| 0.001 | Uranium | 0507 | U | 31-Oct-94 | 0001 | |
| 0.002 | Uranium | 0508 | | 04-Nov-93 | 0001 | |
| 0.001 | Uranium | 0508 | U | 04-Nov-93 | N001 | |
| 0.001 | Uranium | 0508 | U | 30-Oct-94 | 0001 | |
| 0.001 | Uranium | 0509 | U | 05-Nov-93 | 0001 | F |
| 0.001 | Uranium | 0509 | U | 05-Nov-93 | N001 | F |
| 0.001 | Uranium | 0509 | U | 29-Oct-94 | 0001 | |
| 0.004 | Uranium | 0510 | | 03-Nov-93 | 0001 | |
| 0.001 | Uranium | 0510 | | 03-Nov-93 | N001 | |
| 0.002 | Uranium | 0510 | | 31-Oct-94 | 0001 | |
| 0.005 | Selenium | 0401 | U | 07-Aug-86 | 0001 | F |
| 0.005 | Selenium | 0401 | U | 31-Oct-93 | 0001 | |
| 0.005 | Selenium | 0405 | U | 30-Oct-93 | 0001 | F |
| 0.005 | Selenium | 0406 | U | 02-Nov-93 | 0001 | |
| 0.0011 | Selenium | 0406 | B | 11-Nov-97 | 0001 | L |
| 0.005 | Selenium | 0407 | U | 30-Oct-93 | 0001 | F |
| 0.005 | Selenium | 0408 | U | 31-Oct-93 | 0001 | |
| 0.005 | Selenium | 0409 | U | 02-Nov-93 | 0001 | |
| 0.005 | Selenium | 0410 | U | 07-Aug-86 | 0001 | F |
| 0.002 | Selenium | 0410 | U | 05-Nov-86 | 0001 | FJ |
| 0.002 | Selenium | 0410 | | 28-Jan-87 | 0001 | FJ |
| 0.003 | Selenium | 0410 | | 29-May-87 | 0001 | FJ |
| 0.002 | Selenium | 0410 | | 09-Dec-87 | 0001 | FJ |
| 0.005 | Selenium | 0410 | U | 22-Jun-88 | 0001 | F |
| 0.001 | Selenium | 0410 | U | 08-Dec-88 | 0001 | J |
| 0.005 | Selenium | 0410 | U | 25-May-89 | 0001 | F |
| 0.005 | Selenium | 0410 | U | 04-Jan-90 | 0001 | F |
| 0.005 | Selenium | 0410 | U | 31-Jul-90 | 0001 | F |
| 0.005 | Selenium | 0410 | U | 07-Feb-91 | 0001 | F |
| 0.005 | Selenium | 0410 | U | 01-Aug-91 | 0001 | F |
| 0.005 | Selenium | 0410 | U | 15-Jan-92 | 0001 | F |
| 0.0015 | Selenium | 0410 | U | 06-Aug-92 | 0001 | F |
| 0.005 | Selenium | 0410 | U | 20-Jul-93 | 0001 | F |
| 0.005 | Selenium | 0410 | U | 30-Oct-93 | 0001 | F |
| 0.005 | Selenium | 0410 | U | 28-Oct-94 | 0001 | F |
| 0.001 | Selenium | 0410 | U | 12-Nov-97 | 0001 | L |
| 0.005 | Selenium | 0412 | U | 06-Aug-86 | 0001 | |
| 0.005 | Selenium | 0412 | U | 06-Aug-86 | 0002 | |
| 0.005 | Selenium | 0412 | U | 06-Aug-86 | 0003 | |
| 0.005 | Selenium | 0412 | U | 06-Aug-86 | 0004 | |
| 0.005 | Selenium | 0412 | U | 06-Aug-86 | 0005 | |
| 0.002 | Selenium | 0412 | U | 06-Nov-86 | 0001 | J |
| 0.002 | Selenium | 0412 | | 29-Jan-87 | 0001 | J |
| 0.001 | Selenium | 0412 | U | 29-May-87 | 0001 | J |
| 0.007 | Selenium | 0412 | | 08-Dec-87 | 0001 | |
| 0.007 | Selenium | 0412 | | 22-Jun-88 | 0001 | |
| 0.01 | Selenium | 0412 | | 08-Dec-88 | 0001 | |
| 0.005 | Selenium | 0412 | U | 25-May-89 | 0001 | |
| 0.005 | Selenium | 0412 | U | 05-Jan-90 | 0001 | |
| 0.03 | Selenium | 0412 | U | 01-Aug-90 | 0001 | F |
| 0.005 | Selenium | 0412 | U | 07-Feb-91 | 0001 | |
| 0.005 | Selenium | 0412 | U | 01-Aug-91 | 0001 | |
| 0.0015 | Selenium | 0412 | U | 07-Aug-92 | 0001 | |
| 0.005 | Selenium | 0412 | U | 20-Jul-93 | 0001 | |
| 0.005 | Selenium | 0412 | U | 29-Oct-93 | 0001 | |
| 0.005 | Selenium | 0412 | U | 28-Oct-94 | 0001 | F |
| 0.001 | Selenium | 0412 | U | 12-Nov-97 | 0001 | |
| 0.005 | Selenium | 0413 | U | 07-Aug-86 | 0001 | F |
| 0.002 | Selenium | 0413 | U | 04-Nov-86 | 0001 | FJ |
| 0.002 | Selenium | 0413 | | 27-Jan-87 | 0001 | FJ |
| 0.002 | Selenium | 0413 | | 27-Jan-87 | 0002 | FJ |

Monitor Well Data for Selected Constituents from the SEE.UMTRA Database

| | | | | | | |
|---|---|---|---|---|---|---|
| 0.002 | Selenium | 0413 | | 27-Jan-87 | 0003 | FJ |
| 0.002 | Selenium | 0413 | | 27-Jan-87 | 0004 | FJ |
| 0.004 | Selenium | 0413 | | 27-Jan-87 | 0005 | FJ |
| 0.001 | Selenium | 0413 | U | 29-May-87 | 0001 | FJ |
| 0.001 | Selenium | 0413 | U | 29-May-87 | 0002 | FJ |
| 0.001 | Selenium | 0413 | U | 29-May-87 | 0003 | FJ |
| 0.001 | Selenium | 0413 | U | 29-May-87 | 0004 | FJ |
| 0.001 | Selenium | 0413 | U | 29-May-87 | 0005 | FJ |
| 0.006 | Selenium | 0413 | | 08-Dec-87 | 0001 | F |
| 0.006 | Selenium | 0413 | | 23-Jun-88 | 0001 | F |
| 0.008 | Selenium | 0413 | | 23-Jun-88 | 0002 | F |
| 0.008 | Selenium | 0413 | | 23-Jun-88 | 0003 | F |
| 0.008 | Selenium | 0413 | | 23-Jun-88 | 0004 | F |
| 0.007 | Selenium | 0413 | | 23-Jun-88 | 0005 | F |
| 0.003 | Selenium | 0413 | | 08-Dec-88 | 0001 | FJ |
| 0.005 | Selenium | 0413 | U | 25-May-89 | 0001 | F |
| 0.005 | Selenium | 0413 | U | 04-Jan-90 | 0001 | F |
| 0.03 | Selenium | 0413 | U | 31-Jul-90 | 0001 | F |
| 0.005 | Selenium | 0413 | U | 07-Feb-91 | 0001 | F |
| 0.005 | Selenium | 0413 | U | 02-Aug-91 | 0001 | F |
| 0.0027 | Selenium | 0413 | | 07-Aug-92 | 0001 | F |
| 0.005 | Selenium | 0413 | U | 20-Jul-93 | 0001 | F |
| 0.005 | Selenium | 0413 | U | 20-Jul-93 | 0002 | F |
| 0.005 | Selenium | 0413 | U | 28-Oct-93 | 0001 | F |
| 0.005 | Selenium | 0413 | UW | 29-Oct-94 | 0001 | FJ |
| 0.0605 | Selenium | 0413 | | 12-Nov-97 | 0001 | L |
| 0.005 | Selenium | 0414 | U | 05-Aug-86 | 0001 | |
| 0.002 | Selenium | 0414 | U | 05-Nov-86 | 0001 | FJ |
| 0.002 | Selenium | 0414 | | 23-Jan-87 | 0001 | FJ |
| 0.001 | Selenium | 0414 | U | 29-May-87 | 0001 | J |
| 0.002 | Selenium | 0414 | | 09-Dec-87 | 0001 | J |
| 0.005 | Selenium | 0414 | U | 23-Jun-88 | 0001 | F |
| 0.001 | Selenium | 0414 | U | 08-Dec-88 | 0001 | J |
| 0.005 | Selenium | 0414 | U | 25-May-89 | 0001 | F |
| 0.005 | Selenium | 0414 | U | 04-Jan-90 | 0001 | F |
| 0.005 | Selenium | 0414 | U | 01-Aug-90 | 0001 | F |
| 0.005 | Selenium | 0414 | U | 07-Feb-91 | 0001 | F |
| 0.005 | Selenium | 0414 | U | 01-Aug-91 | 0001 | F |
| 0.005 | Selenium | 0414 | U | 15-Jan-92 | 0001 | F |
| 0.0015 | Selenium | 0414 | U | 06-Aug-92 | 0001 | F |
| 0.005 | Selenium | 0414 | U | 28-Oct-93 | 0001 | |
| 0.005 | Selenium | 0414 | UW | 29-Oct-94 | 0001 | J |
| 0.005 | Selenium | 0414 | UW | 29-Oct-94 | 0002 | J |
| 0.001 | Selenium | 0414 | U | 11-Nov-97 | 0001 | L |
| 0.005 | Selenium | 0423 | U | 04-Nov-93 | 0001 | |
| 0.005 | Selenium | 0423 | UW | 30-Oct-94 | 0001 | J |
| 0.005 | Selenium | 0424 | U | 04-Nov-93 | 0001 | |
| 0.005 | Selenium | 0424 | UW | 29-Oct-94 | 0001 | J |
| 0.001 | Selenium | 0424 | U | 11-Nov-97 | 0001 | |
| 0.001 | Selenium | 0424 | U | 11-Nov-97 | 0002 | |
| 0.005 | Selenium | 0425 | U | 03-Nov-93 | 0001 | |
| 0.005 | Selenium | 0425 | UW | 28-Oct-94 | 0001 | J |
| 0.005 | Selenium | 0502 | U | 05-Nov-93 | 0001 | |
| 0.005 | Selenium | 0502 | U | 05-Nov-93 | 0002 | |
| 0.005 | Selenium | 0502 | UW | 31-Oct-94 | 0001 | J |
| 0.005 | Selenium | 0503 | U | 01-Nov-93 | 0001 | |
| 0.005 | Selenium | 0503 | U | 01-Nov-93 | 0002 | |
| 0.005 | Selenium | 0504 | U | 06-Aug-86 | 0001 | |
| 0.002 | Selenium | 0504 | U | 04-Nov-86 | 0001 | J |
| 0.003 | Selenium | 0504 | | 28-Jan-87 | 0001 | J |
| 0.001 | Selenium | 0504 | U | 29-May-87 | 0001 | J |
| 0.003 | Selenium | 0504 | | 08-Dec-87 | 0001 | J |

Monitor Well Data for Selected Constituents from the SEE.UMTRA Database

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|---|---|---|---|---|---|---|
| 0.003 | Selenium | 0504 | | 08-Dec-87 | 0002 | J |
| 0.002 | Selenium | 0504 | | 08-Dec-87 | 0003 | J |
| 0.003 | Selenium | 0504 | | 08-Dec-87 | 0004 | J |
| 0.003 | Selenium | 0504 | | 08-Dec-87 | 0005 | J |
| 0.005 | Selenium | 0504 | U | 22-Jun-88 | 0001 | |
| 0.002 | Selenium | 0504 | | 08-Dec-88 | 0001 | J |
| 0.005 | Selenium | 0504 | | 25-May-89 | 0001 | F |
| 0.005 | Selenium | 0504 | U | 04-Jan-90 | 0001 | |
| 0.005 | Selenium | 0504 | U | 04-Jan-90 | 0002 | |
| 0.005 | Selenium | 0504 | U | 04-Jan-90 | 0003 | |
| 0.005 | Selenium | 0504 | U | 04-Jan-90 | 0004 | |
| 0.005 | Selenium | 0504 | U | 04-Jan-90 | 0005 | |
| 0.01 | Selenium | 0504 | U | 31-Jul-90 | 0001 | |
| 0.005 | Selenium | 0504 | U | 07-Feb-91 | 0001 | |
| 0.05 | Selenium | 0504 | UI | 01-Aug-91 | 0001 | F |
| 0.005 | Selenium | 0504 | U | 15-Jan-92 | 0001 | F |
| 0.0015 | Selenium | 0504 | U | 06-Aug-92 | 0001 | |
| 0.005 | Selenium | 0504 | U | 20-Jul-93 | 0001 | |
| 0.005 | Selenium | 0504 | U | 02-Nov-93 | 0001 | |
| 0.005 | Selenium | 0504 | UW | 29-Oct-94 | 0001 | J |
| 0.005 | Selenium | 0505 | U | 05-Aug-86 | 0001 | |
| 0.002 | Selenium | 0505 | U | 03-Nov-86 | 0001 | J |
| 0.002 | Selenium | 0505 | U | 03-Nov-86 | 0002 | J |
| 0.002 | Selenium | 0505 | U | 03-Nov-86 | 0003 | J |
| 0.002 | Selenium | 0505 | U | 03-Nov-86 | 0004 | J |
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| 0.001 | Selenium | 0505 | U | 08-Dec-88 | 0003 | J |
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| 0.005 | Selenium | 0505 | U | 31-Jul-90 | 0001 | |
| 0.005 | Selenium | 0505 | U | 07-Feb-91 | 0001 | |
| 0.005 | Selenium | 0505 | U | 02-Aug-91 | 0001 | F |
| 0.005 | Selenium | 0505 | U | 15-Jan-92 | 0001 | |
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| 0.005 | Selenium | 0505 | UW | 20-Jul-93 | 0001 | |
| 0.005 | Selenium | 0505 | U | 02-Nov-93 | 0001 | |
| 0.005 | Selenium | 0505 | UW | 30-Oct-94 | 0001 | J |
| 0.005 | Selenium | 0506 | U | 06-Aug-86 | 0001 | |
| 0.002 | Selenium | 0506 | U | 06-Nov-86 | 0001 | J |
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| 0.03 | Selenium | 0506 | U | 01-Aug-90 | 0001 | F |
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| 0.05 | Selenium | 0506 | UI | 02-Aug-91 | 0001 | |
| 0.0015 | Selenium | 0506 | U | 07-Aug-92 | 0001 | |

Monitor Well Data for Selected Constituents from the SEE.UMTRA Database

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|---|---|---|---|---|---|---|
| 0.005 | Selenium | 0506 | UW | 20-Jul-93 | 0001 | |
| 0.005 | Selenium | 0506 | UW | 03-Nov-93 | 0001 | |
| 0.0001 | Selenium | 0506 | U | 04-Dec-96 | 0001 | |
| 0.001 | Selenium | 0506 | U | 12-Nov-97 | 0001 | |
| 0.005 | Selenium | 0507 | U | 04-Nov-93 | 0001 | |
| 0.005 | Selenium | 0507 | UW | 31-Oct-94 | 0001 | J |
| 0.005 | Selenium | 0508 | U | 04-Nov-93 | 0001 | |
| 0.005 | Selenium | 0508 | UW | 30-Oct-94 | 0001 | J |
| 0.005 | Selenium | 0509 | U | 05-Nov-93 | 0001 | F |
| 0.005 | Selenium | 0509 | UW | 29-Oct-94 | 0001 | J |
| 0.005 | Selenium | 0510 | U | 03-Nov-93 | 0001 | |
| 0.005 | Selenium | 0510 | UW | 31-Oct-94 | 0001 | J |

# Appendix C

# Documentation of Ground Water and Surface Water Modeling

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# C.1 Introduction

The purpose of this report is to provide supporting information for the proposed action of no remediation through the application of alternate concentration limits (ACL) for the UMTRA Project site at Canonsburg, Pennsylvania. Two models were performed to evaluate potential effects on ground water and surface water at the site. The Groundwater Analysis and Network Design Tool (GANDT) model was used to evaluate uncertainties in the fate and transport of uranium in ground water at the site. A surface-water model published by the U.S. Nuclear Regulatory Commission (NRC) was used to evaluate the effects of stream-aquifer discharges (NRC 1982). Summary information on the modeling results, analysis of alternative remedies, and cost-benefit analyses are provided in the report; this appendix is intended to provide more detailed information about the model. The format of this appendix is based on model documentation guidance from the American Society for Testing and Materials (ASTM 1995).

# C.2 Modeling Objectives

The main objective of the modeling is to evaluate the likelihood of success of applying ACLs at the Canonsburg site. To help meet this objective, a probabilistic modeling approach was applied, using Monte Carlo methods to quantify uncertainties. Specific objectives include:

- Model the transport of constituents within and from a contaminated source zone, using a pulsed leaching algorithm due to the fact that the contaminated materials have been removed and encapsulated in an engineered disposal cell at the site.

- Model the fate and transport of constituents through the vadose zone beneath the former contaminated area.

- Model the fate and transport of constituents (e.g., natural attenuation) in ground water in the uppermost surficial aquifer at the site.

- Perform Monte Carlo analyses to quantify the uncertainty in the distribution of contaminants in the aquifer over time.

- Condition the Monte Carlo simulation results on known water quality data (i.e., automated calibration based on the concentration data collected from local monitoring wells).

- Develop average concentration distributions for the constituents of concern, based on the probabilistic analyses.

- Develop probability distributions for the likelihood that the concentrations do not exceed the maximum concentration limit (MCL) to visually illustrate the likelihood of meeting ground water standards over time.

- Develop statistical ranges of water quality data at key monitor well locations through time to be used to verify the progress of the natural attenuation processes.

- Model the stream-aquifer interaction and assess the water quality in Chartiers Creek.

- Develop conclusions/recommendations regarding the likelihood of success for the application of ACLs at the site.

## C.3 Model Function

For the past several years, Sandia National Laboratory (SNL) has been developing the Groundwater Analysis and Network Design Tool, or GANDT, to provide DOE environmental restoration programs with a comprehensive system for analyzing ground water flow and associated contaminant transport, while directly accounting for transport uncertainty and providing decision analysis capabilities for monitor well network design. As a point of reference, GANDT began its development under the name Borehole Optimization Support System, or BOSS, but was changed due to copyright considerations. A draft report detailing the technical attributes of the GANDT code is under development and available for review (Knowlton et al., in press). A draft user's manual has also been developed and is available from SNL.

GANDT is a comprehensive ground water analysis package that provides the following features:

- Uses flow and transport models in a probabilistic framework to account for uncertainty in contaminant movement and fate.

- Simplifies the analysis of natural attenuation potential and provides an estimate of the likelihood of the success of this option, thereby possibly avoiding costly and time-consuming pump-and-treat options for ground water remediation.

The GANDT code contains a number of tools that, when combined, make it a unique modeling system:

- The ability to simulate leaching from a contaminant source term, including a pulsed leaching time to account for source removal.

- The ability to simulate either aqueous- or vapor-phase movement of contaminants in the unsaturated zone and account for contaminant transfer into the underlying aquifer.

- Analytical and numerical solutions for the saturated zone (including FTWORK, a 3–D numerical finite difference code for flow and advective/dispersive transport [Faust et al. 1994]).

- An automatic grid generation module to simplify the numerical model input (and also automatically account for grid orientation when the user specifies uncertainty in the ground water flow direction).

- Monte Carlo technique employed to propagate input parameter uncertainties into flow and transport uncertainties.

- Latin Hypercube Sampling (LHS) technique employed to minimize computational burden by reducing the number of simulation runs required for the Monte Carlo analysis (Iman and Shortencarrier 1984).

- Spatial variability explicitly accounted for using a geostatistical simulator (e.g., sequential Gaussian simulator), which honors observed hydraulic conductivity estimates.

- Conditioning of simulation results on observed water quality data using statistical methods (e.g., essentially a built-in calibration method to honor water quality data).

- An intuitive graphical user interface and graphical display of results for ease of use on PC Windows and Macintosh platforms.

GANDT currently has the capability to simulate flushing, dilution, and radioactive decay. The numerical simulation option in the GANDT code is currently set up to perform steady-state flow simulations and transient fate and transport analyses.

In conventional flow and transport simulations a calibration procedure is manually performed to "match" model results with observed site data, such as measured water levels and water quality data. One of the model parameters that is commonly adjusted to achieve a better match between observed and computed values is aquifer hydraulic conductivity. The calibration process can be tedious and time consuming. SNL has built an automated calibration capability in GANDT that effectively conditions, or honors, observed concentrations in the saturated zone through use of statistical analysis techniques. Any Monte Carlo simulation with a cumulative measure of the differences between observed and computed concentrations, commonly called residuals, that does not meet a specified statistical tolerance is omitted from the probabilistic analysis. This feature is extremely important when the user is interested in probabilistic (i.e., Monte Carlo) analyses, where many simulations are performed to get a statistical representation of the uncertainty in model results. The user has the ability to choose from a chi-square test (Haan 1977) for acceptance of a run or a root mean squared error (RMSE) analysis (Anderson and Woessner 1992). To apply the chi-square method, the residuals must be normally or log-normally distributed. GANDT can graphically display data distributions to evaluate normality, giving the user great flexibility in selecting conditioning criteria.

The version of GANDT used for this study is limited to conditioning on water quality data. That is, conditioning to hydraulic heads (i.e., water levels) has not yet been included in the software due to the fact that, of the possible types of data used for model calibration in ground water contamination investigations, water quality information is most effective in reducing transport uncertainty. This phenomenon was illustrated by Van Rooy and Rosbjerg (1988), who compared the relative ability of three different parameter estimation approaches— geostatistical conditional simulations of transmissivity, selection of groundwater flow model runs based on observed hydraulic heads, and selection of transport model runs based on measured concentrations—to produce a model that best approximated actual site conditions in a case study. Similar results were reported by McLaughlin et al. (1993), who used three comparable parameter estimation techniques to clearly show that the greatest reduction in model uncertainty was achieved by conditioning on water quality measurements. Though the current version of GANDT does not use water levels as calibration targets, SNL's experience with the code shows that it does quite

well in matching hydraulic heads at sites characterized by relatively uniform flow fields. In addition, mass balance reports from individual simulations are provided, enabling the user to compare computed groundwater flow quantities with those that are expected for a site.

GANDT has the ability to display the results of probabilistic analyses in a variety of ways. Two-dimensional visualization graphics that the user can observe include hydraulic conductivity distribution plots, contaminant distribution plots, and probability of exceedance plots. Contaminant distributions can be displayed for all user-specified time steps, and for each of as many as seven layers in a numerical simulation. The following types of contaminant plots are available:

- Plume concentrations from each Monte Carlo simulation, with user-specified color mapping of the contaminant concentrations, and an optional player mode that cycles the Monte Carlo simulation output in an "animation" format.
- Average plume distribution from all Monte Carlo runs.
- Standard deviation plot.
- Variance plot.
- Coefficient of variation plot.
- Probability plots, wherein the user specifies a threshold contaminant concentration (e.g., MCL), and the resulting plot displays the probability of exceeding that concentration.

The probability plot option is extremely important in evaluating the likelihood of success of a natural attenuation approach to remediation.

Modeling the surface-water quality in Chartiers Creek involved the use of an NRC model (NRC 1982) for point-source discharges to a river and a superposition method to account for the aquifer discharge along the length of the river. The superposition method is commonly used to account for a distributed source (Whelan et al. 1996).

## C.4 Conceptual Model

Because this investigation focuses on the potential application of an ACL for compliance with the ground water protection standards, the main fate and transport phenomena of interest are related to natural attenuation processes. Development of a conceptual model for the Canonsburg site therefore focuses on both general hydrogeologic processes and the phenomena that more specifically help to attenuate contaminant concentrations, including:

- Dilution from areal recharge.

- Dispersion as part of the transport process.

- Natural flushing to Chartiers Creek (i.e., aquifer discharge to the gaining stream).

The ground water system at the site is hydraulically connected to the unsaturated zone, which at one time contained the contaminant source in the form of contaminated materials at the main processing area (Areas A and B), and also at Area C where liquid effluent was discharged. The GANDT code simulates the leaching of contaminants from the source zone, subsequent transport through the unsaturated zone, and mass flux into and within underlying aquifers. Thus each of these zones must be examined in the conceptual model. In addition, the time frame of interest is several decades. This is because the facility was established in 1911 and major processing operations began in 1930. Monitoring data from 1997 are used for the conditioning of transport simulations, and several decades into the future are considered when analyzing the potential for MCLs to be achieved by natural processes. Given the time frame of interest, it is assumed that the seasonal, transient behavior of the hydrologic system will be dampened, allowing the system to approximate some average form of behavior. Accordingly, steady-state flow conditions are assumed to be appropriate. Uncertainty associated with the long-term average flow conditions, such as the magnitude of the gradient and the direction of ground water flow, is taken into account by establishing statistical distributions for these parameters in the Monte Carlo analysis.

## C.4.1 Aquifer System

The aquifer system at the Canonsburg site consists of a surficial, unconfined unit and a deeper semi-confined bedrock unit. The main aquifer of interest for ground water compliance is the surficial unit. A limited amount of testing has been performed on this uppermost aquifer and has been documented by DOE (DOE 1983, 1984, and 1995b). The depth to ground water is relatively shallow and ranges from 5.5 to 7.5 feet in Areas A and B. Area C at one time had a very shallow depth to ground water and contained a wetland, but fill material has since been added to the area. The surficial aquifer is about 10 feet thick and assumed to be hydraulically connected to Chartiers Creek, located downgradient of the processing area. This hydraulic connection is assumed to be one in which Chartiers Creek is a gaining stream, with the aquifer discharging to it.

## C.4.2 Hydrologic Boundaries

For the purposes of this ACL and natural attenuation analysis, a steady-state flow system is assumed. This approach is based on the premise that, although hydraulic heads change with both sporadic and periodic stresses (e.g., recharge from precipitation, high river conditions, flooding, and pumping), the average, long-term ground water flow conditions (i.e., flow direction and flow rate) remain generally the same. This assumption corresponds with a state of "dynamic equilibrium," in which there are no long-term (several years) changes or trends in regional and local groundwater levels (Freeze 1969).

Although there are clear indications of short-term changes in hydraulic head at and near the Canonsburg site, there is little evidence thus far to clearly demonstrate that the regional groundwater flow system is undergoing major, lasting alterations. The observed hydraulic head variations are considered small in the context of transient flow conditions. Further evaluation of

water levels at the site shows that the local hydraulic gradient can vary about the mean of 0.0022. This variability is represented in GANDT using the probabilistic modeling features of the code. In addition, ground water flow direction can be treated as an uncertain parameter in GANDT. Consequently, assigning a probability distribution to this parameter may make it possible to capture some of the influences of temporally variable flow directions occurring in response to enhanced infiltration during periods of high precipitation, river flooding, and other system stresses. The assumption of steady-state flow conditions is made not only with respect to the time period between the start of processing activities and recent years, but also with respect to future conditions, extending as much as 30 years hence.

In GANDT, steady-state flow is established by controlling boundary conditions in the code's flow simulator. The user specifies the hydraulic gradient (or a distribution representative of a range of gradients) and the groundwater flow direction. The code's automatic grid generator constructs a finite-difference grid oriented along the longitudinal axis of flow. Initially, the upgradient and downgradient ends of the model domain are set as constant head boundaries such that the specified hydraulic gradient is maintained. In cases where a gaining stream is located downgradient of the contaminant source, the river trace is used to establish and replace the model's downgradient boundary condition. Linear interpolation is used to establish the constant head conditions in the river, based on the prescribed gradient. The boundaries parallel to the flow system are set as no-flow boundaries.

Because Chartiers Creek is assumed to be a gaining stream downgradient of the site area, the creek is treated as a boundary, with flow from the aquifer entering the creek. The creek is assumed to act as a sink for all ground water flow intersecting it, and no flow or contaminant transport occurs beyond the creek. A head-dependent boundary condition, similar to that found in U.S. Geological Survey ground water flow models (e.g., MODFLOW [McDonald and Harbaugh 1988]), is employed to determine discharges to the creek, which in turn affect hydraulic heads upgradient of the creek. Surface water levels in the creek are specified using hydraulic heads initially established with the grid generation package and additional data from the user reflecting the degree to which stream levels are expected to divert local ground water levels from regional gradient levels (e.g., head drop at the stream-aquifer interface).

The assumption that Chartiers Creek downgradient of the site is a gaining stream may be questioned due to the lack of conclusive evidence to support it. However, in addition to the analyses mentioned above, there are reasons to believe that the creek is indeed gaining in the study area. In particular, it is typical of perennial streams like the rivers in this region to benefit from ground water inflows due to topography effects (Freeze and Cherry 1979). Ground water typically flows from higher areas, where recharge is relatively significant and water levels are elevated by the recharge, to lower areas, where streams are commonly found. Consequently, surface water bodies such as streams, rivers, lakes, and wetlands tend to act as discharge sites for the upland recharge. For this natural recharge-discharge mechanism to be upset, in which a stream begins losing its water to the subsurface rather than gaining from it, very large withdrawals of ground water on a regional scale are quite often necessary (Peterson and Wilson 1988). On the basis of data presented in DOE reports (1983, 1984, and 1995b), there is no indication that such a reversal in flow has occurred at the Canonsburg site, especially not within the surficial aquifer.

## C.4.3 Hydraulic Properties

A limited amount of field and laboratory tests have been performed to estimate hydraulic properties for the surficial, unconfined aquifer. Results of these analyses are summarized in DOE reports (1983, 1984, and 1995b). Uncertainty and variability are important with regard to hydraulic properties such as hydraulic conductivity. However, there are insufficient hydraulic conductivity measurements to explicitly account for spatial variability in the simulation sets. Therefore, the uncertainty is addressed through the use of the LHS method within the Monte Carlo framework. With the LHS method, a statistical distribution is assigned to a parameter to describe its uncertainty and a sampling set is derived from this distribution to apply to each Monte Carlo model run. In the case of hydraulic conductivity, for instance, the assumption is made that the unconfined aquifer is homogeneous, but that each model run in the Monte Carlo suite has a different value of hydraulic conductivity, each value of which was derived from a lognormal distribution. Therefore, the fate and transport results from the Monte Carlo analysis explicitly account for the uncertainty in hydraulic conductivity.

## C.4.4 Sources and Sinks

There are no existing pumping or injection wells in the model domain selected for the site. In Section 3.0 of this report, a hypothetical pumping withdrawal system was evaluated to determine the efficacy of hastening the cleanup of the aquifer. Results of modeling the pumping withdrawal scenario were used in support of a cost-benefit analysis as part of NRC's As Low As Reasonably Achievable (ALARA) guidelines. The conceptual framework for the pump-and-treat system consisted of two pumping wells discharging 10 gallons per minute of contaminated ground water over a 10-year period. The placement of the wells was constrained by the location of the disposal cell and the proximity of Chartiers Creek.

## C.4.5 Water Budget

Water budget considerations for the steady-state model used to simulate the surficial aquifer flow include (1) infiltration of water through the source area, (2) ground water discharge to Chartiers Creek, and (3) areally distributed recharge throughout the site. The first of these is assumed in GANDT to influence contaminant transport from the tailings, but to have no effect on the general hydraulic gradients and flow directions currently occurring in the model area. Reasons for this latter assumption were discussed previously as part of the rationale for adopting steady-state flow conditions (Section C.5.2). The second component, ground water discharge, is determined in GANDT as a result of boundary conditions established in the code's automatic grid generation package and is included in mass balance reports produced by the ground water flow model. The third, areal recharge, is an input parameter for the Monte Carlo simulations and will contribute to the contaminant dilution.

An additional concern regarding water balances is the transient nature of overbank flooding from Chartiers Creek. These effects may have influenced the contaminant concentrations in monitor wells, such as well 423, which has a markedly lower uranium concentration than neighboring wells (see Appendix B for monitor well data). These episodic flooding events are not easily handled or predicted in a decades-long time window for conducting predictive simulations. Again, treating the hydraulic gradient and flow direction as uncertain is a method for simulating

the long-term effects of occasional stresses such as those associated with flooding. If the objectives of this modeling study were aimed at ascertaining short-term system effects, influences like flood events would be addressed explicitly.

### C.4.6 Contaminant Source Term

Three constituents of concern at the Canonsburg site were identified in the Baseline Risk Assessment (BLRA): uranium, manganese, and molybdenum (DOE 1995b). Other contaminants exist at the site but are no longer present in concentrations sufficient to be of concern. Manganese does not have an UMTRA Project regulatory standard and would likely flush from the aquifer system much the same as uranium. Molybdenum concentrations in ground water have decreased below the MCL of 0.1 mg/L (see Appendix B). Therefore, molybdenum is no longer of concern. Uranium is therefore the primary constituent of concern. Uranium concentrations in the main source area and in Area C when the contaminated materials were present are unknown. The concentration distribution is generally established on the basis of expert judgment and trial and error in the modeling process. This also holds true for the overall physical dimensions of the source area, which are uncertain. The source term dimensions are established on the basis of measurements of the site layout and from information in various DOE publications relative to the site (DOE 1983, 1984, and 1995b). Each of these types of source-term variables is treated as uncertain in the GANDT analyses.

### C.4.7 Fate and Transport Properties

Model fate and transport properties are derived from field and laboratory testing (e.g., sorption tests), as well as literature values; experimental data are available on sorption coefficients for uranium. A wide range of sorption coefficient values is reported.

## C.5 Computer Code Description

The GANDT code can be used to analyze flow and transport of contaminants from a source area in the unsaturated zone, through the unsaturated soils underlying the source material, and subsequently into and within the saturated zone. Uncertainty analyses are directly addressed in GANDT through probabilistic simulations based on the Monte Carlo method in conjunction with LHS of stochastic model parameters. Probabilistic results from the code can help to provide estimates of the likelihood of occurrence of specific transport scenarios. GANDT contains options for simulating subsurface contaminant movement using screening level, analytical solutions of advective-dispersive transport. A numerical, three-dimensional, finite-difference ground water flow and transport solution based on the public-domain code FTWORK (Faust et al. 1994) can also be employed. The numerical simulator is used for this study because of its ability to account for ground water discharge to a stream, including a sinuous waterway. Spatial variability of hydraulic conductivity is accounted for through the use of geostatistical conditional simulation (Peck et al. 1988), the algorithms for which are taken from the GSLIB system of codes (Deutsch and Journel 1992). GANDT is unique because of its ability to automatically

condition model runs on observed water quality data, which essentially provides the model user with a built-in calibration technique. The code employs an automatic grid generator for ease of use in setting up a finite-difference grid when employing FTWORK. Data input and the examination of results from probabilistic analyses are handled easily through an intuitive user interface.

A draft reference report detailing the algorithms used in GANDT is currently undergoing revision (Knowlton et al., in press), but is available for review. A draft user's manual for GANDT is also available.

## C.5.1 Assumptions

The draft reference manual for GANDT (Knowlton et al., in press) presents a complete description of the flow and transport models and geostatistical algorithms employed in the software. Many of the assumptions from which both the analytical and numerical simulators in the code have been developed are also provided in the reference manual. More detailed explanations of the FTWORK model are presented in Faust et al. (1994).

## C.5.2 Limitations

Potential limitations of the modeling software that may be relevant to this natural attenuation evaluation include:

- ***Steady-state flow conditions***—the current version of the code does not simulate transient ground water flow.

- ***User-defined boundary and initial conditions***—boundary conditions within the model are currently established through an automatic grid generator within the code, thus limiting the ability of users to define their own boundary and initial conditions.

- ***Honoring of hydraulic head information***—water levels and hydraulic heads are now available for display in the model's graphical output, but the user does not have the ability to calibrate to the flow conditions of the site.

- ***Single time frame for conditioning***—at this time, the user can only specify one time to be used for conditioning of model results on measured ground water concentrations.

- ***Single source term***—currently, the GANDT user is limited to specifying a single source area for each transport simulation.

## C.5.3 Solution Techniques

Both analytical and numerical models of subsurface flow and transport are provided in GANDT, discussion of which is presented in the draft reference manual (Knowlton et al., in press).

### C.5.4 Effects on Model

Perhaps the biggest concern regarding the application of GANDT to this evaluation of natural attenuation is the model's use of steady-state flow solutions, as developed within the code using the automatic grid generation package in conjunction with the numerical simulator. However, as discussed in Section C.5.2 use of steady-state conditions in the current study appears to be a legitimate approach to assessing the long-term prospects for natural attenuation and the ACL approach at the Canonsburg site.

## C.6 Model Construction

The GANDT system is designed to be user friendly and minimize work associated with data input. As a consequence, many of the ground water flow and transport modeling steps that are necessary for conventional model construction have been simplified or automated. Some of these features are identified below.

### C.6.1 Model Domain

A local model domain is generated within each Monte Carlo simulation conducted with the numerical flow and transport model. The size of the domain and the quantity and size of the finite-difference blocks depends on parameters used to define the simulation. Before a probabilistic analysis is conducted, a global domain must be established that encompasses an area significantly larger than the area of contamination and any region potentially affected by future plume movement. The code's automatic grid generator uses the parameter set sampled for a given model run and executes a number of decision rules to evaluate the probable impacts of the fate and transport model over the full simulation period. This information is used to design an appropriately sized local grid, along with the proper grid orientation. Other checks and balances are made by the automatic grid generator to ensure that mass balance is conserved and that phenomena such as numerical dispersion are minimized (Knowlton et al., in press).

### C.6.2 Hydraulic Parameters

Hydraulic parameters used in this study were derived from DOE reports on the Canonsburg site (DOE 1983, 1984, and 1995b). Additional model parameters (e.g., porosity) were selected from publications discussing the site and from other literature sources. The resulting parameter values, including the distribution descriptors for uncertain parameters, are listed for the contaminant source term, the unsaturated zone, and the saturated zone in Tables C–1, C–2, and C–3, respectively, for the plume simulations associated with the main processing area. Tables C–4, C–5, and C–6 show the model parameters for the source term, unsaturated zone, and saturated zone, respectively, for the Area C plume.

*Table C–1. Source Term Parameters for Main Processing Plume Scenario*

| Type of Parameter | Name of Parameter | Value or Distribution | Justification for Data |
|---|---|---|---|
| Geometry | Center of mass, X coord. (ft) | 4410 | Site measurements (DOE 1984) |
| | Center of mass, Y coord. (ft) | 4290 | Site measurements (DOE 1984) |
| | Length (ft) | 250 | Site measurements (DOE 1984) |
| | Width (ft) | 225 | Site measurements (DOE 1984) |
| | Thickness (ft) | 3.3 | Based on DOE information (DOE 1984) |
| Flow | Infiltration rate (ft/yr) | Uniform, min = 1.31, max = 2.30 | Expert judgment; model trials |
| | Saturated hydraulic conductivity (ft/day) | Lognormal, min = 2.2, max = 29 | DOE information (DOE 1984) |
| | Porosity | Normal, $\mu$ = 0.35, $\sigma$ = 0.02 | DOE information (DOE 1984) and general literature |
| | Residual water content | Uniform, min = 0.05, max = 0.09 | General literature |
| | van Genuchten n factor | Normal, $\mu$ = 3.9, $\sigma$ = 0.5 | General literature |
| Fate and Transport | Initial Soil Concentration (ppm) | Uniform, min = 0.5, max = 1.0 | Expert judgment; model trials |
| | Solubility of contaminant (ppm) | 100 | General literature |
| | Distribution coefficient (cc/g) | Uniform, min = 0.1, max = 0.3 | DOE information (DOE 1993), general literature, and model trials |
| | Dry bulk density (g/cc) | 1.7 | General literature |
| | Time since waste release (yr) | 67 | DOE information (DOE 1984) |
| | Pulse duration (yr) | 54 | Expert judgment; model trials |

*Table C–2. Unsaturated Zone Parameters for Main Processing Plume Scenario*

| Type of Parameter | Name of Parameter | Value or Distribution | Justification for Data |
|---|---|---|---|
| **Geometry** | Thickness (ft) | 7 | DOE information (DOE 1984) |
| **Flow** | Saturated hydraulic conductivity (ft/day) | Lognormal, min = 2.2, max = 29 | DOE information (DOE 1984) |
| | Porosity | Normal, $\mu$ = 0.3, $\sigma$ = 0.02 | DOE information (DOE 1984) and general literature |
| | Residual water content | Normal, $\mu$ = 0.05, $\sigma$ = 0.002 | General literature |
| | van Genuchten $\alpha$ coefficient (1/ft) | Normal, $\mu$ = 0.099, $\sigma$ = 0.015 | General literature |
| | van Genuchten n factor | Normal, $\mu$ = 3.9, $\sigma$ = 0.5 | General literature |
| **Fate and Transport** | Longitudinal dispersivity (ft) | Uniform: min = 2.5, max = 3.3 | Expert judgment and general literature |
| | Distribution coefficient (cc/g) | Uniform, min = 0.1, max = 0.3 | DOE information (DOE 1993), general literature, and model trials |
| | Dry bulk density (g/cc) | 1.8 | General literature |

*Table C–3. Saturated Zone Parameters for Main Processing Plume Scenario*

| Type of Parameter | Name of Parameter | Value or Distribution | Justification for Data |
|---|---|---|---|
| **Geometry** | Thickness (ft) | Uniform, min = 5, max = 6 | DOE information (DOE 1984) |
| **Flow** | Down gradient flow direction (degrees) | Normal, $\mu$ = 48, $\sigma$ = 3 | DOE information (DOE 1984) and expert judgment |
| | Hydraulic gradient (horizontal) | Normal, $\mu$ = 0.0022, $\sigma$ = 0.0002 | DOE information (DOE 1984) and expert judgment |
| | Recharge rate (ft/yr) | Normal, $\mu$ = 1.08, $\sigma$ = 0.098 | Expert judgment and general literature |
| | Saturated hydraulic conductivity [ft/day] | Lognormal, min = 9, max = 25 | DOE information (DOE 1984) |
| | Hydraulic conductivity anisotropy (H/V) | 100 | Expert judgment and general literature |
| | Porosity | Normal, $\mu$ = 0.34, $\sigma$ = 0.02 | DOE information (DOE 1984) and general literature |
| **Fate and Transport** | Longitudinal dispersivity (ft) | Uniform: min = 16, max = 33 | Expert judgment and general literature |
| | Dispersion anisotropy (longitudinal/transverse) | Uniform: min = 10, max = 20 | Expert judgment and general literature |
| | Distribution coefficient (cc/g) | Uniform, min = 0.3, max = 0.6 | DOE information (DOE 1993), general literature, and model trials |
| | Dry bulk density (g/cc) | 1.8 | General literature |
| | Tortuosity | 0.39 | General literature |

*Table C–4. Source Term Parameters for Area C Plume Scenario*

| Type of Parameter | Name of Parameter | Value or Distribution | Justification for Data |
|---|---|---|---|
| **Geometry** | Center of mass, X coord. (ft) | 5064 | Site measurements (DOE 1984) |
| | Center of mass, Y coord. (ft) | 3980 | Site measurements (DOE 1984) |
| | Length (ft) | 145 | Site measurements (DOE 1984) |
| | Width (ft) | 213 | Site measurements (DOE 1984) |
| | Thickness (ft) | 3.3 | DOE information (DOE 1984) |
| **Flow** | Infiltration rate (ft/yr) | Uniform, min = 1.31, max = 2.30 | Expert judgment; model trials |
| | Saturated hydraulic conductivity (ft/day) | Lognormal, min = 2.2, max = 29 | DOE information (DOE 1984) |
| | Porosity | Normal, $\mu$ = 0.35, $\sigma$ = 0.02 | DOE information (DOE 1984) and general literature |
| | Residual water content | Uniform, min = 0.05, max = 0.09 | General literature |
| | van Genuchten n factor | Normal, $\mu$ = 3.9, $\sigma$ = 0.5 | General literature |
| **Fate and Transport** | Initial Soil Concentration (ppm) | Uniform, min = 0.5, max = 1.0 | Expert judgment; model trials |
| | Solubility of contaminant (ppm) | 100 | General literature |
| | Distribution coefficient (cc/g) | Uniform, min = 0.1, max = 0.3 | DOE information (DOE 1993), general literature, and model trials |
| | Dry bulk density (g/cc) | 1.7 | General literature |
| | Time since waste release (yr) | 67 | DOE information (DOE 1984) |
| | Pulse duration (yr) | 54 | Expert judgment; model trials |

*Table C–5. Unsaturated Zone Parameters for Area C Plume Scenario*

| Type of Parameter | Name of Parameter | Value or Distribution | Justification for Data |
|---|---|---|---|
| **Geometry** | Thickness (ft) | 7 | DOE information (DOE 1984) |
| **Flow** | Saturated hydraulic conductivity (ft/day) | Lognormal, min = 2.2, max = 29 | DOE information (DOE 1984) |
| | Porosity | Normal, $\mu$ = 0.3, $\sigma$ = 0.02 | DOE information (DOE 1984) and general literature |
| | Residual water content | Normal, $\mu$ = 0.05, $\sigma$ = 0.002 | General literature |
| | van Genuchten $\alpha$ coefficient (1/ft) | Normal, $\mu$ = 0.099, $\sigma$ = 0.015 | General literature |
| | van Genuchten n factor | Normal, $\mu$ = 3.9, $\sigma$ = 0.5 | General literature |
| **Fate and Transport** | Longitudinal dispersivity (ft) | Uniform: min = 2.5, max = 3.3 | Expert judgment and general literature |
| | Distribution coefficient (cc/g) | Uniform, min = 0.1, max = 0.3 | DOE information (DOE 1993), general literature, and model trials |
| | Dry bulk density (g/cc) | 1.8 | General literature |

*Table C–6. Saturated Zone Parameters for Area C Plume Scenario*

| Type of Parameter | Name of Parameter | Value or Distribution | Justification for Data |
|---|---|---|---|
| Geometry | Thickness (ft) | Uniform, min = 5, max = 6 | DOE information (DOE 1984) |
| Flow | Down gradient flow direction (degrees) | Normal, $\mu$ = 48, $\sigma$ = 3 | DOE information (DOE 1984) and expert judgment |
| | Hydraulic gradient (horizontal) | Normal, $\mu$ = 0.0022, $\sigma$ = 0.0002 | DOE information (DOE 1984) and expert judgment |
| | Recharge rate (ft/yr) | Normal, $\mu$ = 1.08, $\sigma$ = 0.098 | Expert judgment and general literature |
| | Saturated hydraulic conductivity (ft/day) | Lognormal, min = 9, max = 25 | DOE information (DOE 1984) |
| | Hydraulic conductivity anisotropy (H/V) | 100 | Expert judgment and general literature. |
| | Porosity | Normal, $\mu$ = 0.34, $\sigma$ = 0.02 | DOE information (DOE 1984) and general literature |
| Fate and Transport | Longitudinal dispersivity (ft) | Uniform: min = 16, max = 33 | Expert judgment and general literature |
| | Dispersion anisotropy (longitudinal/transverse) | Uniform: min = 10, max = 20 | Expert judgment and general literature |
| | Distribution coefficient (cc/g) | Uniform, min = 0.3, max = 0.6 | DOE information (DOE 1993), general literature, and model trials |
| | Dry bulk density (g/cc) | 1.8 | General literature |
| | Tortuosity | 0.39 | General literature |

## C.6.3 Sources and Sinks

There are currently no point sources or sinks (e.g. pumping wells) at the Canonsburg site. However, for an ALARA analysis, several configurations of a hypothetical pump-and-treat system were evaluated. The scenario selected for the analysis used two pumping wells, each pumping 10 gallons per minute for 10 years, to reduce ground water contaminant concentrations to reasonable levels. Results of this analysis are included in Section 3.2 of this report.

## C.6.4 Boundary Conditions

The flow model in GANDT is set up for steady-state conditions. The user-specified gradient is used to establish constant head boundaries on the upgradient and downgradient ends of the local domain for each Monte Carlo run. Side boundaries of each local domain are treated as no-flow boundaries.

## C.6.5 Selection of Calibration Targets and Goals

The GANDT method relies on calibrating, or honoring, water quality data. This is accomplished through what is termed a post-conditioning exercise, which occurs after the Monte Carlo simulations have been completed. At this time, GANDT does not specifically honor head data.

Consequently, it cannot be used to perform a conventional flow field calibration on the basis of observed hydraulic heads. The current version of the model is limited to conditioning on ground water contaminant concentrations, as water quality data provide the means for effecting the greatest reduction in uncertainty of plume movement and contaminant fate (Van Rooy and Rosbjerg 1988 and McLaughlin et al. 1993).

The current GANDT code is capable of performing a conditioning analysis only on the basis of one time period. Thus, ground water quality data from a single point in time are desired to perform the calibration. The year chosen for the data conditioning in this investigation was 1997. Figures 2–1, 2–2 and 2–3 show the monitoring history of water quality data at wells 412, 413, and 414, respectively. The model calibration targets essentially consists of the November 1997 ground water concentration data.

Two types of tests are available in the GANDT code for honoring water quality data through a post-conditioning statistical test. The first is a chi-square distribution test (Haan 1977) on the transport model residuals (i.e., differences between measured and simulated concentrations). For a chi-square test to be valid, the residuals must be either normally or lognormally distributed. Such a requirement was not met in the preliminary model runs made with GANDT. Consequently, a second method of assessing the differences between simulated and measured concentrations, the root mean squared error (RMSE) approach (Anderson and Woessner 1992), was employed. A trial-and-error method, in which various parameter choices are tested to determine their effect on model residuals, was required to establish an appropriate RMSE value. Generally, an RMSE value on the order of the observed calibration targets (i.e., water quality concentrations) is typical. The RMSE criterion ultimately selected for the uranium simulations was 0.06 mg/L.

### C.6.6 Numerical Parameters

The input parameters and distributions used in the simulations to analyze the plume emanating from the main processing area are shown in Tables C–1, C–2, and C–3, for source term, unsaturated zone, and saturated zone parameters, respectively. A parameter not included in the tables is the half-life of uranium, which is assumed to be $1 \times 10^9$ years. The data presented in these tables were derived from several sources (1) site specific data and analyses, when available, (2) literature, and (3) expert judgment, including trial and error in the modeling runs. The tables are annotated with the source of the information used for each of the parameters. The simulations performed to analyze the plume emanating from Area C have slightly different input data and assumptions. Tables C–4, C–5, and C–6 show the input parameters, distributions, and data justifications for the source term, unsaturated zone, and saturated zone parameters, respectively.

## C.7 Calibration

The procedures used in GANDT to assure that model runs match site conditions is quite different from traditional flow model calibration techniques based on matching observed hydraulic heads. Specifically, GANDT employs a post-conditioning algorithm that is based on the comparison of observed and simulated water quality data. The post-conditioning exercise is automated in the Monte Carlo simulation framework.

### C.7.1 Qualitative/Quantitative Analysis

Post-conditioning results are somewhat a reflection of the appropriateness of available water quality data. Occasionally, when limited field data or inappropriate data (e.g., lab data that do not reflect field conditions) are used, few, if any, simulations meet the conditioning criteria. If the collected concentration data are representative of site contamination, one would expect a greater number of model runs to honor these data and pass the conditioning tests.

In a Monte Carlo analysis that incorporates LHS, it is theoretically possible to quantify uncertainties in the modeling results with as few runs as 4/3 times the number of uncertain variables. In practice a factor of 2 to 4 is recommended. There are 23 uncertain parameters in the analyses performed for the Canonsburg site. Therefore, a minimum of 46 runs passing the conditioning test is desired. The results of these analyses are presented in a subsequent section.

### C.7.2 Sensitivity Analysis

A formal sensitivity analysis with the Canonsburg simulations was not performed. The GANDT analysis resulted in a quantitative expression of the flow and transport uncertainty, which is a higher order step than intended by a conventional sensitivity analysis in terms of addressing variability or reliability in the results.

### C.7.3 Model Application Verification

No additional time steps were evaluated against observed data for a verification analysis. The built-in conditioning/calibration step is considered adequate in defending the representativeness of the simulations.

## C.8 Predictive Simulations

Results of the predictive modeling simulations are quite encouraging with regard to the potential for natural attenuation to complement the application of ACLs in achieving compliance with the ground water protection standards at the Canonsburg site. The modeling in this study yields a tremendous amount of information in the form of both graphical and quantitative results. Most of the predictive modeling results are graphically presented for the purpose of showing the likelihood of natural attenuation, the ACL approach, and a hypothetical pump-and-treat operation as a potential remedial alternative.

As part of this exercise, two types of plots were selected for inclusion in the report. The first type contains the mean, or average, concentration distribution from all Monte Carlo runs that have met the conditioning criteria. The transient nature of the plume is visualized by displaying four separate time steps for the constituent of concern, which is uranium. The second type of graphic consists of a probability plot illustrating the spatial distribution of the probability that concentrations are less than the MCL. Such results are useful in evaluating the likelihood of success of the proposed alternative. A plot indicating a high probability that concentrations are

less than the MCL is interpreted as a high likelihood of success for the ACL application. The MCL is used as the concentration threshold in the uranium simulations (the MCL for uranium is 0.044 mg/L).

Several models were performed to support this ACL application. First, an evaluation of the migration potential of the plume emanating from the main processing area was performed. Figures C–1 through C–7 show the mean contaminant plume distributions for uranium through time. Figure C–1 represents the plume distribution in 1997, the time at which the post-conditioning analysis was performed. Figures C–8 through C–15 show the results of the spatial distribution of the probability that concentrations are less than the MCL for uranium. The second simulation suite was performed to evaluate the migration potential of uranium in Area C. The average uranium concentration distribution results through time are shown in Figures C–16 through C–20. Figures C–21 through C–25 display the distribution of the probability that concentrations are less than the MCL. The third simulation suite was performed to evaluate the behavior of a hypothetical pump-and-treat operation to clean up the aquifer more quickly than the ACL approach. The average uranium concentration distribution results through time are shown in Figures C–26 through C–33. Figures C–34 through C–40 display the distribution of the probability that concentrations are less than the MCL. Conclusions drawn from these results are summarized in Section 3 of this report.

Results of this analysis suggest a high likelihood that natural attenuation processes will be effective if an ACL is implemented at the Canonsburg site. The uranium predictive simulations show a 100 percent probability that concentrations will be less than the MCL (0.044 mg/L) after 30 years of natural attenuation. The hypothetical pump-and-treat operation is not significantly more effective than the natural attenuation processes. A verification-monitoring program is essential to determine the likelihood of success, as suggested by the simulations in this study. This is particularly true because the model runs presented here are primarily an aid in decision making.

The GANDT code has the capability of supplying the user with the predicted water quality concentrations at each monitor well for each run in a Monte Carlo suite. Therefore, a distribution of concentrations is obtained for each well from the probabilistic analyses. This distribution of predicted concentrations is a good indicator of the probable concentrations that would be observed in the verification-monitoring program. Of greatest importance in evaluating the potential for natural attenuation is the statistical bounds of the predicted concentrations at the verification monitor wells. A plot of average concentrations at each output time, together with the minimum and maximum predicted concentrations, will serve as a guide to the verification monitoring activities. If future monitoring of these wells indicates that uranium concentrations are within the predicted ranges, the site would likely be on track for meeting ACL guidelines. If, however, the observed concentrations are above the predicted ranges, the site will need to be reassessed.

The verification monitoring wells (412, 413, and 414) are within the area of the contaminant plume. Figures 4–1, 4–2, and 4–3, respectively, show the uranium concentration versus time at each of these wells. The data points represent the average concentration predicted from the simulations, and the error bars in the plot represent the minimum and maximum predicted concentrations. The min-max bounds in the plot represent the acceptable range of verification

monitoring results that would produce a situation where natural attenuation allowed the site to comply with the ACL guidelines. Also included in these plots is a horizontal line representing the MCL.

*Table C–7 Concentration Limits for Ground Water Constituents*

| Constituent | EPA MCL for UMTRA Project 40 CFR 192.02 (mg/L) | Health Advisories 10-kg child, 10-day[a] | Health Advisories 70-kg adult, lifetime[a] |
|---|---|---|---|
| | | | |
| **Inorganics** | | | |
| Antimony | NA | 0.01 | 0.003 |
| Arsenic | 0.05 | NA | NA |
| Barium | 1.0 | NA | 2 |
| Boron | NA | 0.9 | 0.6 |
| Cadmium | 0.01 | 0.04 | 0.005 |
| Chromium | 0.05 | 1.0 | 0.1 |
| Lead | 0.05 | NA | 0.015[b] |
| Mercury | 0.002 | NA | 0.002 |
| Molybdenum | 0.1 | 0.04 | 0.04 |
| Nickel | NA | 1.0 | 0.1 |
| Nitrate (as $NO_3$) | 44[c] | 44[c] | NA |
| Selenium | 0.01 | NA | NA |
| Silver | 0.05 | 0.2 | 0.1 |
| Strontium | NA | 25.0 | 17 |
| Zinc | NA | 6.0 | 2 |
| **Radionuclides** | | | |
| Radium-226/228 | 5 pCi/L[d] | | NA |
| Uranium (U-234/238) | 30 pCi/L[d] (0.044 mg/L) | 0.03 mg/L [e,f] | 0.1 mg/L [e] |

[a] EPA 1995
[b] Action level
[c] Equals 10 mg/L nitrate as nitrogen
[d] pCi/L = picocuries per liter
[e] Proposed values (EPA, 1989)
[f] Longer-term health advisory
NA – not available

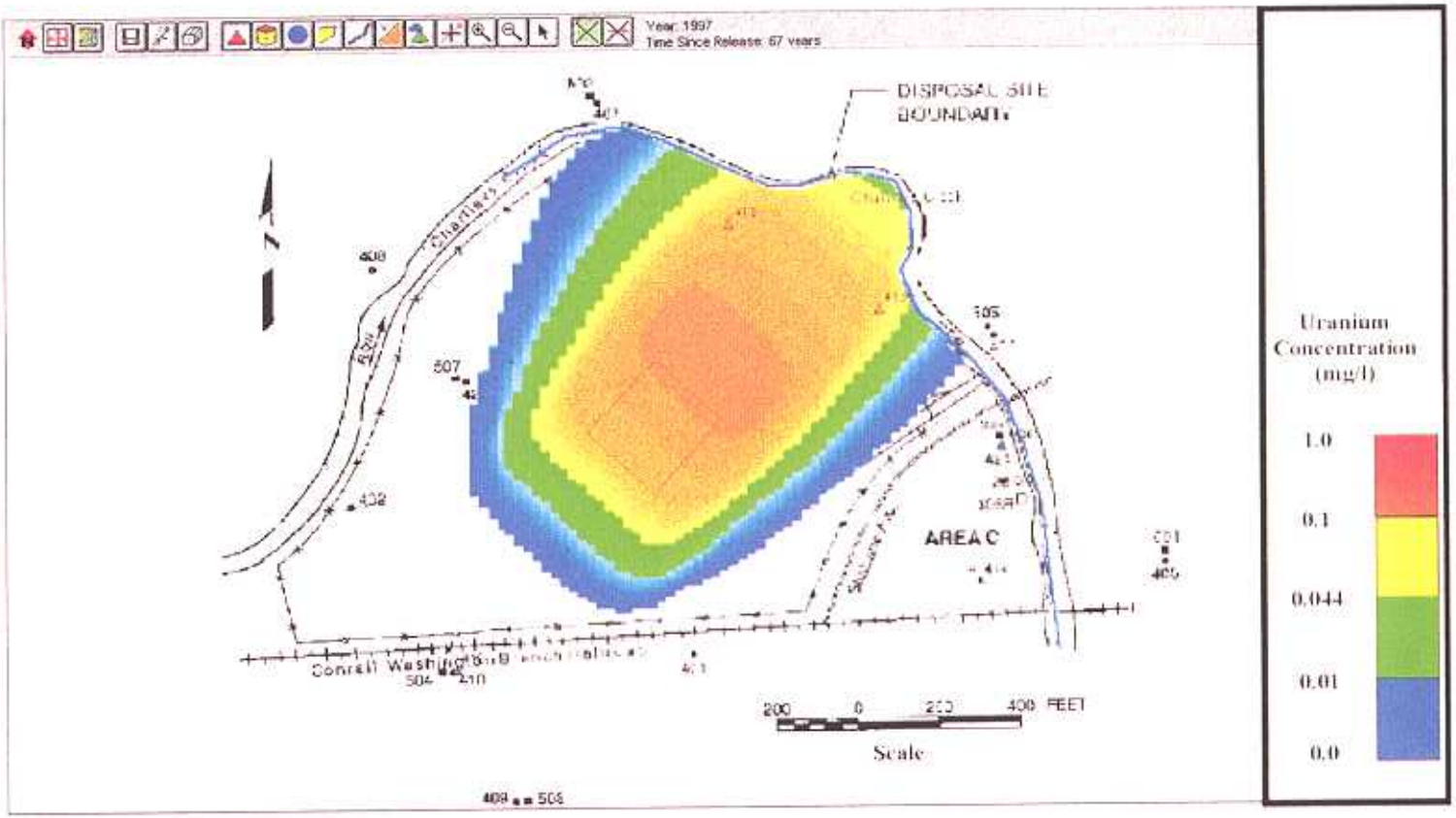


*Figure C–1. Simulated Average Uranium Concentrations in Ground WaterBeneath the Main Tailings Area—Year 1997*

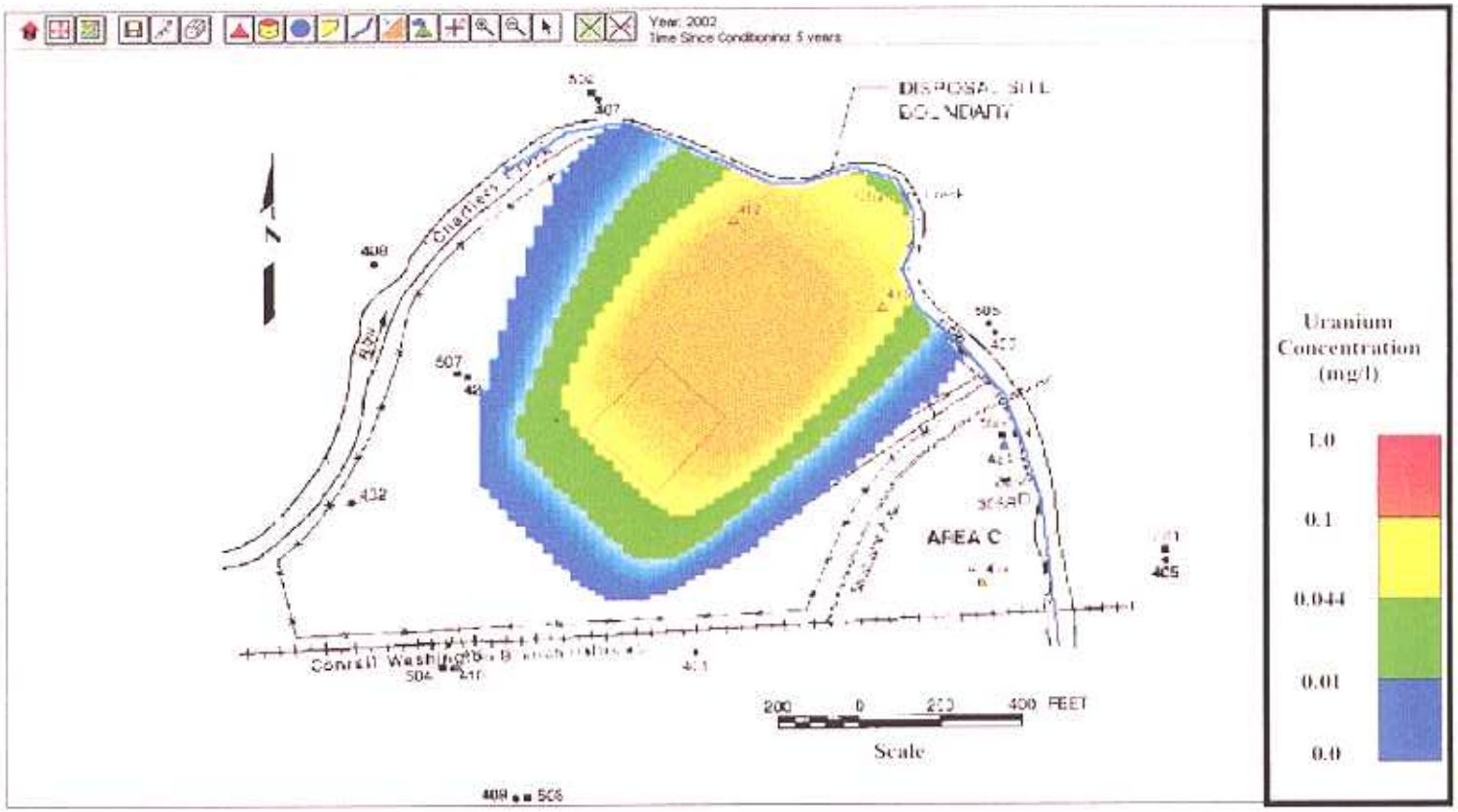


*Figure C–2. Simulated Average Uranium Concentrations in Ground Water Beneath the Main Processing Area—Year 2002*

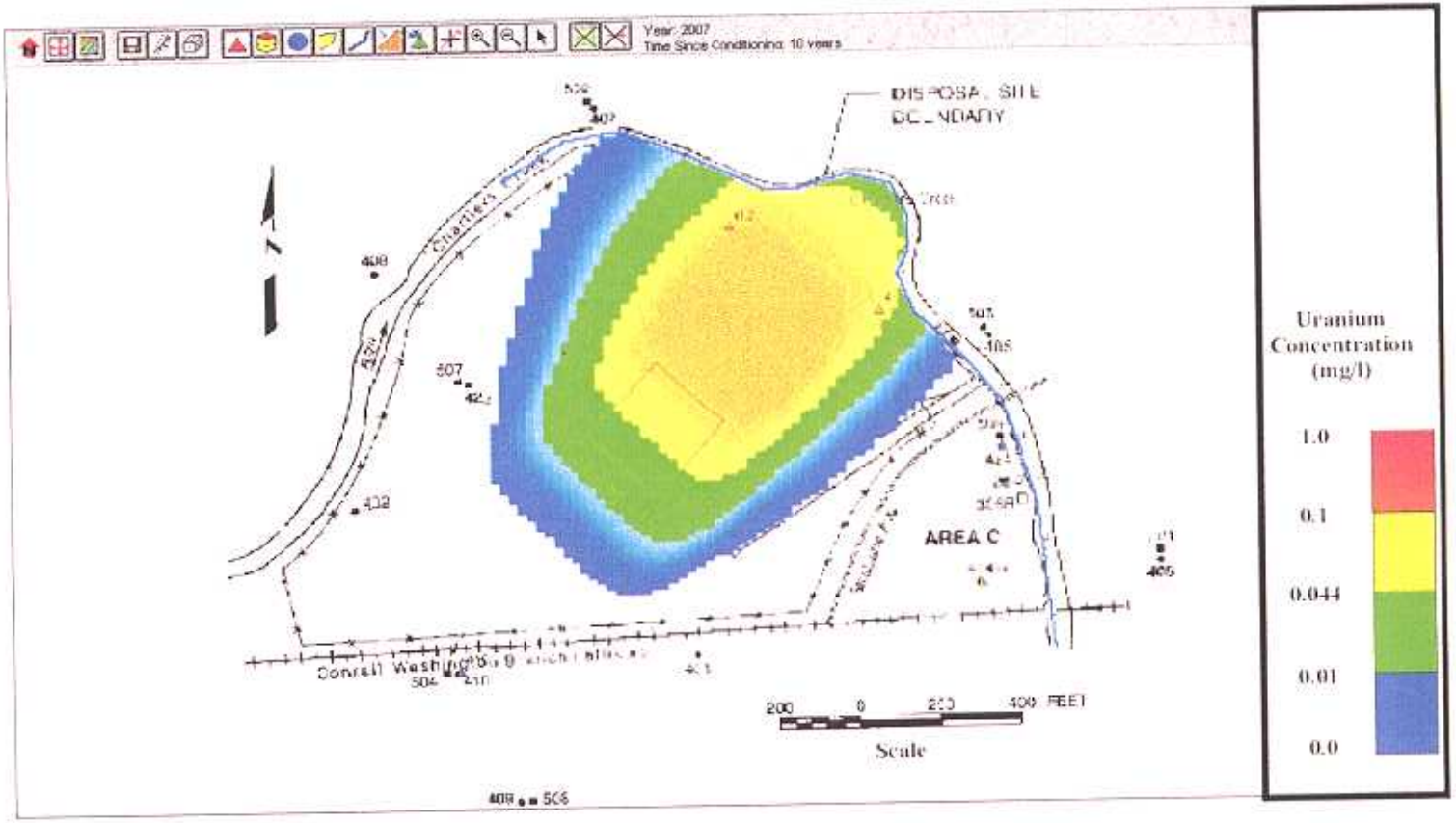


*Figure C–3. Simulated Average Uranium Concentrations in Ground Water Beneath the Main Processing Area—Year 2007*

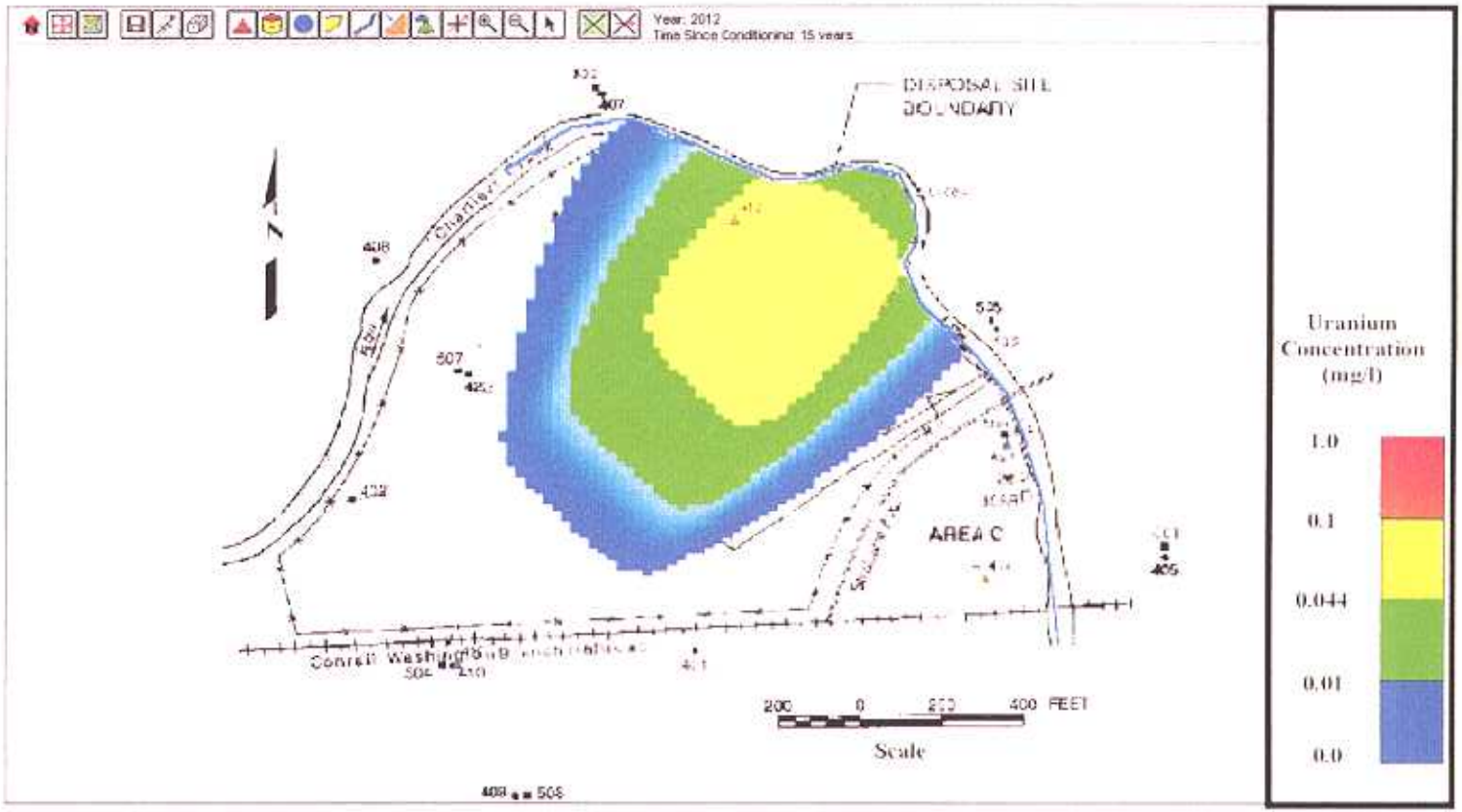


*Figure C–4. Simulated Average Uranium Concentrations in Ground Water Beneath the Main Processing Area—Year 2012*

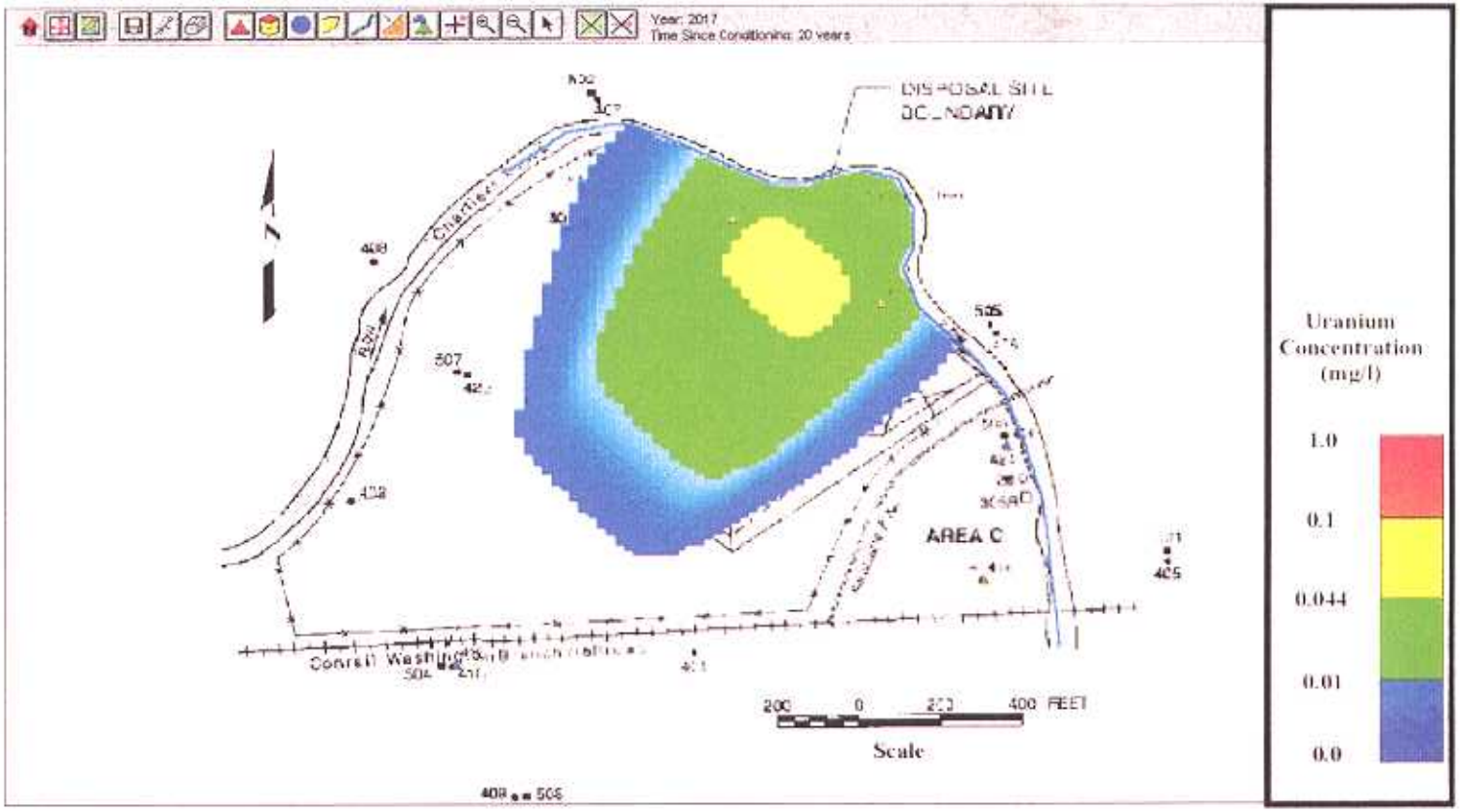


*Figure C–5. Simulated Average Uranium Concentrations in Ground Water Beneath the Main Processing Area—Year 2017*

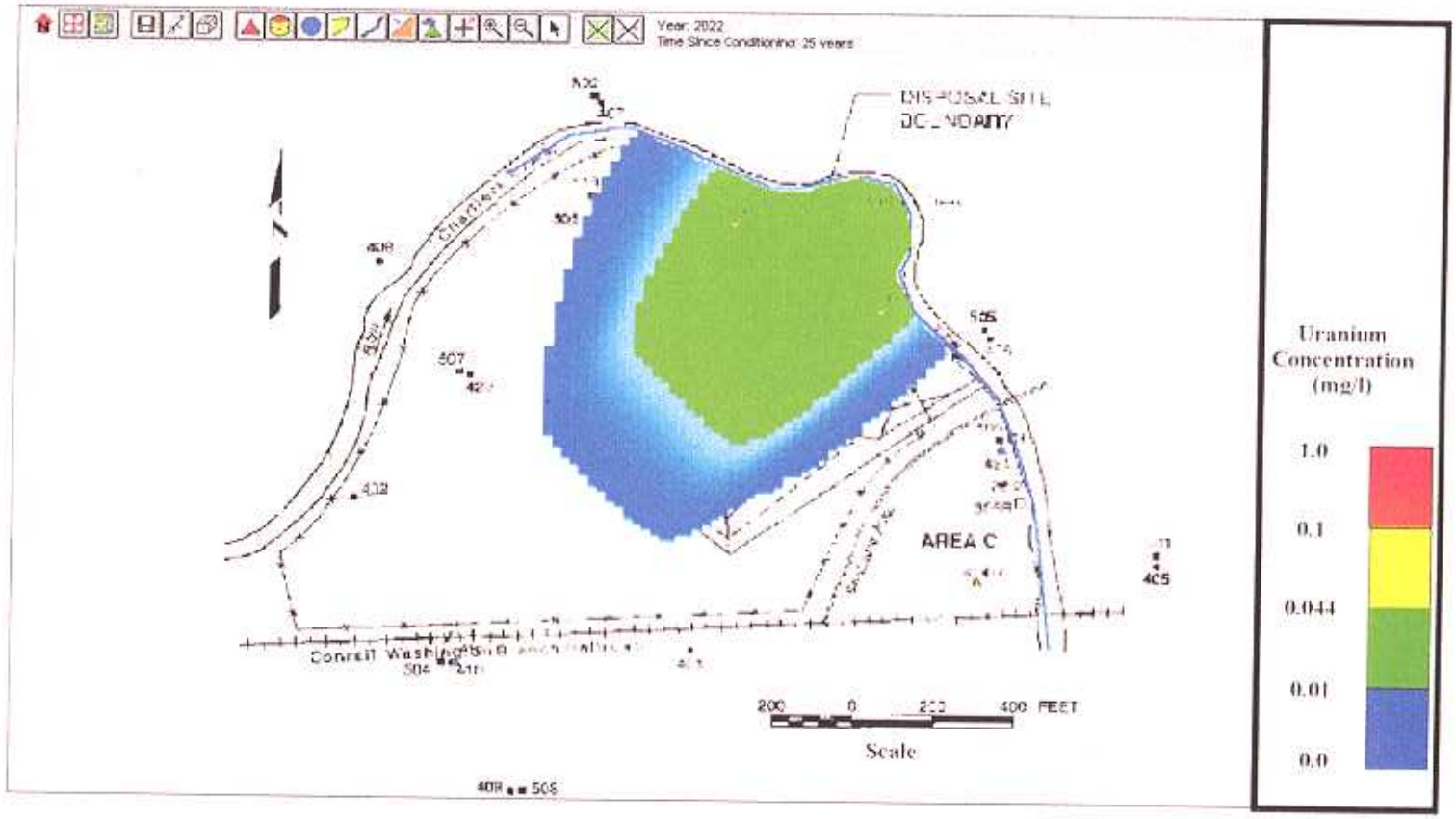


*Figure C–6. Simulated Average Uranium Concentrations in Ground Water Beneath the Main Processing Area—Year 2022*

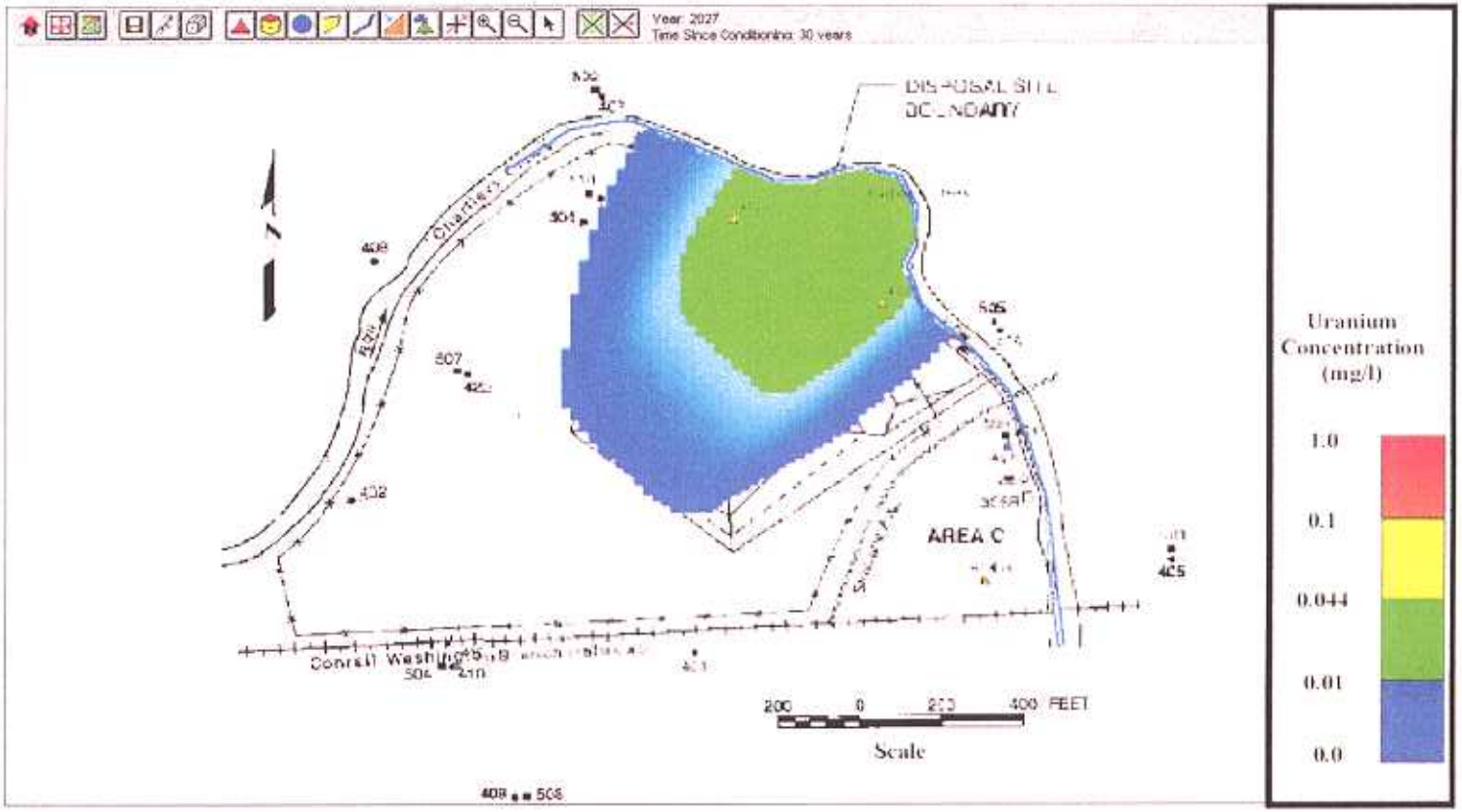


*Figure C–7. Simulated Average Uranium Concentrations in Ground Water Beneath the Main Processing Area—Year 2027*

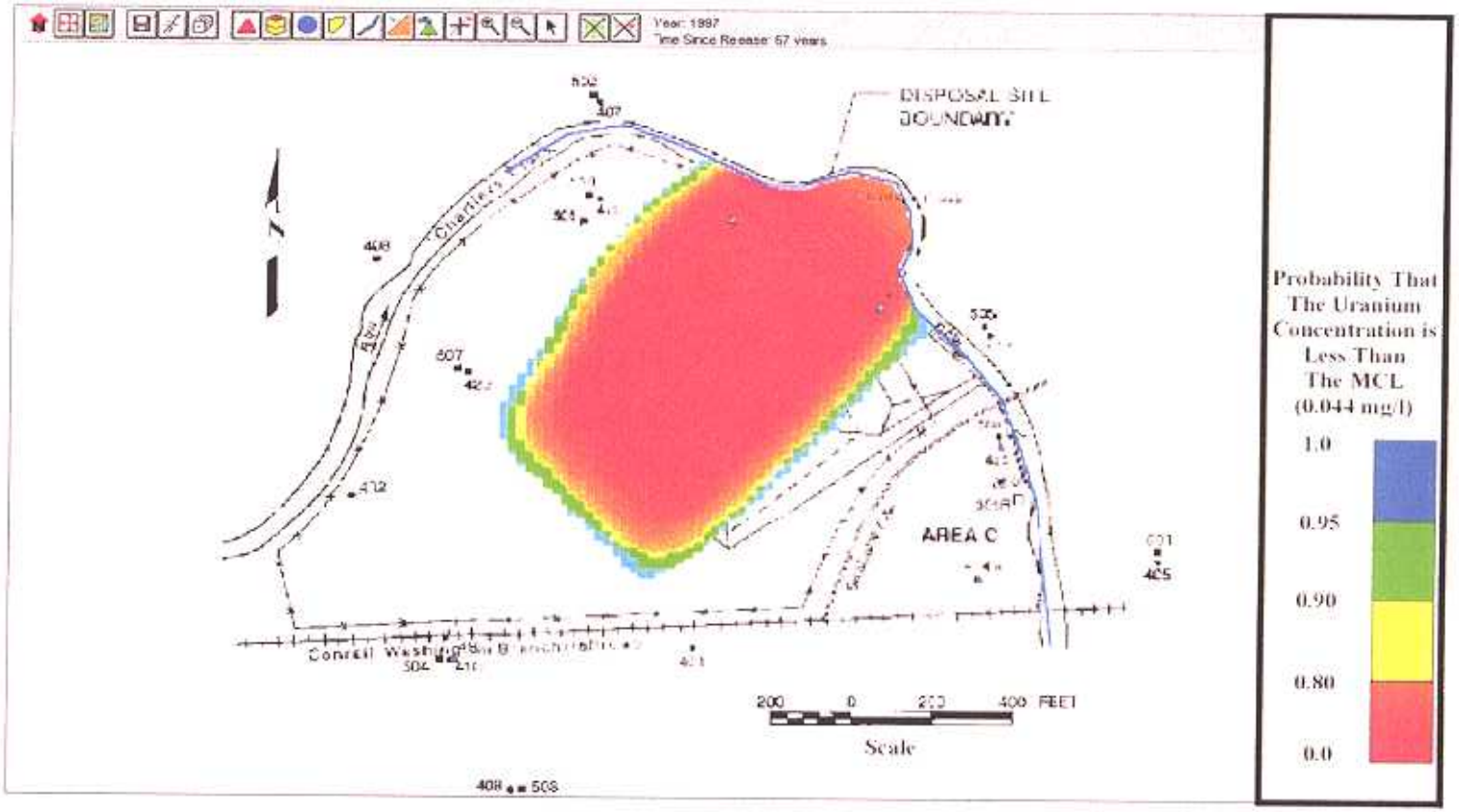


*Figure C–8. Probability That Uranium Concentrations Are Less Than the MCL in Ground Water Beneath the Main Processing Area—Year 1997*

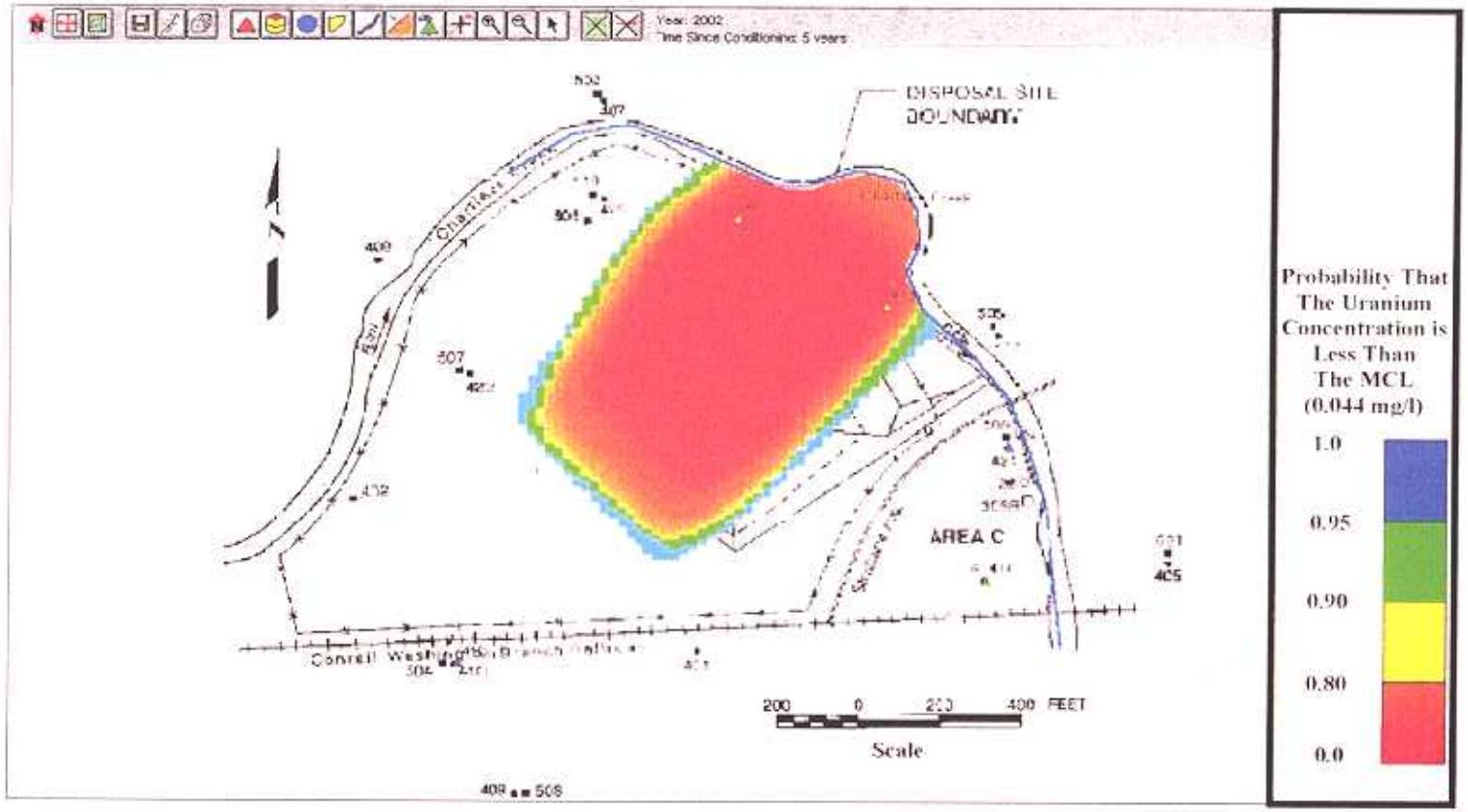


*Figure C–9. Probability That Uranium Concentrations Are Less Than the MCL in Ground Water Beneath the Main Processing Area—Year 2000*

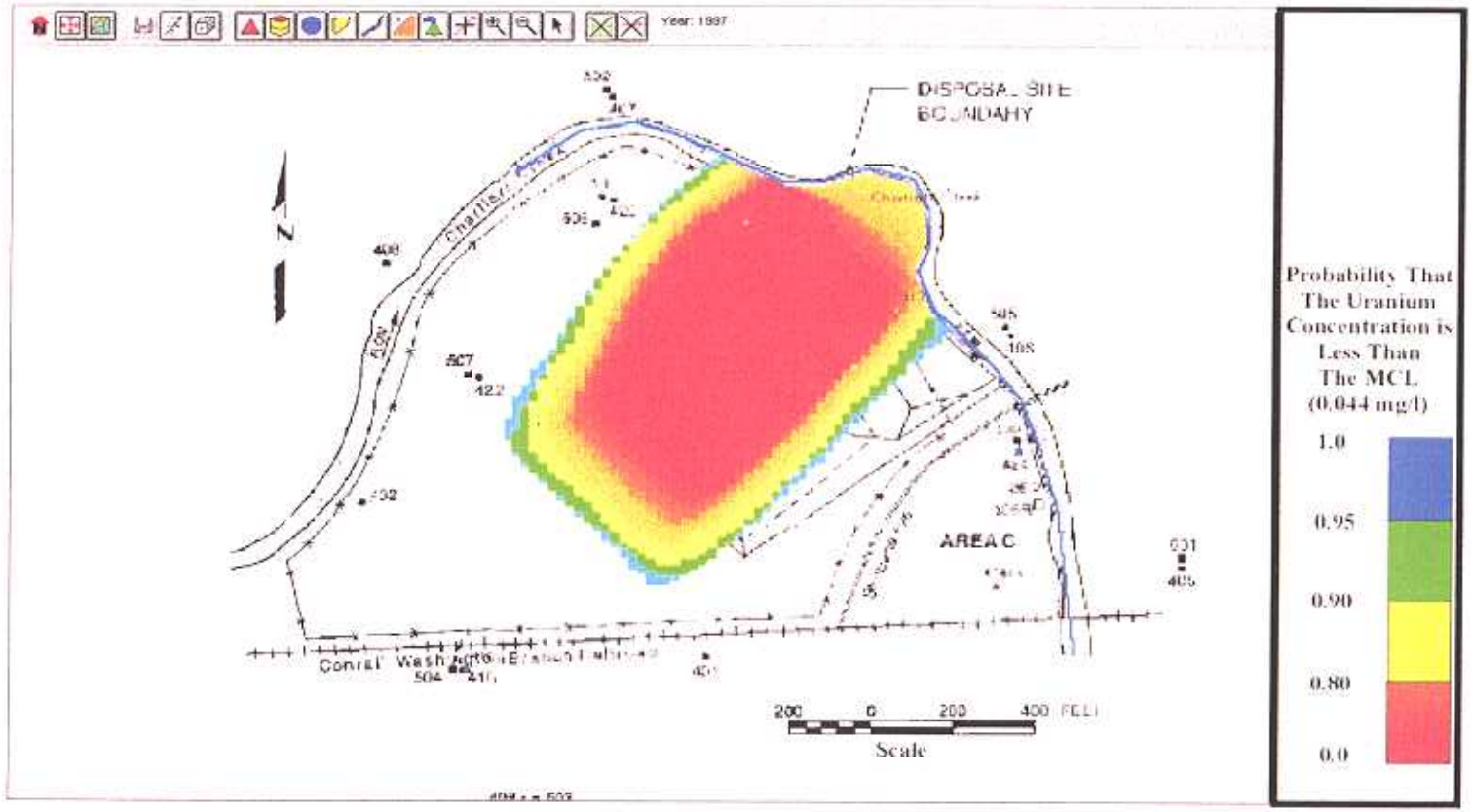


*Figure C–10. Probability That Uranium Concentrations Are Less Than the MCL in Ground Water Beneath the Main Processing Area—Year 2007*

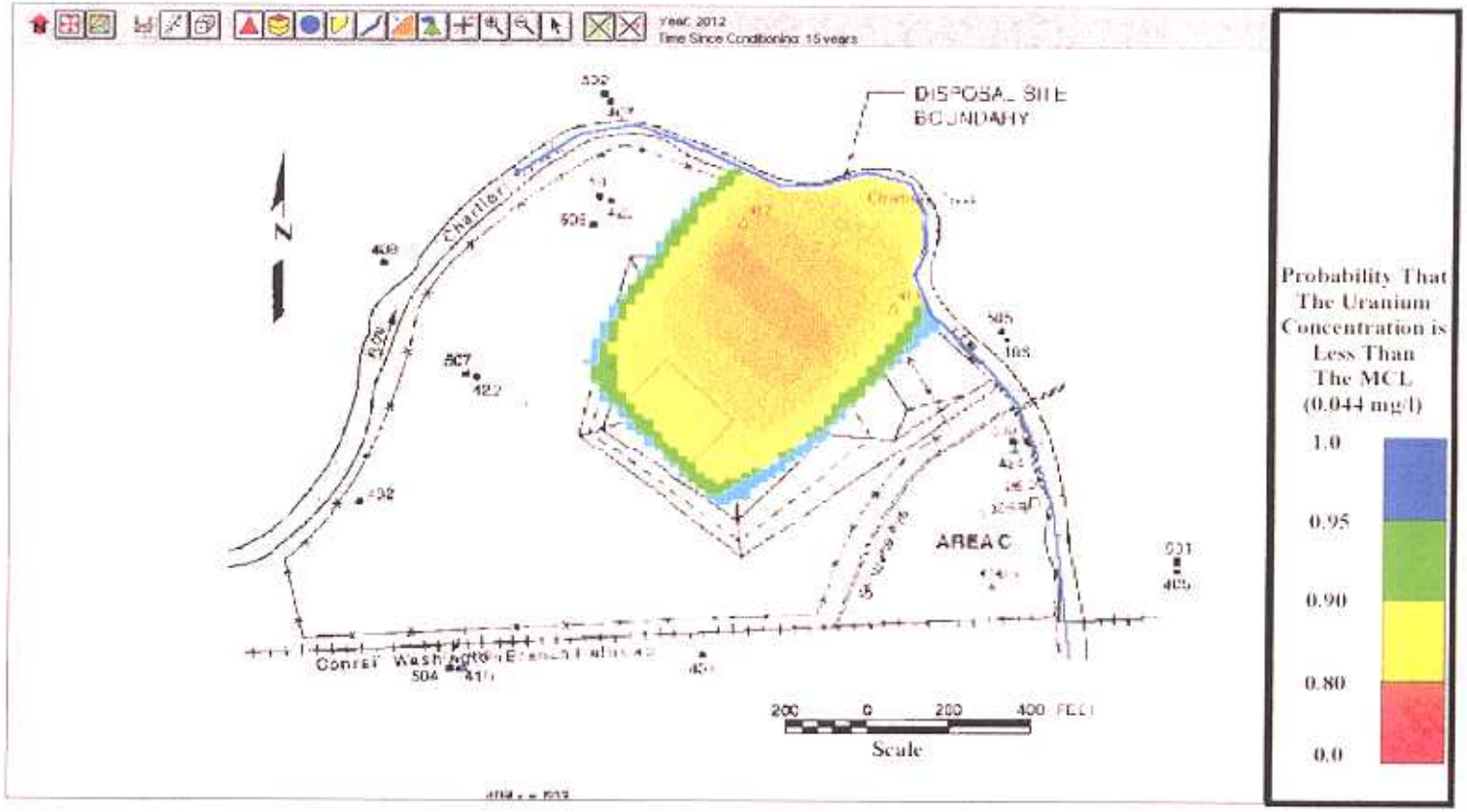


*Figure C–11. Probability That Uranium Concentrations Are Less Than the MCL in Ground Water Beneath the Main Processing Area—Year 2012*

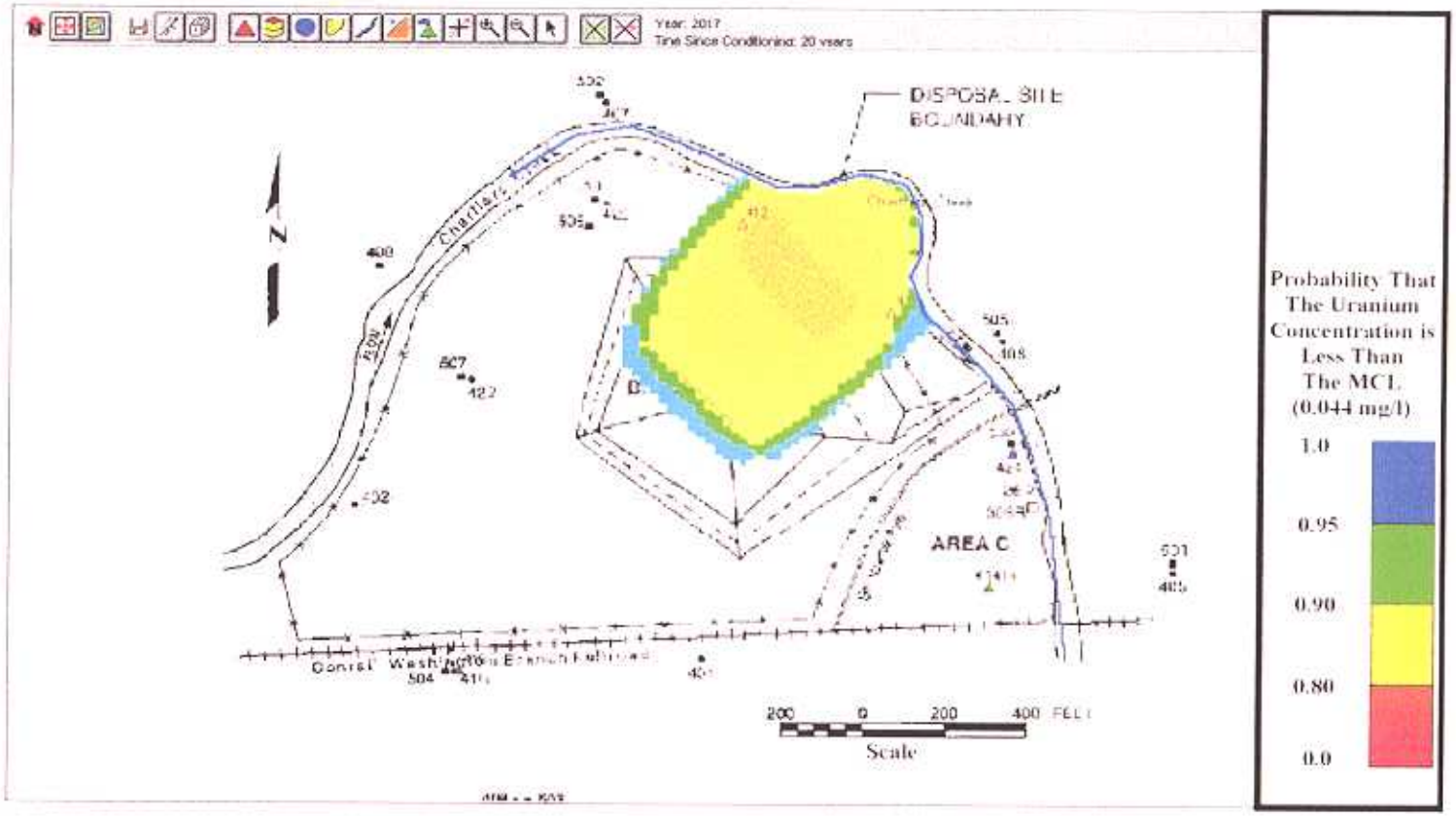


*Figure C–12. Probability That Uranium Concentrations Are Less Than the MCL in Ground Water Beneath the Main Processing Area—Year 2017*

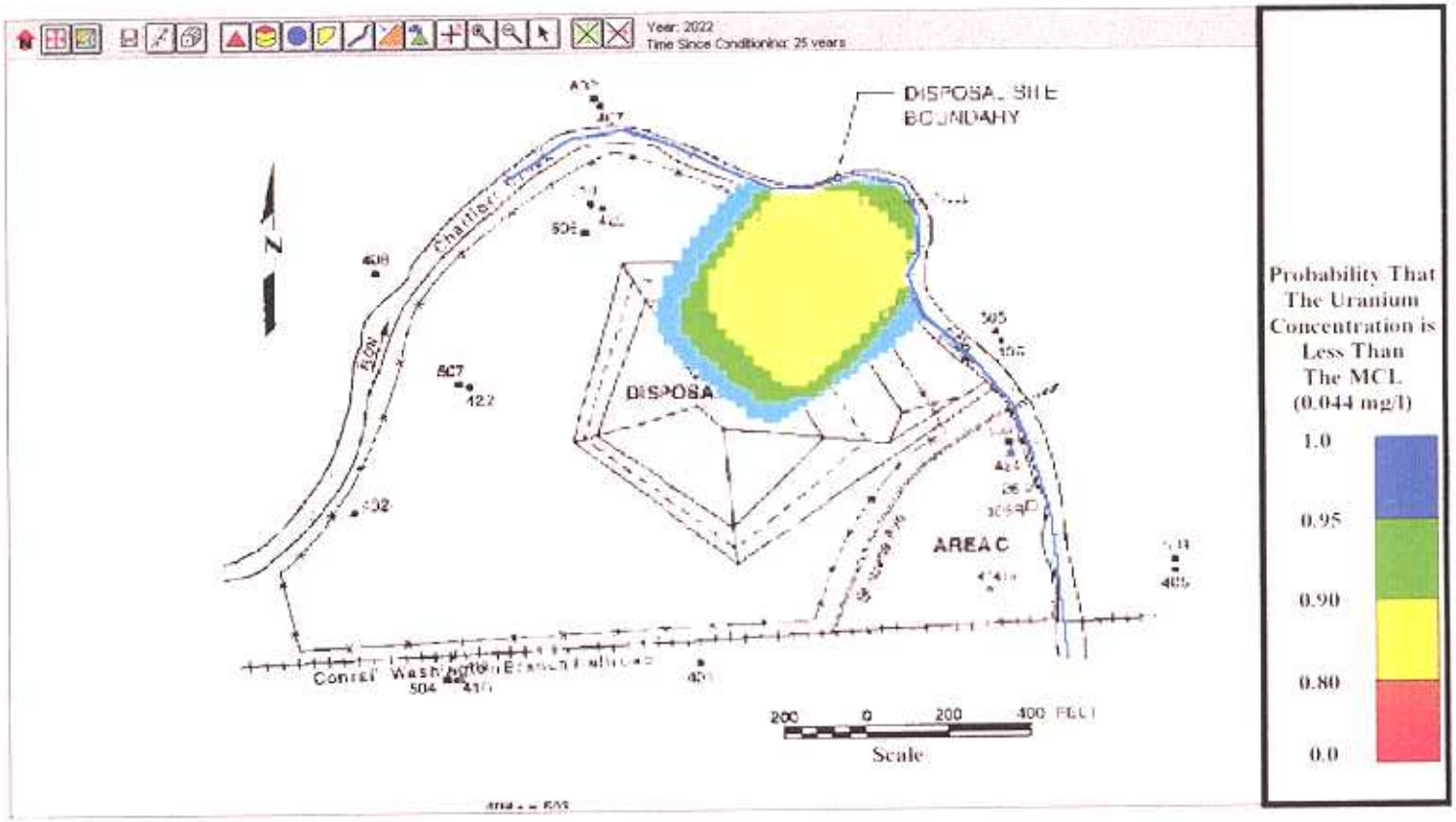


*Figure C–13. Probability That Uranium Concentrations Are Less Than the MCL in Ground Water Beneath the Main Processing Area—Year 2022*

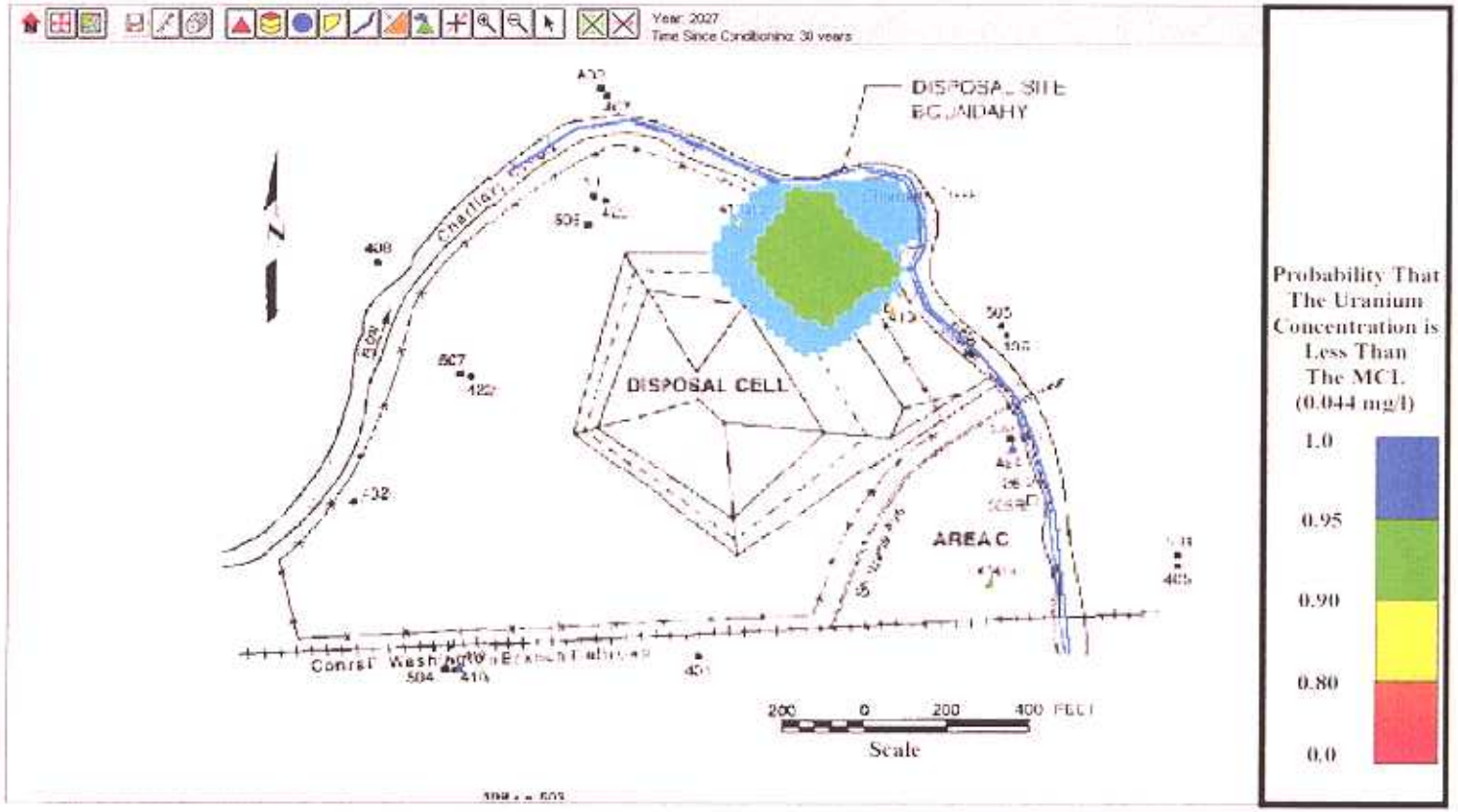


*Figure C–14. Probability That Uranium Concentrations Are Less Than the MCL in Ground Water Beneath the Main Processing Area—Year 2027*

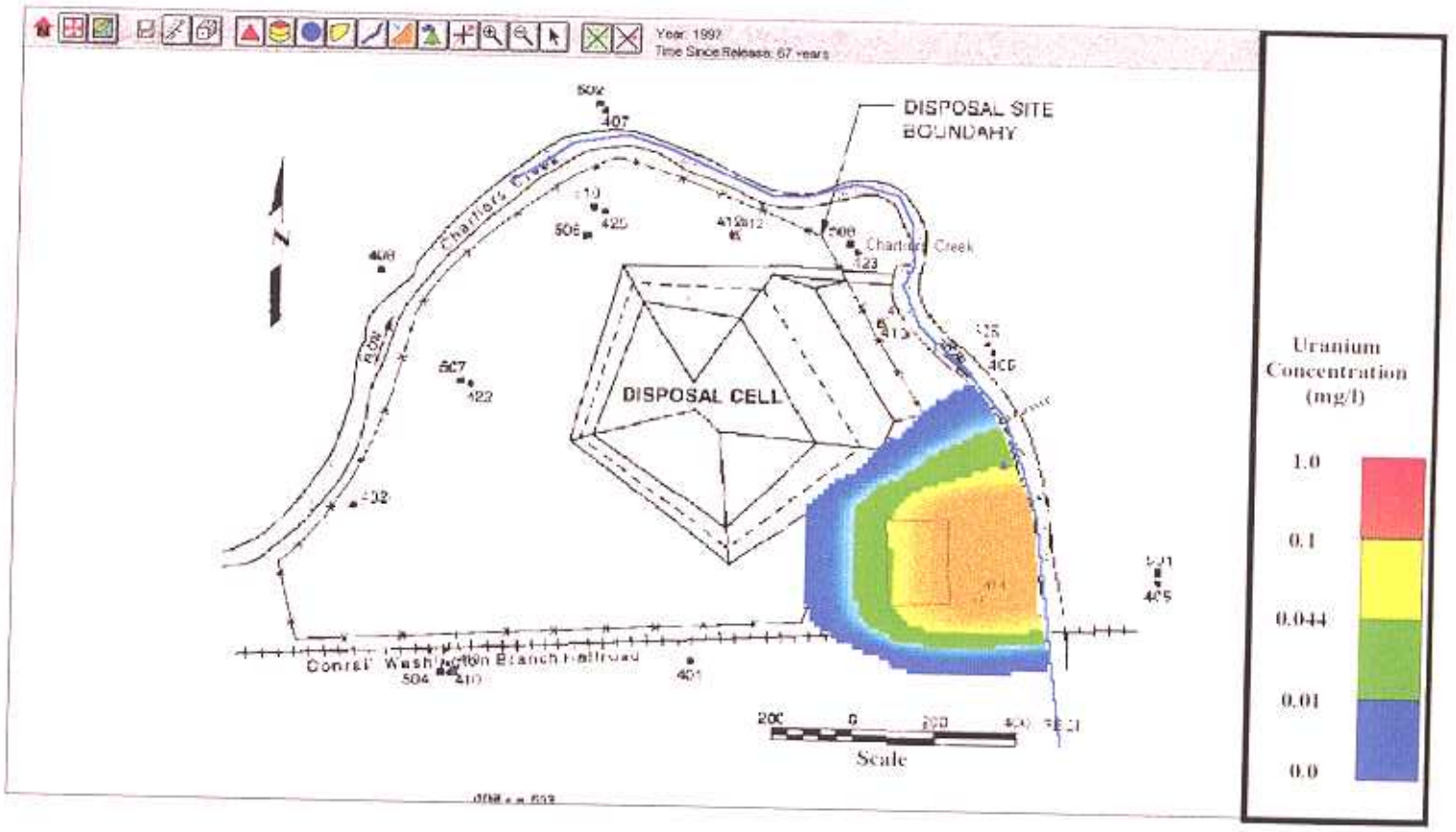


*Figure C–15. Simulated Average Uranium Concentrations in Ground Water Beneath Area C—Year 1997*

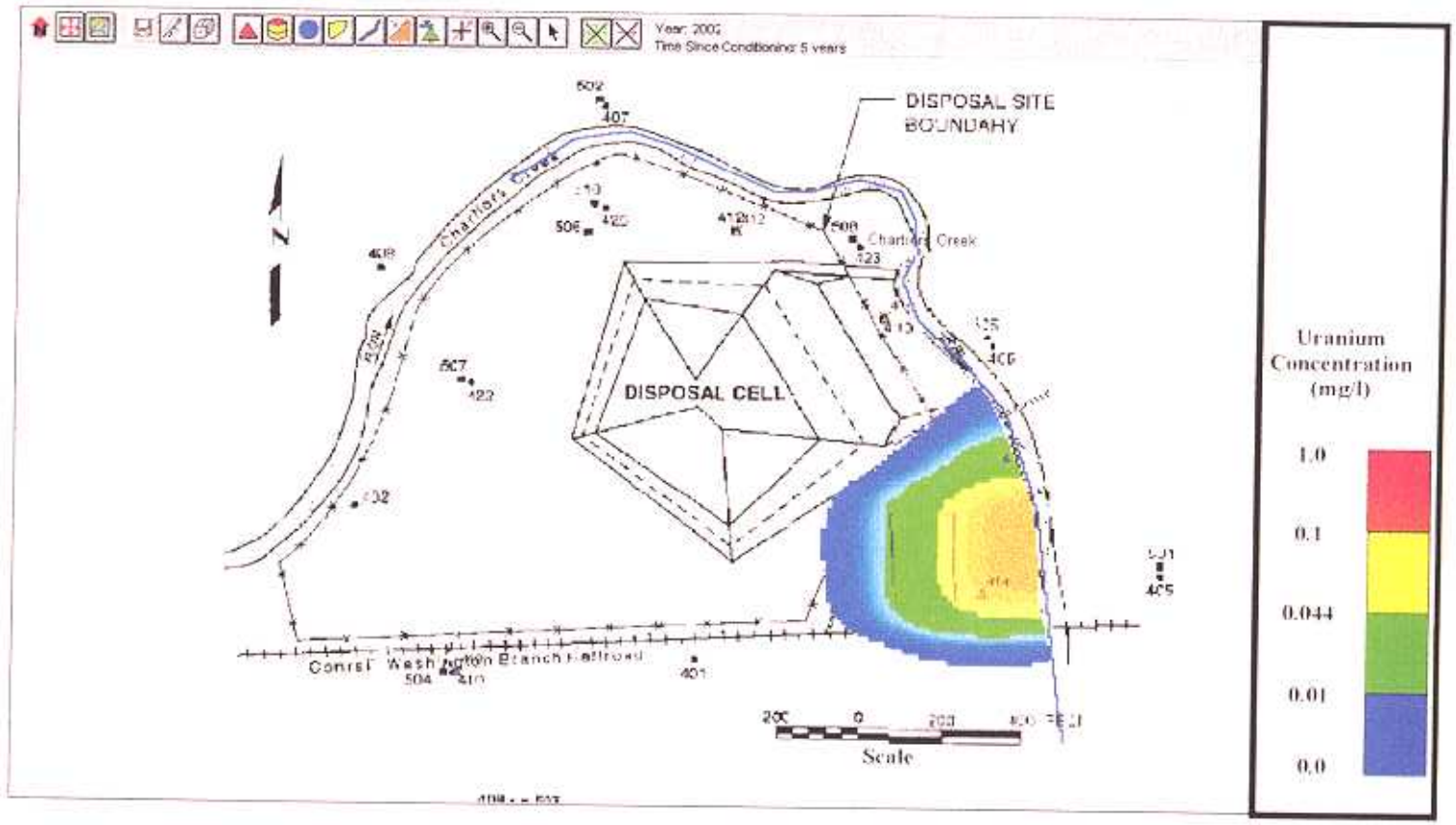


*Figure C–16. Simulated Average Uranium Concentrations in Ground Water Beneath Area C—Year 2002*

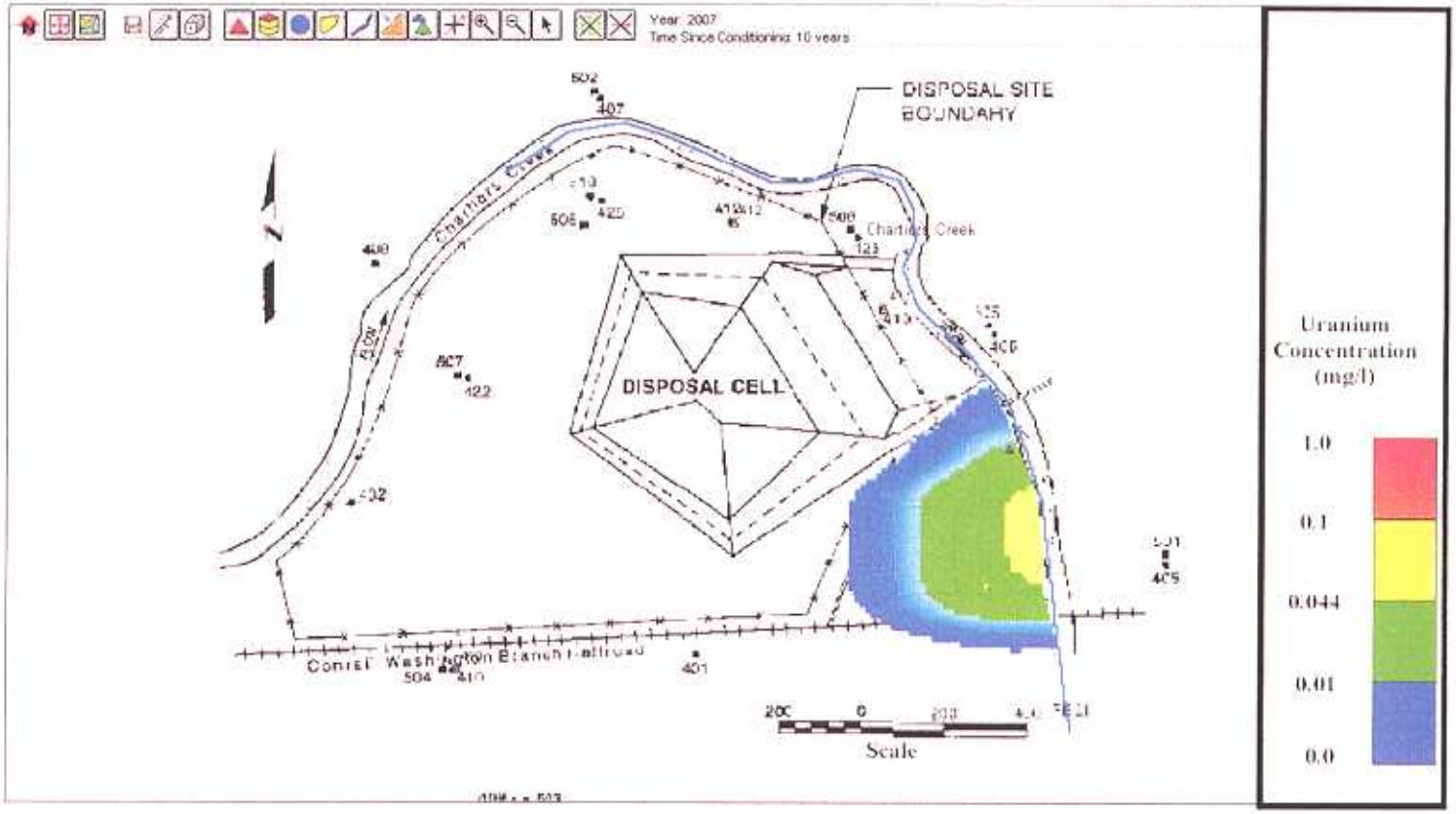


*Figure C–17. Simulated Average Uranium Concentrations in Ground Water Beneath Area C—Year 2007*

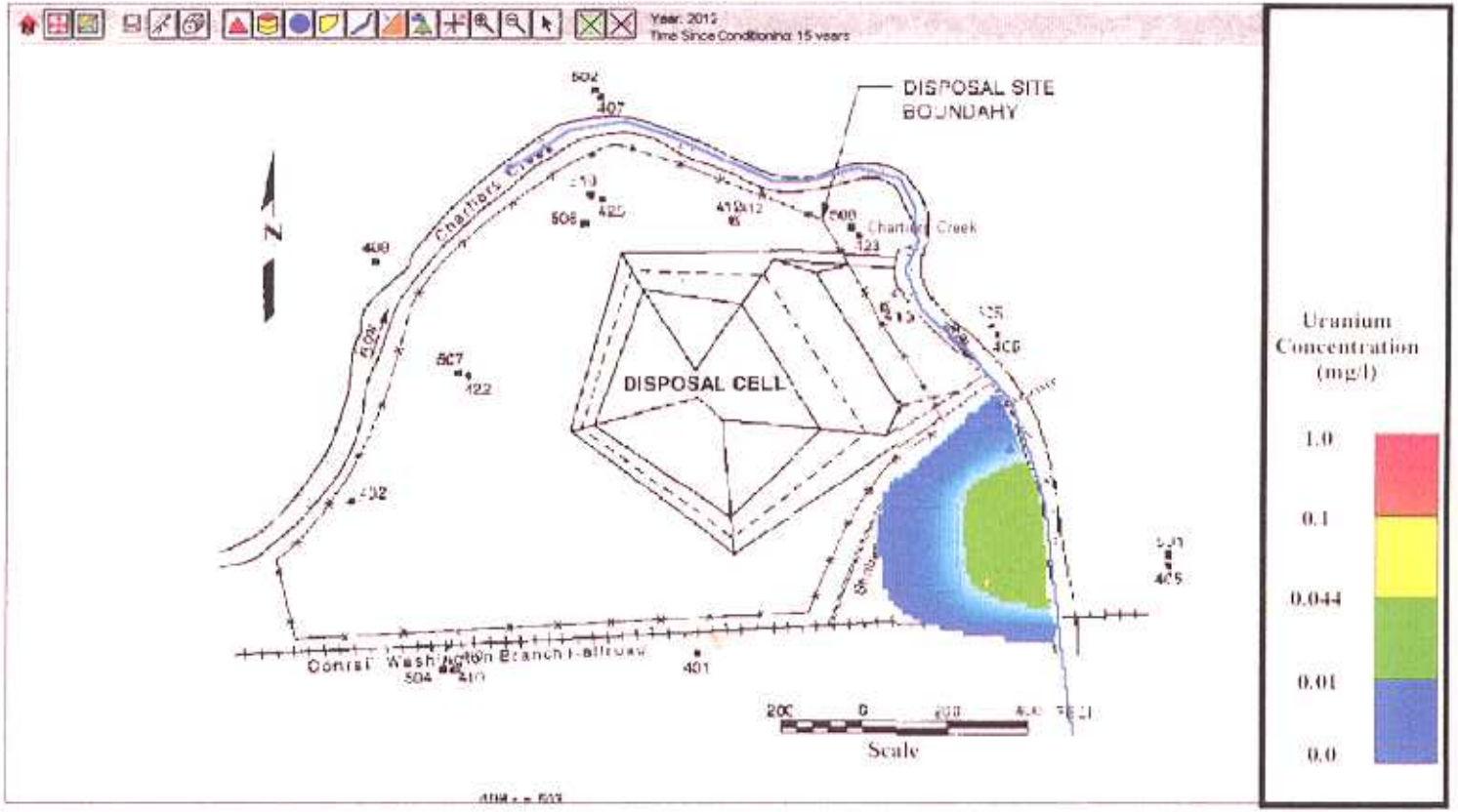


*Figure C–18. Simulated Average Uranium Concentrations in Ground Water Beneath Area C—Year 2012*

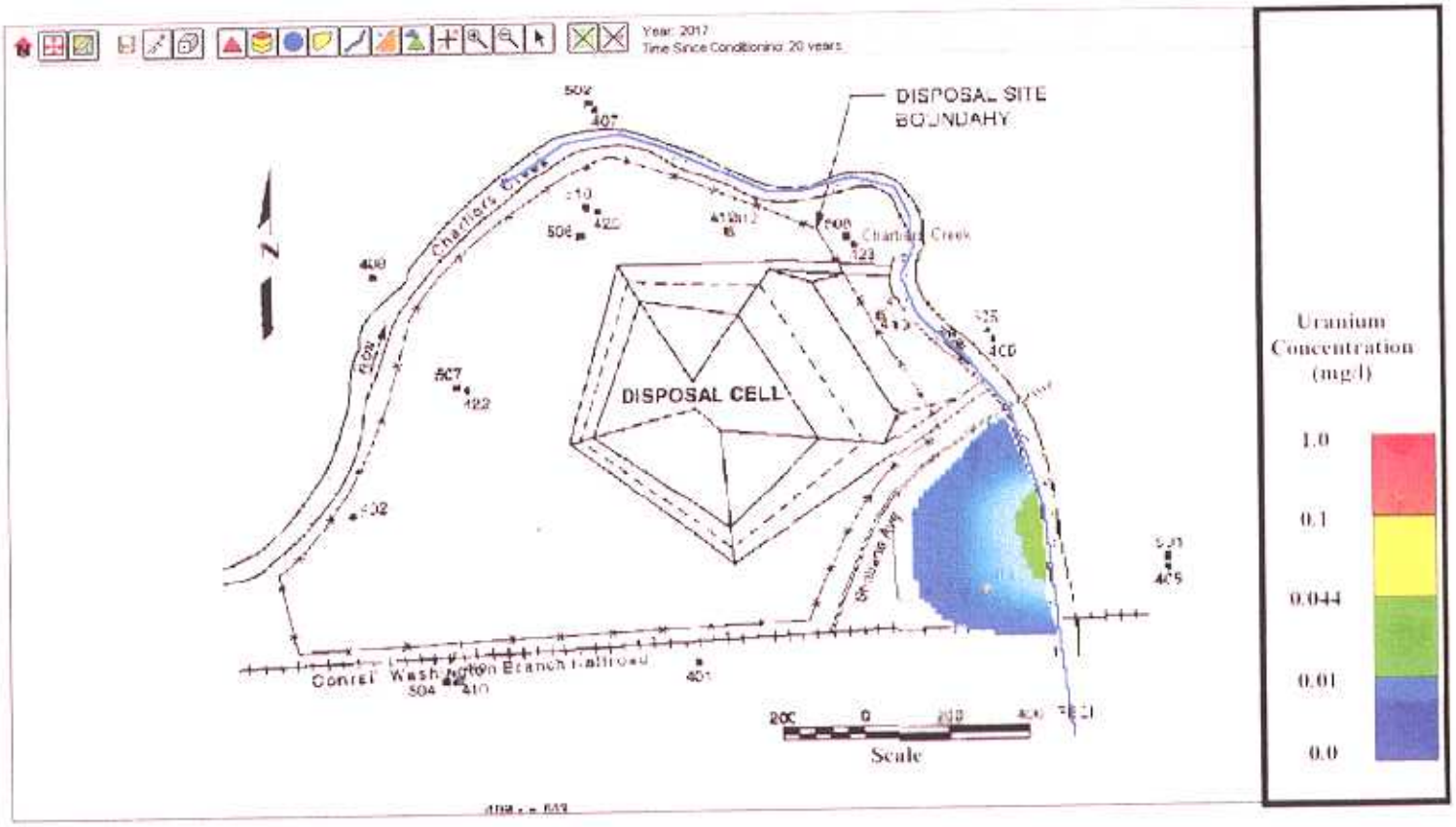


*Figure C–19. Simulated Average Uranium Concentrations in Ground Water Beneath Area C—Year 2017*

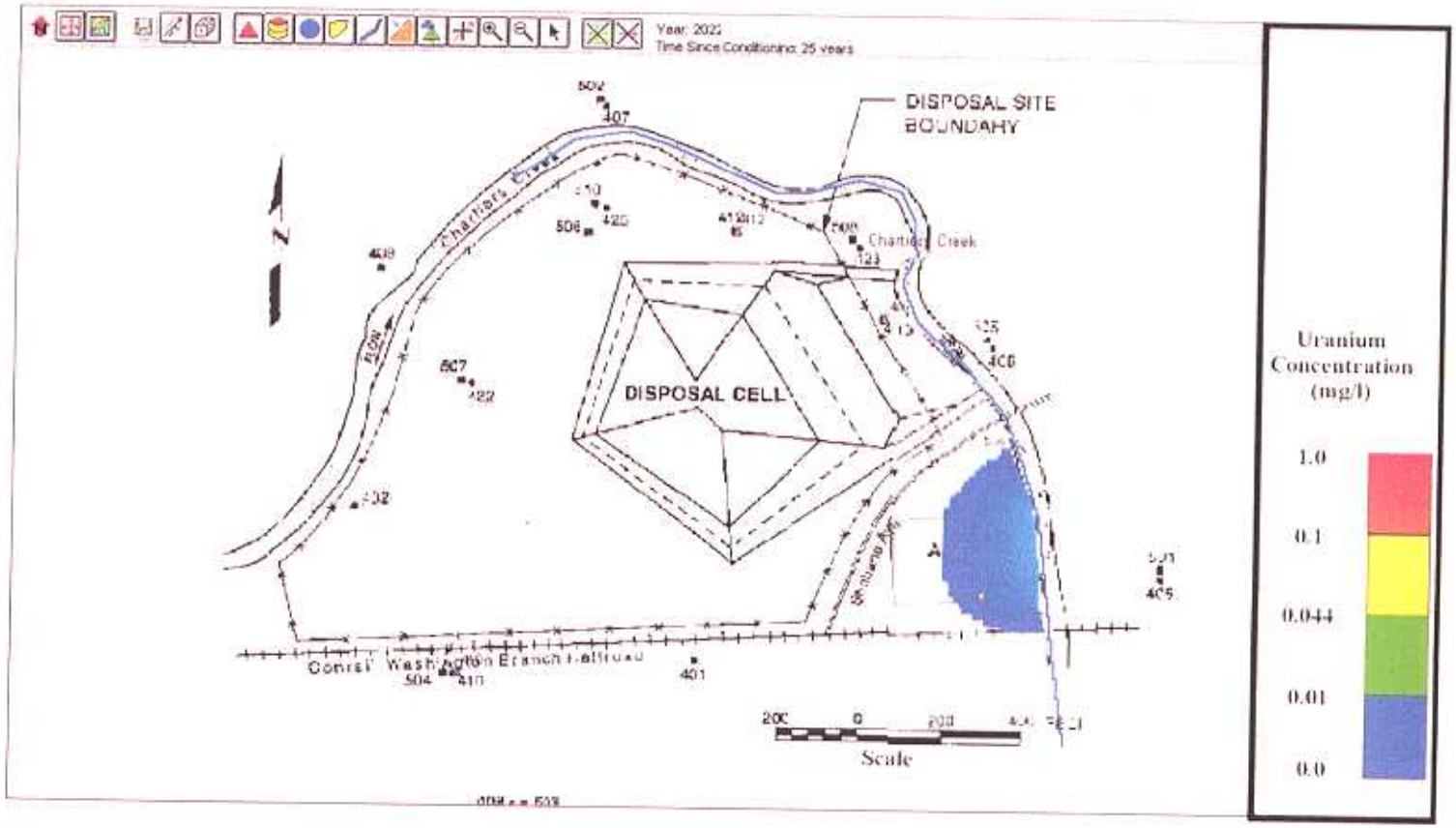


*Figure C–20. Simulated Average Uranium Concentrations in Ground Water Beneath Area C—Year 2022*

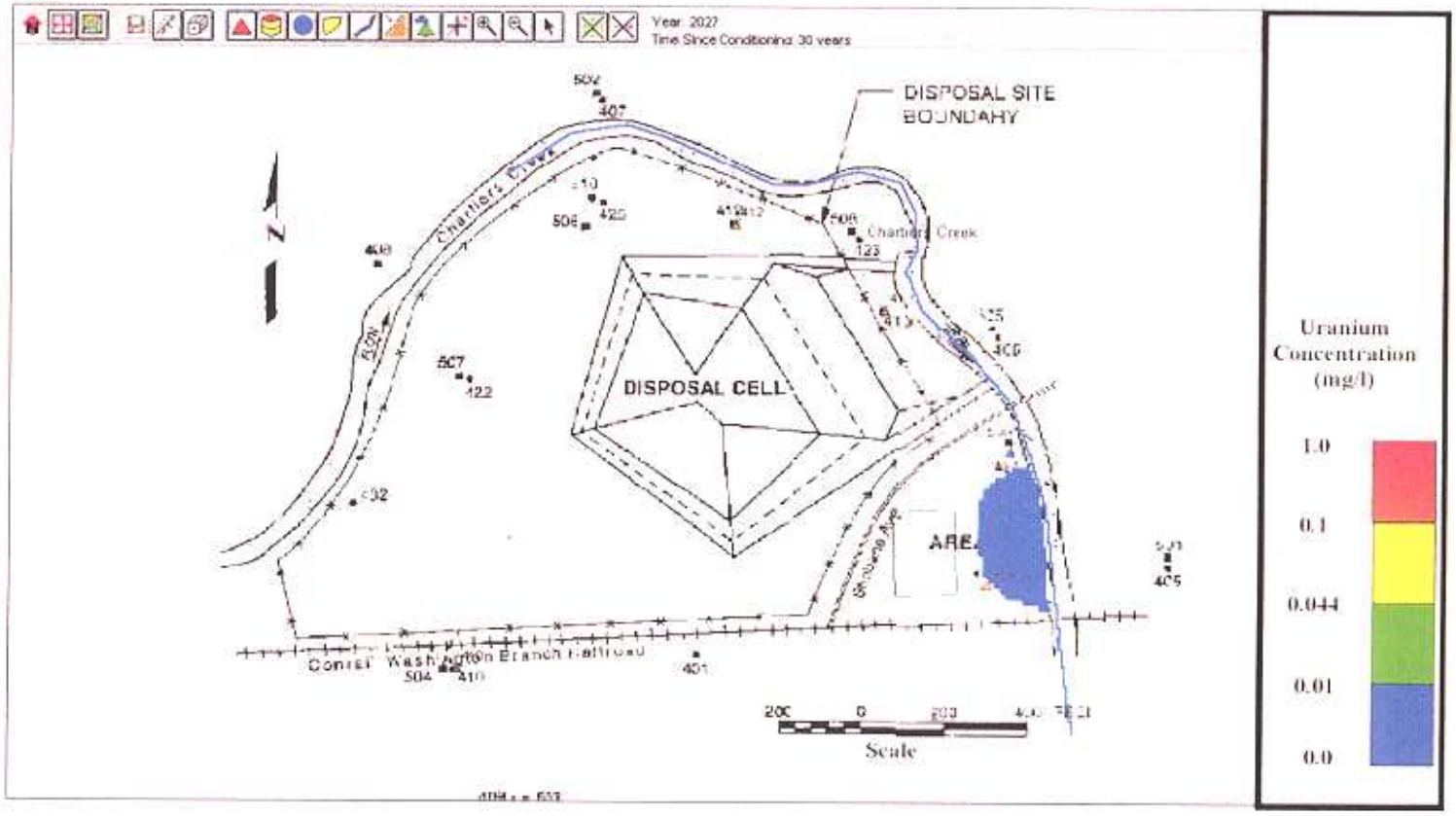


*Figure C–21 Simulated Average Uranium Concentrations in Ground Water Beneath Area C—Year 2027*

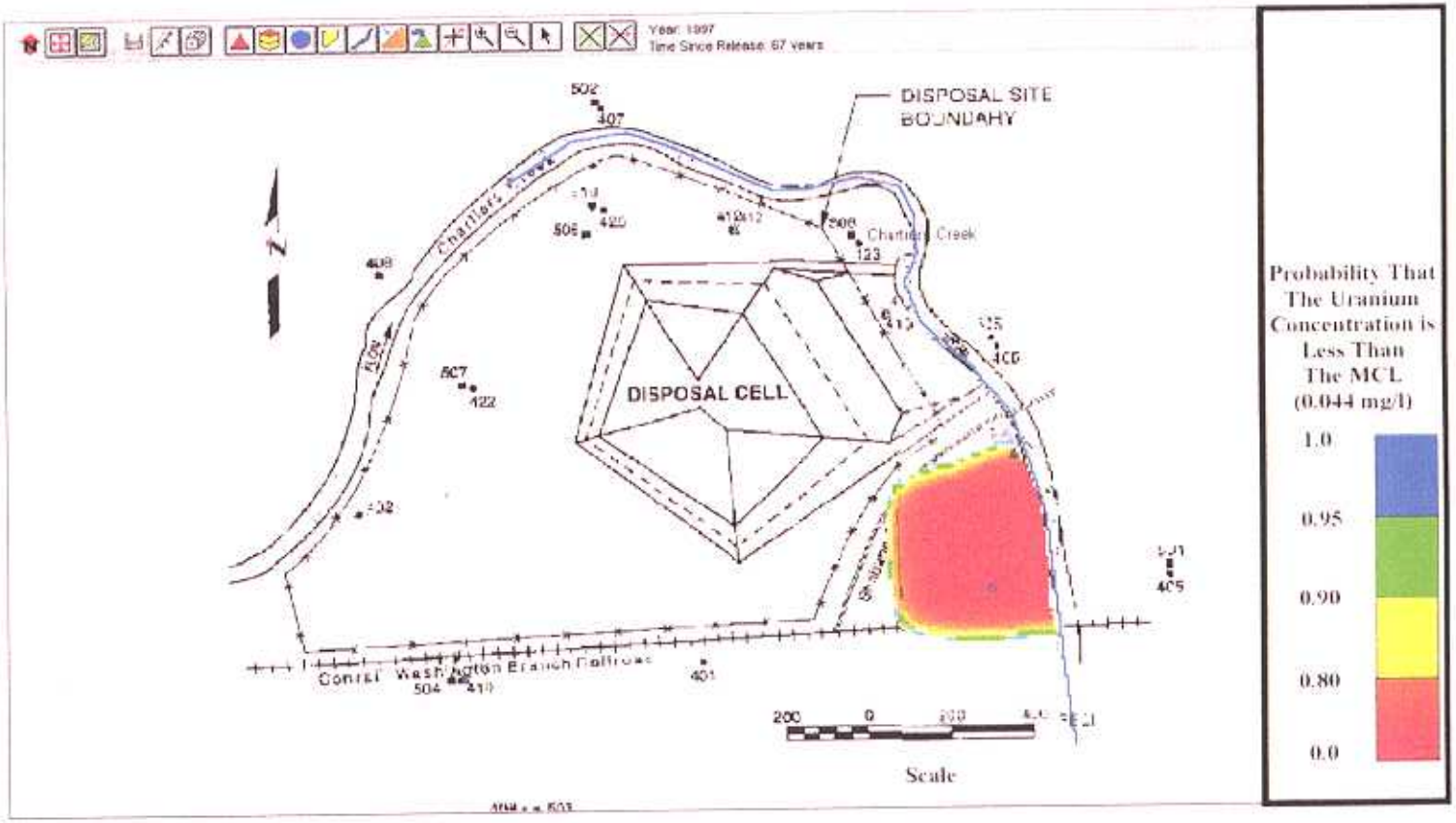


*Figure C–22. Probability That Uranium Concentrations Are Less Than the MCL in Ground Water Beneath Area C—Year 1997*

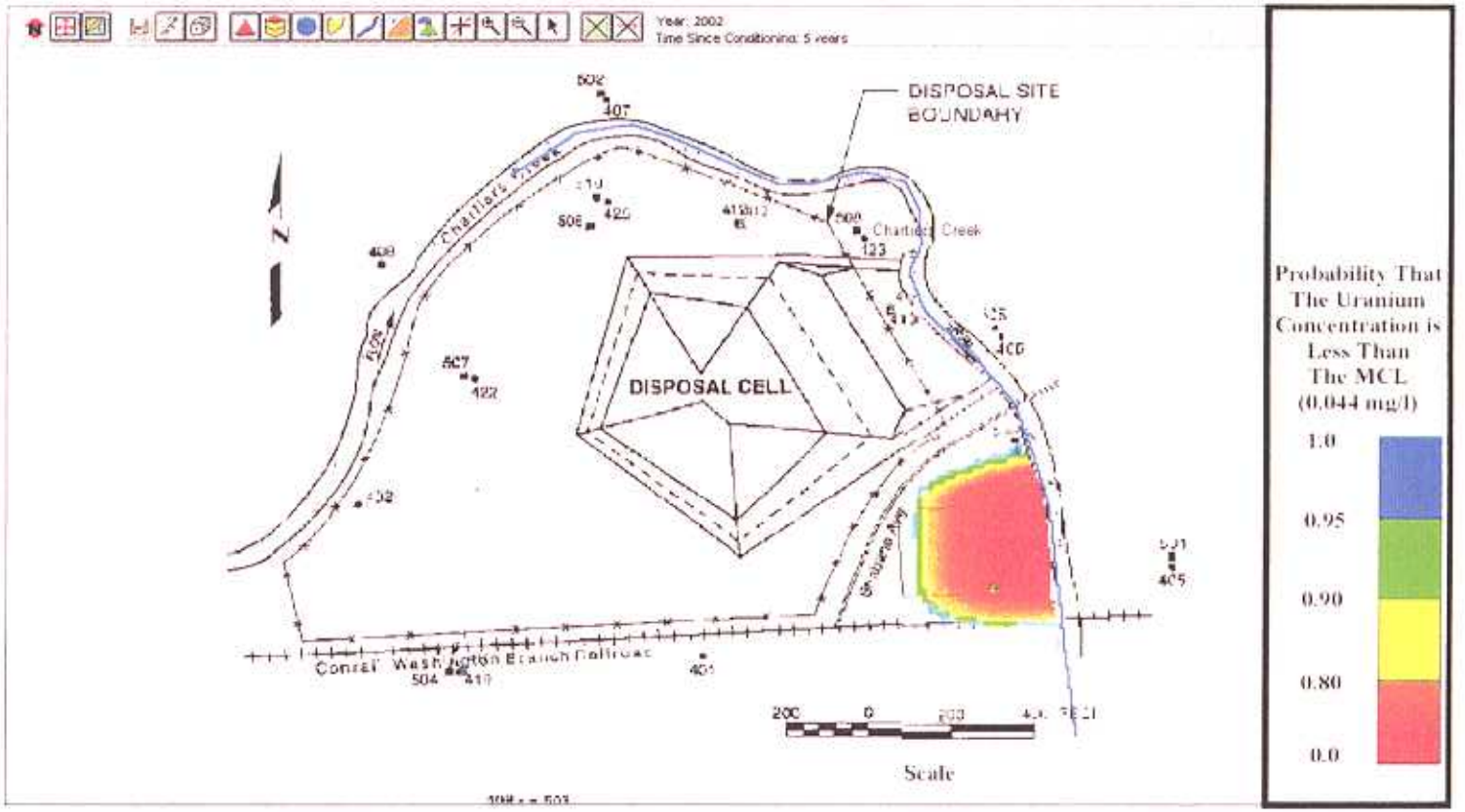


*Figure C–23 Probability That Uranium Concentrations Are Less Than the MCL in Ground Water Beneath Area C—Year 2002*

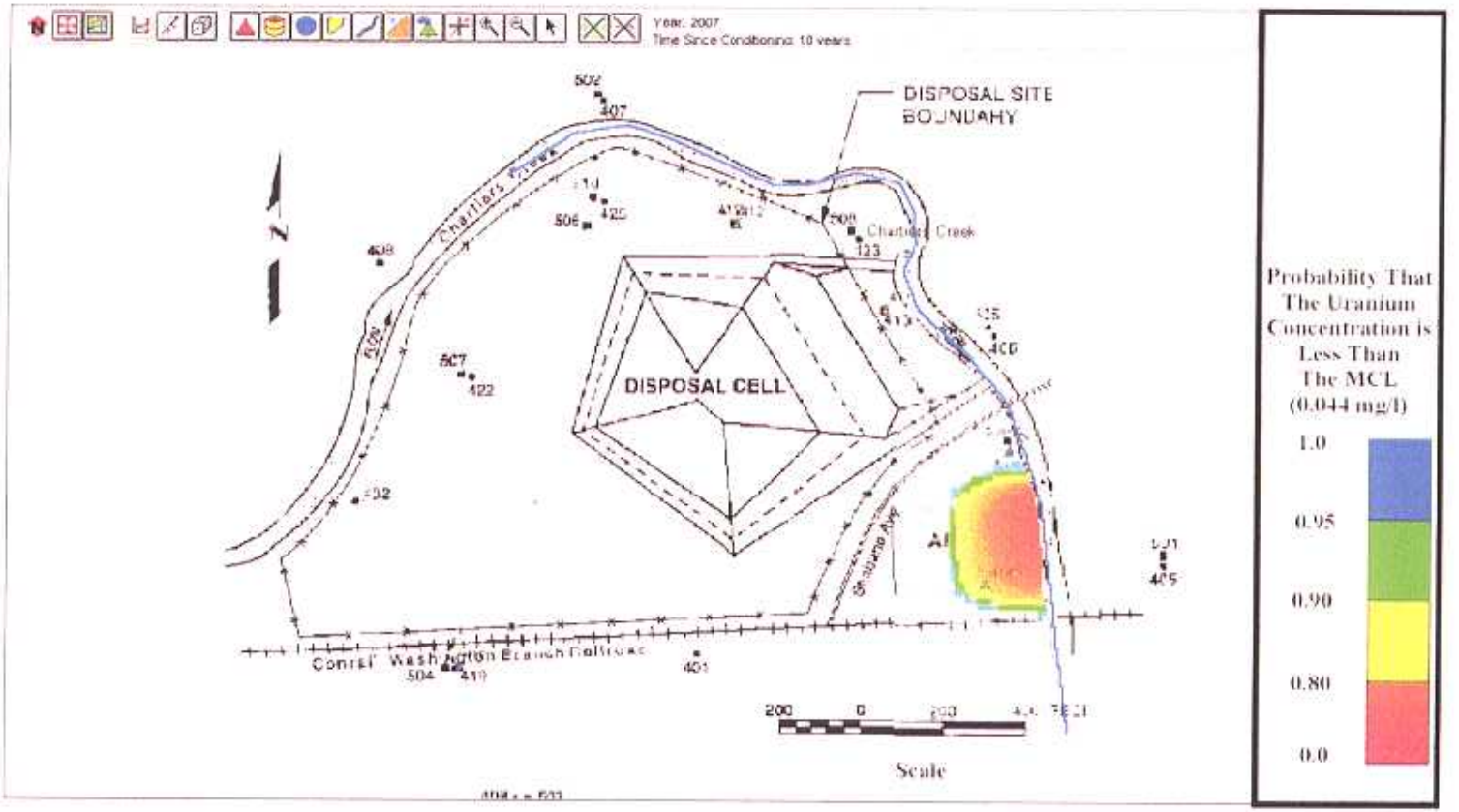


*Figure C–24. Probability That Uranium Concentrations Are Less Than the MCLin Ground Water Beneath Area C—Year 2007*

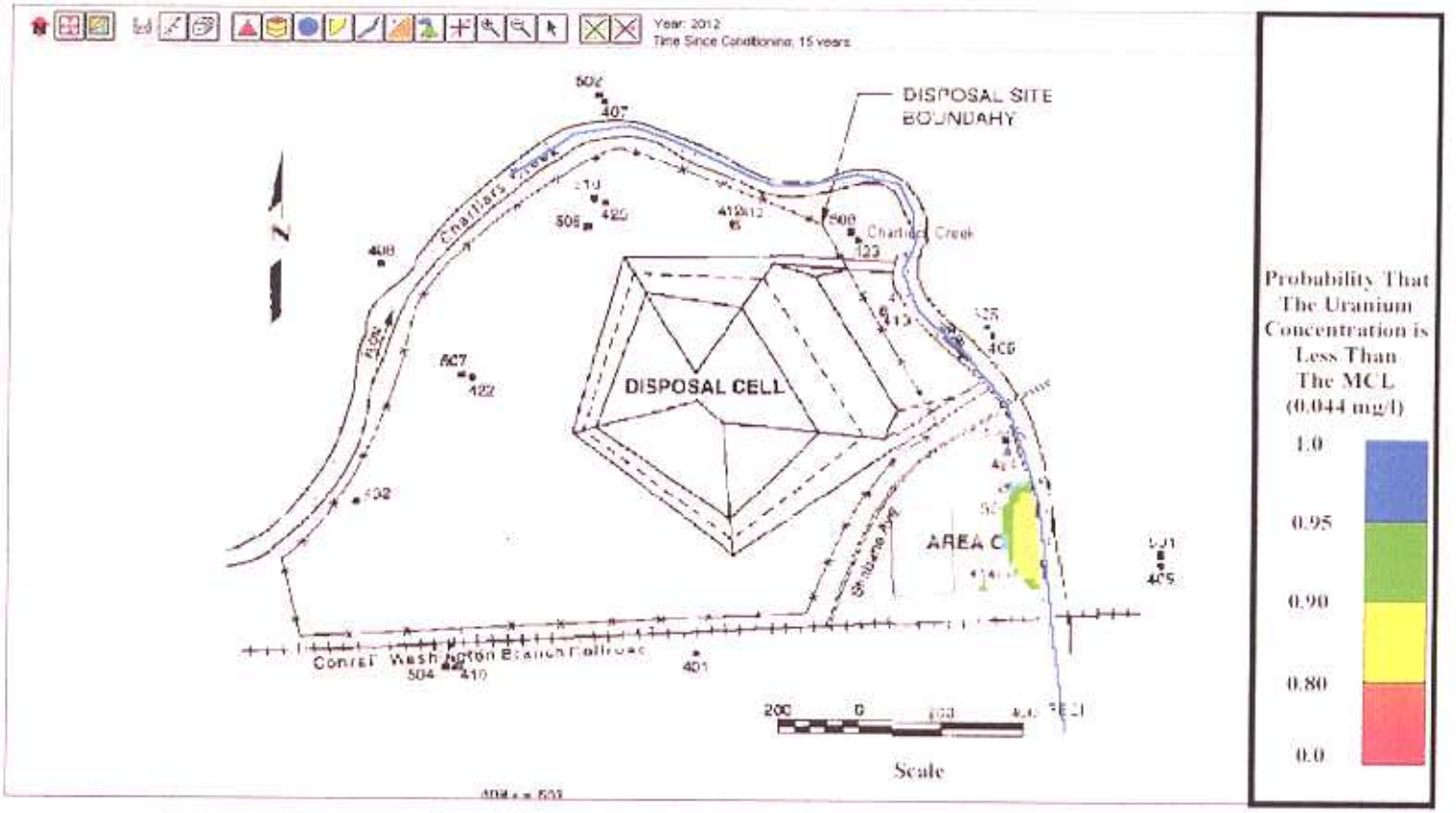


*Figure C–25. Probability That Uranium Concentrations Are Less Than the MCL in Ground Water Beneath Area C—Year 2012*

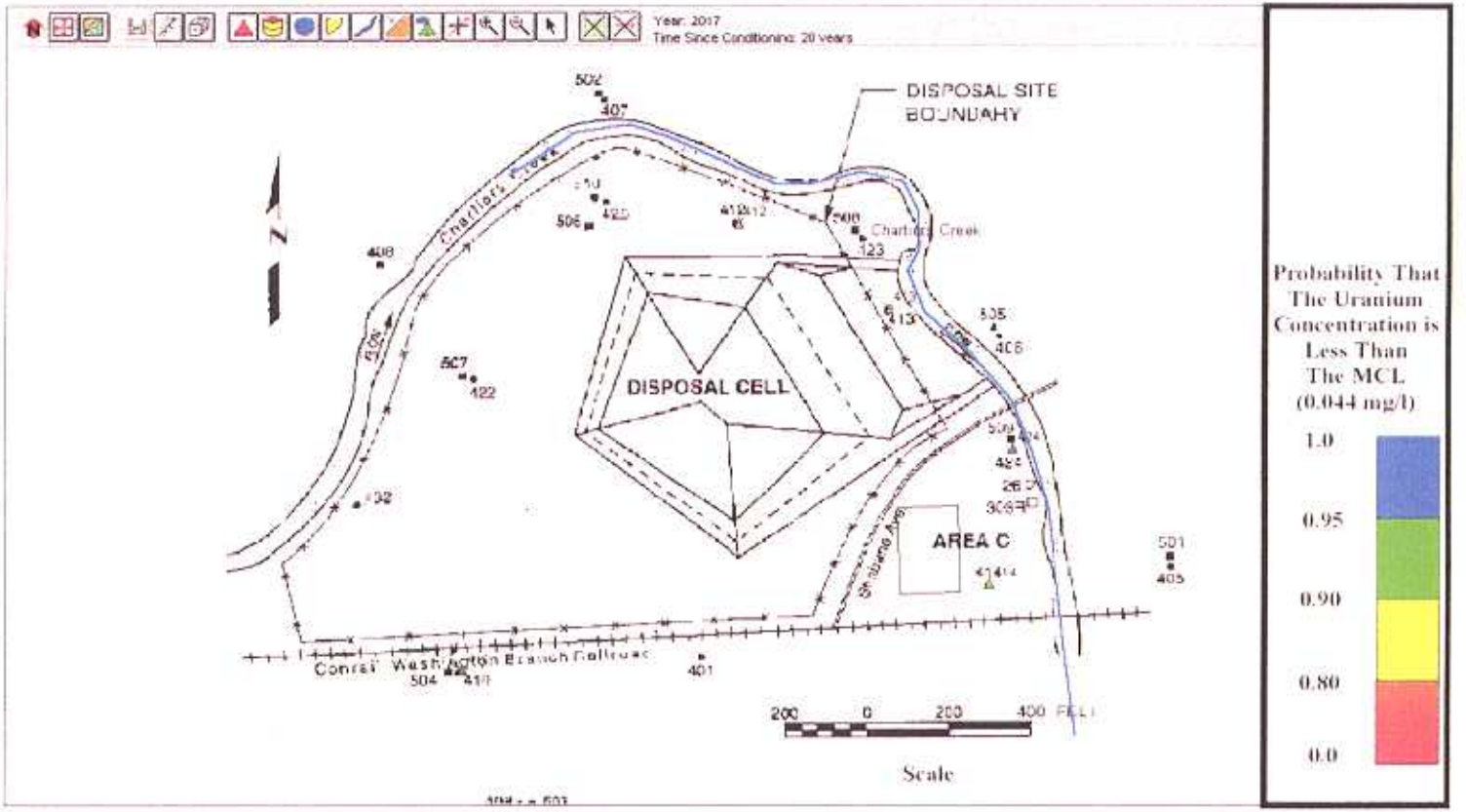


*Figure C–26 Probability That Uranium Concentrations Are Less Than the MCL in Ground Water Beneath Area C—Year 2017*

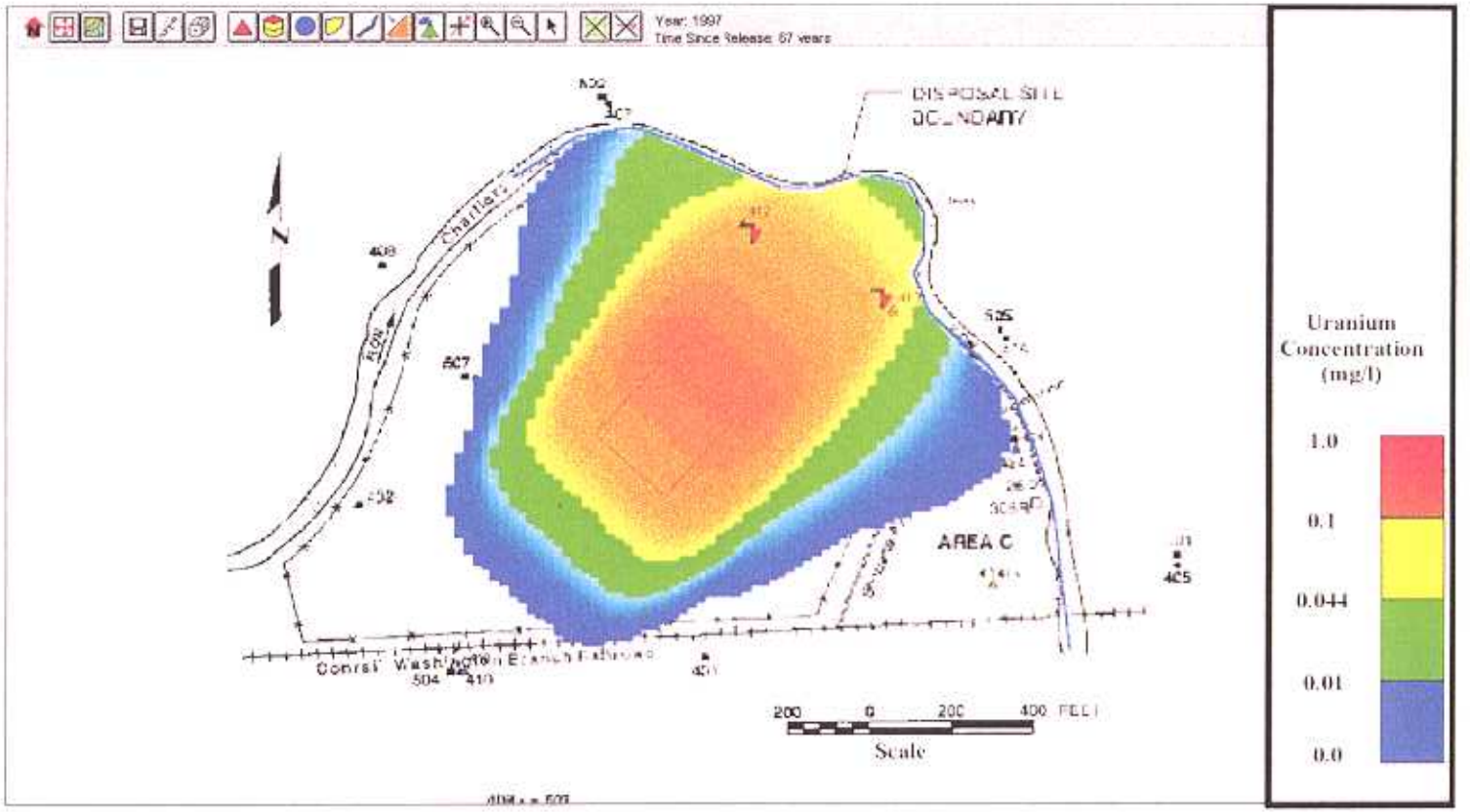


*Figure C–27. Simulated Average Uranium Concentrations in Ground Water Beneath the Main Processing Area Before the Start of Pump and Treat—Year 1997*

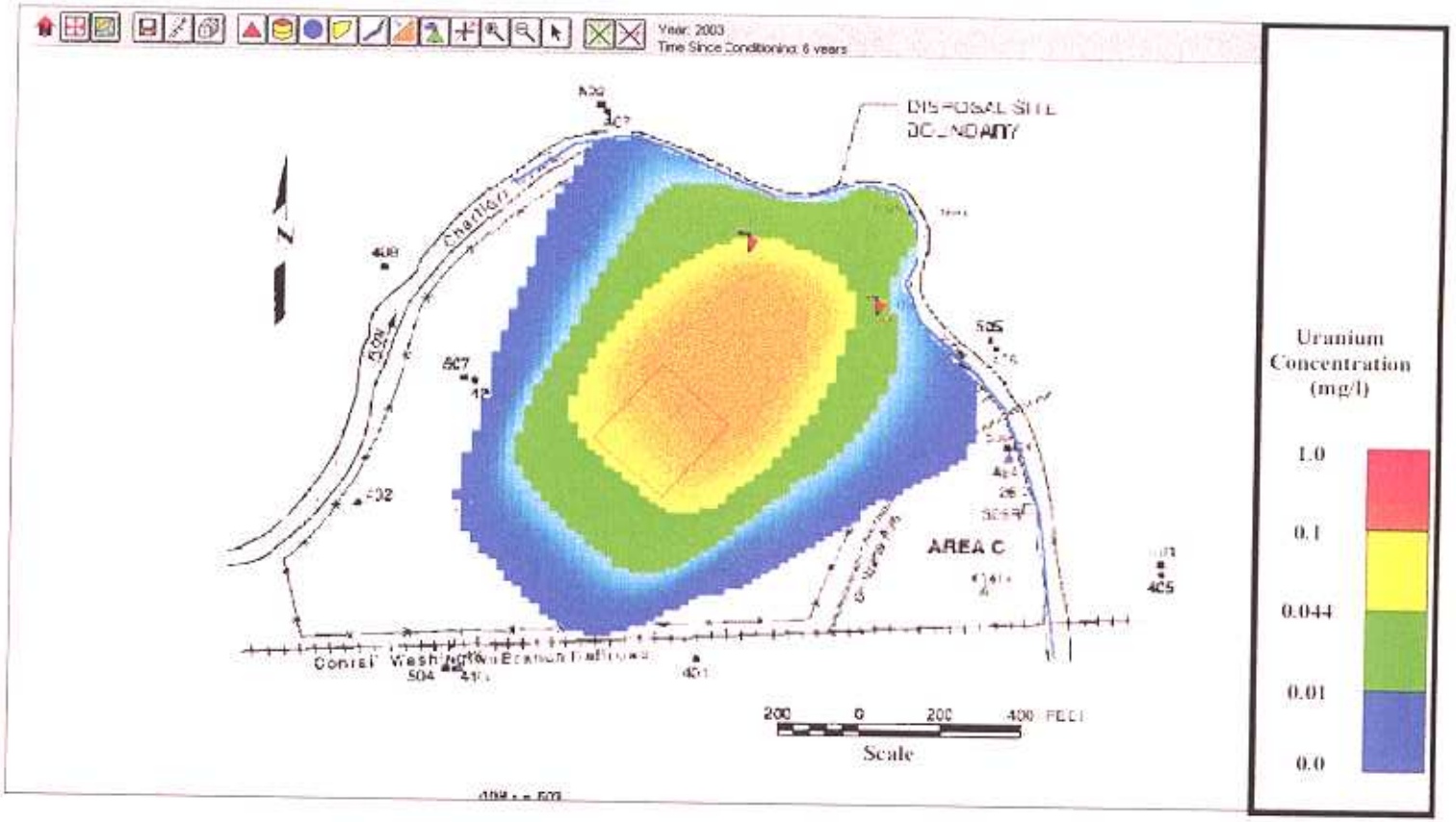


*Figure C–28. Simulated Average Uranium Concentrations in Ground Water Beneath the Main Processing Area After 5 Years of Pump and Treat—Year 2003*

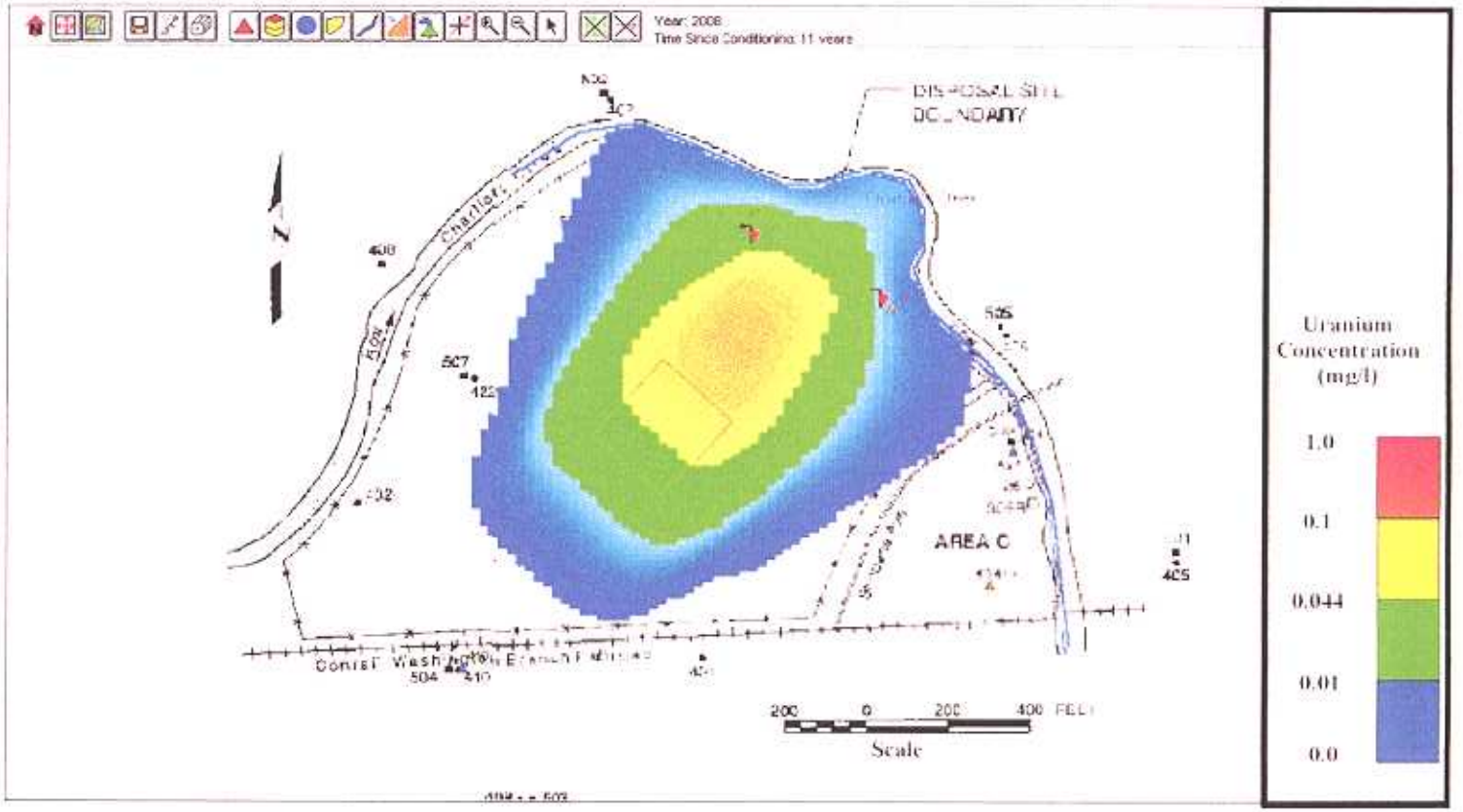


*Figure C–29. Simulated Average Uranium Concentrations in Ground Water Beneath the Main Tailings Area After 10 Years of Pump and Treat—Year 2008*

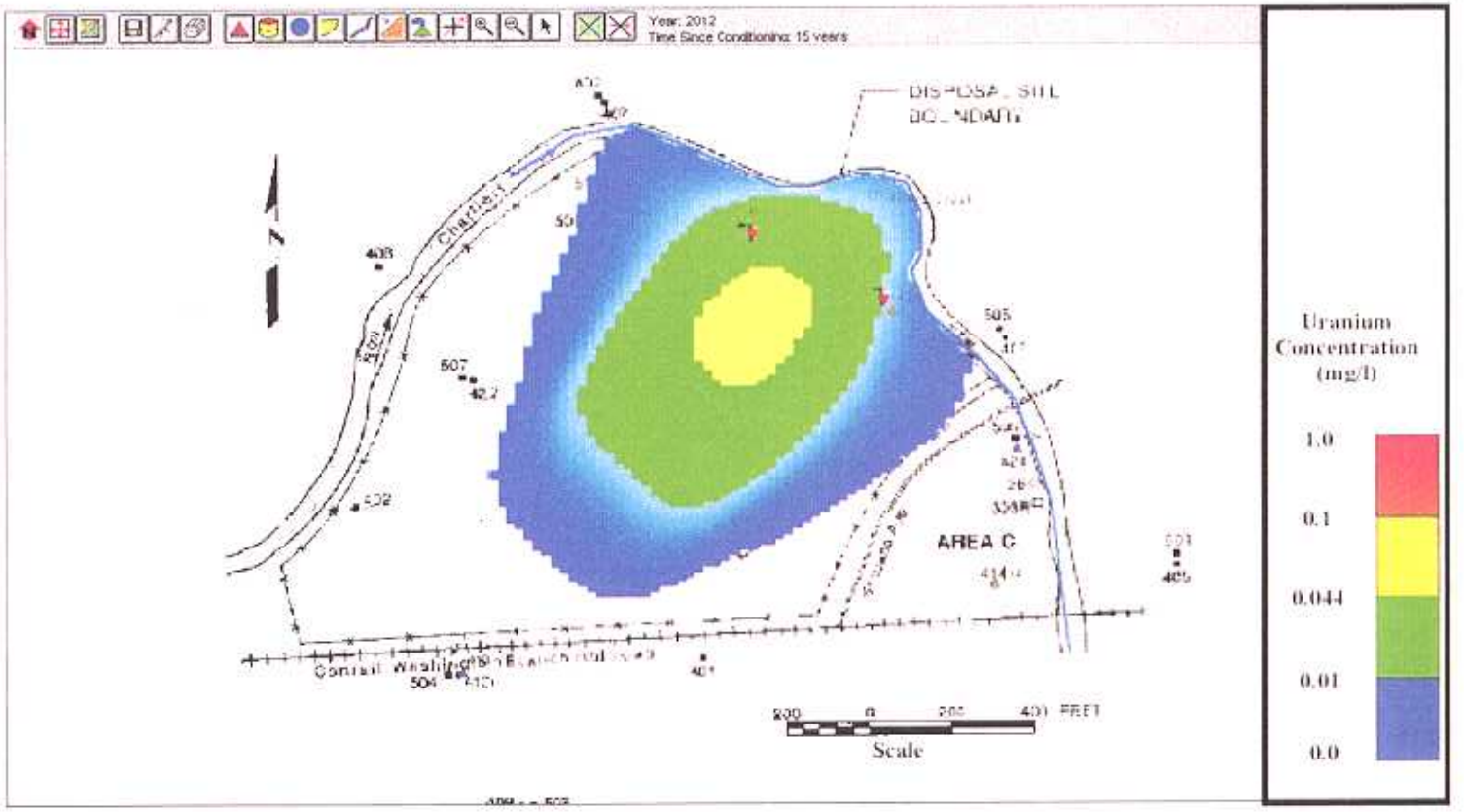


*Figure C–30. Simulated Average Uranium Concentrations in Ground Water Beneath the Main Processing Area 5 Years After Cessation of a 10-Year Pump-and-Treat Scenario—Year 2013*

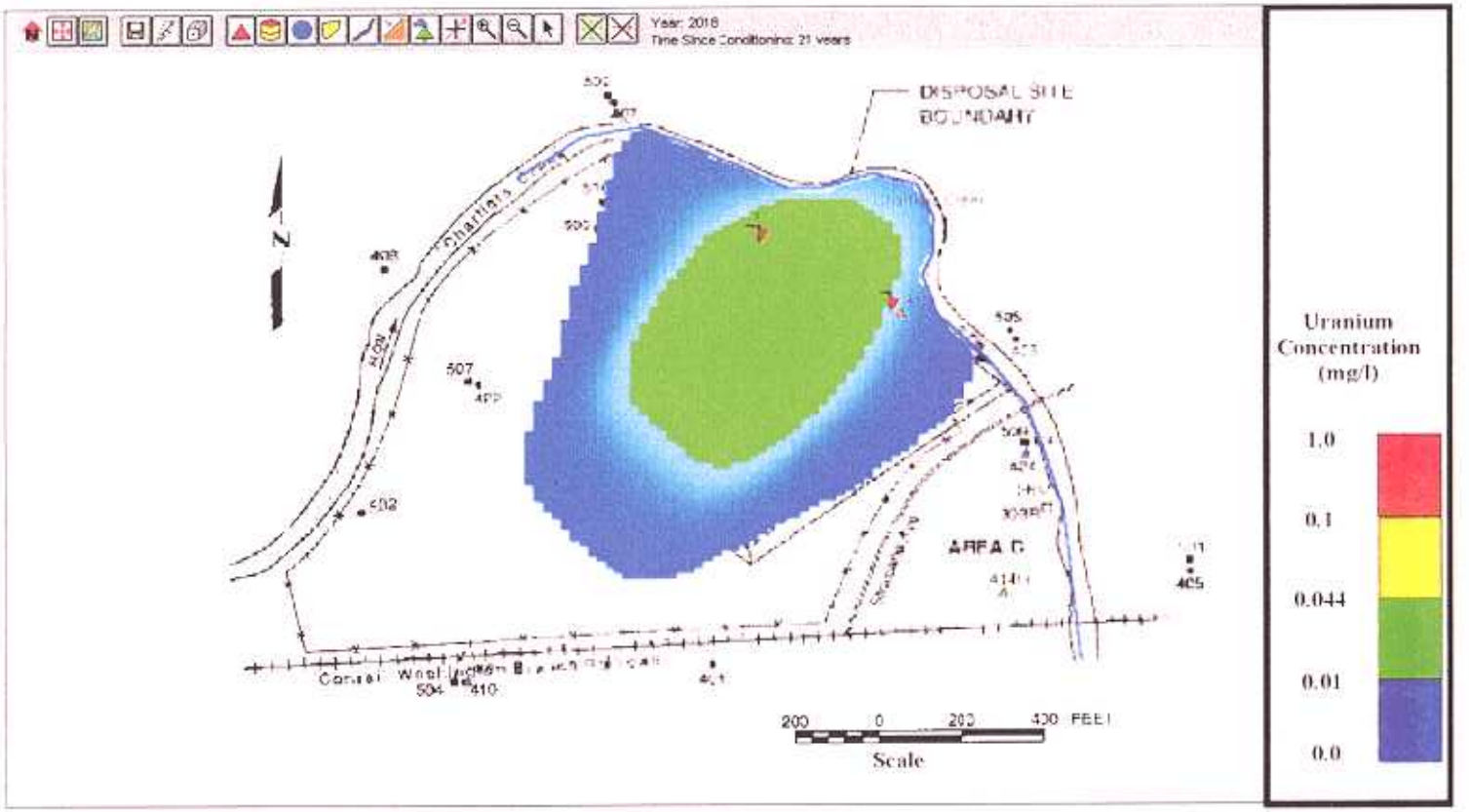


*Figure C–31. Simulated Average Uranium Concentrations in Ground Water Beneath the Main Processing Area 10 Years After Cessation of a 10-Year Pump-and-Treat Scenario—Year 2018*

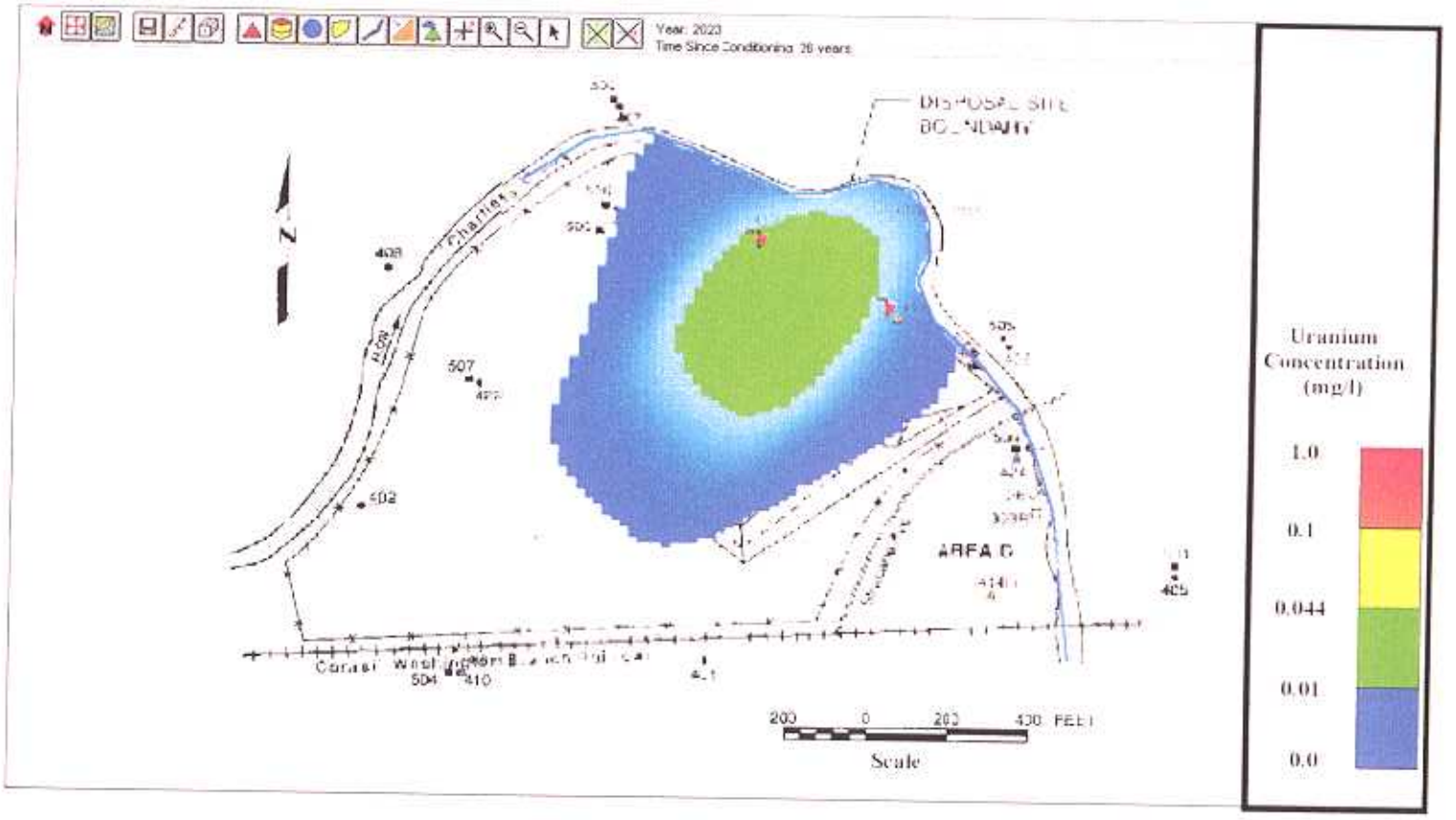


*Figure C–32. Simulated Average Uranium Concentrations in Ground Water Beneath the Main Processing Area 15 Years After Cessation of a 10-Year Pump-and-Treat Scenario—Year 2023*

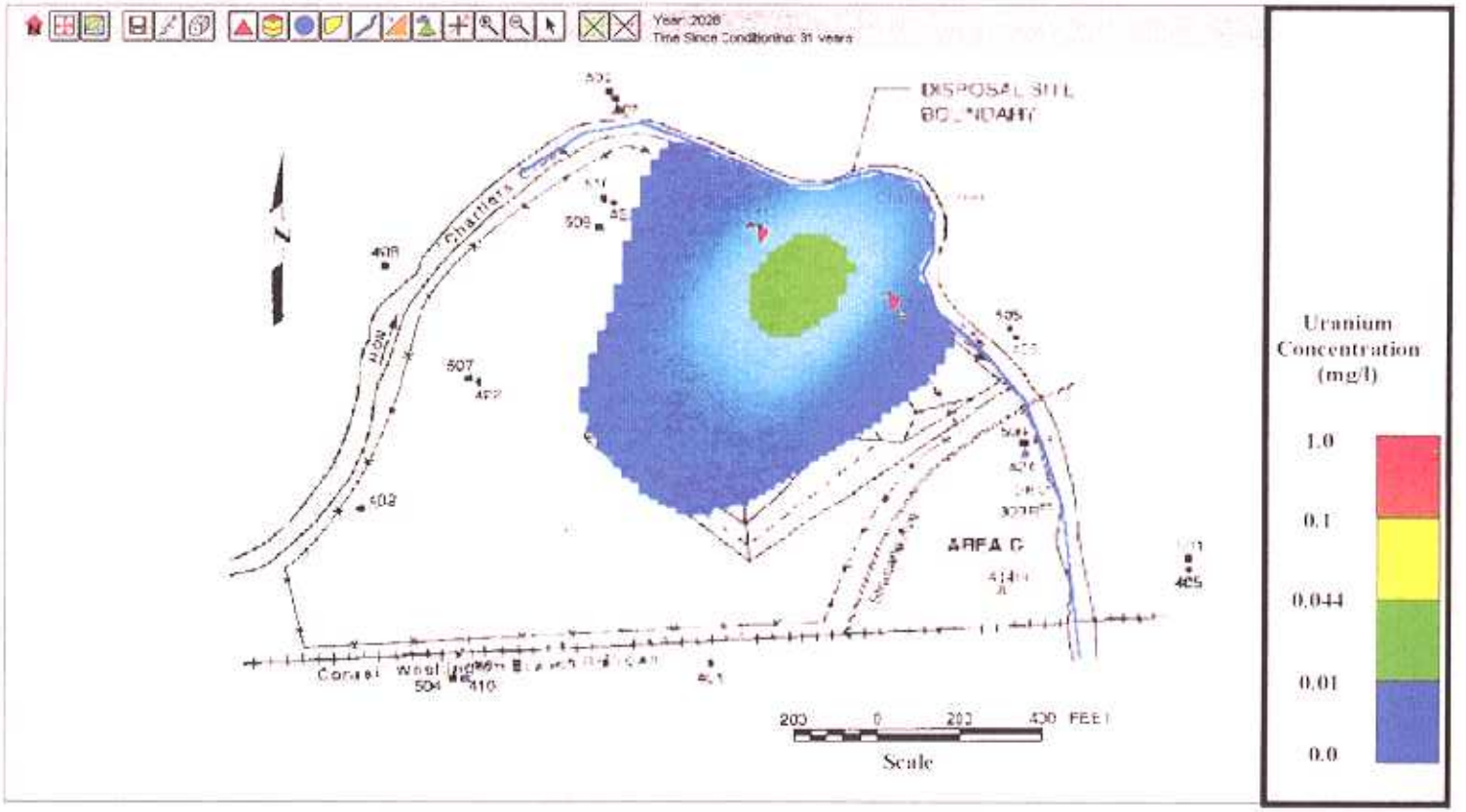


*Figure C–33. Simulated Average Uranium Concentrations in Ground Water Beneath the Main Processing Area 20 Years After Cessation of a 10-Year Pump-and-Treat Scenario—Year 2028*

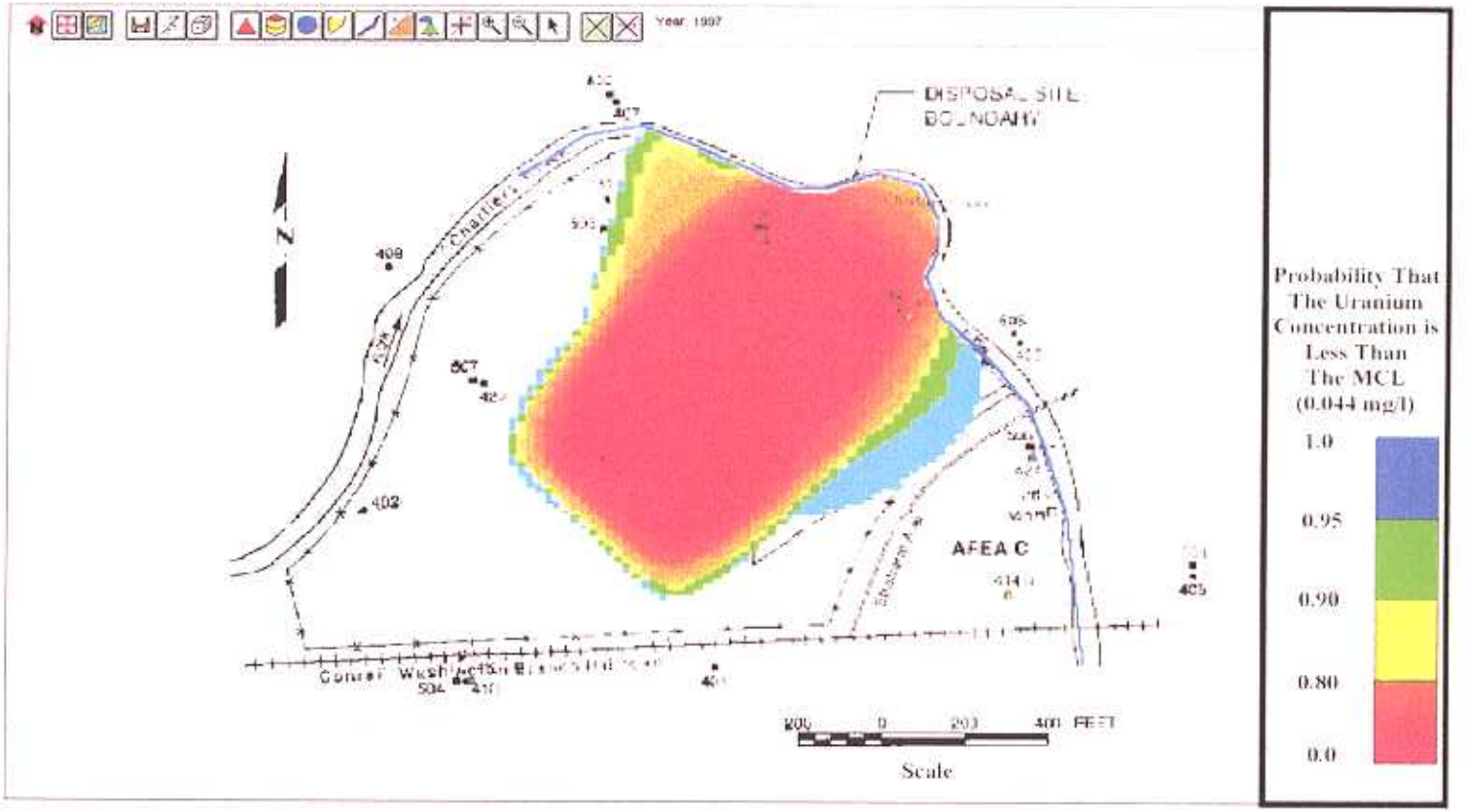


*Figure C–34. Probability That Uranium Concentrations Are Less Than the MCL in Ground Water Beneath the Main Processing Area Before the Start of Pump and Treat—Year 1997*

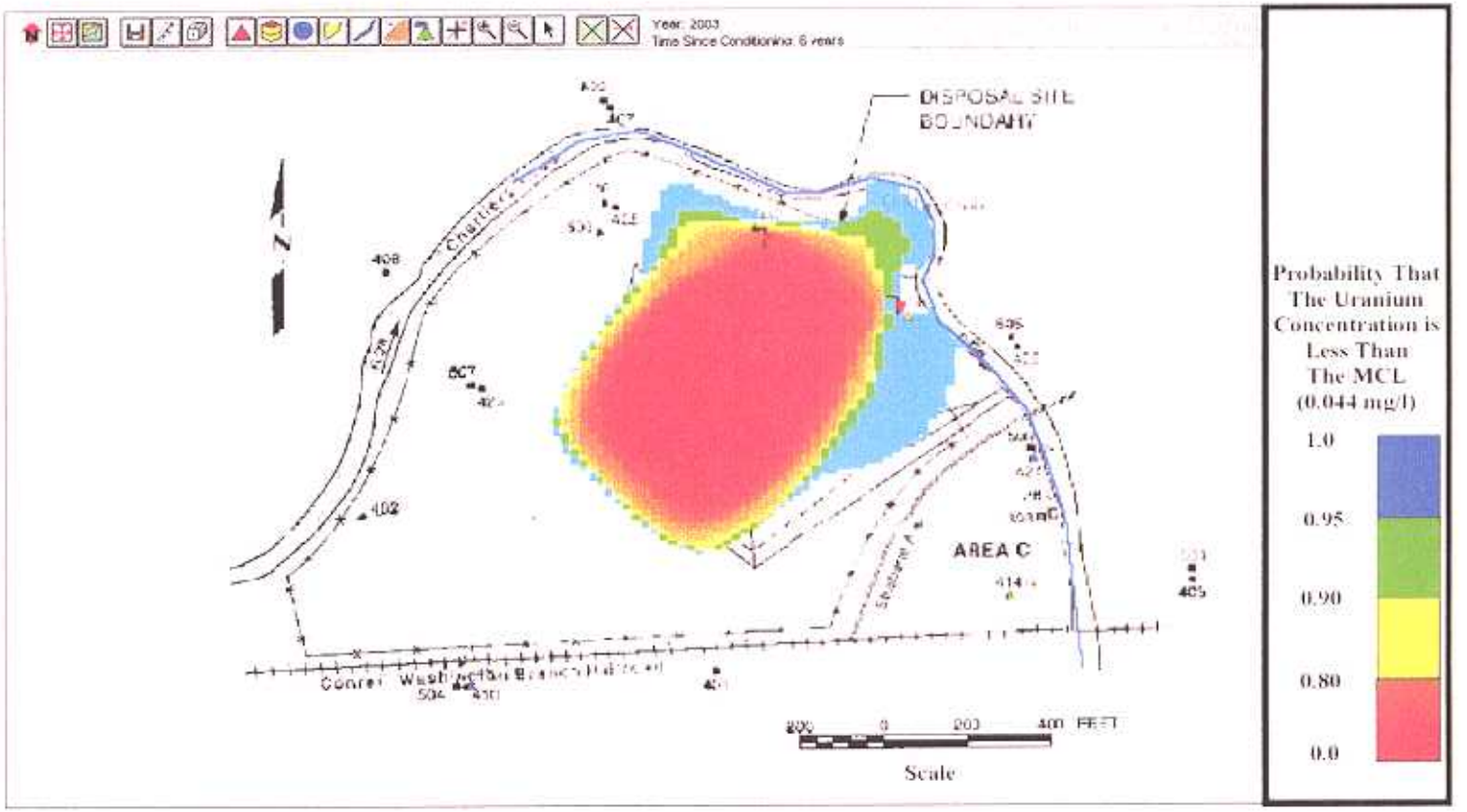


*Figure C–35. Probability That Uranium Concentrations Are Less Than the MCL in Ground Water Beneath the Main Processing 5 Years After the Start of Pump and Treat—Year 2003*

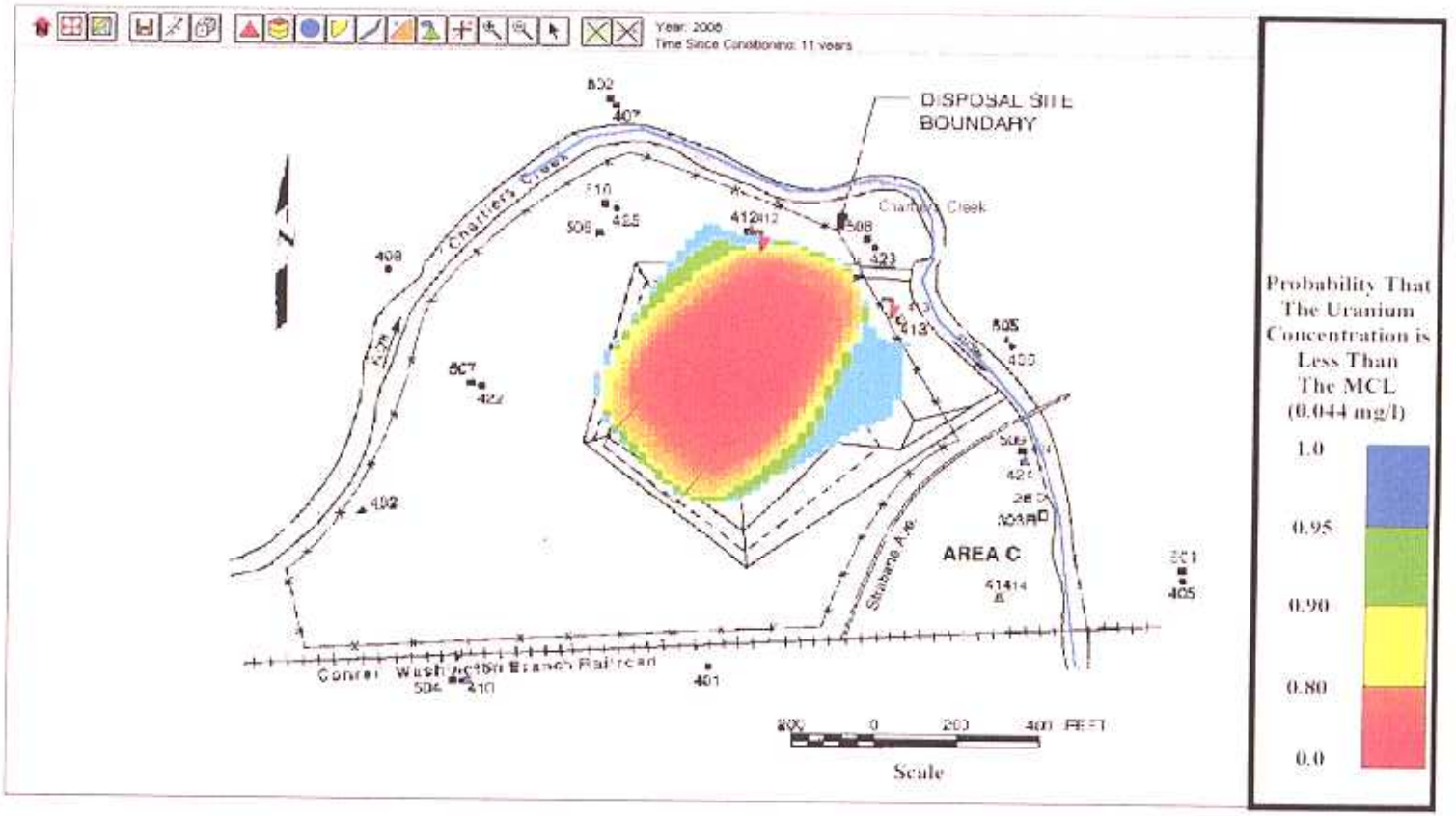


*Figure C–36. Probability That Uranium Concentrations Are Less Than the MCL in Ground Water Beneath the Main Processing Area 10 Years After the Start of Pump and Treat—Year 2008*

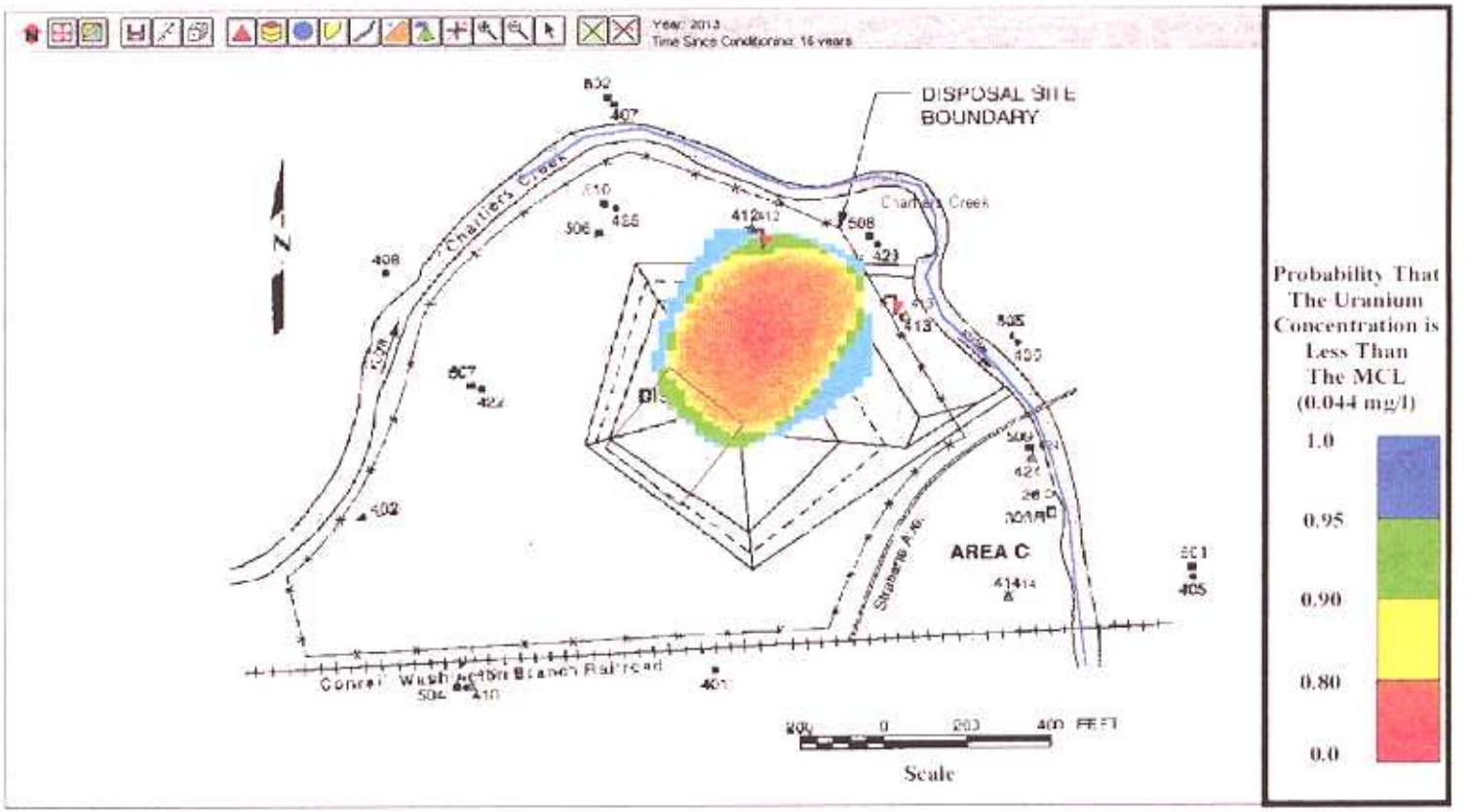


*Figure C–37. Probability That Uranium Concentrations Are Less Than the MCL in Ground Water Beneath the Main Processings Area 5 Years After Cessation of a 10-Year Pump-and-Treat Scenario—Year 2013*

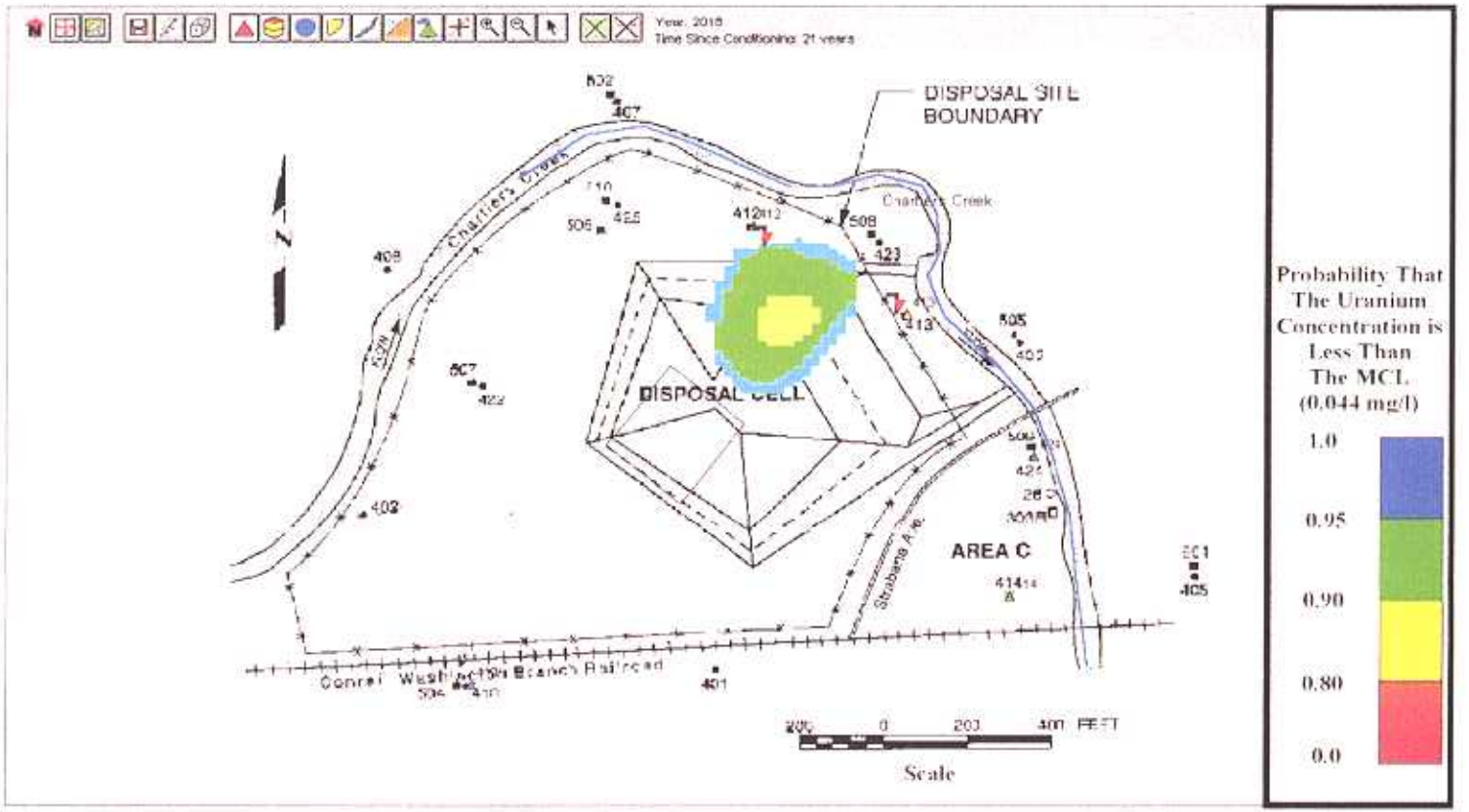


*Figure C–38. Probability That Uranium Concentrations Are Less Than the MCL in Ground Water Beneath the Main Processing Area 10 Years After Cessation of a 10-Year Pump-and-Treat Scenario—Year 2018*

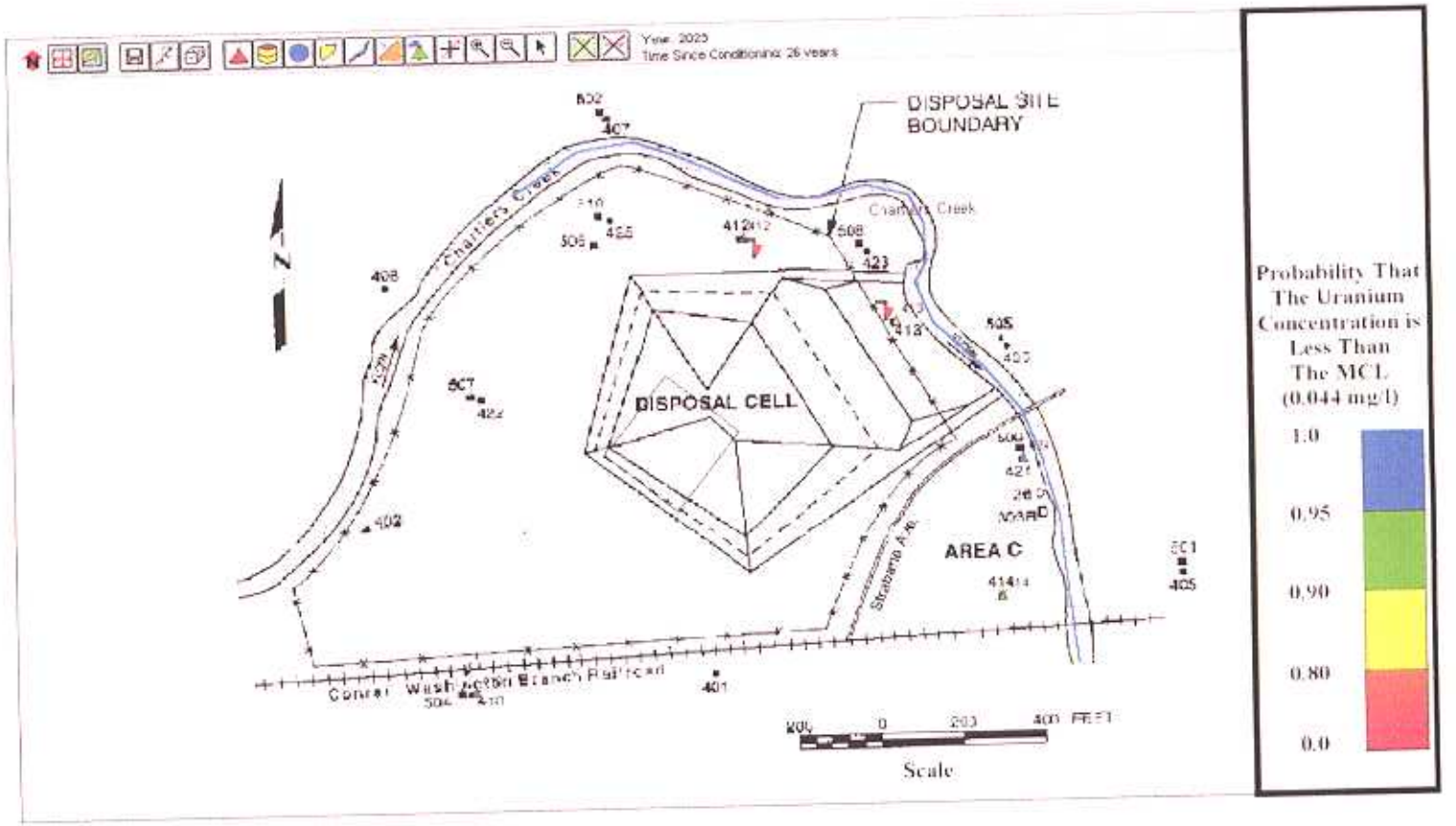


*Figure C–39. Probability That Uranium Concentrations Are Less Than the MCL in Ground Water Beneath the Main Processings Area 15 Years After Cessation of a 10-Year Pump-and-Treat Scenario—Year 2023*

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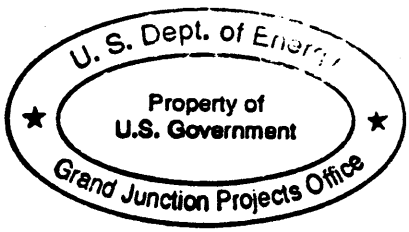
# BASELINE RISK ASSESSMENT OF GROUND WATER CONTAMINATION AT THE URANIUM MILL TAILINGS SITE NEAR CANONSBURG, PENNSYLVANIA

November 1995

Prepared for
U.S. Department of Energy
Environmental Restoration Division
UMTRA Project Team
Albuquerque, New Mexico

Prepared by
Jacobs Engineering Group Inc.
Albuquerque, New Mexico

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# CITIZENS' SUMMARY

## INTRODUCTION

The Uranium Mill Tailings Remedial Action (UMTRA) Project consists of two phases. Phase I is the Surface Project, and phase II is the Ground Water Project.

For the UMTRA Project site located near Canonsburg, Pennsylvania (the Canonsburg site), the Surface Project cleanup occurred from 1983 to 1985, and involved removing the uranium processing mill tailings and radioactively contaminated soils and materials from their original locations and placing them in a disposal cell located on the former Canonsburg uranium mill site. This disposal cell is designed to minimize radiation emissions and further contamination of ground water beneath the site.

The Ground Water Project will evaluate the nature and the extent of ground water contamination resulting from uranium processing at the former Canonsburg uranium mill site, and will determine a ground water strategy for complying with the U.S. Environmental Protection Agency's (EPA) ground water standards established for the UMTRA Project. This ground water strategy must protect public health and the environment from radiological and nonradiological hazards. A risk assessment is one of the tools used to evaluate these hazards.

A risk assessment describes the source of uranium processing contamination and shows how people and the environment could be exposed to the contamination. As part of the risk assessment, the amount of contamination exposure is calculated and the result is used to characterize the possible public health or environmental effects that could result from this exposure.

The Canonsburg site consists of the disposal site area and Area C. Access to the disposal site area has been permanently restricted so Area C is the only part of the Canonsburg site being considered for future public use. Consequently, the potential health risk resulting from possible use of ground water beneath only Area C have been evaluated. Thus, when reference is made to "the Canonsburg site," the term "site" refers to Area C.

For the Canonsburg site, an evaluation was made to determine whether exposure to ground water contaminated by uranium processing could affect people's health. This exposure could occur from drinking water pumped from a hypothetical well drilled in the contaminated ground water area. Risks to public health and the environment could also result from people, plants, or animals being exposed to any surface water that has mixed with the contaminated ground water.

This risk assessment report is the first site-specific document prepared for the UMTRA Ground Water Project at the Canonsburg site. The results of this report and further site characterization of the Canonsburg site will be used to determine how to protect public health and the environment, and how to comply with the EPA standards.

## RISK SUMMARY

There are currently no human health risks associated with the contaminated ground water at the Canonsburg site because no one is using the water for domestic purposes. In addition, no one is using the contaminated ground water for irrigation. This favorable risk situation will continue if land and water uses on the site do not change. Changes of land and water uses may or may not create future human health and environmental risks. When specific future land and water uses are determined for the Canonsburg site, these uses should be evaluated to identify potential health and environmental risks from the contaminated ground water.

Contaminated ground water probably discharges into Chartiers Creek. However, swimming, fishing, or wading would not be considered as human health risks because the contamination is diluted by the flowing creek water to near background levels.

Because future land and water uses at the Canonsburg site are not known, this risk assessment evaluates a hypothetical worst-case future scenario of a hypothetical well drilled in the most contaminated portion of the aquifer beneath the Canonsburg site. In this hypothetical future scenario, the hypothetical water well would be the only source of drinking water for people and wildlife, and the only source of water for crop irrigation. Drinking this contaminated ground water could cause health problems for these people. Crops could also be harmed by the contaminated ground water. Based on the findings of this risk assessment, the contaminated ground water beneath the Canonsburg site should not be used. In addition, before any other Canonsburg site ground water is used, its possible effects should first be evaluated.

## GROUND WATER QUALITY

### Background ground water quality

Background ground water quality is the quality of water that would exist in the Canonsburg site area if uranium milling had never occurred. Ground water occurs in the uppermost aquifer (the upper aquifer) at approximately 3 feet (ft) (1 meter [m]) beneath the land surface. The upper aquifer consists of a sequence of unconsolidated materials overlying shallow bedrock and is underlined by a deep bedrock aquifer. Within the upper aquifer, ground water in the unconsolidated materials moves into the shallow bedrock through cracks in the rock, but it does not move into the deep bedrock aquifer because these two aquifers are separated by a low permeability rock formation. The upper aquifer is not considered a potable water resource, because it contains very little water and the water quality is naturally poor. Potable water is obtained from surface water sources or from ground water at depths greater than 100 ft (30 m) below the ground surface.

### Site-related ground water quality

The main contaminants in ground water in the upper aquifer beneath the Canonsburg site are manganese, molybdenum, and uranium. The contamination appears to be confined within the area bordered by Chartiers Creek. If any contaminated ground water discharges into Chartiers Creek, it is quickly diluted to near background levels.

## HUMAN HEALTH RISK ASSESSMENT

### Methods

A risk assessment begins by identifying constituents present in ground water contaminated by the uranium milling process. First, water quality in wells drilled on the Canonsburg site is compared to water quality in wells from the background area. Second, possible human health problems resulting from drinking the water containing these constituents are evaluated. Factors such as eating garden produce irrigated with this water, incidental ingestion of water and sediment while swimming in the Chartiers Creek, or consumption of fish from the creek are also considered.

This risk assessment evaluates both current and possible future health risks. To evaluate possible current risks, it must be determined whether anyone is now drinking the contaminated ground water or swimming, wading, or fishing in the Chartiers Creek. To evaluate possible future human risks, it is assumed that the sole source of water for drinking or irrigating is from a hypothetical well drilled in the most contaminated area beneath the Canonsburg site.

Health risks, other than cancer, were evaluated for children because the ratio of contaminants to body weight is the greatest for children. Children 1 to 10 years old are the most likely population group to experience health problems from drinking contaminated water. To estimate cancer risks, a lifetime exposure was assumed and these risks were evaluated for adults.

Possible health effects vary in seriousness because of several factors. The levels of contaminants in ground water vary from one well sampling to the next; people vary in their body weight, how much water they drink, and how their body reacts to chemical exposure. Whenever possible, all of these differences are considered in this risk assessment.

This risk assessment provides a series of graphs showing the different exposure levels that might occur and the most current scientific information on the types of health effects that may result from this hypothetical exposure.

### Results

No drinking water or irrigation wells exist in the contaminated ground water beneath the Canonsburg site. Therefore, there are currently no associated health problems because no one uses this ground water for these purposes. This favorable situation will remain the same in the future if there are no changes in land and water uses at the Canonsburg site. Furthermore, based on existing data, no health problems would be expected to occur from people swimming or wading in Chartiers Creek, or from people eating fish caught in the creek.

Additionally, in the future, it is unlikely that people will ever use the contaminated ground water for drinking. The upper aquifer is not considered as a potable water resource in the

Canonsburg site area, and good quality water is available from the municipal water supply system.

If anyone used the contaminated ground water for drinking, based on the concentration of contaminants found in the most contaminated wells, there are possible human health risks. Table CS.1 provides information on the nature of possible health problems that could be expected.

**Table CS.1 Hypothetical future human health effects from drinking contaminated ground water from the Canonsburg site**

| | Possible effects from drinking water from the upper aquifer[a] | |
|---|---|---|
| **Contaminant** | **Short-term** | **Long-term** |
| Manganese | None | Neurological symptoms include memory loss, irritability, muscle rigidity, tremors. |
| Molybdenum | None | None |
| Uranium | None | None |

[a]The effects could vary from person to person depending on the amount of water a person drinks, body weight, dietary habits, and individual sensitivities such as the preexisting kidney, liver, or heart diseases, and other factors.

Only people whose sole source of drinking water comes from a hypothetical well placed in the most contaminated ground water could be expected to experience the health problems described in Table CS.1. Consequently, the table provides the upper limit of possible risks; real future risks would probably be lower.

Manganese is the only possible health hazard in the contaminated ground water of the upper aquifer. Manganese ingestion in the amounts found in the contaminated ground water could affect the nervous system, causing memory loss, muscle rigidity, or tremors.

People's health would not be affected from eating homegrown garden produce irrigated with this water.

## ECOLOGICAL RISK ASSESSMENT

### Methods

The ecological risk assessment presented in this document is a screening level assessment that relies on limited environmental sampling and literature. The field of ecological risk assessment has many uncertainties because of limited scientific knowledge. Information is lacking on how some chemicals affect plants and animals. Also, the impact on plants and animals of a mixture of chemicals is poorly understood.

The possible effects of the contaminants on wildlife and agricultural crops are being evaluated. This evaluation is done by comparing the concentration values of contaminants in the most contaminated ground water from the upper aquifer with available guideline values from regulatory agencies and related literature. The contaminants present in surface water and in sediment from Chartiers Creek are evaluated because the Canonsburg site contaminated ground water discharges into Chartiers Creek. The assumption that plant roots extend into the upper aquifer and take up the most contaminated ground water from the upper aquifer is also evaluated.

### Agricultural results

There are currently no risks to crops from the contaminated ground water beneath the Canonsburg site because crops are not irrigated with that water. If, in the future, the ground water beneath the most contaminated part of the Canonsburg site were used as a sole irrigation water source, manganese could harm manganese-sensitive plants such as spinach and soybean.

### Ecological results

No ecological risks exist to plants at harvestable maturity whose roots may have extended into soils containing contaminated ground water.

Limited environmental sampling and available guidelines from literature and regulatory agencies were not sufficient to fully evaluate possible long-term impacts of the affected ground water or surface water on plants or animals.

## CONCLUSIONS

Ground water contamination beneath the Canonsburg site is limited to the uppermost aquifer. The contamination appears to be confined within the Canonsburg site area. Chartiers Creek probably creates a barrier for this contamination. Currently, there are no drinking water or irrigation wells drilled into the contaminated ground water at the Canonsburg site. Consequently, based on existing data, there are no current human health risks associated with the Canonsburg site contaminated ground water.

This risk assessment has determined that there could be certain health problems in people if, in the future, contaminated ground water were used for drinking. Therefore, no one should use contaminated ground water for this purpose. Crops irrigated with contaminated ground water could also be adversely affected. Consequently, contaminated ground water should not be used for irrigation.

The Canonsburg site evaluation is ongoing and will include further study of ground water quality, water levels, and ground water movement. In addition, sampling of surface water and sediment will be considered in future work plans. This risk assessment and future investigations will be used to determine how to deal with the contaminated ground water. In addition, if specific plans for land and water uses at the Canonsburg site are determined, the possible risks from those uses should be evaluated.

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# LIST OF ACRONYMS

| Acronym | Definition |
|---|---|
| ACL | alternate concentration limit |
| AEC | Atomic Energy Commission |
| BCF | bioconcentration factor |
| DOE | U.S. Department of Energy |
| EPA | U.S. Environmental Protection Agency |
| HEAST | Health Effects Assessment Summary Tables |
| IRIS | Integrated Risk Information System |
| LD | lethal dose |
| LOAEL | lowest-observed-adverse-effect level |
| MCL | maximum concentration limit |
| MSL | mean sea level |
| NCP | National Contingency Plan |
| NEPA | National Environmental Policy Act |
| NOAEL | no-observed-adverse-effect level |
| NRC | Nuclear Regulatory Commission |
| PEIS | Programmatic Environmental Impact Statement |
| Rfd | reference dose |
| TAC | technical assistance contractor |
| TDS | total dissolved solids |
| UMTRA | Uranium Mill Tailings Remedial Action |
| UMTRCA | Uranium Mill Tailings Control Act |

# 1.0 INTRODUCTION

The purpose of this baseline risk assessment is to determine whether ground water contamination at the Canonsburg, Pennsylvania, uranium processing site could adversely affect human health or the environment. The Canonsburg site is one of 24 abandoned uranium processing sites undergoing remediation in accordance with the requirements of the *Uranium Mill Tailings Radiation Control Act* (UMTRCA) of 1978 (42 USC §7901 *et seq.*) under the oversight of the U.S. Department of Energy (DOE) Uranium Mill Tailings Remedial Action (UMTRA) Project.

Under the UMTRA Surface Project, the DOE has stabilized contaminated materials in a disposal cell that minimizes radon and other radiation emissions and further contamination of ground water. Remedial action at the Canonsburg site was completed in 1985 with stabilization of tailings, contaminated materials, and soils in a disposal cell at the former uranium processing site.

This risk assessment is a baseline assessment in the sense that it describes existing ground water conditions at the site. This document evaluates the potential for public health or environmental risks related to ground water contamination that may need attention before the site is fully characterized.

The risk assessment is based on available ground water data from wells and surface water data at the processing site. Major exposure pathways have been identified and thoroughly examined for this risk assessment.

This risk assessment follows the basic framework outlined by the U.S. Environmental Protection Agency (EPA) (1989a) for evaluating hazardous waste sites to assess potential health and environmental impacts. The risk assessment process consists of the following steps:

- Contamination characterization and data evaluation.
  - Selecting chemical data for the risk assessment.
  - Comparing sample results with background data.
  - Selecting chemicals of potential concern.
  - Discussing contaminant fate and transport.
- Exposure assessment.
  - Characterizing exposure settings.
  - Identifying exposure pathways.
  - Identifying potentially exposed populations.
  - Quantifying exposures.

- Toxicity assessment.
  - Identifying toxicity values.
  - Evaluating noncarcinogenic effects of chemicals.
  - Evaluating carcinogenic effects of radionuclides and chemical carcinogens.
- Public health risk characterization.
  - Comparing toxicity ranges with predicted exposure ranges.
  - Combining risks across exposure pathways and multiple contaminants.
  - Characterizing noncarcinogenic and carcinogenic risks.
- Environmental risk.
  - Characterizing potential biota exposure pathways.
  - Identifying potential ecological receptors.
  - Evaluating environmental risk qualitatively.

The framework is incorporated in the methodology developed to evaluate current human health risks at UMTRA Project sites and to estimate risks from potential future use of contaminated ground water or surface water near the former uranium processing site (DOE, 1994).

This risk assessment will support decisions made for the UMTRA Ground Water Project. The DOE was authorized to conduct ground water remediation under the UMTRCA Amendments Act (42 USC §7922 *et seq.*) and will determine site-specific ground water compliance strategies for each site. This risk assessment provides information to assist in determining the site-specific ground water compliance strategy for the Canonsburg site.

# 2.0 SITE DESCRIPTION

The Canonsburg site is in the southwestern corner of the borough of Canonsburg, Washington County, in southwestern Pennsylvania. The site lies approximately 20 miles (mi) (30 kilometers [km]) southwest of downtown Pittsburgh (Figure 2.1) in a mixed commercial/residential area and comprises approximately 30 acres (ac) (12 hectares [ha]). The Canonsburg site is bounded by Chartiers Creek to the west, north, and east and by Conrail railroad tracks to the south (Figure 2.2).

## 2.1 SITE BACKGROUND

In the early 1900s, the Standard Chemical Company developed a method to extract and concentrate radium from carnotite ore. The company established its radium processing facilities at Canonsburg, Pennsylvania, and produced the first marketable quantities of radium in 1913. The company ceased processing operations in the early 1920s (DOE, 1983a,b).

The Vitro Manufacturing Company purchased the Canonsburg facility in 1933 to extract uranium, vanadium, and radium from various ores, concentrates, and residues. From 1942 until the facility's closing in 1957, the operations focused on producing uranium concentrates. The only customer during this period was the U.S. Government. The uranium, and other rare metals, were extracted from both company-owned and government-owned ores, concentrates, and residues. Ores, concentrates, and scrap materials were brought from a number of Atomic Energy Commission (AEC) installations to the Canonsburg site for uranium recovery. All solid process wastes were stored temporarily on the Canonsburg site. The liquid process wastes were discharged into the former swamp in Area C, which subsequently drained into Chartiers Creek. Area C has since been cleaned up to unrestricted use criteria in accordance with EPA regulations (MK-F, 1986). The area is backfilled with clean soil.

On 1 November 1953 the U.S. Government and the Vitro Corporation entered into a contract requiring Vitro to process certain government-owned materials. The contract required Vitro to store the residues from this operation until 1 November 1955, because the AEC believed the residues might contain recoverable uranium. After attempts by the AEC to identify commercial interest in the material, the uranium in the residue was deemed "unrecoverable" and the AEC approved the transfer of 11,600 tons (10,500 tonnes) of material to the Burrell site, which is about 50 mi (80 km) northeast of the Canonsburg site. This material contained approximately 6 tons (5.4 tonnes) of uranium oxide and was transported to the Burrell site during late 1956 and early 1957.

Recovery operations at the Vitro plant ceased by 1957. Vitro stored the remaining residues and processing wastes on the site. Vitro's final source-material license expired, and in May 1961, Vitro applied to the AEC for another source-material license. On 21 June 1961 the AEC granted Vitro a license for

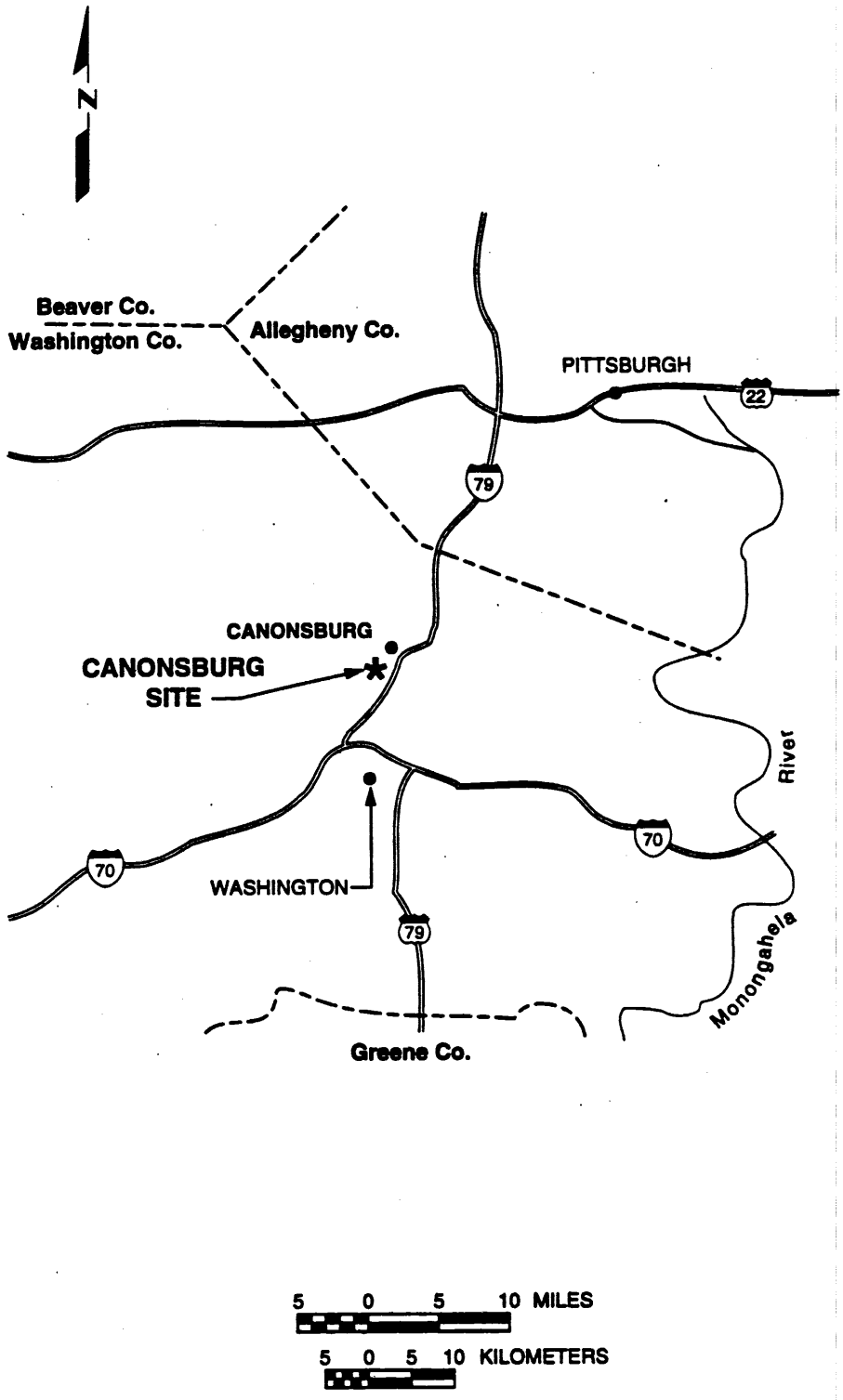



**FIGURE 2.1**
**CANONSBURG, PENNSYLVANIA, SITE**

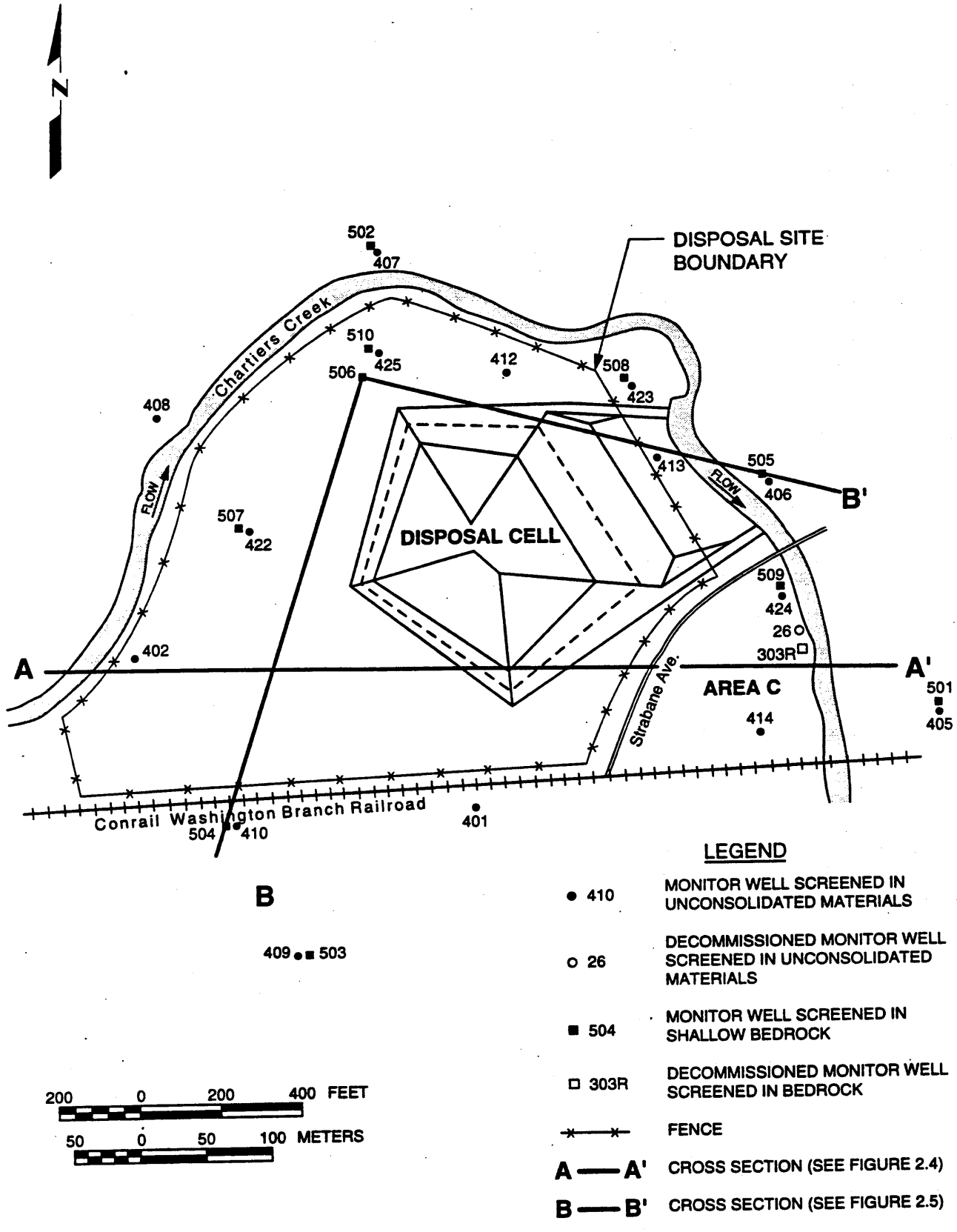



**FIGURE 2.2**
**SITE MAP SHOWING LOCATION OF MONITOR WELLS**
**CANONSBURG, PENNSYLVANIA, SITE**

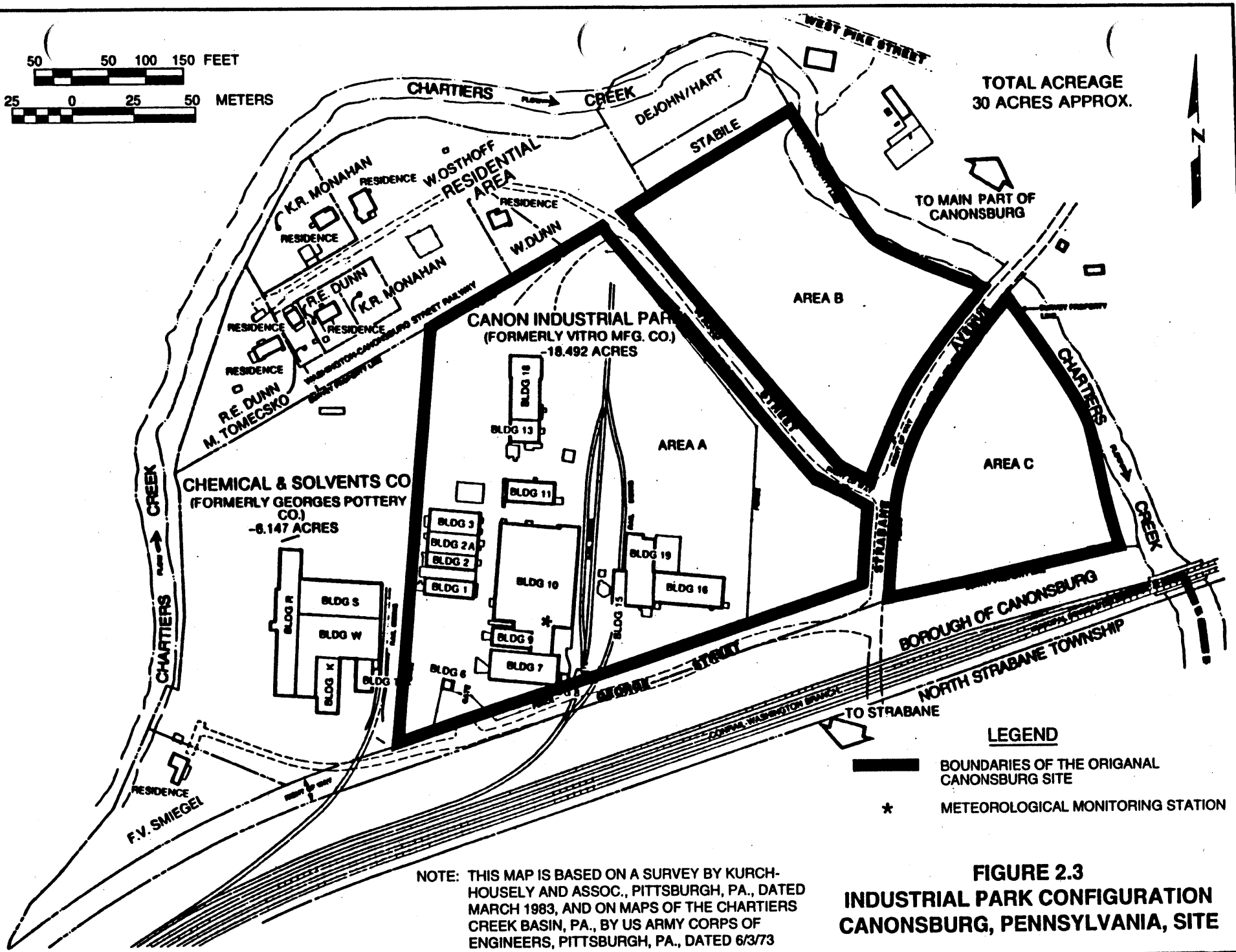
storage of up to 23 tons (21 tonnes) of uranium contained in approximately 4500 tons (4080 tonnes) of material.

The real property was sold to developers in 1962, while Vitro retained title to the uranium-containing materials. Before 1964 an effort was made to decontaminate the immediate plant area, and all contaminated material was moved to a main stockpile of uranium-bearing material located in Area A. In 1965 the commonwealth of Pennsylvania granted Vitro a permit to move this pile to Area C where it was buried beneath a relatively impermeable layer of slag and covered by clean fill. Vitro's source-material license was then terminated and the Canonsburg site was developed into the Canon Industrial Park in 1966 (Figure 2.3).

On 8 November 1979 the DOE designated the Canonsburg site as eligible for remedial action under the UMTRCA. Effective 5 September 1980, the DOE and the commonwealth of Pennsylvania entered into a cooperative agreement (under the UMTRCA) that set forth the terms and conditions for a DOE and commonwealth cooperative remedial action effort (DOE, 1983a, 1983b). In 1982 the commonwealth of Pennsylvania acquired the Canonsburg site in accordance with the cooperative agreement between the state and the DOE (Licensing Implementation Plan, 1992).

Between 1984 and 1986 contaminated soils and materials (including those from Area C) were stabilized in a permanent disposal cell (Figure 2.2). Approximately 172,000 cubic yards ($yd^3$) (132,000 cubic meters [$m^3$]) of contaminated materials were stabilized in the disposal cell, which covers approximately 6 ac (2.4 ha) of the site (MK-Ferguson, 1986; Licensing Implementation Plan, 1992). The eastern toe of the cell was placed on fill material above the existing grade. The remainder of the site was evenly and smoothly graded to provide adequate site drainage and was revegetated with native grasses (DOE, 1983b). As shown in Figure 2.2, fencing was installed around the majority of the site, including Areas A and B. Area C, southeast of the designated disposal site, is not fenced and is being evaluated for public use.

The site is being monitored according to the *Surveillance and Maintenance Plan* for the Canonsburg site (DOE, 1992). The site will remain in the post-stabilization, prelicensing status until the U.S. Nuclear Regulatory Commission (NRC) issues a license for long-term surveillance and maintenance under the provisions of 10 CFR Part 40. The general license becomes effective for the Canonsburg site after the NRC concurs with the completion of the surface remedial action and approves the long-term surveillance plan. Upon licensing, ownership of the site, with the exception of Area C, will transfer from the commonwealth of Pennsylvania to the U.S. Government under the oversight of the DOE. The state will retain ownership of Area C.




NOTE: THIS MAP IS BASED ON A SURVEY BY KURCH-HOUSELY AND ASSOC., PITTSBURGH, PA., DATED MARCH 1983, AND ON MAPS OF THE CHARTIERS CREEK BASIN, PA., BY US ARMY CORPS OF ENGINEERS, PITTSBURGH, PA., DATED 6/3/73

**FIGURE 2.3**
**INDUSTRIAL PARK CONFIGURATION**
**CANONSBURG, PENNSYLVANIA, SITE**



MAC: SITE/CAN/BRA/CURCON

## 2.2 CLIMATE

The Canonsburg site is in the humid continental climatic region. This region experiences distinct seasons with seasonal variations slightly moderated by the Great Lakes and the Atlantic seaboard (DOE, 1983a).

The average annual temperature at the Canonsburg site is 50 degrees Fahrenheit (°F) (10 degrees Celsius [°C]), based on data collected on the site from 1979 to 1981. Based on these data, the winter temperatures at the site range from -6° to 63°F (-21° to 17°C), with an average temperature of 28°F (-2°C); the summer temperatures range from 36° to 95°F (2° to 35°C), with an average temperature of 70°F (21°C). Generally mild summers are frequently humid due to invasions of tropical air from the Gulf of Mexico. The winter months are brisk with occasional periods of extreme cold. Spring and fall are transitional seasons, with moderate-to-cool temperatures. Rapid and wide variations in day-to-day weather conditions are common during the spring and fall (DOE, 1983a).

Based on data from the Pittsburgh International Airport from 1941 to 1980, the average annual precipitation in the area is 38 inches. March and June are the wettest months, each averaging 3.8 inches, while February and November are the driest, each averaging 2.4 inches. The average annual snowfall in the site vicinity is 45 inches. The snow season typically occurs from October to May, with the heaviest snowfall in January (DOE, 1983a).

The Canonsburg site is situated in the east-to-west-oriented Chartiers Creek valley, which channels wind flows. As a result, the predominant wind direction is west-to-northwest. Cross-valley winds (north and south) are limited to periods of relatively high wind speeds typically occurring in the winter as northerly winds. The average annual wind speed as measured from 1979 to 1980 at the Canonsburg site was 4.7 mi (7.6 km) per hour (DOE, 1983a).

## 2.3 PHYSIOGRAPHIC SETTING

The Canonsburg site is in southwestern Pennsylvania where the geologic structural setting consists of subparallel folds with northeastern axis orientation. Landfilling and earth-moving activities have altered the topography of the Canonsburg site, originally a low-lying flood plain. The site lies in the Chartiers Creek basin along the creek's southern bank, approximately 15 mi (24 km) upstream from its confluence with the Ohio River.

## 2.4 HYDROGEOLOGY

### 2.4.1 Geology

The Canonsburg site is on a sequence of unconsolidated materials overlying bedrock of the Pennsylvanian Casselman Formation (Figures 2.4 and 2.5).

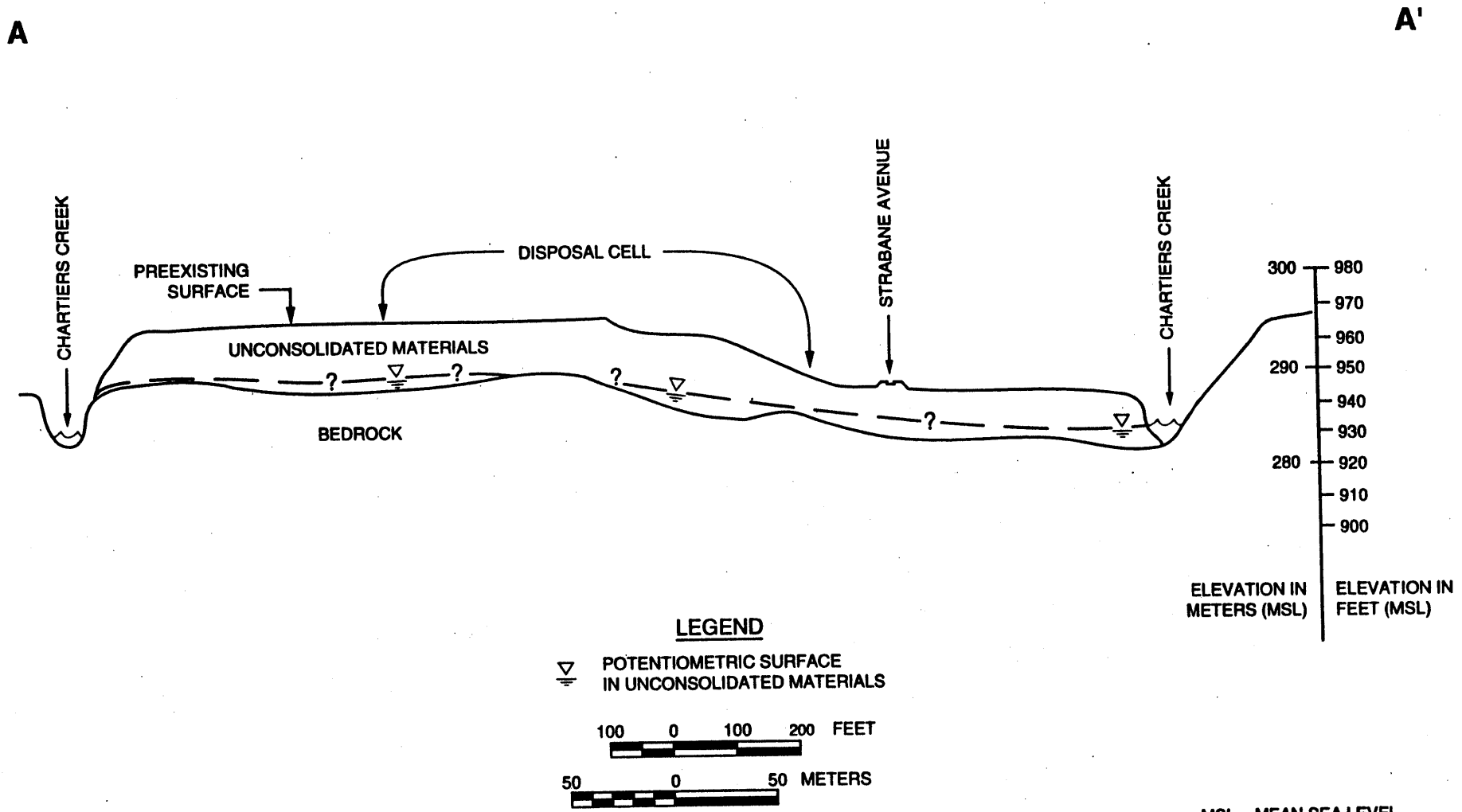



**FIGURE 2.4**
**HYDROGEOLOGIC CROSS SECTION (A-A')**
**CANONSBURG, PENNSYLVANIA, SITE**



MAC: SITE/CAN/BRA/HYDROX-SEC(A-A')

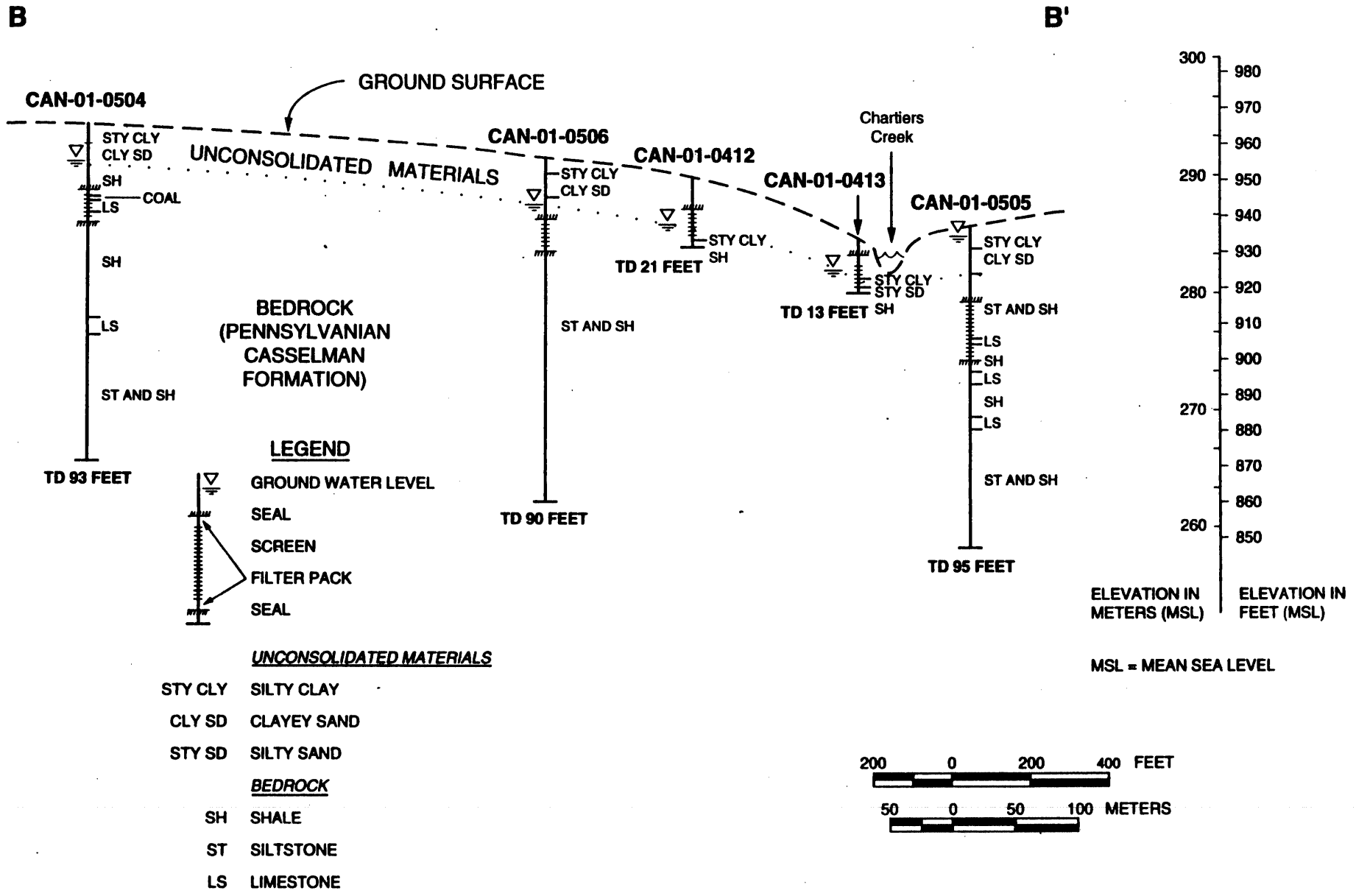



**FIGURE 2.5**
**HYDROGEOLOGIC CROSS SECTION (B-B')**
**CANONSBURG, PENNSYLVANIA, SITE**



MAC: SITE/CAN .../HYDROX-SEC(B-B')

Unconsolidated materials

The unconsolidated materials generally consist of up to 30 feet (ft) (9 meters [m]) of soil (sandy loam to silty clay loam), clay, alluvium, and fill material (cinders mixed with soil, stones/cobbles, and building rubble). The unconsolidated materials are heterogeneous beneath the site and do not form discrete, continuous units. Also, the permeability is variable due to the types and placement of the materials.

Bedrock

The lithology of the bedrock to a depth of 95 ft (29 m), based on lithologic logs of monitor wells CAN-01-0504 through -0506, consists predominantly of gray siltstone and shale, with some interbedded limestone, and sparse coal seams (Figure 2.5). Shale near the bedrock surface is broken and weathered to thin, brittle plates. The bedrock surface generally dips northeast at less than 1 degree. Fracturing was observed in core samples in the upper 5 to 20 ft (2 to 6 m) of the bedrock beneath the site. The interval of interest for evaluating potential bedrock contamination is the upper 25 ft (7 m) beneath the contact with the unconsolidated material, referred to as the "shallow bedrock." The shallow bedrock has been observed at the surface in the site vicinity.

## 2.4.2 Hydrology

Ground water is present in two distinct units beneath the site: the unconsolidated materials and the bedrock. Hydraulic interconnection appears between the two lithologic units with a generally downward vertical gradient from the unconsolidated materials to the shallow bedrock. The dominant boundary condition for ground water movement in the unconsolidated materials and shallow bedrock is Chartiers Creek. This creek surrounds the site on the west, north, and east and is the normal discharge zone for the water table and shallow bedrock ground water systems. Although Chartiers Creek is principally a gaining stream, minor gradient reversal in ground water flow may occur near the creek during periods of maximum flow. However, this should not substantially impact potential contaminant migration.

Although ground water is present in the unconsolidated materials and shallow bedrock beneath the site, neither unit is considered as an aquifer. This is primarily because the materials are not ideal for aquifer formation, the source of recharge to the shallow units is limited, and sustained yield to a well from these units is probably lacking.

Unconsolidated materials

Ground water occurs in the unconsolidated materials under unconfined (water table) conditions. Depth to ground water in the unconsolidated materials ranges from 3 to 14 ft (0.9 to 4.3 m) beneath the ground surface. Figure 2.6 shows the configuration of the potentiometric surface and the approximate direction of

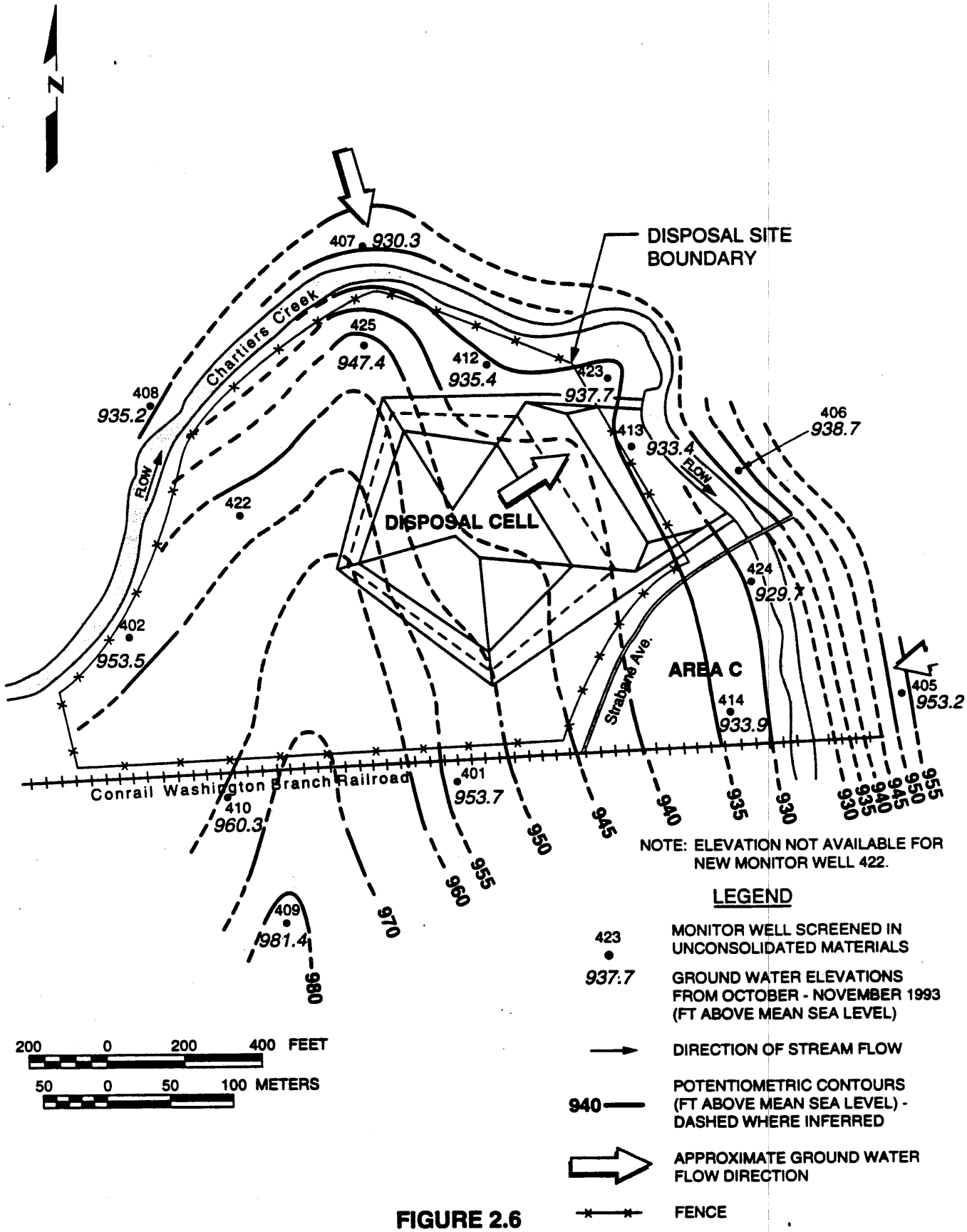



**FIGURE 2.6**

**POTENTIOMETRIC SURFACE MAP FOR THE UNCONSOLIDATED MATERIALS CANONSBURG, PENNSYLVANIA, SITE**

ground water flow in this unit; because of discontinuities and heterogeneities of the materials, the degree of hydraulic interconnection between areas beneath the site and the exact flow direction may be variable. Ground water in the unconsolidated materials is a result of precipitation infiltrating the unit with downward migration toward contact with the shallow bedrock. Water may perch on clay layers within the unit or on the shallow bedrock. Lateral continuity of ground water in this unit has not been definitively determined. Transmissivity, based on aquifer pumping tests in well 26, averaged 300 square feet ($ft^2$) per day (3.22 square centimeters [$cm^2$] per second) in the unconsolidated materials (DOE, 1983a), which, along with the estimated saturated thickness of 10 ft (3 m), a porosity of 0.2, and a gradient of 0.027, results in an approximate ground water velocity of 4 ft per day ($1.4 \times 10^{-3}$ cm per second).

Bedrock

Ground water occurs in the underlying shallow bedrock under semiconfined conditions. Figure 2.7 shows the potentiometric surface configuration and the approximate ground water flow direction in the shallow bedrock unit; because of discontinuities and the accumulation of ground water in fractured and weathered zones, the degree of hydraulic interconnection between areas beneath the site and the exact flow direction may be variable. Ground water in the shallow bedrock results from water infiltration from above into zones of secondary porosity where the shale bedrock is weathered or fractured. Some ground water appears to be present in deeper zones in the bedrock associated with limestone or more porous zones. This ground water is probably not related to surface infiltration due to intervening shale layers acting as aquitards, but is a result of ground water underflow. Transmissivity, based on aquifer pumping tests in well 303R, ranged from 0.167 to 3.94 $cm^2$ per second in the shallow bedrock (DOE, 1983a), which, along with an estimated saturated thickness of 20 ft (6 m), a porosity of 0.2, and a gradient of 0.016 results in an approximate ground water velocity range of 0.1 to 3 ft per day ($4.3 \times 10^{-5}$ to $1.0 \times 10^{-3}$ cm per second).

## 2.5 SURFACE WATER

The Canonsburg site lies along the southern bank of Chartiers Creek (Figure 2.2), a meandering stream 75 to 100 ft (23 to 30 m) wide and about 10 ft (3 m) deep. Chartiers Creek drains an area of approximately 80 square miles ($mi^2$) (200 square kilometers [$km^2$]) upstream from the site and drains into the Ohio River 15 mi (24 km) downstream from the site. The average flow of Chartiers Creek past the site is 90 to 130 $ft^3$ per second (2.5 to 3.7 $m^3$ per second). As discussed in Section 2.4.2, ground water in the unconsolidated material discharges into Chartiers Creek.

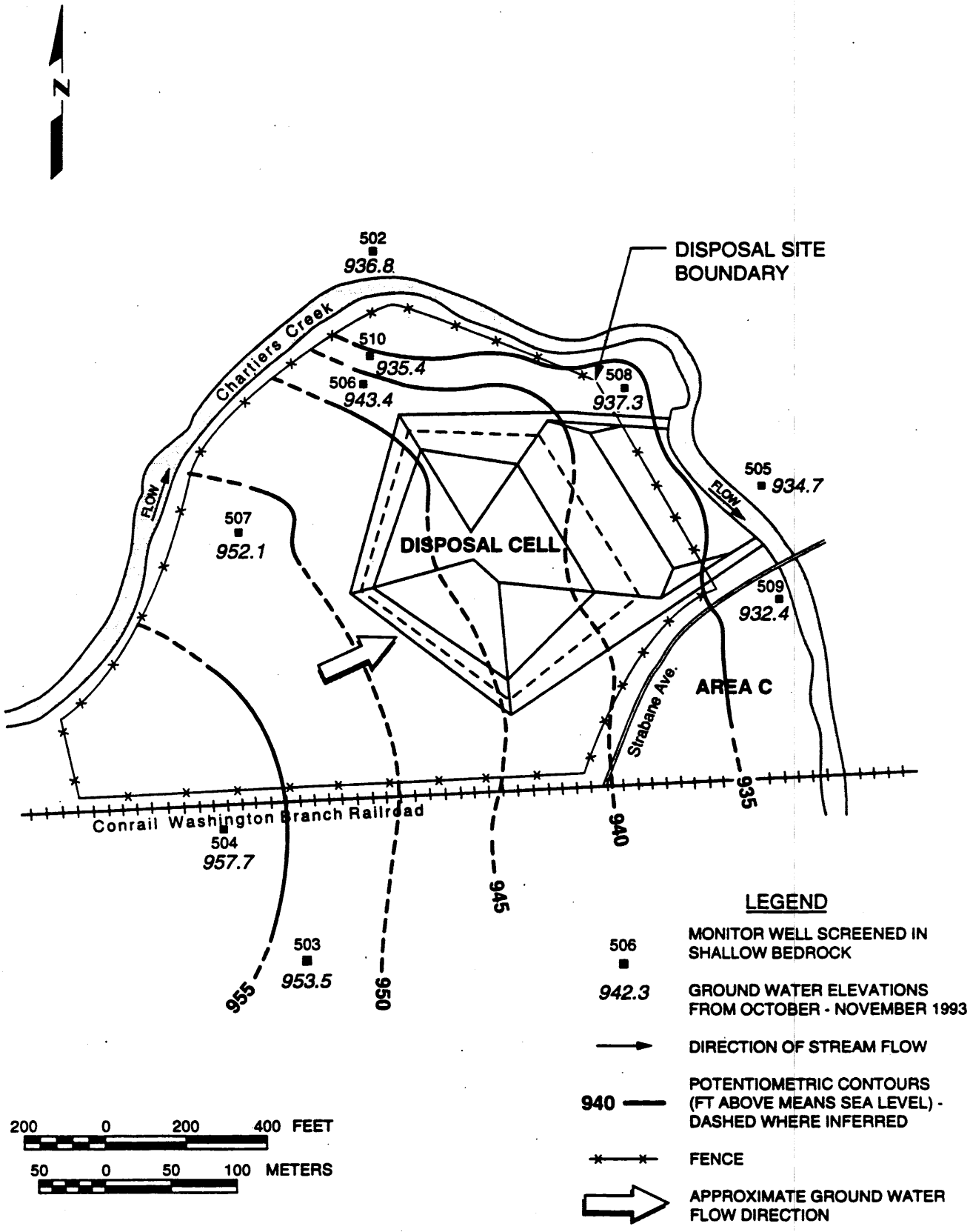



**FIGURE 2.7**
**POTENTIOMETRIC SURFACE MAP FOR THE SHALLOW BEDROCK**
**CANONSBURG, PENNSYLVANIA, SITE**

MAC: SITE/CAN/BRA/BASE-POTGWSH(NEW)

## 2.6 LAND USE

The former uranium processing site at Canonsburg, Pennsylvania is currently owned by the commonwealth of Pennsylvania. The site consists of the disposal site area and Area C (Figure 2.2). As discussed in Section 2.1, the disposal site area is within the zone where land use has been restricted. Upon the site licensing, ownership of the disposal site area will transfer from the commonweath of Pennsylvania to the U.S. Government under the oversight of the DOE. The state will retain ownership of the remaining portion of the Canonsburg site, Area C. That part of the site (Area C) is being considered for future public use.

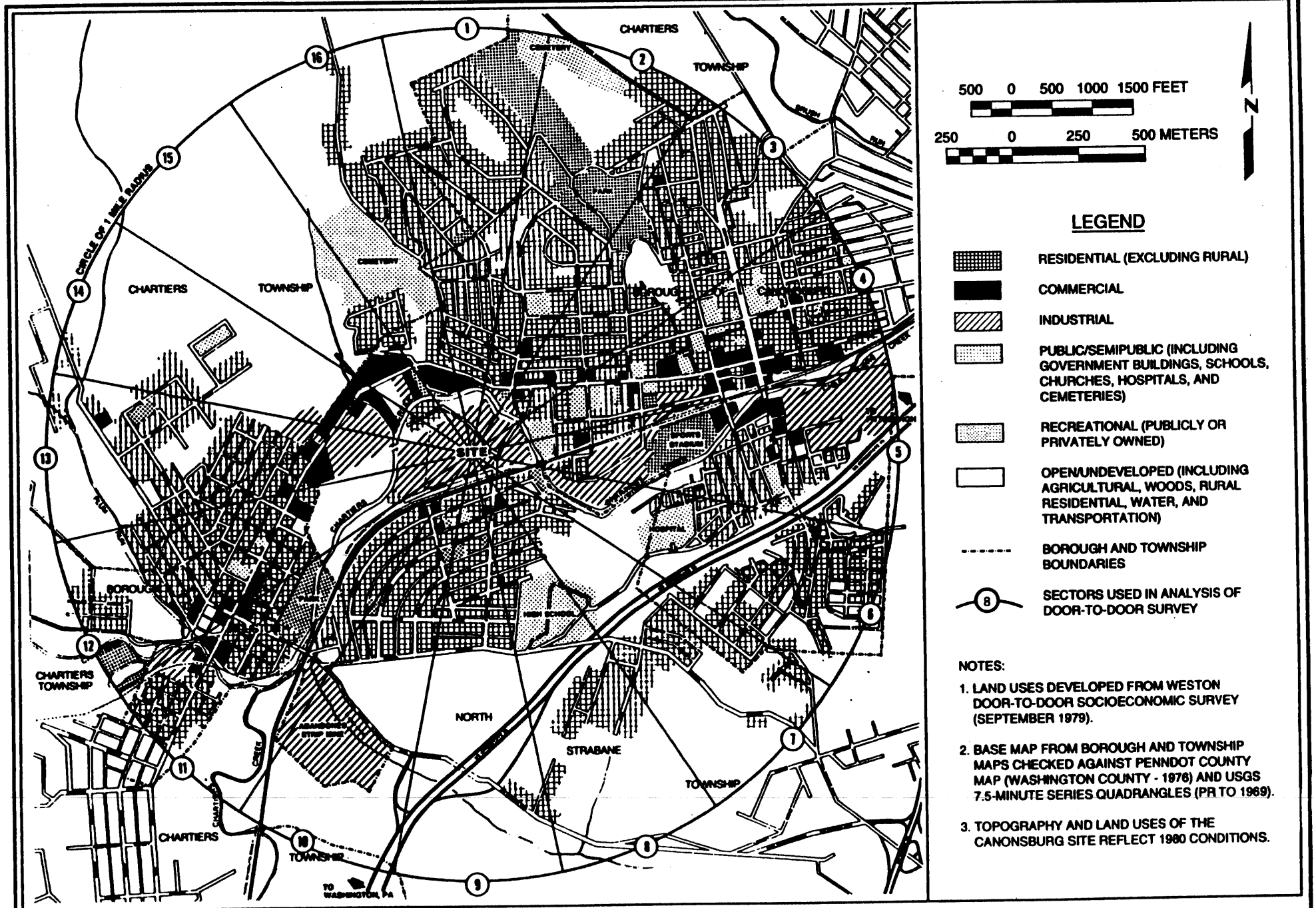
A 1-mi (1.6-km) radius around the site encompasses four municipalities: the borough of Canonsburg, the borough of Houston, Chartiers Township, and North Strabane Township. The borough of Houston and North Strabane Township are hydrologically upgradient or crossgradient of the site. The two other municipalities, the borough of Canonsburg and Chartiers Township, are on the opposite side of Chartiers Creek relative to the site. Ground water from their location flows toward the site and discharges into the creek. Therefore, these municipalities are not expected to be influenced by ground water flow from the site.

The primary land use in the site vicinity is residential. The closest residences are approximately 80 to 100 ft (24 to 30 m) east of the site along Strabane Avenue and adjacent streets in the borough of Canonsburg. Residences are also directly south of the site in North Strabane Township on Latimer Avenue and west and southwest of the site in the borough of Houston.

North of the site along West Pike Street is a commercial and light industrial area. Businesses in this area include a gas station, car wash, car repair shop, car dealerships, woodcrafting company, and a heating and cooling company. Residences are north of this commercial/industrial area on Pike Street. A light industrial area is also located southwest of the site. Undeveloped areas are primarily northwest of the site in Chartiers Township and south of the site in North Strabane Township. Figure 2.8 shows the land uses within a 1-mile (1.6-km) site radius. This map, taken from the Final Environmental Impact Statement for the Canonsburg site (DOE, 1983a), was based on information obtained from maps and local surveys. Recent site visits in 1994 indicate that land uses have changed only slightly with the possible addition of some new residential and commercial areas. Figure 2.9 shows the current land use zoning within this same area.

Based on 1990 data (Washington County Planning Commission, 1993), the populations of the municipalities in the site vicinity are as follows:

- Borough of Canonsburg - 9200
- Borough of Houston - 1445

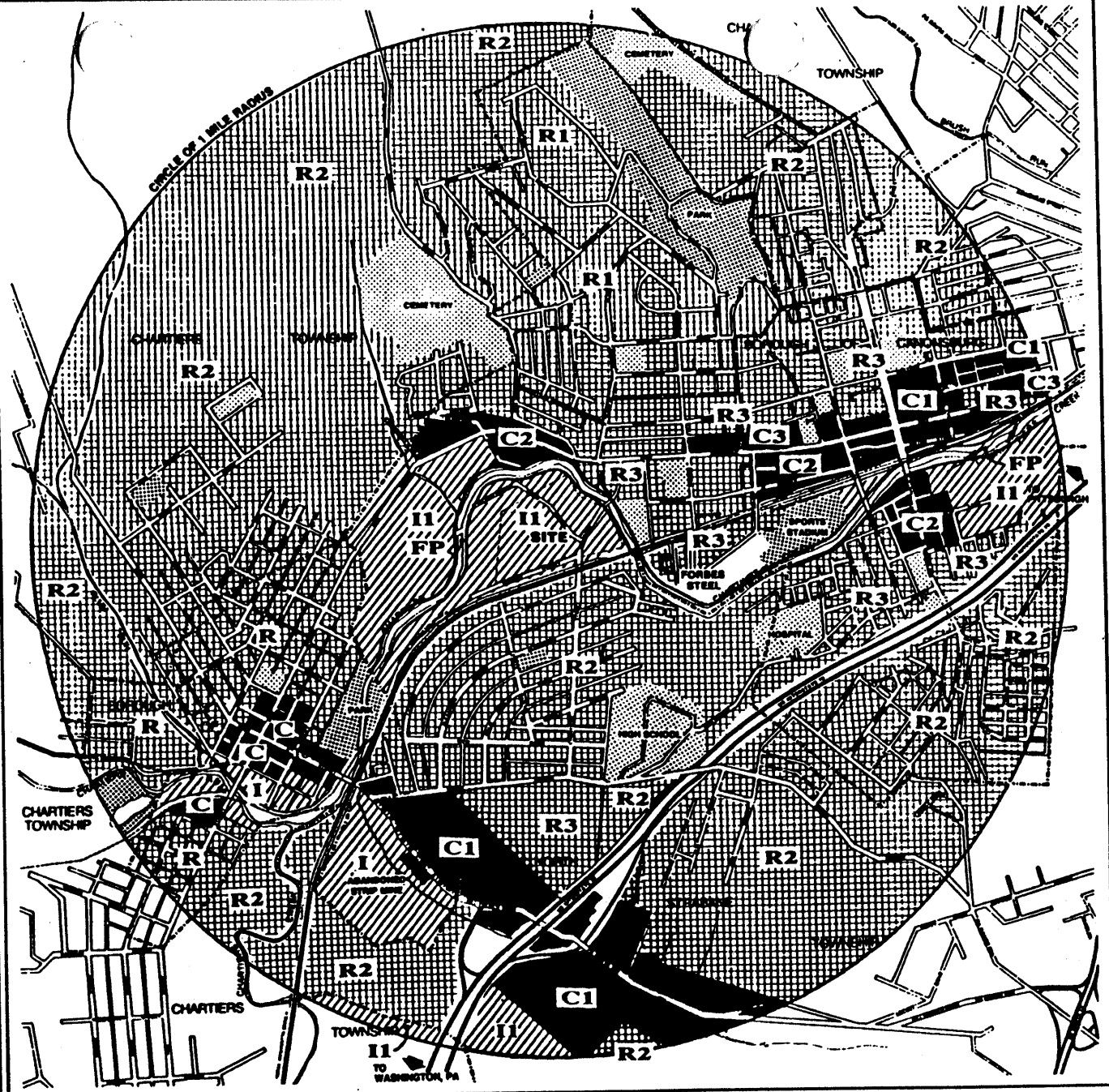



SOURCE: DOE, 1983a - FINAL ENVIRONMENTAL IMPACT STATEMENT

**FIGURE 2.8**

**EXISTING LAND USES (1980), CANONSBURG, PENNSYLVANIA, SITE VICINITY**

MAC: SITE/CAN... /EXISTLANDUSES




500 0 500 1000 1500 FEET

250 0 250 500 METERS

N

## LEGEND

GENERALIZED ZONING CATEGORIES

- RESIDENTIAL (EXCLUDING RURAL)
- COMMERCIAL
- INDUSTRIAL

EXISTING VARIATIONS TO ZONING (LARGE AREAS ONLY)

- PUBLIC/SEMIPUBLIC
- RECREATIONAL (PUBLICLY OWNED ONLY)
- OTHER (INCLUDING INDUSTRIAL, OPEN WATER, FLOODPLAIN [FP], AND TRANSPORTATION/UTILITIES)
- BOROUGH AND TOWNSHIP BOUNDARIES

NOTES:

1. ZONING BY MUNICIPALITY:
   BOROUGH OF CANONSBURG
   RESIDENTIAL AREA - BY DENSITY
   **R1** - LOW **R2** - MEDIUM **R3** - HIGH
   COMMERCIAL - BY TYPE
   **C1** - CENTRAL **C2** - GENERAL **C3** - SPECIAL
   INDUSTRIAL - BY TYPE **I1** - LIGHT

   BOROUGH OF HOUSTON - ZONING ORDINANCE MAP, 1985 (NO FURTHER BREAKDOWN THAN SHOWN ABOVE)

   NORTH STRABANE TOWNSHIP - ZONING MAP - REVISED TO 1991 RESIDENTIAL AREA - BY DENSITY
   **R2** - URBAN **R3** - HIGH
   COMMERCIAL - BY TYPE **C1** - GENERAL
   INDUSTRIAL - BY TYPE **I1** - LIGHT

   CHARTIERS TOWNSHIP - OFFICIAL ZONING MAP, 10/24/92
   RESIDENTIAL - BY DENSITY **R2** - RESIDENCE DISTRICT
   INDUSTRIAL - BY TYPE **I1** - INDUSTRIAL DISTRICT

2. BASE MAP FROM BOROUGH AND TOWNSHIP MAPS CHECKED AGAINST PENNDOT COUNTY MAP (WASHINGTON COUNTY - 1976) AND USGS 7.5-MINUTE SERIES QUADRANGLES (PR TO 1969).

3. TOPOGRAPHY AND LAND USES OF THE CANONSBURG SITE REFLECT 1980 CONDITIONS.

SOURCE: DOE, 1983a - FINAL ENVIRONMENTAL IMPACT STATEMENT

**FIGURE 2.9**

**LAND USE ZONING, CANONSBURG, PENNSYLVANIA, SITE VICINITY**

MAC: SITE/CAN/BRA/LANDUSEZONING

- Chartiers Township - 7603
- North Strabane Township - 8157

The population of Washington County has fluctuated but has remained at more than 200,000 for the past few decades. Based on data from 1990, the population for the county is 204,584 (Washington County Planning Commission, 1993).

The 1992-1993 Industrial Directory for Washington County lists 491 industries and businesses that employ 19,980 persons. Washington County's resident civilian labor force was approximately 95,400 in 1991, with approximately 66,860 persons working in the county. By categories, the major employers in the county are steel (1989 employees), electronics (1789 employees), mining (1276 employees), and plastics (1212 employees) (Washington County Board of Commissioners, 1993). Manufacturing in Washington County has declined over the years, primarily in steel and glass and their supporting industries. However, employment has increased in the government, wholesale/retail trade, and service industries. The major manufacturing employer in Canonsburg is Cooper Power Systems that employs approximately 1080 persons (Washington County Board of Commissioners, 1993).

Approximately 1590 farms are in Washington County, with an average size of 137 ac (55 ha). The main products are milk and dairy (Washington County Board of Commissioners, 1993).

## 2.7 WATER USE

Most residents of Canonsburg, Houston, North Strabane, and Chartiers, in the site vicinity, are connected to a municipal water supply system operated by the Pennsylvania-American Water Company. The Monongahela River, located east of the site, supplies the water for the system. There are two water intake stations: in Aldridge and in Pittsburgh, Pennsylvania. The Aldridge plant can treat about 60 million gallons (gal) (230 million liters [L]) of water per day, and the Pittsburgh plant can treat 80 million gal (300 million L) of water per day (Taylor, 1994). Washington District residents use approximately 10 million gal (38 million L) of water daily.

In April 1994 a water use survey was conducted within a 1-mi (1.6-km) radius of the Canonsburg site. The purpose of the survey was to verify locations and status of domestic well information listed in previous surveys (DOE, 1983a), either provided by the Pennsylvania Geologic Survey (PGS, 1994) or obtained from personal communications with local residents. From this water use survey, approximately 16 wells were identified within a 1-mi (1.6-km) site radius. Of these wells, 1 was in use, 11 were not in use, and 4 were abandoned. Figure 2.10 shows the locations of the 12 wells that were not abandoned. Seven of these wells are upgradient of the site and would not be affected by any potentially migrating site-related contaminants. The remaining five wells are on the opposite side of Chartiers Creek relative to the site. Of these five

**FIGURE 2.10**
**DOMESTIC WELL LOCATIONS**
**CANONSBURG, PENNSYLVANIA, SITE VICINITY**

wells, only one is in use. This well is approximately 400 ft (122 m) north of the site and is used for washing cars, mixing cement, and watering the garden. Due to the location of this well it is not expected to be influenced by any ground water flow from the site. The ground water from this location flows toward the site and discharges into Chartiers Creek (Figure 2.6).

Figure 2.10 also shows the locations of five wells situated immediately outside the 1-mi (1.6-km) radius. These wells are used for drinking as well as for all other domestic purposes. Three of these wells are just over 1 mi (1.6 km) south of the site. The municipal water supply does not service houses further south of this area; thus, individuals residing in this area most likely use well water. These wells are upgradient of the site and thus would not be affected by any potentially migrating contamination from the site. An additional two wells are approximately 1.3 mi (2.1 km) north of the site. Houses further north of this area also are not serviced by the municipal water supply system, and these residents also most likely use well water. Due to the distance from the site and the fact that these wells are located crossgradient (rather than downgradient) of the site, any ground water contamination potentially migrating from the site is not expected to affect ground water in this area.

Chartiers Creek, which flows along the western, eastern, and northern boundaries of the site, is designated by the commonwealth of Pennsylvania for the maintenance and propagation of fish species and protection of additional flora and fauna indigenous to a warm water habitat (PADER, 1992). The creek is not a potable water resource due to its ambient contamination upstream of the site (see Section 3.5 for detailed discussion). Local residents use the creek for fishing, swimming, and wading. Children have also been observed playing in the creek and on its banks. The types of fish found in the creek include carp, catfish, and bluegill (Templeton, 1993).

# 3.0 EXTENT OF CONTAMINATION

Figure 2.2 is a map of the Canonsburg processing/disposal site showing the locations of the disposal cell, the DOE monitor well network, and other features mentioned in this discussion. Ground water is found at the site in unconsolidated near-surface materials and in the underlying bedrock. Filtered water quality data from 22 monitor wells were used to characterize background ground water and the nature and extent of ground water contamination at the site (DOE, 1995). Unfiltered water quality data are available for one sampling round (October 1993) for a limited number of constituents. For water samples from those wells used in this risk assessment, these data are generally consistent with the filtered water samples data (DOE, 1995). Therefore, unfiltered ground water data were not used for this risk assessment. However, for samples from other wells, some parameters indicated higher concentrations in unfiltered than in filtered water samples. Water quality data for unfiltered samples from six surface water locations were used to evaluate surface water quality (DOE, 1995). This risk assessment evaluates inorganic contamination at the Canonsburg site. Water samples were collected following applicable standard operating procedures in the Albuquerque Operations Manual (JEG, n.d.). Table 3.1 provides monitor well and surface water sampling site information, including the formations of completion and locations of monitor wells, years sampled, sampling rounds, and well depths.

## 3.1 BACKGROUND GROUND WATER QUALITY DATA SUMMARY

Background ground water quality is defined as ground water quality that would exist at this site if uranium processing had not occurred. Statistical and geochemical analyses have evaluated background ground water quality at the Canonsburg site.

Monitor wells 401, 409, and 410, completed in the near-surface, unconsolidated materials, were evaluated as potential background wells. Monitor well 410 was most appropriate for estimating background levels in the unconsolidated material because it was completed in fill material that is characteristic of the site. Monitor well 409, on the other hand, is located off of the site and completed in unconsolidated alluvium and soils with different characteristics. Monitor well 401 was not used because, while the chemistry of ground water in well 401 is basically similar to that in well 410, the concentrations of the radionuclides thorium-230 and polonium-210 are slightly higher than in well 410. Because no historical ground water quality data exist for well 401, the possibility of site-related contamination could not be ruled out. Therefore, monitor well 401 was not included in the determination of background values.

Monitor wells 503 and 504 were considered potential background wells for the bedrock unit. Monitor well 503 is a deep well (112.9 ft [34.4 m]) screened in a limestone unit and, thus, is not representative of ground water conditions on the

**Table 3.1 Monitor well and surface water sampling information, Canonsburg, Pennsylvania, site**

| Well number | Location | Years sampled | Number of rounds | Screen interval (ft) |
|---|---|---|---|---|
| **Unconsolidated materials** | | | | |
| Background wells | | | | |
| 401 | south of disposal cell | 1986, 1993 | 2 | 7.5-12.2 |
| 409 | southwest of disposal cell | 1993 | 1 | 18.3 (a) |
| 410 | southwest of disposal cell | 1986-1993 | 16 | 11.4-16.0 |
| Downgradient wells | | | | |
| 405 | across river from disposal cell | 1993 | 1 | 14.0 (a) |
| 406 | across river from disposal cell | 1993 | 1 | 14.0 (a) |
| 407 | across river from disposal cell | 1993 | 1 | 20.0 (a) |
| 408 | across river from disposal cell | 1993 | 1 | 21.0 (a) |
| 412 | north of disposal cell | 1986-1993 | 15 | 14.3-19.3 |
| 413 | northeast of disposal cell | 1986-1993 | 15 | 7.0-12.0 |
| 414 | southeast of disposal cell (Area C) | 1986-1993 | 16 | 4.5-14.5 |
| 422 | east of disposal cell | 1993 | dry | 18.0-23.0 |
| 423 | north of disposal cell | 1993 | 1 | 8.0-13.0 |
| 424 | east of disposal cell (Area C) | 1993 | 1 | 12.0-17.0 |
| 425 | north of disposal cell | 1993 | 1 | 12.5-17.5 |
| **Bedrock** | | | | |
| Background wells | | | | |
| 503 | southwest of disposal cell | 1993 | 1 | 112.9 (a) |
| 504 | southwest of disposal cell | 1986-1993 | 16 | 19.9-24.9 |
| Downgradient wells | | | | |
| 502 | across river from disposal cell | 1993 | 1 | 82.3 (a) |
| 505 | across river from disposal cell | 1986-1993 | 16 | 25.4-35.4 |
| 506 | northwest of disposal cell | 1986-1993 | 16 | 21.0-26.0 |
| 507 | west of disposal cell | 1993 | 1 | 38.0-43.0 |
| 508 | north of disposal cell | 1993 | 1 | 27.0-32.0 |
| 509 | east of disposal cell (Area C) | 1993 | 1 | 29.5-34.5 |
| 510 | north of disposal cell | 1993 | 1 | 32.0-37.0 |

**Table 3.1 Monitor well and surface water sampling information, Canonsburg, Pennsylvania, site (Concluded)**

| Well Number | Location | Years sampled | Number of rounds |
|---|---|---|---|
| **Surface water - Chartiers Creek** | | | |
| Downstream locations | | | |
| 602 | east of site, north of railroad | 1989-1993 | 9 |
| 603 | east of site, south of RR | 1993 | 1 |
| 604 | east of site, north of Strabane Ave | 1993 | 1 |
| 605 | north of site | 1993 | 1 |
| 606 | north of site | 1993 | 1 |
| Upstream location | | | |
| 601 | southwest of site, north of railroad | 1989-1993 | 9 |

(a) Total depth (ft)

site. Therefore, monitor well 504 was selected to represent background bedrock ground water conditions at Canonsburg.

A trilinear plot of the background water from the two units (Figure 3.1) shows that ground water in monitor well 504 has a mixed anionic composition with roughly equal amounts of chloride, sulfate, and bicarbonate. Calcium is the dominant cation. Conversely, the ground water from background well 410 has a mixed cationic composition with roughly equal amounts of sodium and calcium and slightly less magnesium. Sulfate, with slightly less bicarbonate and chloride, dominates the anionic composition of this ground water. As can be seen from the concentration versus time plots (Figure 3.2, plots a, b, c, and d), the pH, alkalinity, sulfate concentrations, and total dissolved solids (TDS) are much higher in the bedrock background ground water. Conversely, iron and manganese concentrations are higher in ground water from the shallow unconsolidated unit than from the deeper bedrock unit (Figure 3.2, plots e and f).

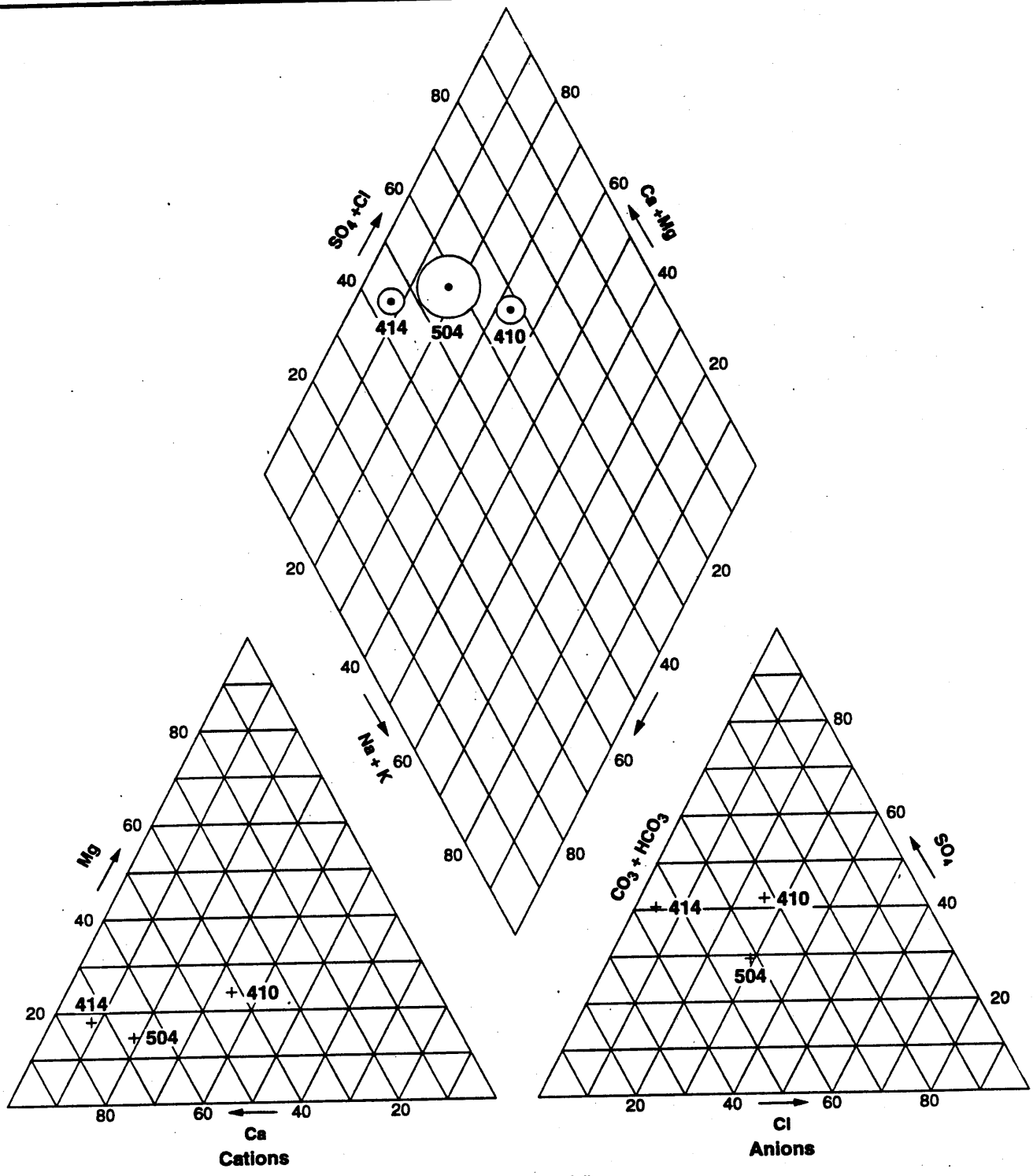
## 3.2 MAGNITUDE AND EXTENT OF SITE-RELATED GROUND WATER CONTAMINATION

Geochemical and statistical analyses of the available chemical data from the unconsolidated and bedrock units suggest that major, minor, and trace constituents are elevated in some downgradient wells relative to background ground water (DOE, 1995).

### 3.2.1 Unconsolidated materials

Wells completed in the unconsolidated material with the highest levels of site-related contamination are 412, 413, and 414 (Figures 3.3 and 3.4). Wells 412 and 413 are within the restricted zone and, as discussed in Section 2.4, contamination in these wells is not expected to migrate to potentially accessible ground water areas. Monitor wells 414 and 424 are in Area C, southeast of the disposal cell. One round of ground water samples was collected from monitor well 424, within 2 weeks after the well was completed. Comparison of water quality data from monitor wells 414 and 424 indicates that monitor well 414 shows higher levels of some constituents (boron, potassium, manganese, molybdenum, uranium, lead-210, radium-226, and thorium-230) than are seen in monitor well 424. Conversely, monitor well 424 shows higher levels of other constituents (notably, ammonium, arsenic, calcium, chloride, iron, sodium, sulfate, and radium-228) (Table 3.2). Because only one round of data is available from monitor well 424, these results have not been confirmed. For this reason, and because Area C is being considered for public use, discussion of contamination will focus on monitor well 414.

A trilinear diagram (Figure 3.1) can illustrate some of the major elemental differences between background ground water from upgradient monitor well 410 and contaminated ground water from downgradient well 414 in unconsolidated materials. The contaminated ground water of the shallow



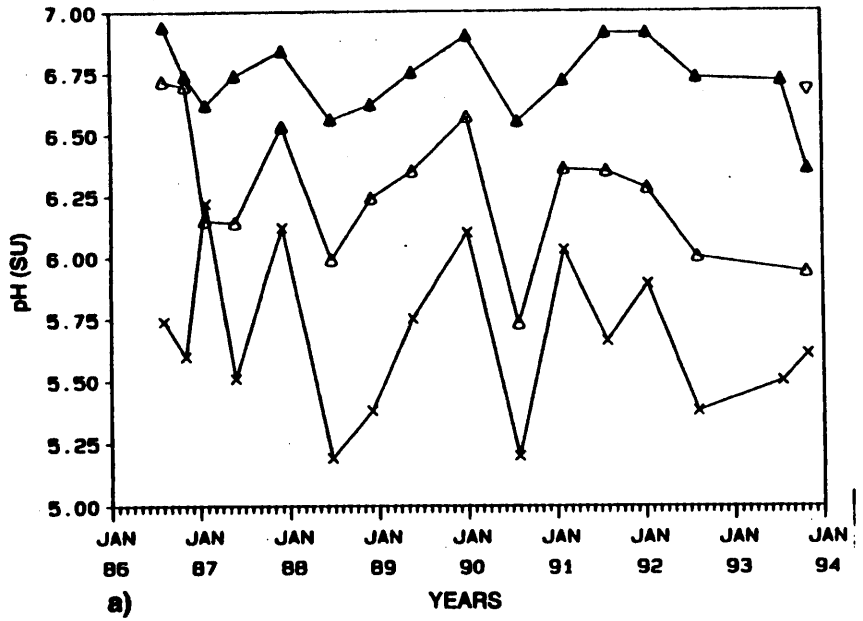

% of Total MEQ/L
4 Samples

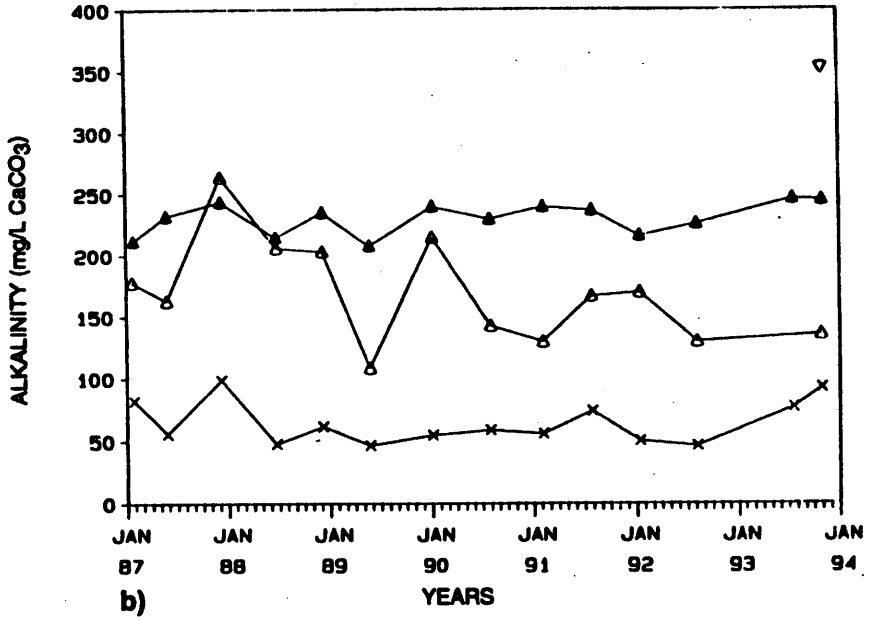
LEGEND

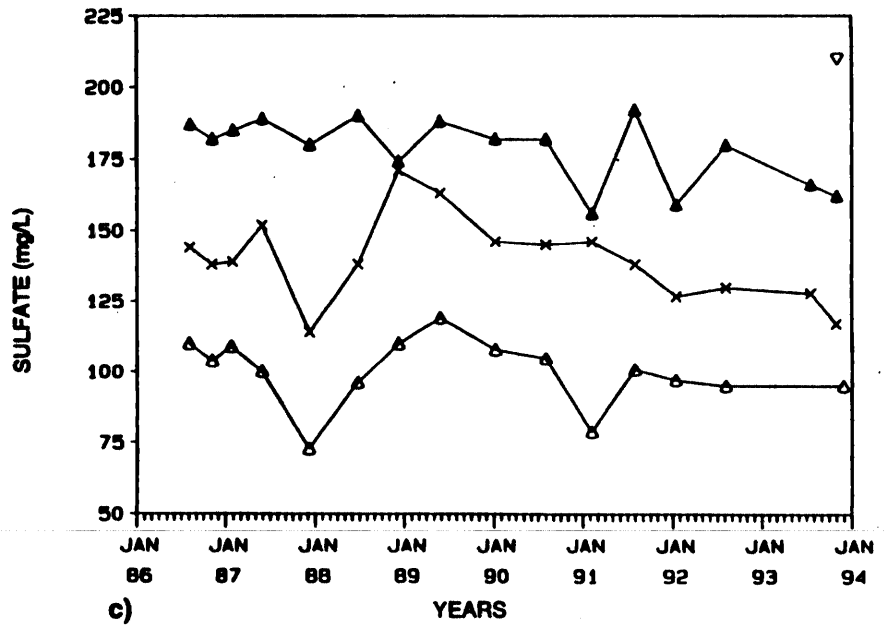
| NUMBER | TDS | WELL NAME |
|---|---|---|
| 504 | 829 | BACKGROUND WELL |
| 414 | 380 | DOWNGRADIENT WELL |
| 410 | 420 | BACKGROUND WELL |

2000 0 2000 mg/L per INCH

**FIGURE 3.1**
**TRILINEAR PLOT SHOWING ANION-CATION COMPOSITION OF BACKGROUND WELLS 410 AND 504 AND DOWNGRADIENT WELL 414 CANONSBURG, PENNSYLVANIA, SITE**



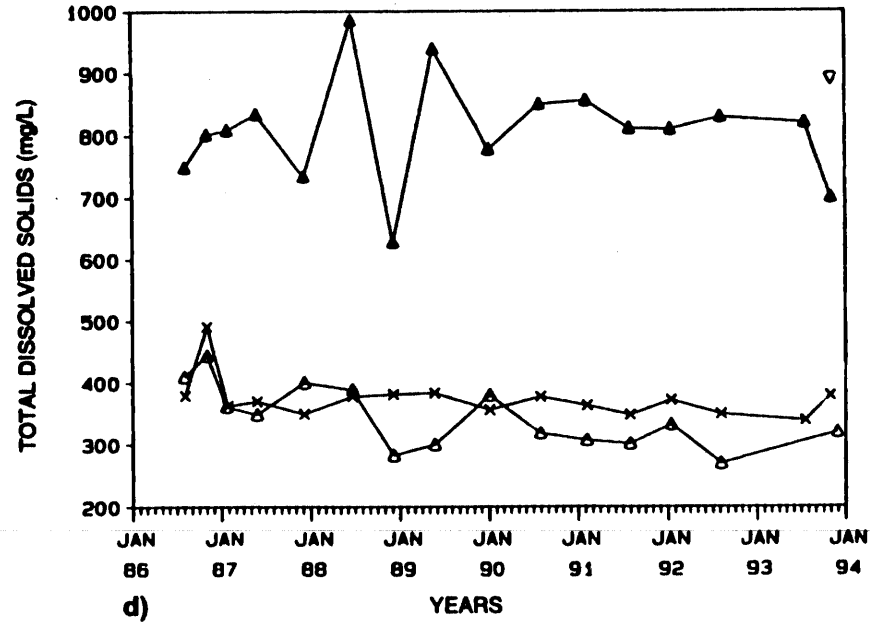
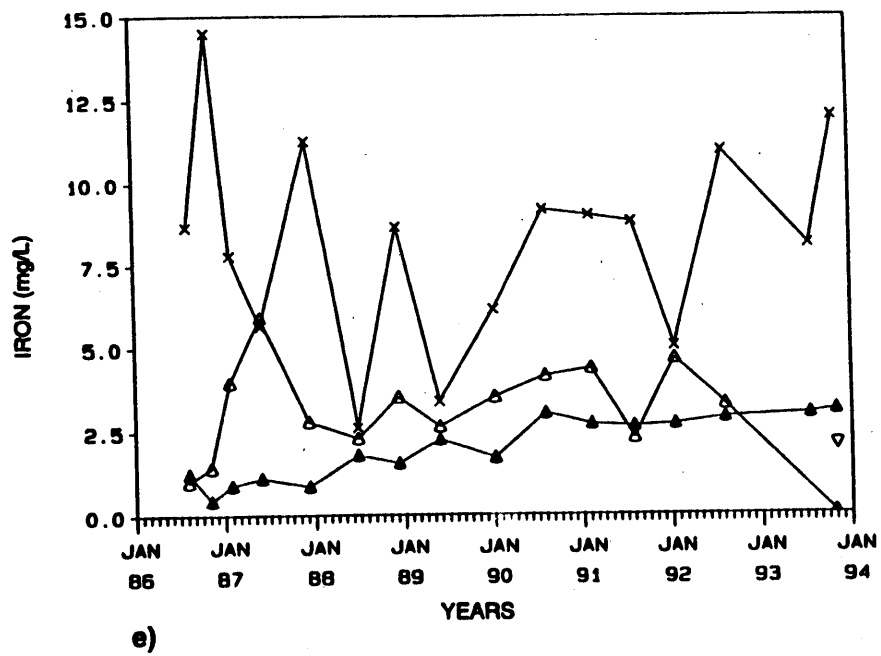



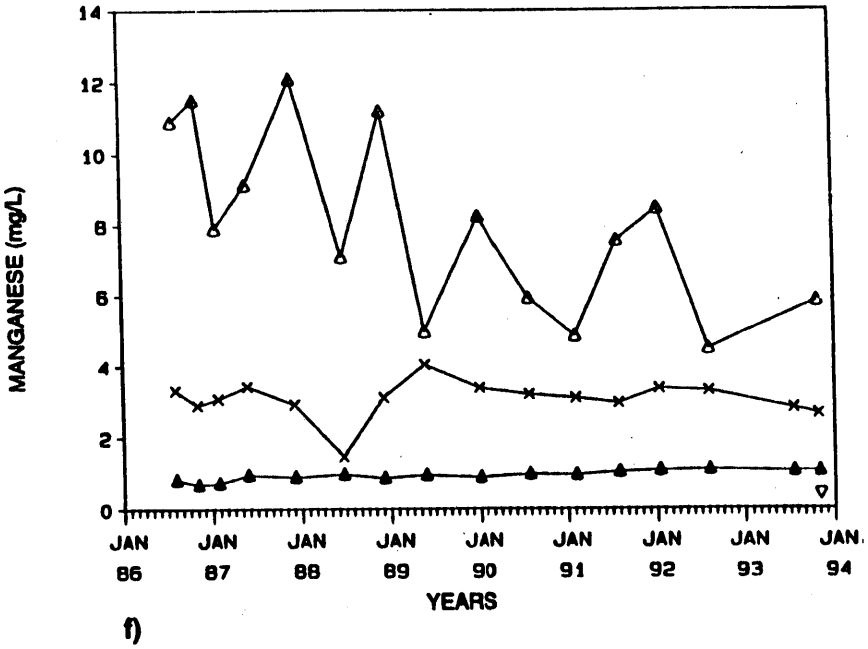

**FIGURE 3.2**
**GROUND WATER PARAMETER VERSUS TIME PLOTS OF WELLS 410, 414, 504, AND 509 CANONSBURG, PENNSYLVANIA, SITE**

LEGEND
X 0410 ▲ 0504
△ 0414 ▽ 0509



MAC: SITE/CA...\GWVSTIME1




LEGEND

X 0410 ▲ 0504

△ 0414 ▽ 0509

**FIGURE 3.2 (CONCLUDED)**
**GROUND WATER PARAMETER VERSUS TIME PLOTS OF WELLS 410, 414, 504, AND 509 CANONSBURG, PENNSYLVANIA, SITE**

MAC: SITE/CAN/BRA/GWVSTIME2

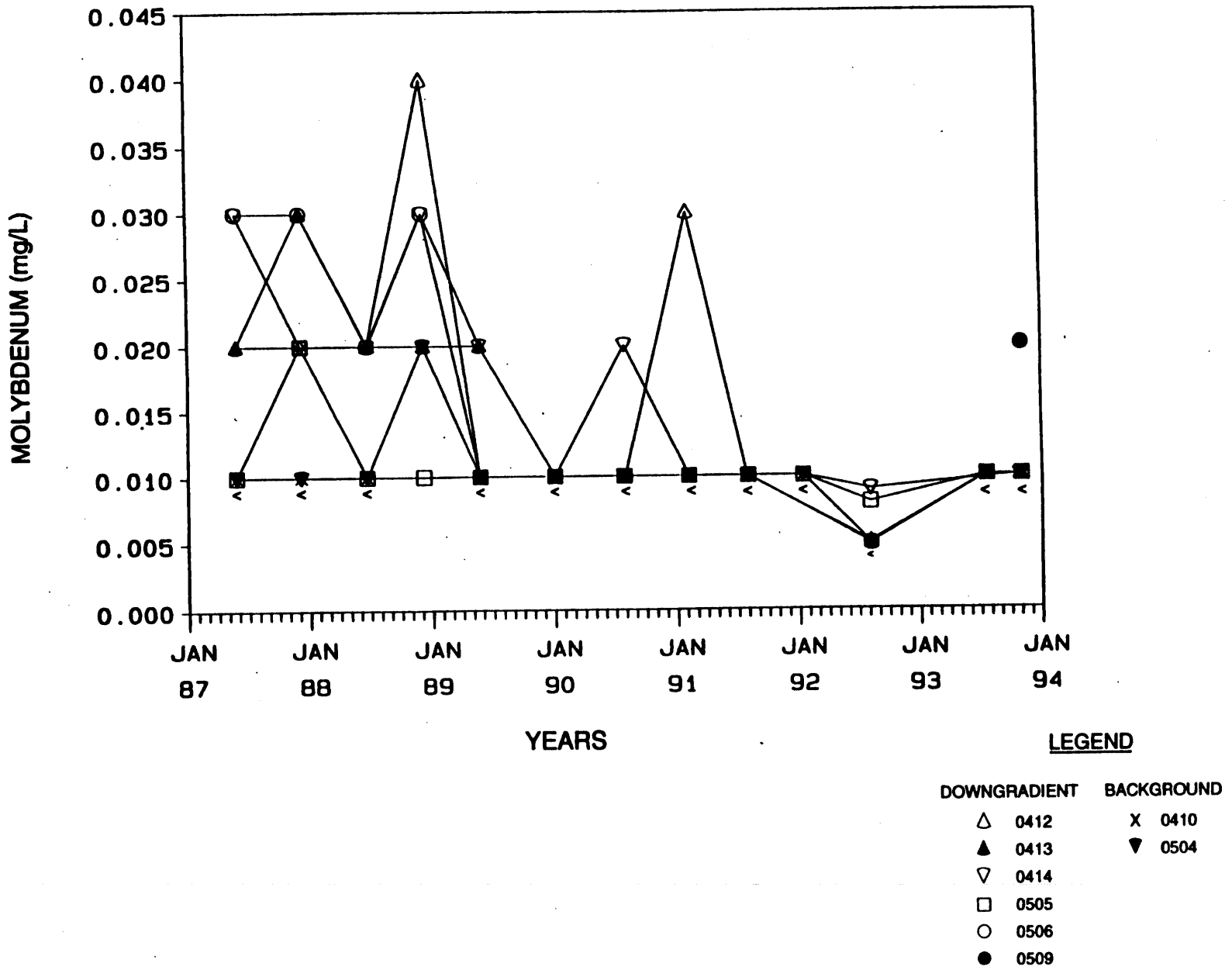



**FIGURE 3.3**
**MOLYBDENUM VERSUS TIME PLOT FOR BACKGROUND WELLS 410 AND 504 AND DOWNGRADIENT WELLS 412, 413, 414, 505, 506, AND 509 CANONSBURG, PE 'SYLVANIA, SITE**



MAC: SITE/CAN/BRA/GWVSTIME3A

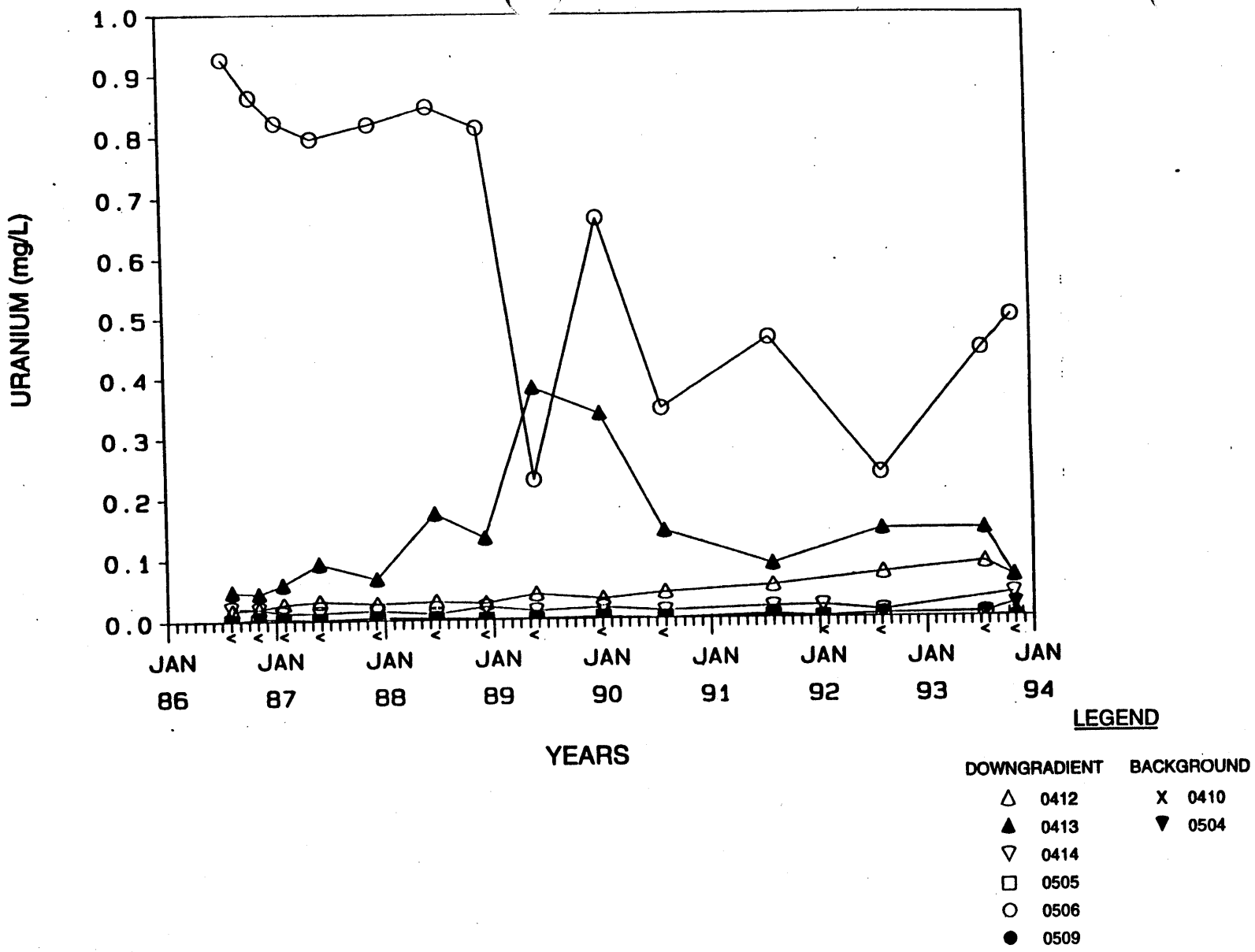



**FIGURE 3.4**
**URANIUM VERSUS TIME PLOT FOR BACKGROUND WELLS 410 AND 504 AND DOWNGRADIENT WELLS 412, 413, 414, 505, 506, AND 509 CANONSBURG, PENNSYLVANIA, SITE**



MAC: SITE/CAN/BRA/GWVSTIME4

**Table 3.2 Comparison of background and on-site ground water quality data from the unconsolidated materials, Canonsburg, Pennsylvania, site (1986-1993, filtered water samples)**

| Parameter | Above detection[a] | Minimum | Median[b] | Maximum |
|---|---|---|---|---|
| **Inorganics** | | | mg/L | |
| Aluminum | | | | |
| Background[c] | 4/7 | 0.03 | 0.03 | 0.30 |
| Downgradient[d] | 5/7 | <0.05 | 0.08 | 0.30 |
| Well 424[e] | 0/1 | - | <0.05 | - |
| Ammonium[f,g] | | | | |
| Background | 1/6 | <0.06 | - | 0.10 |
| Downgradient | 5/5 | 0.35 | 0.80 | 1.30 |
| Well 4240 | 1/1 | - | 12.0 | - |
| Antimony | | | | |
| Background | 0/2 | <0.003 | - | <0.003 |
| Downgradient | 0/2 | <0.003 | - | <0.003 |
| Well 424 | NA | - | - | - |
| Arsenic | | | | |
| Background | 1/7 | <0.001 | - | <0.01 |
| Downgradient | 3/7 | <0.001 | - | <0.01 |
| Well 424 | 1/1 | - | 0.008 | - |
| Barium | | | | |
| Background | 2/2 | 0.10 | 0.20 | 0.30 |
| Downgradient | 2/2 | 0.10 | 0.15 | 0.20 |
| Well 424 | NA | - | - | - |
| Beryllium | | | | |
| Background | 0/2 | <0.005 | - | <0.01 |
| Downgradient | 0/2 | <0.005 | - | <0.01 |
| Well 424 | NA | - | - | - |
| Boron[g] | | | | |
| Background | 4/7 | 0.03 | 0.03 | 0.20 |
| Downgradient | 6/7 | <0.10 | 0.23 | 0.39 |
| Well 424 | 0/1 | - | <0.2 | - |
| Bromide | | | | |
| Background | 1/1 | 0.10 | - | 0.10 |
| Downgradient | 0/1 | <0.10 | - | <0.10 |
| Well 424 | 1/1 | - | 0.2 | - |
| Cadmium | | | | |
| Background | 0/5 | <0.001 | - | <0.001 |
| Downgradient | 0/5 | <0.001 | - | <0.001 |
| Well 424 | 0/1 | - | <0.001 | - |

**Table 3.2 Comparison of background and on-site ground water quality data from the unconsolidated materials, Canonsburg, Pennsylvania, site (1986-1993, filtered water samples) (Continued)**

| Parameter | Above detection[a] | Minimum | Median[b] | Maximum |
|---|---|---|---|---|
| | | mg/L | | |
| Calcium[f,g] | | | | |
| Background[c] | 11/11 | 39.4 | 43.6 | 50.1 |
| Downgradient[d] | 10/10 | 70.0 | 74.0 | 92.8 |
| Well 424[e] | 1/1 | - | 96.7 | - |
| Chloride[f] | | | | |
| Background | 11/11 | 36.0 | 43.0 | 51.9 |
| Downgradient | 10/10 | 2.10 | 3.85 | 7.20 |
| Well 424 | 1/1 | - | 136 | - |
| Chromium[f] | | | | |
| Background | 1/6 | <0.01 | - | 0.04 |
| Downgradient | 1/6 | <0.01 | - | 0.05 |
| Well 424 | 0/1 | - | <0.01 | - |
| Cobalt | | | | |
| Background | 1/5 | 0.03 | - | <0.05 |
| Downgradient | 0/5 | <0.03 | - | <0.05 |
| Well 424 | 0/1 | - | <0.05 | - |
| Copper | | | | |
| Background | 1/2 | <0.02 | - | 0.02 |
| Downgradient | 1/2 | <0.02 | - | 0.02 |
| Well 424 | NA | - | - | - |
| Cyanide[f] | | | | |
| Background | 0/5 | <0.01 | - | <0.01 |
| Downgradient | 2/5 | <0.01 | - | 0.01 |
| Well 424 | NA | - | - | - |
| Fluoride | | | | |
| Background | 7/7 | 0.10 | 0.14 | 0.20 |
| Downgradient | 7/7 | 0.14 | 0.19 | 0.30 |
| Well 424 | 1/1 | - | 0.1 | - |
| Iron[f] | | | | |
| Background | 11/11 | 2.63 | 8.68 | 12.0 |
| Downgradient | 10/10 | 0.07 | 3.40 | 4.66 |
| Well 424 | 1/1 | - | 22.3 | - |
| Lead[f] | | | | |
| Background | 0/11 | <0.001 | - | <0.01 |
| Downgradient | 0/10 | <0.001 | - | <0.01 |
| Well 424 | 0/1 | - | <0.003 | - |

**Table 3.2 Comparison of background and on-site ground water quality data from the unconsolidated materials, Canonsburg, Pennsylvania, site (1986-1993, filtered water samples) (Continued)**

| Parameter | Above detection[a] | Minimum | Median[b] | Maximum |
|---|---|---|---|---|
| | | mg/L | | |
| Magnesium[f] | | | | |
| Background | 11/11 | 14.1 | 15.3 | 17.0 |
| Downgradient | 10/10 | 9.45 | 10.3 | 12.6 |
| Well 424 | 1/1 | - | 26.3 | - |
| Manganese[f,g] | | | | |
| Background[c] | 11/11 | 1.47 | 3.12 | 4.05 |
| Downgradient[d] | 10/10 | 4.50 | 6.52 | 11.2 |
| Well 424[e] | 1/1 | - | 6.43 | - |
| Mercury | | | | |
| Background | 0/2 | <0.0002 | - | <0.0002 |
| Downgradient | 0/2 | <0.0002 | - | <0.0002 |
| Well 424 | NA | - | - | - |
| Molybdenum[f,g] | | | | |
| Background | 1/11 | <0.004 | - | 0.02 |
| Downgradient | 5/10 | 0.009 | - | 0.03 |
| Well 424 | 0/1 | - | <0.01 | - |
| Nickel | | | | |
| Background | 2/5 | <0.01 | - | 0.05 |
| Downgradient | 1/5 | <0.01 | - | <0.04 |
| Well 424 | 0/1 | - | <0.04 | - |
| Nitrate[f] | | | | |
| Background | 1/10 | <0.10 | - | <1.0 |
| Downgradient | 2/10 | <0.10 | - | 1.2 |
| Well 424 | 0/1 | - | <1.0 | - |
| Phosphate | | | | |
| Background | 1/3 | <0.01 | - | 0.20 |
| Downgradient | 1/3 | <0.01 | - | 0.20 |
| Well 424 | 1/1 | - | 0.40 | - |
| Potassium[f,g] | | | | |
| Background | 11/11 | 0.97 | 1.2 | 2.5 |
| Downgradient | 10/10 | 1.82 | 2.1 | 4.6 |
| Well 424 | 1/1 | - | 3.2 | - |
| Selenium[f] | | | | |
| Background | 0/11 | <0.001 | - | <0.005 |
| Downgradient | 0/10 | <0.001 | | <0.005 |
| Well 424 | 0/1 | - | <0.005 | - |

**Table 3.2 Comparison of background and on-site ground water quality data from the unconsolidated materials, Canonsburg, Pennsylvania, site (1986-1993, filtered water samples) (Continued)**

| Parameter | Above detection[a] | Minimum | Median[b] | Maximum |
|---|---|---|---|---|
| | | mg/L | | |
| Silica | | | | |
| Background | 3/3 | 6.0 | 6.8 | 13.8 |
| Downgradient | 3/3 | 3.9 | 5.0 | 11.6 |
| Well 424 | 1/1 | - | 12.1 | - |
| Silver | | | | |
| Background | 0/2 | <0.01 | - | <0.01 |
| Downgradient | 0/2 | <0.01 | - | <0.01 |
| Well 424 | NA | - | - | - |
| Sodium[f] | | | | |
| Background[c] | 11/11 | 38 | 43.9 | 50.1 |
| Downgradient[d] | 10/10 | 5.9 | 7.83 | 17.5 |
| Well 424[e] | 1/1 | - | 157 | - |
| Strontium[f,g] | | | | |
| Background | 2/3 | <0.10 | 0.10 | 0.13 |
| Downgradient | 3/3 | 0.20 | 0.29 | 0.30 |
| Well 424 | 1/1 | - | 0.32 | - |
| Sulfate[f] | | | | |
| Background | 11/11 | 117 | 138 | 171 |
| Downgradient | 10/10 | 79 | 99 | 119 |
| Well 424 | 1/1 | - | 210 | - |
| Sulfur | | | | |
| Background | 0/1 | <0.10 | - | <0.10 |
| Downgradient | 0/2 | <0.10 | - | <0.10 |
| Well 424 | NA | - | - | - |
| Thallium[f] | | | | |
| Background | 0/6 | <0.01 | - | <0.10 |
| Downgradient | 0/6 | <0.01 | - | <0.10 |
| Well 424 | NA | - | - | - |
| Tin | | | | |
| Background | 1/2 | <0.005 | - | 0.011 |
| Downgradient | 0/2 | <0.005 | - | <0.005 |
| Well 424 | NA | - | - | - |
| Uranium[f,g] | | | | |
| Background | 2/10 | <0.001 | - | 0.003 |
| Downgradient | 9/9 | 0.01 | 0.02 | 0.04 |
| Well 424 | 0/1 | - | <0.001 | - |

**Table 3.2 Comparison of background and on-site ground water quality data from the unconsolidated materials, Canonsburg, Pennsylvania, site (1986-1993, filtered water samples) (Concluded)**

| Parameter | Above detection[a] | Minimum | Median[b] | Maximum |
|---|---|---|---|---|
| | | | mg/L | |
| Vanadium[f] | | | | |
| Background | 2/10 | <0.001 | - | 0.02 |
| Downgradient | 2/9 | <0.001 | - | 0.02 |
| Well 424 | 0/1 | - | <0.01 | - |
| Zinc | | | | |
| Background | 7/7 | 0.033 | 0.079 | 0.157 |
| Downgradient | 6/7 | <0.005 | 0.014 | 0.051 |
| Well 424 | 0/1 | - | <0.005 | - |
| **Radionuclides** | | | pCi/L | |
| Lead-210 | | | | |
| Background[c] | 1/1 | 1.1 | - | 1.1 |
| Downgradient[d] | 2/2 | ND | 2.5 | 5.0 |
| Well 424[e] | NA | - | - | - |
| Polonium | | | | |
| Background | 1/1 | 0.10 | - | 0.10 |
| Downgradient | 2/2 | ND | 0.05 | 0.10 |
| Well 424 | NA | - | - | - |
| Radium-226[f] | | | | |
| Background | 6/6 | ND | 0.105 | 0.30 |
| Downgradient | 5/5 | ND | 0.10 | 0.70 |
| Well 424 | 1/1 | - | 0.2 | - |
| Radium-228[f] | | | | |
| Background | 6/6 | ND | 0.60 | 1.2 |
| Downgradient | 5/5 | ND | 1.15 | 2.3 |
| Well 424 | 1/1 | - | 3.8 | - |
| Thorium-230 | | | | |
| Background | 2/2 | ND | 0.70 | 1.4 |
| Downgradient | 3/3 | ND | 0.10 | 0.7 |
| Well 424 | 1/1 | - | 0.2 | - |

[a]Above detection = Number of samples with detectable concentration/total number of samples.
[b]Median is the 50th percentile of the data. The median cannot be calculated if 50 percent or more of the data are below detection. For parameters having only one round of sampling data, the single reported value is listed in the median column.
[c]DOE well 410 was used as background.
[d]DOE well 414 is located in Area C and was used as the downgradient well.
[e]Monitor well 424 is in Area C and is indicative of downgradient conditions but, with only one sampling round, could not be included in the statistical analysis. The single value for each parameter from this well is reported in the median column.
[f]Data collected from 1988 through 1993 are summarized for these parameters. For all other parameters, all available data from 1986 through 1993 are summarized.
[g]Concentrations are statistically elevated in well 414 above background.
NA – not applicable.
ND – not detected.

unconsolidated unit is relatively more calcium-rich and bicarbonate-rich and chloride-poor than the background ground water from monitor well 410. Concentration versus time plots (Figures 3.2, 3.3, and 3.4) show elevated levels of manganese, molybdenum, and uranium in monitor well 414 relative to background. Note that one component of the unconsolidated unit is iron slag, which was used as fill material (DOE, 1983b). This material contains high concentrations of iron and manganese and its presence in the subsurface could affect iron and manganese concentrations in the ground water. Table 3.2 is a statistical summary of ground water data from background and select downgradient wells in the unconsolidated materials for filtered water samples.

### 3.2.2 Bedrock unit

Well 505 shows no sign of contamination. Uranium concentrations in well 506 have been above 0.2 milligrams per liter (mg/L) since sampling began in 1986 (Figure 3.4). This monitor well was installed in an area containing contaminated material that was not put into the disposal cell (this contaminated material is in a separate covered area), apparently resulting in the locally elevated concentrations of uranium. Monitor well 510 was installed just downgradient from well 506 to verify a possible local source of contamination. The concentration of uranium in ground water from well 510 is low (less than the detection limit), indicating that the above assumption is probably correct. Also, the apparent lack of lateral hydraulic continuity of ground water in the shallow bedrock may be substantiated by these results, indicating that even with an elevated source area, migration of contaminants in this area is minimal. Contamination appears to have affected no other well in the bedrock unit. Comparing data from well 509 (located in Area C) with data from background well 504, it appears that over time, concentrations in well 509 generally fall within the range of levels found in well 504 (DOE, 1995). Thus, current data indicate that the bedrock unit is not contaminated except in the immediate area of monitor well 506. The site will continue to be monitored, and risks can be re-evaluated if there is any indication that contamination has migrated into the bedrock unit.

### 3.2.3 Summary of site-related contamination

It is not possible to delineate a plume due to the variable nature of contamination across the site. However, contamination is limited to shallow ground water in the areas immediately adjacent to and beneath the disposal cell and ground water in Area C. After the extent of contamination was determined, 1986 through 1993 water quality data were evaluated to identify statistically those constituents elevated above background concentrations in the alluvial aquifer (DOE, 1995). Qualitative trend analysis of concentration versus time for all parameters indicated that pre-1988 data generally have greater variability and greater number of anomalies than data collected from 1988 through 1993 (TAC, 1994a). Moreover, the recent data are considered to be more representative of current ground water conditions. For these reasons, when possible, data from sampling events in 1988 through 1993 were preferentially

used in the statistical evaluation over pre-1988 data. For many parameters, however, a limited number of sampling rounds from 1988 through 1993 did not allow for rigorous statistical comparisons. In these cases, data from all sampling events from 1986 through 1993 were used.

For each constituent, a Mann-Whitney test was conducted at the 0.05 level of significance (DOE, 1995). A significant Mann-Whitney test result indicates higher concentrations, on average, in the samples from well 414 than those in background well 410. Table 3.2 is a summary of 1986 through 1993 water quality data in the alluvial aquifer. Those constituents for which only data from 1988 through 1993 were used are identified. Table 3.2 also identifies constituents statistically elevated above background levels.

## 3.3 CONTAMINANTS OF POTENTIAL CONCERN

The data presented in Sections 3.1 and 3.2 were used to compile a list of contaminants of potential concern for the assessment of human health or environmental risks at the Canonsburg site. In general, a contaminant was placed on the list of contaminants of potential concern if it was detected in excess of background levels as measured in upgradient monitor wells and if the site is a possible source for the contaminant.

Table 3.3 presents the list of contaminants of potential concern for ground water. The contaminants listed in column 1 represent those contaminants detected in the unconsolidated material in Area C (represented by well 414) that were statistically elevated from upgradient levels in the unconsolidated material (represented by well 410). These contaminants were further screened for their potential to affect human health in order to develop a final list of contaminants of potential concern for human health. Several constituents were screened out because they are essential nutrients present at levels within the nutritional ranges even when added to expected dietary intake. These constituents include calcium and potassium (DOE, 1994; 1995). Ammonium, boron, and strontium were eliminated as contaminants of potential concern based on low toxicity and/or intakes present at normal dietary levels relative to observed levels (DOE, 1995). Although ammonium is not considered a dietary component, it is produced in the human body at levels exceeding 4000 milligrams (mg) per day (Summerskill and Wolpert, 1970), over 3 orders of magnitude more than would be expected from the ingestion of the maximum ammonium levels in well 414 (1.3 mg/L). Thus, the levels of ammonium in well 414 are not likely to be associated with adverse health effects.

Based on the screening, manganese, molybdenum, and uranium were chosen as final contaminants of potential concern for the human health risk assessment. Also, because uranium decays to radioactive progeny, Section 6.0 will evaluate the longer-lived radioactive isotopes of the uranium decay series (represented by lead-210, polonium-210, radium-226, and thorium-230). These seven constituents form the basis of the human health risk assessment for the unconsolidated material at the Canonsburg site.

**Table 3.3 Contaminants of potential concern in ground water, Canonsburg, Pennsylvania, site**

| Contaminant levels exceeding background | Contaminant levels in nutritional range | Contaminants of low toxicity and/or high dietary range | Contaminants of potential concern for human health[a] |
|---|---|---|---|
| Ammonium | Calcium | Ammonium | Manganese |
| Boron | Potassium | Boron | Molybdenum |
| Calcium | | Strontium | Uranium[b] |
| Manganese | | | |
| Molybdenum | | | |
| Potassium | | | |
| Strontium | | | |
| Uranium | | | |

[a]The screening process starts with the first column; constituents listed in the second and third columns were subtracted from the list of constituents in the first column; the remaining constituents form the list in the last column.

[b]The longer-lived radioactive isotopes of the uranium decay series are represented by radium-226, lead-210, polonium-210, and thorium-230. These radionuclides are evaluated as contaminants of potential concern.

Note: Based on data from well 414 located in the unconsolidated material in Area C.

Because ecological impacts differ from effects on human health, the complete list of contaminants was considered for the ecological evaluation in Section 7.0. In addition, due to other ecological-specific considerations, the ecological evaluation also assessed contaminants from wells 412 and 413 that exceeded background levels. Additional contaminants evaluated in the ecological assessment as a result of the inclusion of these two wells were arsenic, chloride, magnesium, sodium, and sulfate.

Some constituents (ammonium, arsenic, calcium, chloride, iron, sodium, sulfate, and radium-228) were observed at higher levels in ground water from monitor well 424 than 414 (Table 3.2). These constituents could potentially be included in the list presented in column 1 in Table 3.3 if analytical results of the only sampling round from monitor well 424 were used, without further sampling, to identify contaminants of potential concern. Ammonium, calcium, chloride, and sodium would be screened out from this list, because the levels at which they were detected are within either nutritional or normal dietary ranges, even when added to expected dietary intake (Gilman et al., 1990). Sulfate would be screened out because it is not toxic at detected levels (210 mg/L) (EPA, 1992). Potential presence of arsenic, iron, and radium-228 at these levels in well 424 needs to be further evaluated.

## 3.4 CONTAMINANT FATE AND TRANSPORT

At the Canonsburg site, ground water occurs in near-surface unconsolidated materials (including fill material) and in the underlying bedrock. As contaminants migrate through the ground water system, they interact with natural chemical variations in ground water at the site and with the matrix materials. These interactions will produce variations in contaminant concentrations that are not simply the result of physical dispersion. Contaminant interactions are strongly dependent on Eh and pH conditions, ionic strength (generally indicated by TDS), and the speciation of the elements of concern in ground water.

Water from background well 410 completed in the unconsolidated material shows pH in the range of 5.4 to 6.2 and redox potentials near 300 millivolts (mV). Water from downgradient well 414, also completed in the unconsolidated material, shows pH in the range of 5.7 to 6.7 and redox potentials near 400 mV. The downgradient well has a slightly higher pH and a slightly higher redox potential, but both waters are mildly acidic and oxidizing.

In contrast, water in the bedrock system, in addition to having substantially higher TDS, is reducing (Eh near 0 mV) and has a more variable pH. The pH ranges from near 8.5 in well 505, completed in the bedrock unit across Chartiers Creek east of the site, to between 6.5 and 7.0 in background well 504, completed in the bedrock unit at the same location as background well 410. Ground water from downgradient well 414 (January 1991 sampling round), completed in the unconsolidated material, was modeled using the geochemical code PHREEQE (Parkhurst et al., 1980) to predict which species of the contaminants of concern might be present in ground water at the site (DOE, 1995). Information for some species was taken from Brookins (1988). Table 3.4 presents results of the model.

### Manganese

Manganese concentrations ranging from 4.85 to 12.1 mg/L have been observed in downgradient monitor well 414. These values are significantly higher than those observed in background well 410, which range from 1.47 to 3.42 mg/L (Figure 3.3). Water from both wells is mildly oxidizing (redox potentials near 300 mV), with pH values between 5 and 6. Under these conditions, modeling with the geochemical code PHREEQE (Parkhurst et al., 1980) suggests that $Mn^{2+}$ accounts for more than 90 molar percent of manganese species present (Table 3.4). $Mn^{2+}$ is relatively mobile and the major decrease in manganese concentration will likely be adsorption onto matrix materials and dilution as ground water discharges into the adjacent Chartiers Creek. This creek is the primary discharge point for the shallow ground water system on the site.

Water from monitor well 505, completed in the bedrock ground water system, is relatively more reducing (redox potentials near 0 mV) and has a higher pH (near 8.5) compared with well 414 (pH near 6). If there is flow from the shallow ground water table to the bedrock ground water system, creation of solid

**Table 3.4 Stable species of constituents of concern in the ground water system at the Canonsburg, Pennsylvania, site**

| Contaminant of potential concern | Common name | Identity of species in ground water | Approximate molar percentage |
|---|---|---|---|
| Manganese | Manganese ion | $Mn^{2+}$ | 92 |
| | Manganese sulfate | $MnSO_{4\ AQ}$ | 5 |
| | Manganese bicarbonate | $MnHCO_3^+$ | 3 |
| Molybdenum | Molybdate | $MoO_4^{2-}$ | 100 |
| Uranium | Uranyl dicarbonate | $UO_2(CO_3)_2^{2-}$ | 63 |
| | Uranyl carbonate | $UO_2CO_{3\ AQ}$ | 34 |
| | Uranyl tricarbonate | $UO_2(CO_3)_3^{4-}$ | 3 |
| Lead-210 | Lead carbonate | $PbCO_{3\ AQ}$ | 49 |
| | Lead bicarbonate | $PbHCO_3^+$ | 26 |
| | Lead ion | $Pb^{2+}$ | 21 |
| | Lead sulfate | $PbSO_{4\ AQ}$ | 5 |
| Thorium-230[a] | Thorium hydroxide | $Th(OH)_3^+$ | Dominant |
| Polonium-210[a] | Polonium ion | $Po^{2+}$ | 100 |
| Radium[a] | Radium ion | $Ra^{2+}$ | 100 |

[a]Information from Brookins (1988).

Note: Eh = 300 mV and pH = 6.3 (conditions observed in downgradient monitor well 414, completed in the unconsolidated materials, during the January 1991 sampling round).

precipitates could become an important mechanism for attenuation of manganese in the plume. Modeling with PHREEQE (Parkhurst et al., 1980) indicates that mixing with the higher pH water in the lower unit could more strongly stabilize Fe and Mn oxides and hydroxides in the aquifer matrix, and these metals would tend to be adsorbed or precipitated. An increase in pH accompanied by the high alkalinity of the bedrock water could result in precipitation of the mineral rhodochrosite ($MnCO_3$) and manganese attenuation.

Molybdenum

In samples taken since 1987, molybdenum occurs in concentrations from near the detection limit to 0.02 mg/L in background well 410 and from near the detection limit to 0.03 mg/L in downgradient well 414 (Figure 3.3). Samples taken in August 1986 are high for all wells sampled. Values reported for both background well 410 and downgradient well 414 are 0.20 mg/L during that sampling round. Modeling with PHREEQE (Parkhurst et al., 1980) indicates that molybdenum occurs in these waters as the molybdate species $MoO_4^{2-}$ (Table 3.4). This species becomes relatively mobile in water with pH values above 5 (Brookins, 1988). Thus, the primary mechanisms for decreasing molybdenum concentrations will be dilution and dispersion as ground water discharges into Chartiers Creek. Coprecipitation with and adsorption on iron oxides and hydroxides may be a secondary mechanism for removing molybdenum from ground water, particularly if contamination is transported into the bedrock unit.

Uranium

Uranium concentrations of 0.01 to 0.04 mg/L in downgradient well 414 are significantly higher than those in background well 410 (below detection to 0.003 mg/L) (Figure 3.4). Modeling with PHREEQE (Parkhurst et al., 1980) predicts that various uranyl carbonates are the dominant uranium species in solution (Table 3.4). These species are relatively stable in mildly oxidizing and alkaline solutions such as water in the upper ground water system at the Canonsburg site. Thus, the major reduction in uranium concentrations at the site will occur by dilution as ground water discharges into Chartiers Creek. Adsorption on iron and manganese oxides and hydroxides could also be important in removing uranium from the ground water. If uranium were to migrate from the unconsolidated unit to the bedrock system, more reducing conditions could stabilize the mineral uraninite in the system and uranium would be precipitated.

Radium-226 and radium-228

In data from 10 sampling dates for downgradient well 414, radium-226 is above detection only on 28 October 1993, with a value of 0.7 ± 0.5 picocuries per liter (pCi/L) for the filtered sample. Background well 410 also shows values below detection except on 5 November 1986, which shows a value of 2.1 ±0.6 pCi/L. Similarly, radium-228 is above detection in monitor well 414

only once in 10 sampling dates with a value of 2.3 ±1.0 pCi/L on 1 August 1991, and twice in monitor well 410 with a high value of 1.2 ± 1.0 on 1 August 1991. These values are not statistically different.

Radium is an alkaline-earth metal that shares many chemical characteristics with the more common alkaline-earth element barium. Like barium, radium forms a highly insoluble sulfate compound at pH values ranging from 3 to more than 12 (Brookins, 1988), but ion exchange reactions primarily are expected to control solution concentrations. Radium is more strongly adsorbed by clays and iron oxides/hydroxides than are strontium, calcium, and magnesium, suggesting that radium should be essentially immobile in ground water at the Canonsburg site.

Lead-210

Very little data are available for lead-210. Water from background well 410 was analyzed once in 1986 for lead-210 (filtered sample), with results reported as 1.1 ± 1.1 pCi/L, and once in 1993 (unfiltered sample), with results reported as 0.7 ± 1.5 pCi/L. For downgradient well 414, a single analysis in 1986 (filtered sample) shows 5.0 ± 1.2 pCi/L and an analysis in 1993 (unfiltered sample) shows 1.3 ± 1.5 pCi/L. Thus, lead-210 in downgradient well 414 is higher than background for a single analysis in 1986.

Processes affecting lead-210 in the ground water at the Canonsburg site are the same as those affecting lead in general. Modeling by PHREEQE (Parkhurst, et al., 1980) predicts that the dominant species in ground water from well 414 will be various carbonate species (Table 3.4). This water is not saturated with the lead carbonate mineral cerrusite, so it is unlikely that precipitation will remove lead. However, iron oxides and hydroxides are stable in the ground water matrix and these phases strongly adsorb lead. Therefore, lead contamination probably will not extend beyond the confines of the site.

Polonium-210

With only three sample dates reported, Polonium-210 was not detected at downgradient well 414. With two sample dates reported, background well 410 shows one concentration below detection and one at 0.2 ± 0.1 pCi/L.

Polonium-210 is produced by the beta decay of lead-210 (half-life equals 22 years) through the intermediate short-lived daughter bismuth-210 (half-life equals 5.02 days). Polonium-210 has a half-life of 138 days and decays to stable lead-206. Because lead-210 has a much longer half-life than bismuth-210 or polonium-210, the distribution of lead-210 primarily will control the distribution of polonium-210 at this site.

Thorium-230

As with lead-210, data are sparse for this constituent. Thorium-230 in downgradient well 414 is above detection for only one sampling date on which

the values in the filtered sample (0.7 ± 0.3 pCi/L) were found to be higher than those in the unfiltered sample (0.5 ± 0.3 pCi/L). With only two sampling dates, background well 410 also has one sample with values that are above detection (1.4 ± 0.3 pCi/L filtered and 0.3 ± 0.3 pCi/L unfiltered). These values are higher than those in downgradient well 414.

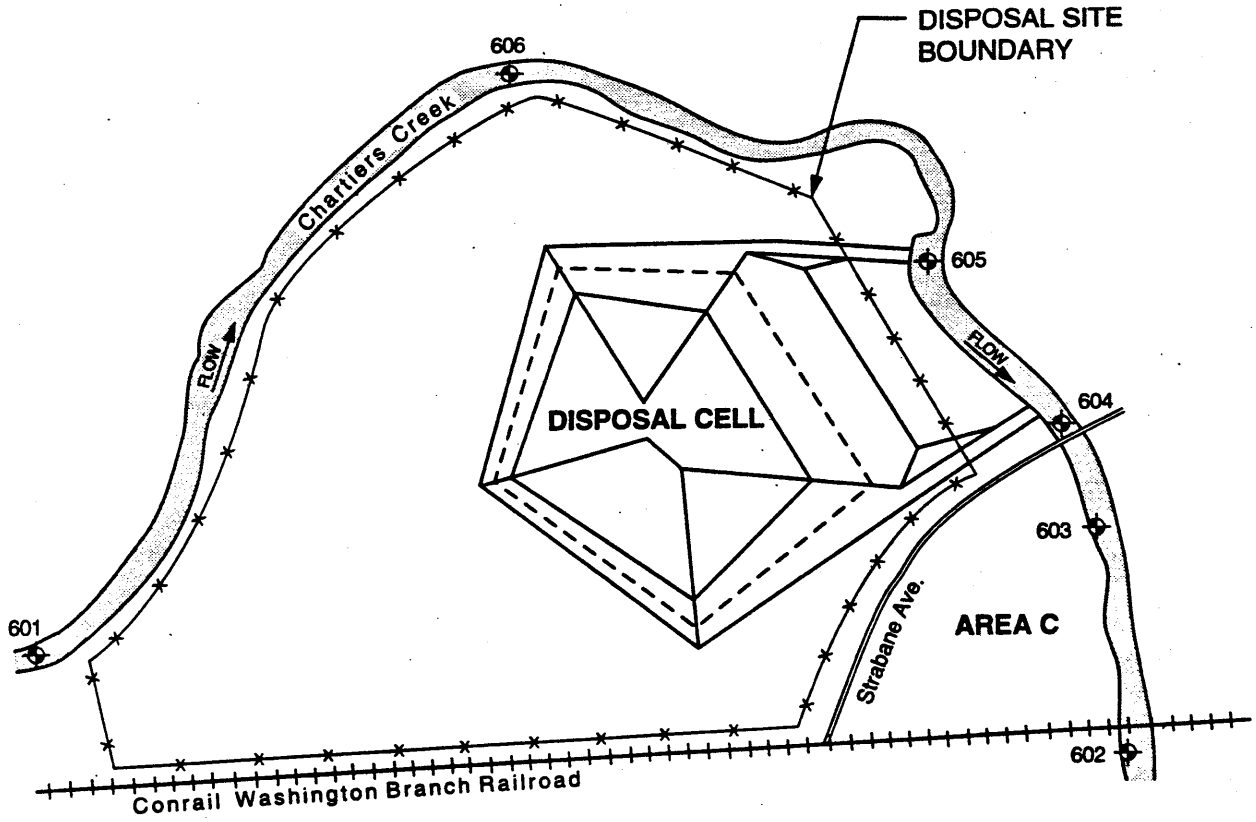
Whatever the source of thorium-230 in these wells, the highly insoluble $Th(OH)_4$ and $ThO_2$ (Brookins, 1988; Langmuir and Herman, 1980) dominate the Eh and pH ranges of ground water at Canonsburg. Therefore, it is likely that the Eh and pH conditions at the Canonsburg site will effectively immobilize thorium-230.

## 3.5 SURFACE WATER MONITORING

Up to six rounds of water quality data are available from surface locations at Chartiers Creek. In addition, one round of sediment data is available from each location. Based on these data, there is no evidence that the site contributes contamination to the creek. Detailed discussion of these data is provided below.

Figure 3.5 shows the six sampling locations (601 through 606). Prior to the October 1993 ecological field survey, only locations 601 (upstream of the site) and 602 (adjacent to Area C) had been sampled. One to three filtered surface water samples were collected from these two locations during 1989 and 1990. One to four unfiltered surface water samples were collected from these locations from 1991 through 1993 (Table 3.5). Comparing the unfiltered water sample data from location 601 with location 602 indicates no statistically significant differences in water quality between the two sampling sites (DOE, 1995). Uranium was not detected (<0.001 mg/L) at either site. Five of the ground water constituents (ammonium, magnesium, manganese, sodium, and sulfate) were detected at the upstream location (601) at median concentrations equal to or greater than concentrations observed at the downstream location (602). For the other four constituents (calcium, chloride, molybdenum, and potassium), the concentrations detected at location 602 were higher than the upstream concentrations. However, the differences in concentrations between the two sites for these four constituents are minimal, ranging from 2 to 6 percent, and do not represent a statistically significant difference (DOE, 1995).

Surface water samples were collected in October 1993 at all sampling locations (601 through 606). Locations 603 through 606 were not sampled prior to this date. The samples collected in October 1993 were analyzed for a select list of constituents (chromium, iron, lead, manganese, molybdenum, selenium, sulfate, uranium, vanadium, and zinc). These constituents were chosen based on a preliminary screening of the ground water data prior to development of this risk assessment. Of these constituents, concentrations of manganese, molybdenum, sulfate, and uranium were identified as exceeding background levels in ground water. An evaluation of the most recent surface water data (October 1993) for all sampling locations (see Section 7.0) indicates that uranium was not detected at any location, and sulfate was detected at the




LEGEND

602 ⊕ SURFACE WATER AND SEDIMENT SAMPLE LOCATION

FENCE

200 0 200 400 FEET

50 0 50 100 METERS

**FIGURE 3.5**
**SURFACE WATER AND SEDIMENT SAMPLE LOCATIONS**
**CANONSBURG, PENNSYLVANIA, SITE**

**Table 3.5 Comparison of upstream and downstream water quality data from Chartiers Creek, Canonsburg, Pennsylvania, site (1989-1993, unfiltered water samples)**

| Parameter[a] | Above detection[b] | Minimum | Median[c] | Maximum |
|---|---|---|---|---|
| **Inorganic parameters** | | | mg/L | |
| Ammonium | | | | |
| Upstream | 3/4 | <0.06 | 0.25 | 0.8 |
| 602 | 3/4 | <0.06 | 0.20 | 0.3 |
| Cadmium | | | | |
| Upstream | 0/1 | - | <0.001 | - |
| 602 | 0/1 | - | <0.001 | - |
| Calcium | | | | |
| Upstream | 5/5 | 80.1 | 83.0 | 112 |
| 602 | 5/5 | 80.0 | 86.7 | 116 |
| Chloride | | | | |
| Upstream | 5/5 | 36 | 50.1 | 99 |
| 602 | 5/5 | 34 | 50.8 | 101 |
| Chromium | | | | |
| Upstream | 0/2 | <0.01 | - | <0.01 |
| 602 | 0/2 | <0.01 | - | <0.01 |
| Downstream[f] | 0/4 | <0.01 | - | <0.01 |
| Cobalt | | | | |
| Upstream | 0/1 | - | <0.05 | - |
| 602 | 0/1 | - | <0.05 | - |
| Cyanide | | | | |
| Upstream | 1/4 | <0.01 | - | 0.02 |
| 602 | 0/4 | <0.01 | - | <0.01 |
| Iron | | | | |
| Upstream | 6/6 | 0.36 | 0.565 | 2.80 |
| 602 | 6/6 | 0.36 | 0.520 | 2.92 |
| Downstream | 4/4 | 0.57 | 0.650 | 0.74 |
| Lead | | | | |
| Upstream | 2/6 | <0.0015 | - | 0.009 |
| 602 | 3/6 | 0.0022 | - | 0.012 |
| Downstream | 2/4 | <0.003 | - | 0.004 |
| Magnesium | | | | |
| Upstream | 5/5 | 16.9 | 18.8 | 29.2 |
| 602 | 5/5 | 16.8 | 18.9 | 29.5 |
| Manganese | | | | |
| Upstream | 6/6 | 0.13 | 0.155 | 0.20 |
| 602 | 6/6 | 0.12 | 0.155 | 0.22 |
| Downstream | 4/4 | 0.12 | 0.140 | 0.17 |

**Table 3.5 Comparison of upstream and downstream water quality data from Chartiers Creek, Canonsburg, Pennsylvania, site (1989-1993, unfiltered water samples) (Continued)**

| Parameter[a] | Above detection[b] | Minimum | Median[c] | Maximum |
|---|---|---|---|---|
| | | mg/L | | |
| Molybdenum | | | | |
| Upstream | 6/6 | 0.04 | 0.080 | 0.22 |
| 602 | 6/6 | 0.04 | 0.085 | 0.17 |
| Downstream | 4/4 | 0.10 | 0.125 | 0.17 |
| Nitrate | | | | |
| Upstream | 5/5 | 0.43 | 11.7 | 31.0 |
| 602 | 5/5 | 0.43 | 11.9 | 26.6 |
| Potassium | | | | |
| Upstream | 5/5 | 3.6 | 6.5 | 10.4 |
| 602 | 5/5 | 3.3 | 6.8 | 10.2 |
| Selenium | | | | |
| Upstream | 0/6 | <0.0015 | - | <0.05 |
| 602 | 0/6 | <0.0015 | - | <0.005 |
| Downstream | 0/4 | <0.005 | - | <0.005 |
| Sodium | | | | |
| Upstream | 5/5 | 36.7 | 62 | 132 |
| 602 | 5/5 | 36.0 | 58 | 135 |
| Sulfate | | | | |
| Upstream | 6/6 | 116 | 207.0 | 383 |
| 602 | 6/6 | 128 | 202.5 | 412 |
| Downstream | 4/4 | 248 | 262.0 | 276 |
| Thallium | | | | |
| Upstream | 0/3 | <0.01 | - | <0.01 |
| 602 | 0/3 | <0.01 | - | <0.01 |
| Uranium | | | | |
| Upstream | 1/5 | <0.001 | - | 0.001 |
| 602 | 1/5 | <0.001 | - | 0.002 |
| Downstream | 0/4 | <0.001 | - | <0.001 |
| Vanadium | | | | |
| Upstream | 2/6 | <0.0019 | - | 0.02 |
| 602 | 2/6 | <0.0019 | - | 0.02 |
| Downstream | 4/4 | 0.01 | 0.025 | 0.03 |
| Zinc | | | | |
| Upstream | 1/1 | - | 0.045 | - |
| 602 | 1/1 | - | 0.199 | - |
| Downstream | 4/4 | 0.040 | 0.047 | 0.064 |

**Table 3.5 Comparison of upstream and downstream water quality data from Chartiers Creek, Canonsburg, Pennsylvania, site (1989-1993, unfiltered water samples) (Concluded)**

| Parameter[a] | Above detection[b] | Minimum | Median[c] | Maximum |
|---|---|---|---|---|
| **Radiological parameters** | | | pCi/L | |
| Radium-226 | | | | |
| Upstream | 4/4 | ND | 0.12 | 0.90 |
| 602 | 4/4 | ND | 0.0 | 0.12 |

[a]Data were available from sampling events as early as 1989. All sampling events were used in this summary.

[b]Above detection = Number of samples with detectable concentration/total number of samples.

[c]Median is the 50$^{th}$ percentile of the data. The median cannot be calculated if 50 percent or more of the data are below detection. For parameters for which only one sampling round of data was available, the one reported value is listed in the median column.

[d]Upstream sampling location 601 was used as background. Sampling data from 1989 through 1993 were available for this location.

[e]Sampling location 602 was the only downstream location for which sufficient historical data were available for statistical evaluation.

[f]Sampling locations 603, 604, 605, and 606 were also considered to be downstream. These locations were sampled only during the October 1993 sampling round, and these samples were analyzed for only 10 inorganic parameters.

highest concentration at the upstream location (Table 3.5). For the other two constituents (manganese and molybdenum), the differences between the upstream concentrations and adjacent or downstream concentrations ranged from 10 to 47 percent, with the highest values detected at location 606. Although the surface water quality data base is limited, the available data suggest that ground water contamination from the site is not affecting the water quality of Chartiers Creek. However, acid mine drainage (the closest of several upstream mines is approximately 1 mi [1.6 km] southwest of the site) and industrial and municipal discharges (FBDU, 1982; Newport, 1973) affect water quality in Chartiers Creek. Concentrations of sulfate, iron manganese, and TDS are elevated in surface water at both upstream and downstream sampling locations (Table 3.5).

Sediment samples were collected at all surface water sampling locations (601 through 606) in October 1993. Table 3.6 is a summary of the sediment sampling data. Sediments are an integral part of the aquatic environment, providing habitat, feeding, and rearing areas for many aquatic organisms (Hull and Suter, 1994). The sediment layer includes solid particles (inorganic and organic) settling on the bottom of a body of water such as a river or a pond, and interstitial water (pore water), which fills the spaces between the sediment particles (Power and Chapman, 1992). In the environment, these particles are derived both from material originally suspended in the water and minerals that precipitate from the water. Pore water usually accounts for over 50 percent (by volume) of the sediment layer. Note that results presented in this risk assessment represent the chemistry of both the solid and pore-water components of the sediment layer. Potentially, site-related ground water could affect sediment concentrations of certain constituents. However, information available from only one sampling round does not allow assessment of this potential. If site-related constituents were to accumulate in sediment they could then act as a source of site-related surface water contamination. However, as discussed in Section 7.0, no evidence suggests that this is now occurring.

**Table 3.6 . Comparison of upstream and downstream sediment data from Chartiers Creek, Canonsburg, Pennsylvania, site (1993)**

| Parameter[a] | Above detection[b] | Minimum | Median[c] | Maximum |
|---|---|---|---|---|
| **Inorganic parameters** | | | mg/L | |
| Chromium | | | | |
| Upstream[d] | 1/1 | - | 96 | - |
| Downstream[e] | 5/5 | 22 | 69 | 189 |
| Iron | | | | |
| Upstream | 1/1 | - | 37,400 | - |
| Downstream | 5/5 | 26,200 | 56,600 | 105,000 |
| Lead | | | | |
| Upstream | 1/1 | - | 80.8 | - |
| Downstream | 5/5 | 0.42 | 49.5 | 53.7 |
| Manganese | | | | |
| Upstream | 1/1 | - | 1,410 | - |
| Downstream | 5/5 | 590 | 1,900 | 2,820 |
| Molybdenum | | | | |
| Upstream | 1/1 | - | 33 | - |
| Downstream | 5/5 | 2 | 16 | 96 |
| Selenium | | | | |
| Upstream | 0/1 | - | <0.5 | - |
| Downstream | 1/5 | <0.5 | <0.5 | 0.7 |
| Uranium | | | | |
| Upstream | 1/1 | - | 2.0 | - |
| Downstream | 5/5 | 1.6 | 2.0 | 2.6 |
| Vanadium | | | | |
| Upstream | 1/1 | - | 42 | - |
| Downstream | 5/5 | 22 | 41 | 126 |
| Zinc | | | | |
| Upstream | 1/1 | - | 252 | - |
| Downstream | 5/5 | 90 | 204 | 268 |

[a]Data were available from a single sampling round in October 1993.
[b]Above detection = Number of samples with detectable concentration/total number of samples.
[c]Median is the 50$^{th}$ percentile of the data. The median cannot be calculated if 50 percent or more of the data are below detection. When data were available from only one sampling round, the single value is reported in the median column.
[d]Upstream sampling location 601 was used as background.
[e]Sampling locations 602, 603, 604, 605, and 606 were combined as downstream.

# 4.0 EXPOSURE ASSESSMENT

This section discusses and estimates the type and magnitude of exposures to the chemicals of potential concern present at the Canonsburg site. The exposure pathways evaluated in this section are based on potential contact with ground water, surface water, and sediment at the site or in the site vicinity.

## 4.1 POTENTIALLY EXPOSED POPULATION

Ground water contaminated by uranium processing at the Canonsburg site is not currently used. The source of drinking water for residents in the site vicinity is the Monongahela River as supplied by the Pennsylvania-American Water Company. As shown in Figure 2.10, a number of residents within a 1-mi (1.6-km) site radius have domestic wells; however, most of these wells are hydrologically upgradient or crossgradient from the site and they are not in use. Additionally, in the future, it is unlikely that residents will ever use these wells for domestic purposes. The shallow ground water is not considered as a potable water resource in the Canonsburg site area, and good quality water is available from the municipal water supply system. Residents located slightly beyond 1 mi (1.6 km) north and south of the site use the ground water for drinking purposes, and one well approximately 400 ft (120 m) north of the site is used for domestic purposes other than drinking. However, contaminated ground water from the site appears to be confined within the Canonsburg site area. Chartiers Creek probably creates a barrier for the contamination. Therefore, site-contaminated ground water has not migrated to off-site locations and is not expected to affect these residents (see Sections 2.4 and 2.7).

Because there are no current human receptors of contaminated ground water, this assessment assumes a future resident ground water use scenario. In the future, a domestic well could be installed in the unconsolidated material in Area C, creating the potential for exposure through drinking, bathing, and irrigation. This assumption is made because Area C is the only portion of the site available for future public use. However, the likelihood for residential development at the site is considered low. The exposure point in this area will be based on data from well 414. Although wells from other areas of the site (i.e., well 412 and 413) have higher levels of some contaminants, data from these wells were not used in this assessment because no one will use the ground water in this area. This portion of the site will be in DOE possession, and development of this area will not be permitted (TAC, 1994b). The ground water in this area discharges to Chartiers Creek. Based on available data, it appears that contamination has not migrated to the bedrock (see Section 2.4).

The future resident scenario evaluates domestic ground water uses consistent with current water uses by the population in the region. The potentially exposed population includes residents of the following age groups: children (1 to 10 years old and 6 to 12 years old) and adults (11 to 65 years old). These age groups were selected for the following reasons:

- Survey data for population variables such as age, weight, and daily water intake are available for these age groups.

- Toxicological variables are similar within these age groups, including responsiveness of sensitive subgroups to the contaminants of concern, consistent intake to body weight ratios, and similar toxicokinetics (a study of the time course of absorption, distribution, metabolism, and excretion of a contaminant in an individual's body).

- Potential exposures to nearby populations may occur in surface waters near the site because ground water in the unconsolidated material at the site discharges into Chartiers Creek. Local residents (adults and older children) could use these waters for wading, swimming, or fishing.

## 4.2 EXPOSURE PATHWAYS

An exposure pathway describes the course a chemical takes from a source to an exposed organism. Exposure can occur only if there is a source of contamination, a point of contact with a population or individual, and a route of exposure (e.g., water ingestion). Because the tailings piles and soils contaminated from uranium operations at the site were removed and relocated to a disposal cell, soil or air exposure pathways (such as accidental soil ingestion, dermal contact with soil, or inhalation of particulates) are not considered. This assessment evaluates both ground water and surface water/sediment pathways. Figure 4.1 presents a conceptual model of the potential ground water and surface water/sediment exposure pathways that may occur at the Canonsburg site. The following subsections discuss these pathways in more detail.

### 4.2.1 Ground water

Area C is the only portion of the site available for future development. As discussed earlier in this document, the majority of the site (the disposal site area—see Figure 2.2 for location), is within a permanently restricted zone. Therefore, only ground water beneath Area C is evaluated for possible future use.

Although it is unlikely that ground water in the site vicinity will be used in the future for drinking purposes because of the existing public water supply system, this risk assessment will assess hypothetical future use of the ground water in the unconsolidated material. Water in the region is primarily used for household purposes such as drinking, cooking, and bathing. Another use typical of the region that could indirectly lead to human exposure is irrigation of garden vegetables. The conceptual model (Figure 4.1) presents the potential ground water exposure routes that could result from these uses and includes drinking water ingestion, dermal absorption, and garden produce ingestion.

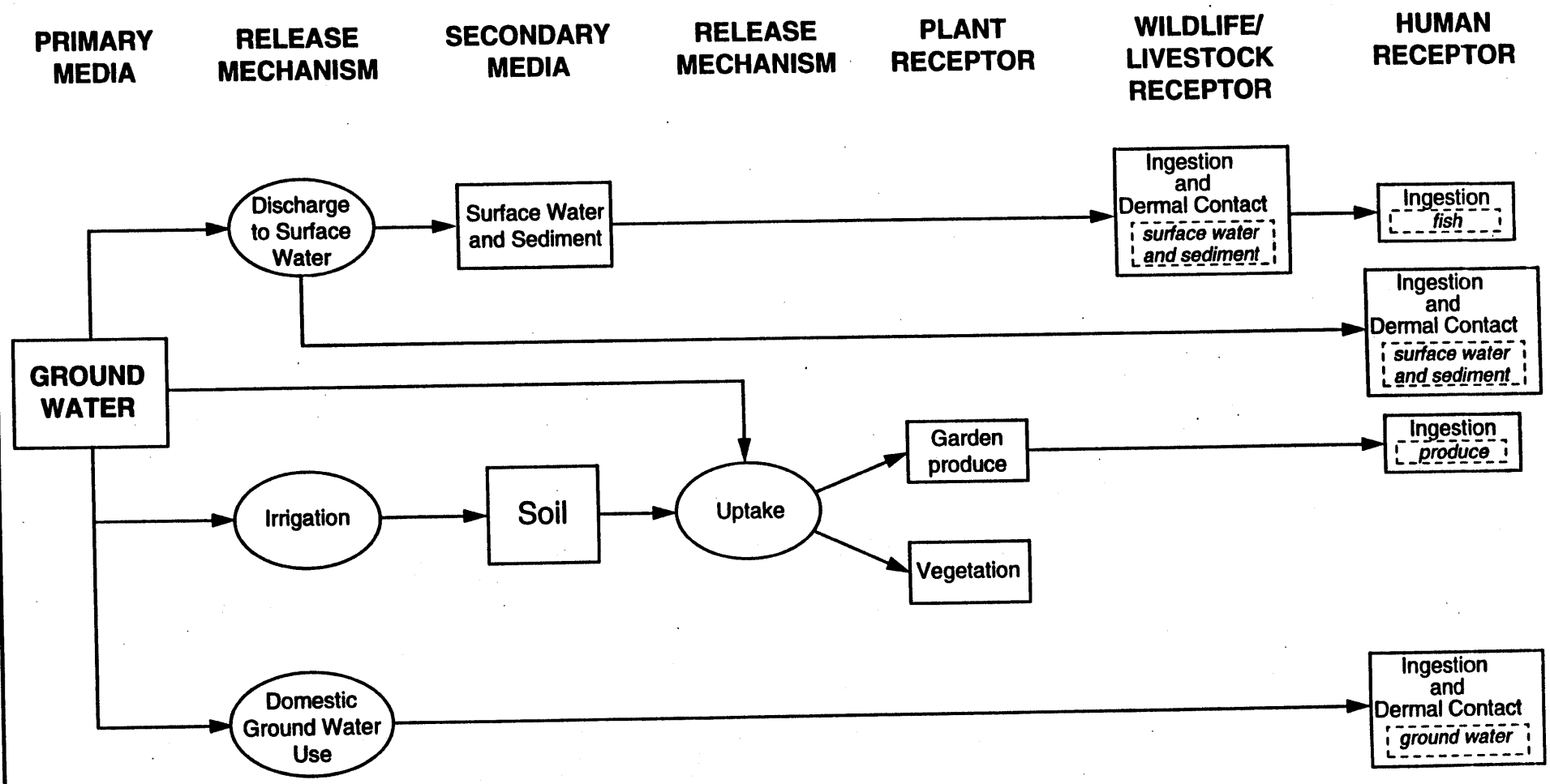



**FIGURE 4.1**
**CONCEPTUAL MODEL**
**CANONSBURG, PENNSYLVANIA, SITE**



MAC: SITE/CAN/BRA/CONCEPTMOD

### Drinking water ingestion

Drinking water ingestion is generally the dominant exposure route for ground water contaminated with metals (DOE, 1994). For this evaluation, drinking water consumption includes water used for drinking and for food preparation (e.g., reconstituted juice, soup, rice, and beans). For comparing relative pathway significance, Table 4.1 presents a screening level assessment of drinking water intake for adults. These screening calculations are based on the estimated 95th percentile of the constituent concentrations measured at well 414.

### Dermal absorption

Dermal absorption is the process by which chemicals coming into contact with the skin are absorbed into the blood vessels near the skin's surface. Some compounds are absorbed easily, although metals do not possess the chemical properties conducive to skin absorption.

To evaluate this exposure pathway, a screening calculation was performed to determine if the dermal absorption dose would be substantial compared with the drinking water ingestion dose for the contaminants of potential concern. Because chemical-specific absorption factors are not available for the contaminants of potential concern, they are assumed to be absorbed across the skin at the same rate as water. This assumption will probably overestimate any potential contribution from dermal absorption.

Table 4.1 provides the results of the screening. Although the dermal dose is an absorbed dose—whereas the drinking water ingestion dose is a total dose of which only some percentage will be absorbed—the very low (0.2 percent) contribution of dermal absorption is assumed to be insignificant compared with drinking water ingestion. Based on these results, the dermal absorption exposure route is eliminated from a more detailed evaluation.

### Ingestion of ground water-irrigated garden produce

The garden produce ingestion pathway could not be evaluated. Although the intake from ground water-irrigated produce ingestion is not likely to be greater than the exposure dose from drinking water ingestion, the incremental contribution could be substantial. There are currently no literature values that could be used to estimate this pathway contribution. However, the UMTRA Ground Water Project is currently conducting plant uptake studies for irrigated vegetables and grasses. The results of these studies will be included in the National Environmental Policy Act (NEPA) document and ground water compliance strategy planning for this site.

**Table 4.1 Exposure dose calculations and equation definitions for ground water ingestion and dermal contact for the future hypothetical adult scenario, Canonsburg, Pennsylvania, site**

| Contaminant of potential concern | Cw | Ground water exposure doses (mg/kg-day) | | Ratio of dermal: ingestion[a] |
|---|---|---|---|---|
| | | Ingestion | Dermal contact | |
| **Noncarcinogenic effects (mg/L)** | | | | |
| Manganese | 10 | 3E-01 | 5E-04 | 0.002 |
| Molybdenum | 0.027 | 7E-04 | 1E-06 | 0.002 |
| Uranium | 0.033 | 9E-04 | 2E-06 | 0.002 |
| **Carcinogenic effects (pCi/L)** | | | | |
| Uranium | 23[b] | 5E+05[c] | 9E+02[c] | 0.002 |

**Equation definitions for exposure dose calculations**

**Ingestion of ground water**

**Chemicals:** Chronic daily intake (mg/kg-day) = $\frac{Cw \times IRw \times EF \times ED}{BW \times AT}$

**Radionuclides:** Lifetime intake (pCi per lifetime) = $Cw \times IRw \times EF \times ED$

**Dermal contact with ground water**

**Chemicals:** Chronic daily intake (mg/kg-day) = $\frac{(Cw \times SA \times Pc \times Cf) \times ET \times EF \times ED}{BW \times AT}$

**Radionuclides:** Lifetime intake (pCi per lifetime) = $Cw \times SA \times Pc \times Cf \times ET \times EF \times ED$

**Where:**

Cw = Contaminant concentration in ground water (upper 95th percentile) (mg/L or pCi/L).
IRw = Ingestion rate for water (L per day) (2 L per day for an adult) (EPA, 1989a).
EF = Exposure frequency (350 days per year) (EPA, 1991).
ED = Exposure duration (30 years for an adult) (EPA, 1989a).
BW = Body weight (70 kilograms [kg] for an adult) (EPA, 1989a).
AT = Averaging time (365 days x ED for noncarcinogens) (EPA, 1989a).
SA = Skin surface area (19,400 $cm^2$; based on 50th percentile total body surface area) (EPA, 1989a).
Pc = Dermal permeability constant (0.001 cm per hour) (EPA, 1989a).
Cf = Conversion factor (0.001 liters per cubic centimeter [$L/cm^3$]).
ET = Exposure time (0.2 hour per day) (EPA, 1989a).

[a]Ratio of the dermal absorption exposure dose to the ground water ingestion dose.
[b]Uranium-234 and uranium-238 combined; 1 mg uranium is assumed to equal 686 pCi.
[c]Units are pCi per lifetime.

mg/kg-day = milligrams per kilogram per day.

**Summary**

The results of the ground water pathway screening analyses indicate that drinking water ingestion is the dominant pathway (see also DOE, 1994). Section 4.4 further evaluates this pathway probabilistically.

### 4.2.2 Surface water/sediment

The surface water/sediment exposure pathway is considered due to the potential access of nearby residents to Chartiers Creek, which receives ground water discharge from the unconsolidated material beneath the site. Individuals have access to the creek for swimming or wading in the summer. The creek also is used for fishing. For these reasons, the surface water and sediment in the creek were selected for a detailed exposure evaluation. The conceptual model (Figure 4.1) presents the potential surface water and sediment exposure pathways that could result, and includes incidental surface water ingestion, dermal absorption from surface water, incidental sediment ingestion, and fish ingestion. Children aged 6 to 12 years are considered the subpopulation most likely to play in the creek, and adults are considered the subpopulation most likely to fish and subsequently consume their catch.

**Incidental ingestion of surface water**

Incidental surface water ingestion could occur when children swim or wade in Chartiers Creek. It is assumed that a child may visit the creek every day during the summer to swim or wade, incidentally ingesting a few tablespoons of water on each visit. Table 4.2 presents the results for this exposure pathway, which is further evaluated in Section 6.0.

**Dermal contact with surface water**

The dermal contact exposure route for surface water was evaluated for the same scenario discussed under incidental ingestion of surface water. A child's total body surface area is assumed to contact surface water while swimming in the creek. Dermal exposure was evaluated for swimming rather than wading because more skin surface area would contact water while swimming. Dermal contact with surface water leads to a potential exposure route from dermal absorption, although metals generally do not absorb well across the skin. Because chemical-specific absorption factors are not available for the contaminants of concern, they were assumed to absorb across the skin at the same rate as water. This assumption probably overestimates any potential contribution from dermal absorption. Table 4.2 presents the results for this exposure route showing that contributions from dermal absorption are approximately 20 percent of the incidental surface water ingestion dose for the selected contaminants of concern. Based on these results, the dermal absorption from the surface water pathway is further evaluated in Section 6.0.

**Table 4.2 Exposure dose calculations and equation definitions for incidental surface water ingestion and dermal contact by children in Chartiers Creek, Canonsburg, Pennsylvania, site**

| Contaminant of potential concern | Csw (mg/L) | Surface water exposure doses (mg/kg-day) | | Ratio of dermal: surface water ingestion[a] |
|---|---|---|---|---|
| | | Ingestion | Dermal contact | |
| Manganese | 0.17[b] | 5E-05 | 1E-05 | 0.2 |
| Molybdenum | 0.17[b] | 5E-05 | 1E-05 | 0.2 |
| Uranium | ND | NA | NA | NA |

**Equation definitions for exposure dose calculations**

**Incidental ingestion of surface water**

$$\text{Chronic daily intake (mg/kg-day)} = \frac{Csw \times IRsw \times EF \times ED}{BW \times AT}$$

**Dermal contact with surface water**

$$\text{Chronic daily intake (mg/kg-day)} = \frac{(Csw \times SA \times Pc \times Cf) \times ET \times EF \times ED}{BW \times AT}$$

**Where:**

Csw = Contaminant concentration in surface water (maximum concentration) (mg/L).
IRsw = Incidental ingestion rate for surface water (0.05 L/day for 6- to 12-year-old children) (EPA, 1989a).
EF = Exposure frequency (90 days; 3 months per year for 7 days per week).
ED = Exposure duration (7 years for 6 to 12 year old children).
BW = Body weight (38.3 kg; based on 90th percentile body weight for 6- to 12-year-old male children) (EPA, 1989b).
AT = Averaging time (365 days x ED) (EPA, 1989a).
SA = Skin surface area (10,937 $cm^2$ for 6- to 12-year-old children; based on 50th percentile total body surface area) (EPA, 1989b).
Pc = Dermal permeability constant (0.001 cm per hour) (EPA, 1989a).
Cf = Conversion factor (0.001 liters per cubic centimeter [$L/cm^3$]).
ET = Exposure time (1 hour per day).

[a]Ratio of the dermal absorption exposure dose to the surface water ingestion dose.
[b]Based on maximum detected value in surface water (sampling location 606).

ND - not detected in surface water.
mg/kg-day = milligrams per kilogram per day.

**Incidental ingestion of sediments**

Children swimming or wading in Chartiers Creek may also be exposed to contaminants of potential concern through the incidental ingestion of sediments. Table 4.3 presents the equation and assumptions for this exposure route. This exposure pathway could not be evaluated for potential carcinogenicity from radioactive uranium due to the lack of monitoring data of uranium radioisotopes in Chartiers Creek sediment. The doses from this exposure pathway exceed those estimated for incidental ingestion of surface water. Section 6.0 further evaluates the incidental ingestion of sediments exposure route.

**Fish ingestion**

The commonwealth of Pennsylvania designated Chartiers Creek for the maintenance and propagation of fish species and protection of additional flora and fauna indigenous to a warm water habitat (PADER, 1992). Fish found in the creek include carp, catfish, and bluegill (Templeton, 1993). The ingestion of fish, which may have accumulated site-related constituents, is a potential exposure pathway for residents who use the creek for fishing.

Table 4.4 presents the results of the screening-level evaluation for the fish ingestion exposure pathway. To evaluate this exposure route, chemical-specific bioconcentration factors (BCF) are needed to estimate fish tissue levels. A BCF for fish was not available in the literature for molybdenum. For manganese, assuming a BCF of 150 for fish, an intake rate higher than that estimated for the surface water ingestion route was calculated. Based on these results, the fish ingestion exposure pathway is further evaluated in Section 6.0.

## 4.3 EXPOSURE CONCENTRATIONS

The exposure concentration of a contaminant in ground water is defined as the concentration contacted by an individual over the period of exposure being considered. Estimates of contaminant concentrations are based on ground water data collected from monitoring wells after surface remediation was completed at the site. In this evaluation, the contaminant concentrations are assumed to be at steady state although actual contaminant concentrations (and therefore potential exposures) are expected to decrease with time because surface remediation has been completed at the site. Nonetheless, these estimates are reasonable for chronic exposure soon after surface remediation. (Chronic exposure for noncarcinogens is considered to be exposure for any period longer than 7 years).

For the unconsolidated material, exposure concentrations are evaluated as a probability of occurrence based on 1988 to 1993 ground water quality data from monitor well 414. The probability distribution selected for each contaminant reflected, to the extent possible, the same mean, standard deviation, and shape observed in actual water quality data. For constituents showing an obvious trend over time, the theoretical distribution is centered

**Table 4.3 Exposure dose calculations and equation definitions for incidental sediment ingestion by children in Chartiers Creek, Canonsburg, Pennsylvania, site**

| Contaminant of potential concern | Csd (mg/kg) | Sediment ingestion exposure doses (mg/kg-day) |
|---|---|---|
| Manganese | 2820[a] | 2E-03 |
| Molybdenum | 96[b] | 6E-05 |
| Uranium | 2.6[a] | 2E-06 |

**Equation definitions for exposure dose calculations**

**Incidental ingestion of sediment**

$$\text{Chronic daily intake (mg/kg-day)} = \frac{\text{Csd} \times \text{Cf} \times \text{IRsd} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}}$$

**Where:**

Csd = Contaminant concentration in sediment (maximum concentration) (mg/kg).
Cf = Conversion factor ($10^{-6}$ milligrams per kilogram [mg/kg]).
IRsd = Incidental ingestion rate for sediment (100 mg per day for 6- to 12-year-old children) (EPA, 1989a).
EF = Exposure frequency (90 days per year; 3 months per year for 7 days per week).
ED = Exposure duration (7 years for 6- to 12-year-old children).
BW = Body weight (38.3 kg; based on 90th percentile body weight for 6- to 12-year-old male children) (EPA, 1989b).
AT = Averaging time (365 days x ED) (EPA, 1989a).

[a]Based on maximum detected value in sediment (sampling location 604, Figure 3.5).
[b]Based on maximum detected value in sediment water (sampling location 605, Figure 3.5).

mg/kg-day = milligrams per kilogram per day.

**Table 4.4 Exposure dose calculations and equation definitions for ingestion of fish from Chartiers Creek by adults, Canonsburg, Pennsylvania, site**

| Contaminant of potential concern | Csw (mg/L) | BCF | Fish ingestion exposure doses (mg/kg-day) | Ratio of fish ingestion:surface water ingestion[a] |
|---|---|---|---|---|
| Manganese | 0.17 | 150[b] | 9E-03 | 180 |
| Molybdenum | 0.17 | NTA | NC | NC |
| Uranium | ND | NA | NA | NA |

**Equation definitions for exposure dose calculations**

**Ingestion of fish**

$$\text{Chronic daily intake (mg/kg-day)} = \frac{Cf \times IR \times EF \times ED \times FI}{BW \times AT}$$

$$Cf = Csw \times BCF$$

**Where**:

Cf = Contaminant concentration in fish (milligrams per kilogram [mg/kg]).
IR = Ingestion rate of fish (0.054 kg per day for an adult) (EPA, 1991).
EF = Exposure frequency (350 days per year) (EPA, 1991).
ED = Exposure duration (30 years for an adult) (EPA, 1989a).
FI = Fraction ingested from contaminated source (0.5 unitless).
BW = Body weight (70 kg for an adult) (EPA, 1989a).
AT = Averaging time (365 days x ED for noncarcinogens) (EPA, 1989a).
Csw = Contaminant concentration in surface water (maximum concentration)(mg/L).
BCF = Bioconcentration factor (chemical-specific; unitless).

[a]Ratio of the fish ingestion dose to the surface water ingestion dose.
[b]BCF based on study on minnows (AQUIRE, 1992); converted from dry to wet weight assuming 75% moisture in fish tissue (EPA, 1993).

ND – not detected in surface water.
NTA – not available.
NA – not applicable, since uranium was not detected in surface water.
NC – could not be calculated.
mg/kg-day = milligrams per kilogram per day.

around the more recently observed concentrations. Because relatively little data are available on which to determine shape, the normal distribution was assumed unless strongly contradicted by the data. The data sets for manganese, molybdenum, and uranium were all determined to reasonably fit a normal distribution. The lower tail of the distribution was truncated at 0 mg/L, and the upper tail of the distributions was truncated at the 99th percentile. For every contaminant, the upper truncated concentration was higher than the maximum observed concentration in the water quality data. The software package @ RISK (Palisade Corp., 1992) was used to generate the probability curves for the contaminants of potential concern. Figures 4.2 through 4.4 show the results.

## 4.4 ESTIMATION OF GROUND WATER INGESTION INTAKE

Within the population of future residents, individuals are expected to vary in their water consumption habits, stable body weight, and length of residence time in the potential contamination zone. Consequently, health risks associated with ground water consumption will vary among members of this population. To adequately describe the range of potential risks to a potential future population ingesting water from the unconsolidated layer, naturally occurring variability in daily intake and body weight were incorporated in this assessment through probability distributions; these distributions were generated from the U.S. public health and census documents. All distributions were truncated at the upper and lower 0.01 percentile. Within the hypothetical population, values disallowed through this truncation may occur with a probability of less than 1 in 10,000.

All of the chemical contaminants of potential concern were evaluated for potential noncarcinogenic effects. In order to evaluate noncarcinogenic effects, exposure to contaminants was estimated as a chronic average daily intake on a body weight basis. Chronic daily intakes were calculated using the following equation:

$$\text{Chronic daily intake (mg/kg-day)} = \frac{\text{Water concentration (mg/L)} \times \text{Ingestion rate (L per day)} \times \text{Exposure duration (years)} \times \text{Exposure frequency (days per year)}}{\text{Averaging time (days)} \times \text{Body weight (kg)}}$$

where mg/kg-day = milligrams per kilogram per day.

Potential carcinogenicity of radionuclides is thought to increase with total intake over time and, thus, is not averaged over a lifetime as for chemical carcinogens. Also, body weight is relatively insignificant in determining risk from exposure. Intake of a radionuclide is therefore quantified as total exposure to radioactivity throughout the residency period of an individual:

$$\text{Lifetime intake (pCi per lifetime)} = \text{Concentration (pCi/L)} \times \text{Ingestion rate (L per day)} \times \text{Exposure duration (years)} \times \text{Exposure frequency (days per year)}$$

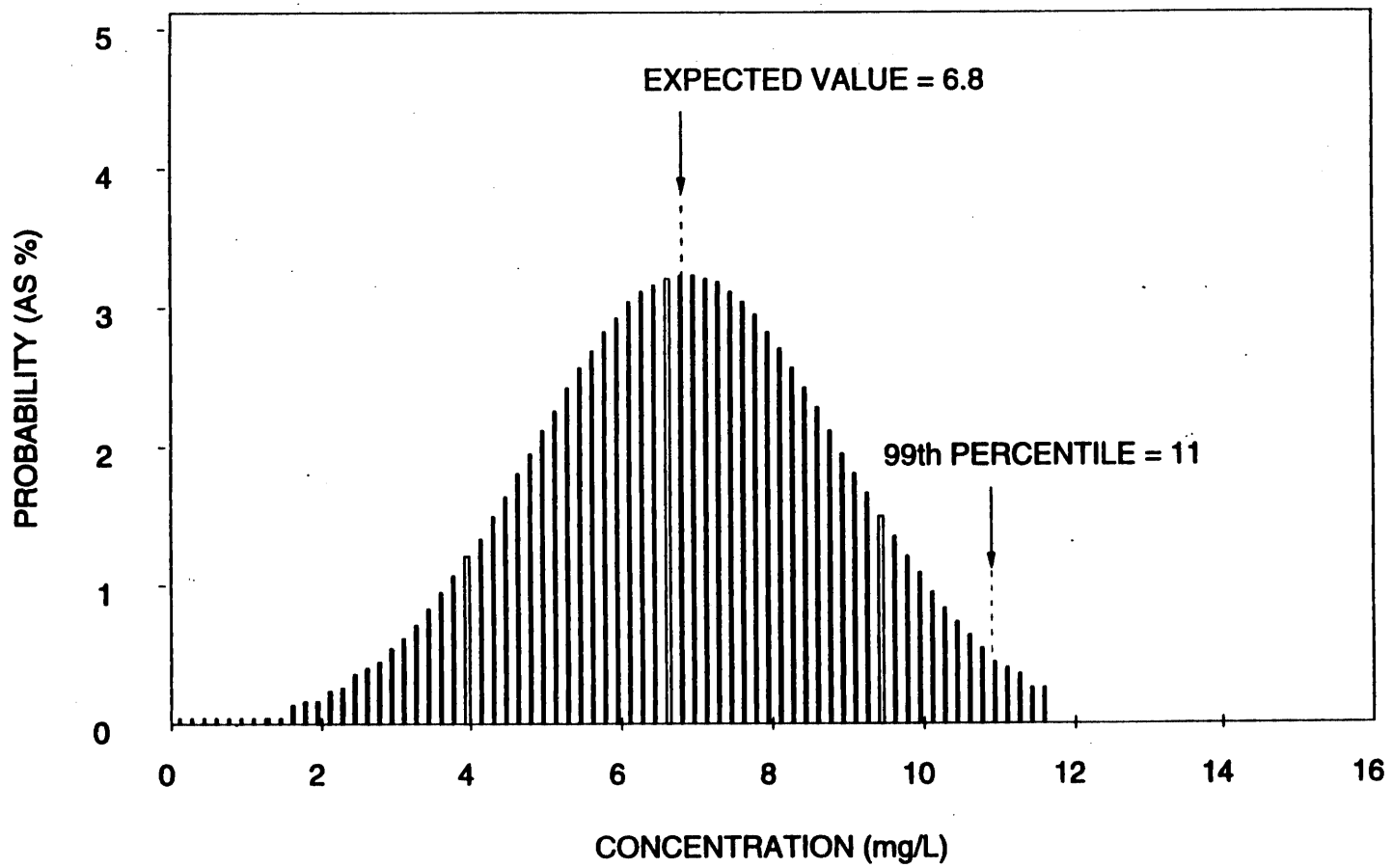



**FIGURE 4.2**
**PROBABILITY DISTRIBUTION OF MANGANESE CONCENTRATIONS FOR THE UNCONSOLIDATED MATERIAL CANONSBURG, PENNSYLVANIA, SITE**

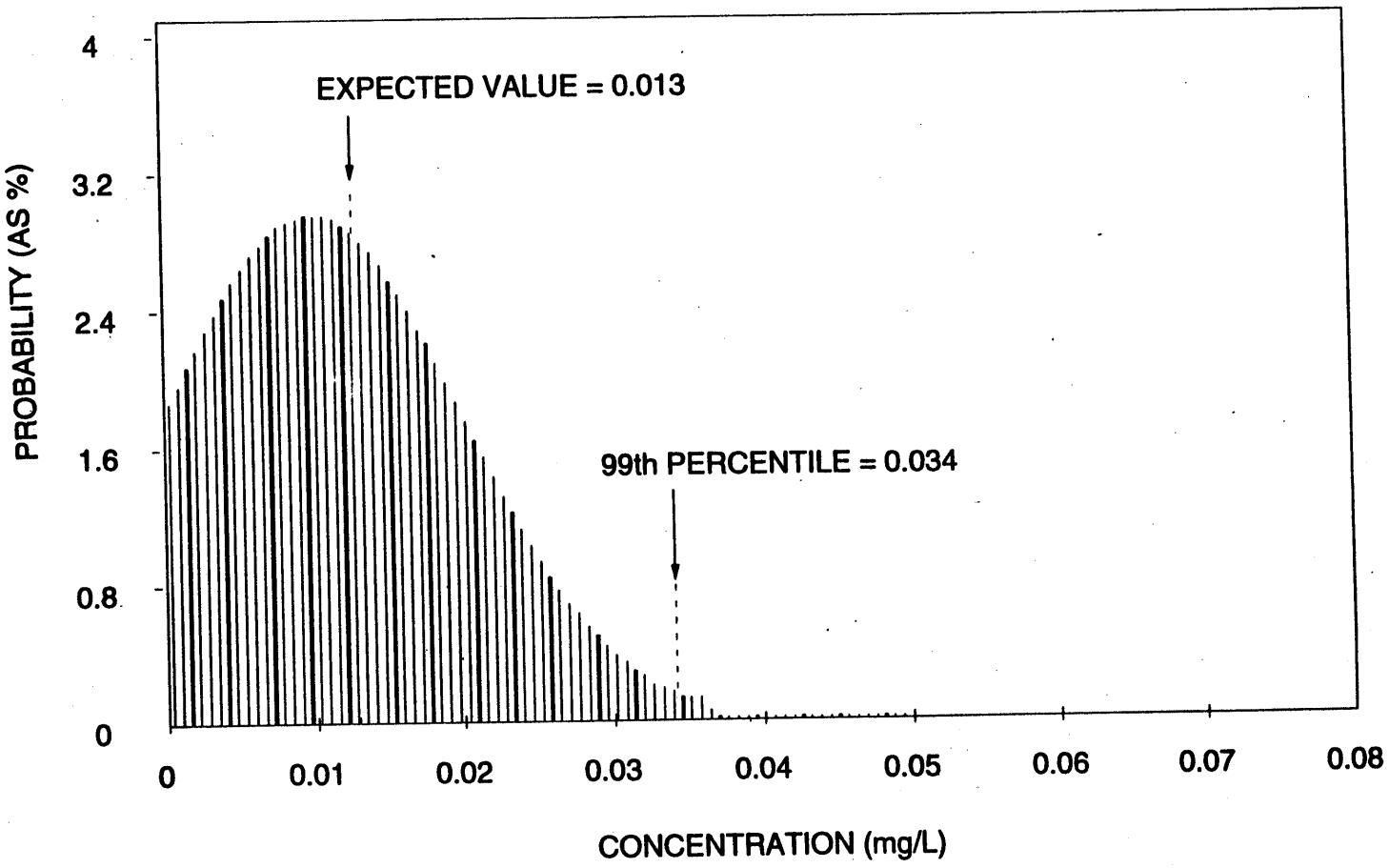



**FIGURE 4.3**
**PROBABILITY DISTRIBUTION OF MOLYBDENUM CONCENTRATIONS FOR THE UNCONSOLIDATED MATERIAL CANONSBURG, PENNSYLVANIA, SITE**

MOLYCONC.DRW

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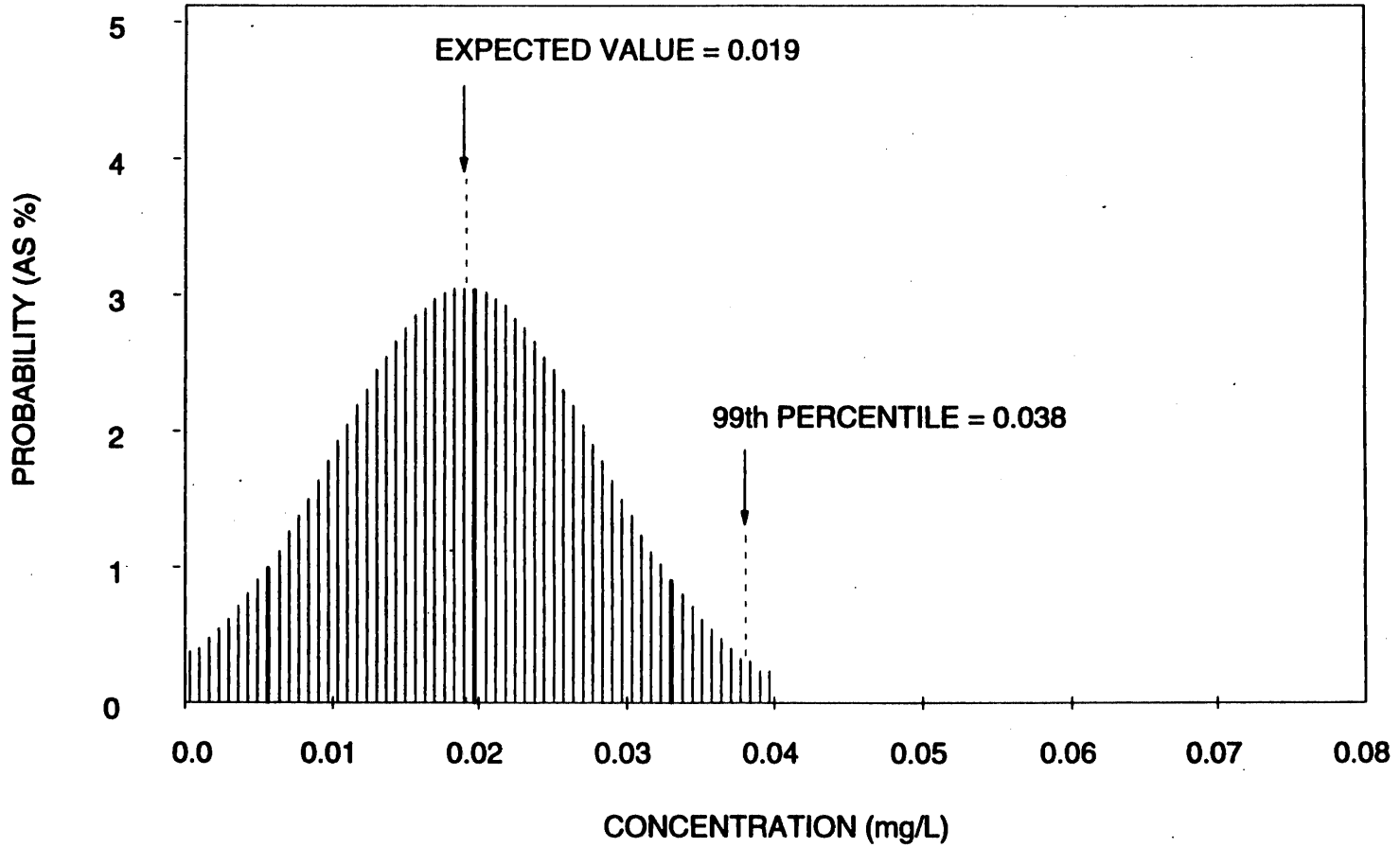



**FIGURE 4.4**
**PROBABILITY DISTRIBUTION OF URANIUM CONCENTRATIONS FOR THE UNCONSOLIDATED MATERIAL CANONSBURG, PENNSYLVANIA, SITE**

### Average daily water intake (L per day)

Lognormal probability distributions were used to describe variations in average daily tap water intake among members of the population (Roseberry and Burmaster, 1992). These distributions were developed from data collected during the 1977-78 National Food Consumption Survey conducted by the U.S. Department of Agriculture. During the survey, total tap water consumption during a 3-day period was recorded for 26,081 survey participants nationwide (Figure 4.5).

The two graphs in Figure 4.5 show on their horizontal axes reasonable water ingestion rates associated with two age groups. The height of the curve at each point along this axis communicated how common the different levels of water ingestion are among members of that age group. For this reason, the vertical scale is labeled as probability. However, theoretically the probability is represented by the area under the curve, not the height of the curve itself. Therefore, the probability that a randomly selected person consumes a given amount of water, within a specified interval, is estimated by multiplying the height of the curve overlying that interval by the width of the interval. This formula is true for all the probability distribution graphs presented in this document.

### Exposure frequency (days per year)

An exposure frequency of 350 days per year was assumed for adults and children (EPA, 1991).

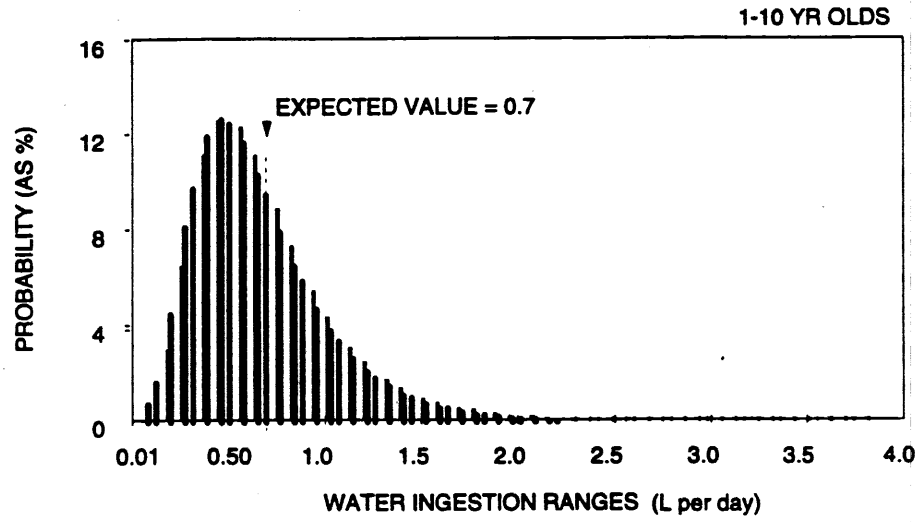
### Exposure duration (years)

Children are the receptors of concern evaluated for the noncarcinogenic effects of the contaminants of concern. A 10-year exposure duration was assumed for 1- to 10-year-old children.

For carcinogens such as uranium and other radionuclides, risk is cumulative throughout the lifetime. For the evaluation of carcinogens, an exposure duration of 30 years was assumed, based on a national upper-bound time (90th percentile) spent at one residence (EPA, 1989a).

### Body weight (kg)

Between 1976 and 1980, the National Health and Nutrition Survey collected extensive national data on the weights of males and females by age (EPA, 1989b). These data were used to develop lognormal probability distributions for body weight by age and by gender. The distributions for males and females were then combined using census data on the national ratio of males and females within each age group (Figure 4.6).



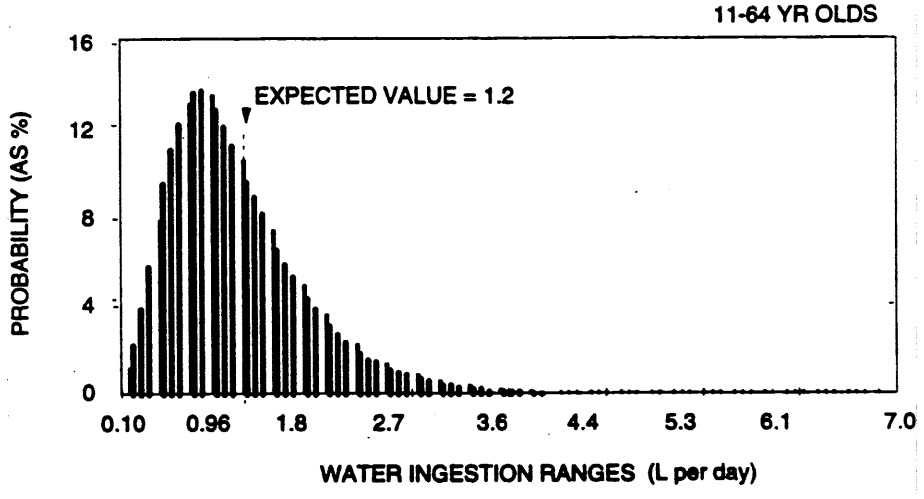
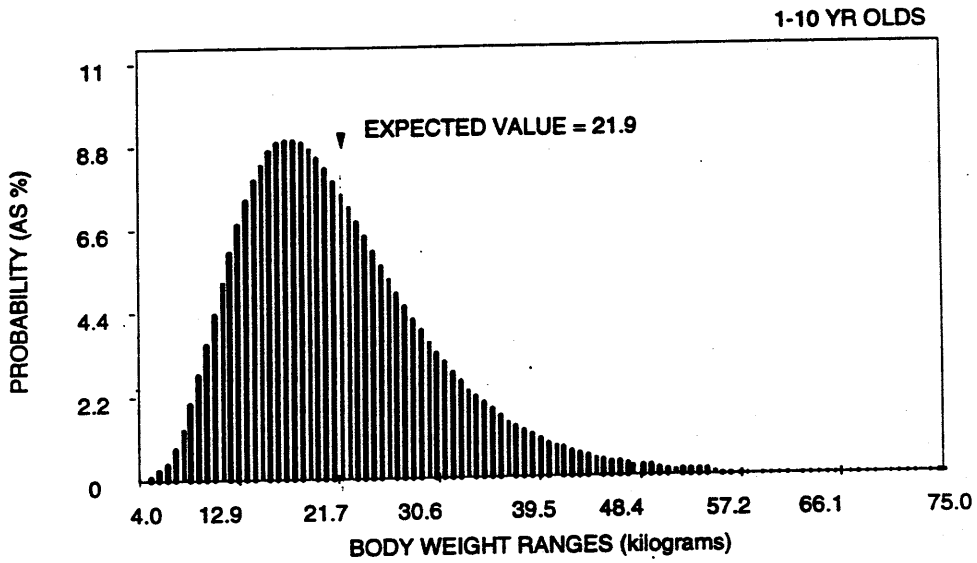




**FIGURE 4.5**
**PROBABILITY DISTRIBUTIONS FOR TAP WATER INGESTION RATES**



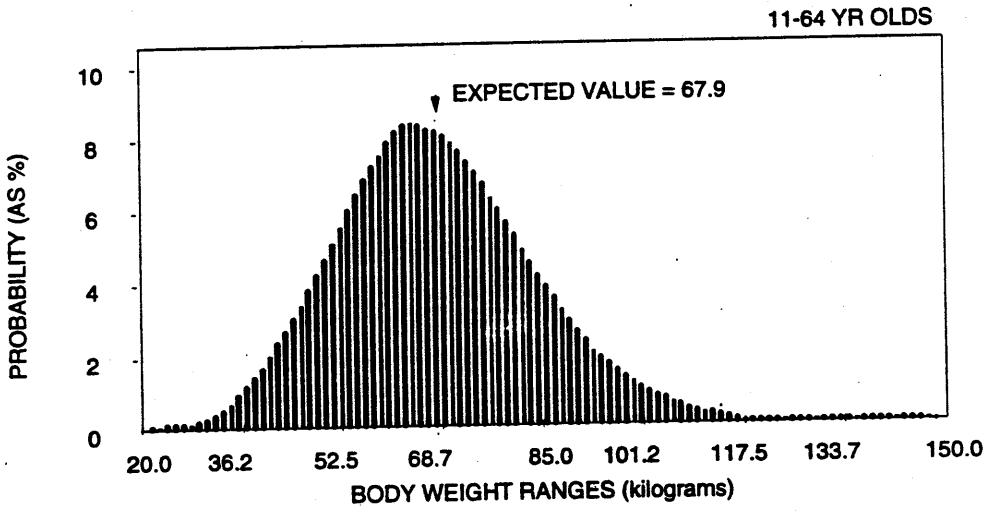




**FIGURE 4.6**
**PROBABILITY DISTRIBUTIONS FOR BODY WEIGHT**

FIG-46.DRW

Averaging time (days)

When evaluating potential noncarcinogenic effects from longer-term exposures, intakes are averaged over the period of exposure. Thus, in evaluating the noncarcinogenic effects of the contaminants of concern, an averaging time of 3650 days (i.e., 10 years x 365 days) was used for children.

Intake distributions

Using the exposure concentration distributions discussed in Section 4.3 and the intake parameter distributions described in this section, total intake distributions were simulated for the receptor populations. The 1- to 10-year-old age group consistently showed the highest intake-to-body weight ratios and is therefore the most conservative age group to evaluate for noncarcinogenic risk. Children are likely more susceptible to metals toxicity than adults because of higher gastrointestinal absorption efficiency and other toxicokinetic factors (Casarett and Doull, 1991). Figures 4.7 through 4.9 present simulated intake distributions for 1- to 10-year-old children for manganese, molybdenum, and uranium, respectively. Figure 4.10 shows the total lifetime intake estimate used to calculate carcinogenic risk for uranium.

## 4.5 EXPOSURE ASSESSMENT UNCERTAINTIES

A number of potential sources of uncertainty may arise in all phases of the exposure assessment, including the following more notable sources:

- Uncertainties resulting from a lack of thorough environmental characterization of the site, which could lead to an underestimation or overestimation in the exposure analysis. In addition, background ground water quality is represented by data from one monitor well. Therefore, natural variability in the background ground water quality could not be captured.

- Uncertainties arising from the assumption that the ground water contaminant sources at the site have reached a steady state and that contaminant concentrations at the exposure point will remain constant for chronic periods of exposure (generally longer than 7 years). Because the major source of contamination at the Canonsburg site has been encapsulated on the site, the assumption of a constant source may lead to an overestimation of risk.

- Uncertainties associated with the use of filtered ground water samples. The results of exposure assessment presented in this document are based on filtered (0.45-micron) ground water samples. Therefore, the potential loss of certain ground water constituents as a consequence of filtration represents an additional source of uncertainty.

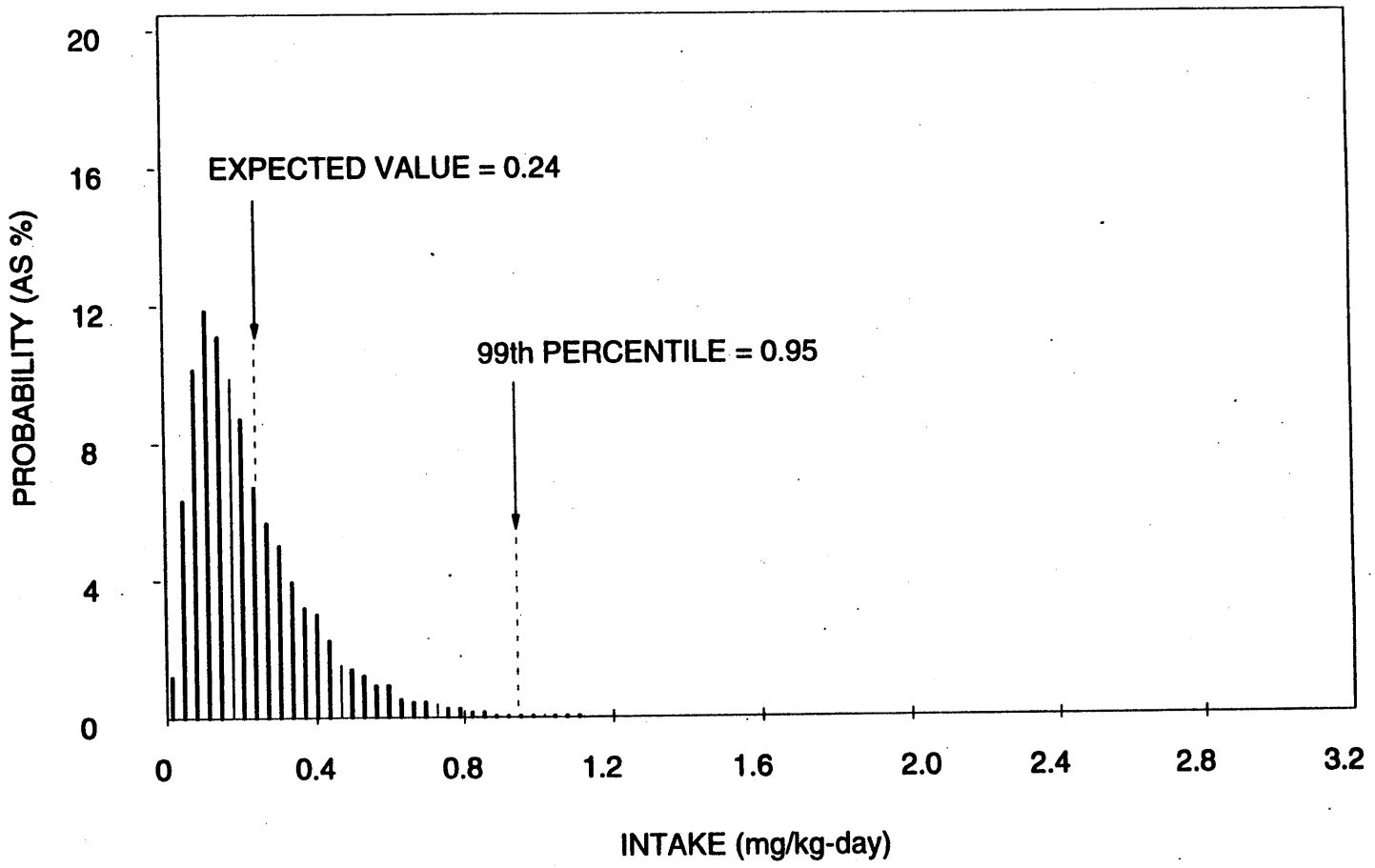



**FIGURE 4.7**
**PROBABILITY DISTRIBUTION OF MANGANESE EXPOSURE TO CHILDREN BASED ON GROUND WATER INGESTION CANONSBURG, PENNSYLVANIA, SITE**



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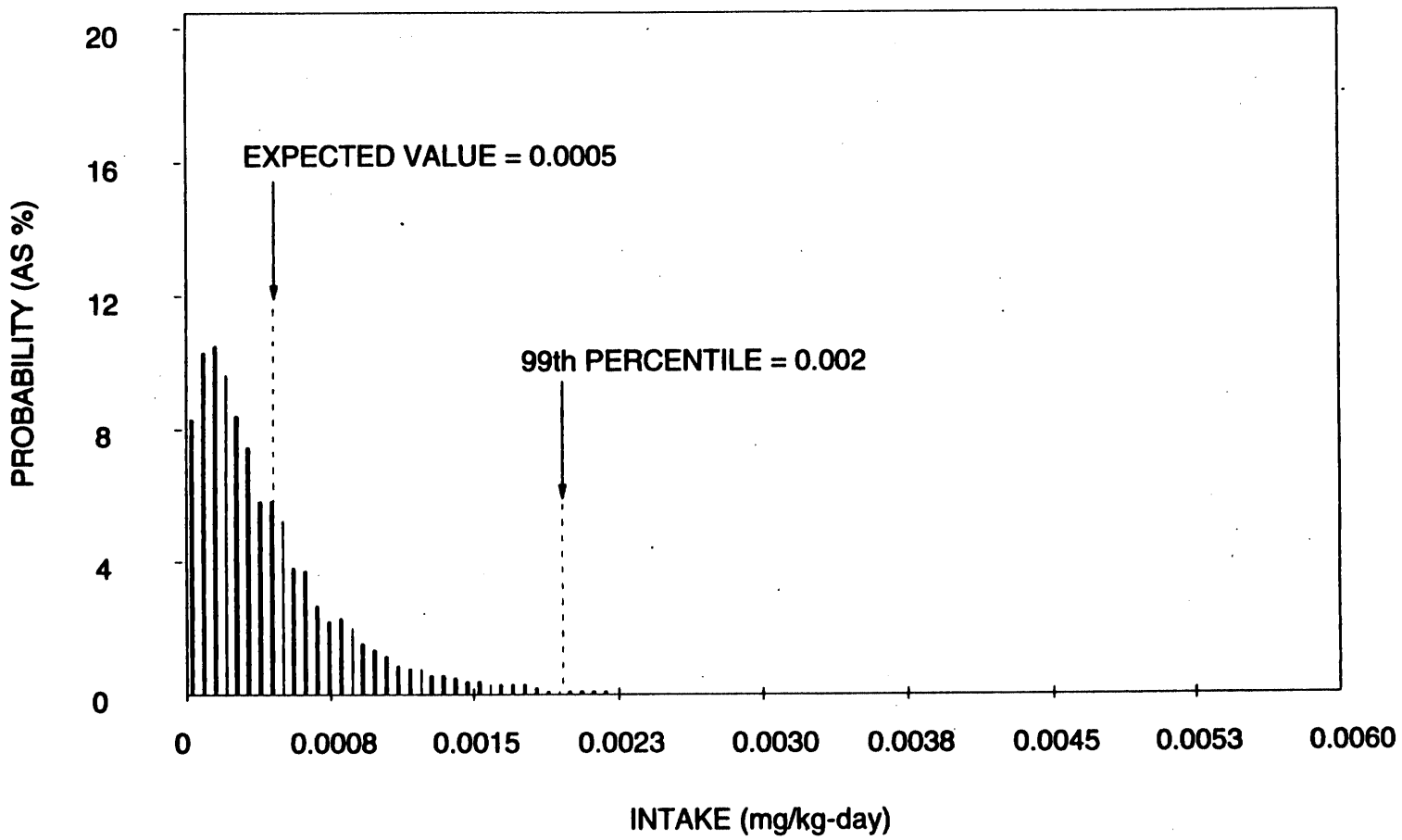


**FIGURE 4.8**
**PROBABILITY DISTRIBUTION OF MOLYBDENUM EXPOSURE TO CHILDREN BASED ON GROUND WATER INGESTION**
**CANONSBURG, PENNSYLVANIA, SITE**

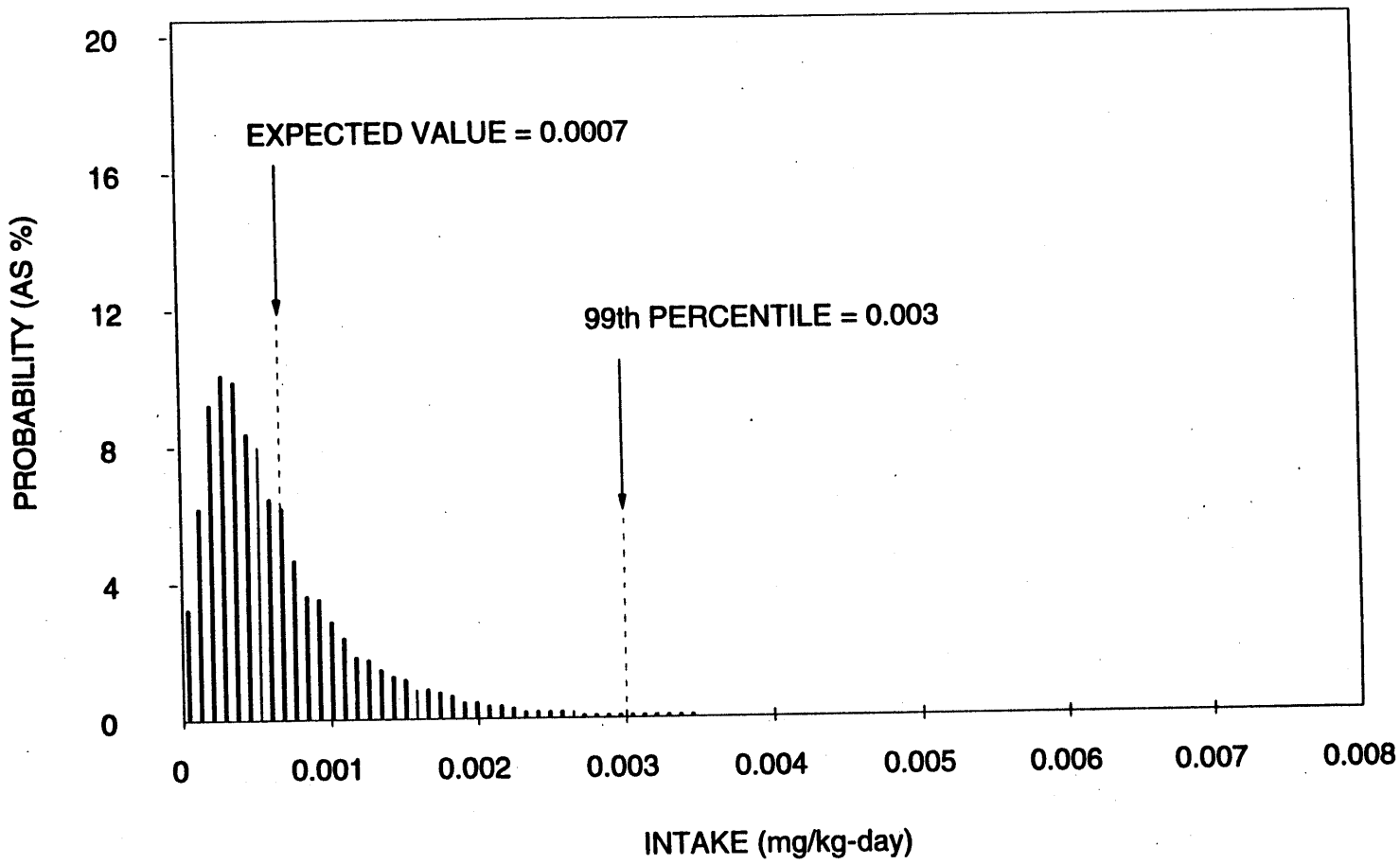


**FIGURE 4.9**
**PROBABILITY DISTRIBUTION OF URANIUM EXPOSURE TO CHILDREN BASED ON GROUND WATER INGESTION CANONSBURG, PENNSYLVANIA, SITE**

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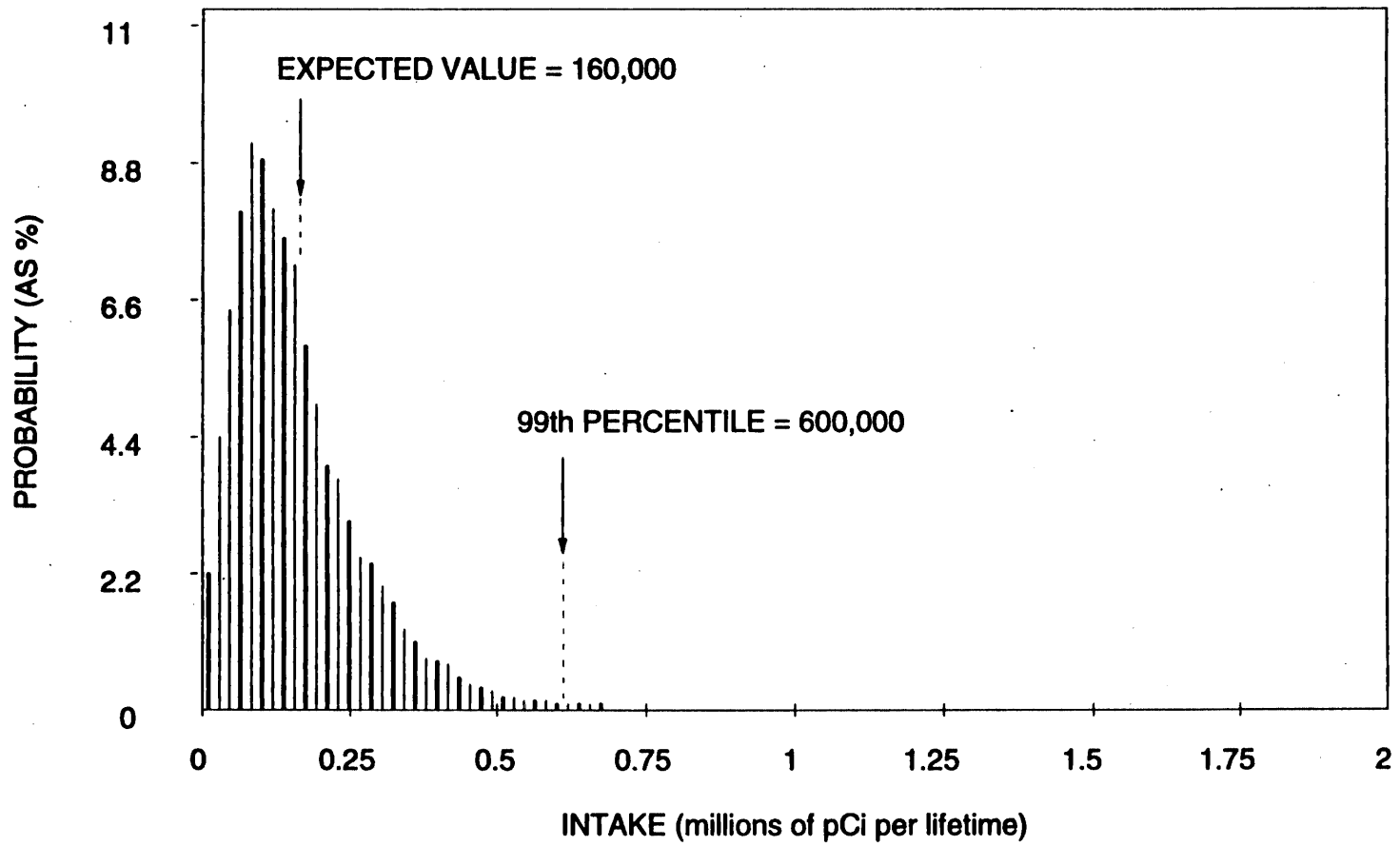



**FIGURE 4.10**
**PROBABILITY DISTRIBUTION OF URANIUM EXPOSURE OVER A LIFETIME BASED ON GROUND WATER INGESTION CANONSBURG, PENNSYLVANIA, SITE**

- Uncertainties associated with the incremental contribution from ingesting ground water-irrigated produce. The drinking water pathway is considered the major determinant of exposure in this risk assessment. The incremental or independent contribution from the ground water-irrigated produce ingestion pathway could not be estimated here.

- Uncertainties associated with the relationship of an applied dose (used in this risk assessment) and an absorbed or effective dose for dermal absorption.

- Uncertainties associated with the exclusion of organic contaminants from consideration as a source of potential exposure. This document evaluates exposures only to inorganic contaminants of ground water at the UMTRA Project site in Canonsburg. Potential organic contaminants related to uranium processing have not been considered.

Despite these uncertainties, using probability distributions that incorporate all definable sources of variability should provide a representative picture of the potential range of exposures from the drinking water ingestion pathway.

# 5.0 TOXICITY ASSESSMENT

Several contaminants that could adversely affect human health and the environment have been detected in ground water at the Canonsburg site. This section summarizes the toxicological effects of the chemical contaminants and the carcinogenic potentials of the radionuclides.

The following source materials were used in developing these toxicological profiles: EPA's Integrated Risk Information System (IRIS) (EPA, 1994a); the Agency for Toxic Substances and Disease Registry Toxicological Profiles published by the Department of Health and Human Services; and the *Handbook on the Toxicology of Metals* (Friberg et al., 1986). Peer-reviewed scientific literature was used when these review documents were not available firsthand. By basing toxicity information on the standardized review documents cited above, the evaluation of risks at UMTRA Project sites should be consistent with evaluations at other sites.

The toxicity profiles presented here focus on drinking water source material in humans, whenever available, and include animal information only when human data are not available. Widely spaced dotted lines represent animal information on the toxicity range graphs. Where uncertainty exists regarding the beginning or end of a range of exposures that produces specific toxic effects, closely spaced dots are used at the appropriate end of the line that denotes range.

## 5.1 CONTAMINANT TOXICITY SUMMARIES

The following summaries address the basic toxicokinetics and toxicity of the contaminants of potential concern at the Canonsburg site based on the contaminant screening discussed in Section 3.3. The contaminants of potential concern are manganese, molybdenum, and uranium and its decay products (radium-226, lead-210, polonium-210, and thorium-230). Although these contaminants have a wide range of toxic effects depending on the exposure levels, the following discussions will focus on toxic effects observed in the exposure range most relevant to contamination at this site.

### 5.1.1 Manganese

#### Absorption

Following ingestion, manganese absorption is homeostatically controlled. The rate of absorption depends on both the amount ingested and tissue levels of manganese. In adult humans, approximately 3 to 4 percent of dietary manganese is absorbed (Saric, 1986). Manganese can be absorbed following exposure by inhalation, ingestion, and dermal contact. In humans, available data indicate that only 3 percent of an ingested dose of manganese chloride is absorbed (Mena et al., 1969). Manganese in water appears to be more efficiently absorbed than manganese in food (EPA, 1994a). Iron and other metals influence the rate of absorption. In states of iron deficiency, manganese

is actively absorbed from the intestine. Individuals with anemia can absorb more than twice the percentage of an ingested dose. However, in states of excess iron, absorption of manganese is by diffusion only (Saric, 1986). High levels of dietary calcium and phosphorus have been shown to increase the requirements for manganese in several species (Lönnerdal et al., 1987). Manganese in water appears to be more efficiently absorbed than manganese in foodstuff (EPA, 1994a).

Tissue accumulation and clearance

Absorbed manganese is widely distributed throughout the body, with the highest concentrations found in the liver and kidney. The biological half-life in humans is 2 to 5 weeks, depending on body stores. Manganese readily crosses the blood-brain barrier and is cleared from the brain more slowly than from other tissues (Goyer, 1991). Although normal concentrations in the brain are low, manganese may accumulate under conditions of excessive absorption due to the longer half-life of manganese in the brain (National Research Council, 1973).

Absorbed manganese is rapidly cleared from the blood and concentrates in mitochondria. Initial concentrations are greatest in the liver. Manganese penetrates the placental barrier in all species and is more uniformly distributed throughout the fetus than in adult tissues. It is secreted into milk.

Absorbed manganese is almost totally secreted in bile and reabsorbed from the intestine as necessary to maintain body levels. Excess manganese is eliminated in the feces; urinary excretion is negligible (Goyer, 1991; Saric, 1986).

Environmental sources of manganese

Food constitutes the major source of manganese intake for humans. The highest manganese concentrations are found in plants, especially wheat and rice. Drinking water generally contains less than 0.1 mg/L. Manganese levels in soil range from 1 to 7000 mg/kg, with an average of 600 to 900 mg/kg. Mining and natural geological background variation can contribute to this variability. Manganese bioaccumulates in marine mollusks up to 12,000-fold, and there is evidence for toxic effects in plants (phytotoxicity) and plant bioaccumulation. The Illinois Institute for Environmental Quality recommends criteria of 1 to 2 mg/kg for manganese in soil and 200 mg/kg in plants (Saric, 1986).

Differences in nutritional habits can explain variations in manganese intake. The intake will be higher in populations where cereals and rice are main food sources than where meat and dairy products make up a larger part of the diet. The average daily intake is estimated to be between 2.0 and 8.8 mg per day (0.03 and 0.13 mg/kg-day) (EPA, 1994a), but intakes as high as 12.4 mg (about 0.2 mg/kg-day) have been reported in countries with high cereal intake (Saric, 1986).

Drinking water generally results in an intake of less than 0.2 mg (0.003 mg/kg-day), although some mineral waters can increase this amount more than threefold (Saric, 1986). One study from Greece reported drinking water concentrations of manganese in excess of 2 mg/L, which would result in daily intakes from 0.06 to 0.07 mg/kg-day (EPA, 1994a).

**Manganese toxicity**

Manganese is an essential nutrient. Estimated safe and adequate daily dietary intakes for adults range from 0.03 to 0.07 mg/kg-day (Saric, 1986). The EPA no-observed-adverse-effect level (NOAEL) for drinking water is identified at 0.005 mg/kg-day while the lowest-observed-adverse-effect level (LOAEL) is 0.06 mg/kg-day. The EPA oral reference dose (RfD) for drinking water of 0.005 mg/kg-day is based on human data (Kondakis et al., 1989). The study group was a population of older adults exposed to manganese in drinking water over a lifetime; because this population was considered sensitive, an uncertainty factor of 1 was applied (EPA, 1994a). The oral RfD for food ingestion is 0.14 mg/kg-day, based on a level at which no adverse effects were observed. Manganese in drinking water appears to be potentially more bioavailable, i.e., more readily absorbed, than manganese in dietary food sources. This would result in toxic effects with lower ingested doses of manganese in drinking water than in food (EPA, 1994a). However, insufficient data exist to quantify these differences.

Inhalation of manganese in industrial settings has provided the largest source of data on chronic manganese toxicity. These data indicate that excess manganese can result in a central nervous system disorder manifested by symptoms of irritability, difficulty in walking, speech disturbances, and compulsive behavior that may include running, fighting, and singing. With continued exposure, this condition can progress to a mask-like face, retropulsion or propulsion, and a Parkinson-like syndrome. These effects are largely irreversible, although some recovery may occur when exposure ceases (DHHS, 1992). Metal chelating agents are ineffective in treatment, but L-dopa has been effective (Goyer, 1991), suggesting that manganese produces a functional deficit in the central nervous system.

Limited information is available on the effects of manganese ingestion. Because effects from drinking water seem to differ from those from food sources, only water consumption studies will be considered here. A Japanese study of 25 people drinking well water with manganese concentrations of 14 mg/L (0.4 mg/kg-day estimated intake) reported symptoms of intoxication, including a mask-like face, muscle rigidity and tremors, and mental disturbances (DHHS, 1992). Two cases (8 percent) of death were reported among intoxicated people. A Greek study of more than 4000 adults at least 50 years old drinking water with manganese concentrations varying from 0.081 to 2.3 mg/L (estimated intake at 2 L per day for a 70-kg individual range from 0.002 to 0.07 mg/kg-day) showed varying degrees of neurological effects in those drinking from 0.007 to 0.07 mg/kg-day, but no effects in those drinking less than 0.005 mg/kg-day (Kondakis et al., 1989). However, there are many limitations to

these studies which make data interpretation difficult. Among the limitations, there is uncertainty regarding the exposure level or whether the effects seen were solely attributable to manganese. Despite the limitations of these studies, the similarity of the effects seen in the cases of oral exposure compared with those associated with inhalation exposure suggests that excess manganese intake by humans might lead to neurological injury (DHHS, 1992).

The chemical form of manganese has complex effects on its toxicity. Although more soluble forms are more readily absorbed from the gastrointestinal tract, they also appear to be more rapidly cleared. Exposure to insoluble forms results in lower manganese absorption, but higher chronic tissue levels and therefore greater toxicity (EPA, 1994a). Limited information is available on the effects of various forms of manganese.

Few data are available on manganese toxicity in infants, but infants probably will be more susceptible to manganese toxicity due to greater absorption and greater penetration into the central nervous system (EPA, 1994a; Saric, 1986).

Figure 5.1 summarizes manganese toxicity.

### 5.1.2 Molybdenum

#### Absorption

Absorption of molybdenum in the gastrointestinal tract depends on the species of the metal. Inorganic hexavalent forms such as molybdenum trioxide, sodium molybdate, and ammonium molybdate are readily absorbed from both food and water, unlike molybdenite. Based on the geochemical models for the Canonsburg, Pennsylvania, site, all the molybdenum exists in the form of easily absorbed molybdate in ground water (Table 3.4). Human absorption rates of 40 to 70 percent have been observed for soluble forms of molybdenum (Robinson et al., 1973; Alexander et al., 1974).

#### Tissue accumulation and clearance

In humans, the highest concentrations of molybdenum occur in the liver, kidneys, and adrenals (Casarett and Doull, 1991). With normal dietary intake, molybdenum levels in the body slowly increase until approximately age 20, when they begin to decline steadily. The principal route of excretion in humans is in the urine. Human studies indicate the biological half-life in humans is considerably longer than in animals and may be as long as 2 weeks (Rosoff and Spencer, 1964).

#### Environmental sources of molybdenum

The occurrence of natural molybdenum is in combination with other metals, including uranium, lead, iron, cobalt, and calcium. Native soil concentrations can vary by as much as 2 orders of magnitude, from 0.1 to 10 mg/kg, leading to

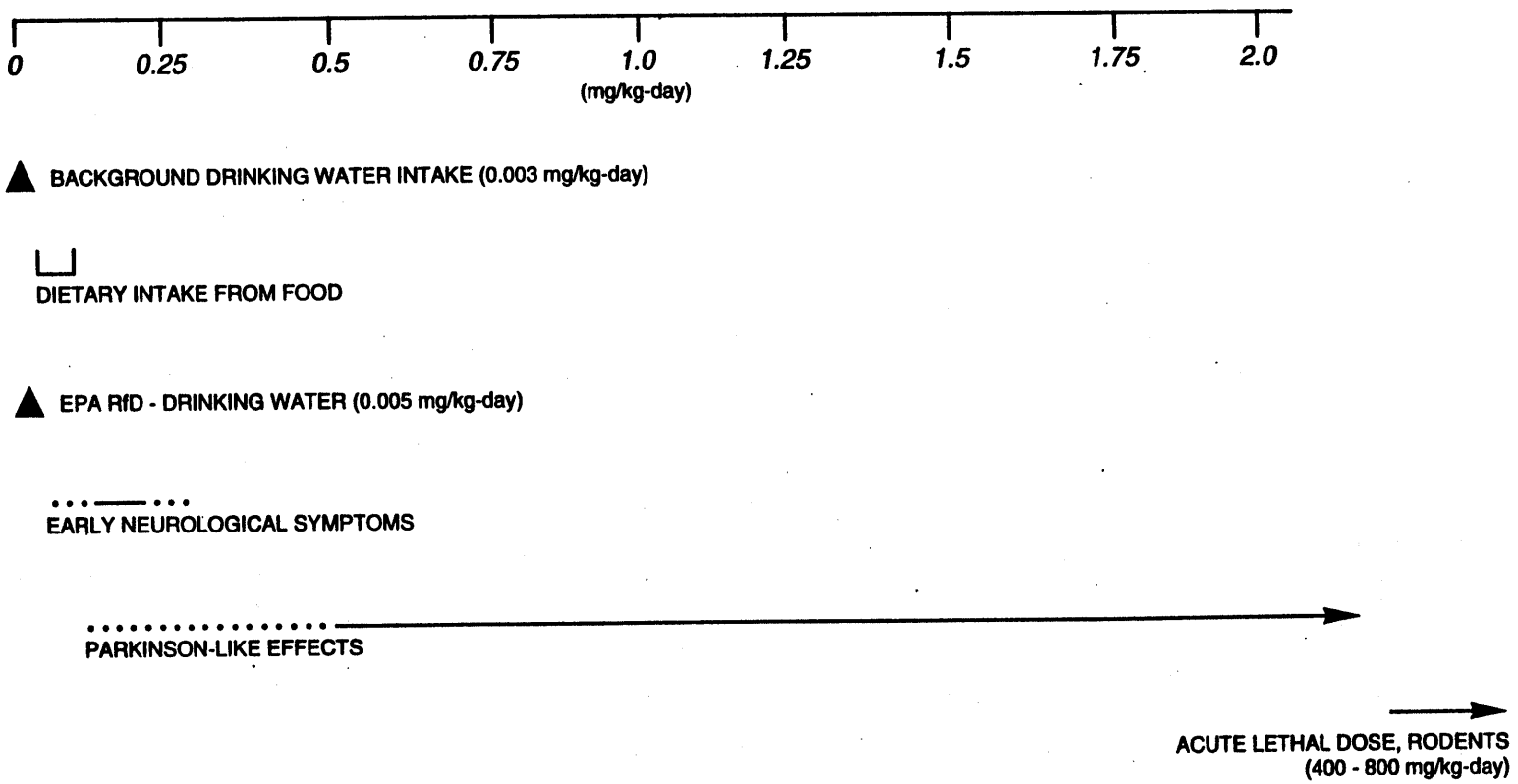



**FIGURE 5.1**
**MANGANESE TOXICITY RANGES**

large variations in the molybdenum concentrations in plant materials. Natural concentrations in ground water have been reported from 0.00011 to 0.0062 mg/L. Human dietary intake of molybdenum is estimated at 0.05 to 0.24 mg per day (0.0007 to 0.003 mg/kg-day). The contribution of drinking water is estimated to range from 0 to 95 percent. The nutritional range of intake for molybdenum is from 0.0015 to 0.0054 mg/kg-day. No symptoms of molybdenum deficiency have been reported in humans. Nonetheless, molybdenum is an essential trace element that functions as a necessary constituent of several enzymes, including xanthine oxidase (which is involved in the metabolism of uric acid) and nitrate reductase (Friberg et al., 1986).

Molybdenum toxicity

Acute effects of molybdenum have not been reported. No adverse health effects have been reported with chronic molybdenum intakes of less than 0.008 mg/kg-day (EPA, 1994a). The primary toxicity of molybdenum is related to its interactions with copper and sulfur, leading to altered excretion patterns for these elements. Increased levels of molybdenum also increase the levels of xanthine oxidase, which is responsible for the production of uric acid. Uric acid can accumulate in joints and lead to symptoms of gout and other joint disorders.

Intake of 0.008 to 0.022 mg/kg-day of molybdenum can produce mineral imbalance as a result of increased copper excretion (EPA, 1994a). Excretion of copper is reported to double with molybdenum intakes at the upper end of this range. Copper is an essential nutrient important in many metabolic pathways, including the synthesis and function of hemoglobin. A copper deficiency resulting from excess excretion will impair the oxygen-carrying capacity of the blood, and severe copper deficiencies can lead to hypochromic microcytic anemia. In humans, gout-like symptoms and joint deformities have been reported in regions of Russia where elevated soil concentrations of molybdenum and subsequent increased molybdenum concentrations in food would lead to molybdenum intakes in the range of 0.14 to 0.21 mg/kg-day. The EPA oral reference dose of 0.005 mg/kg-day for molybdenum was derived from results of these studies (EPA, 1994a). An uncertainty factor of 30 was used for two reasons: to protect the sensitive human population and to use the LOAEL of 0.14 mg/kg-day rather than the preferred NOAEL which should be identified from a long-term study in human population. Figure 5.2 summarizes the health effects of molybdenum as a function of dose.

### 5.1.3 Uranium

Naturally occurring uranium, present at UMTRA Project sites, consists of three radioactive isotopes: uranium-234, uranium-235, and uranium-238. More than 99 percent of natural uranium occurs in the form of uranium-238 (Cothern and Lappenbusch, 1983). Uranium-238 undergoes radioactive decay by emitting alpha particles to form uranium-234, thorium-230, radium-226, radon 222, polonium-210, and other radioisotopes. Figure 5.3 summarizes the radioactive

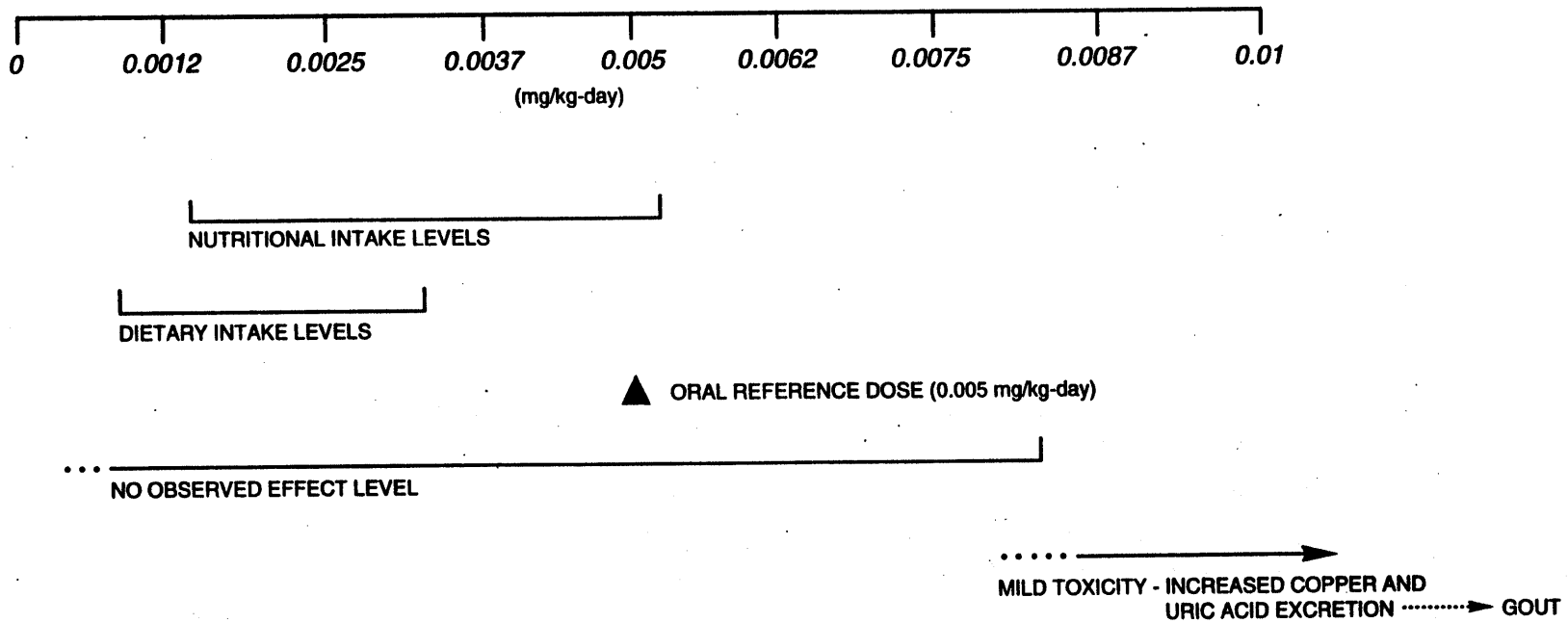
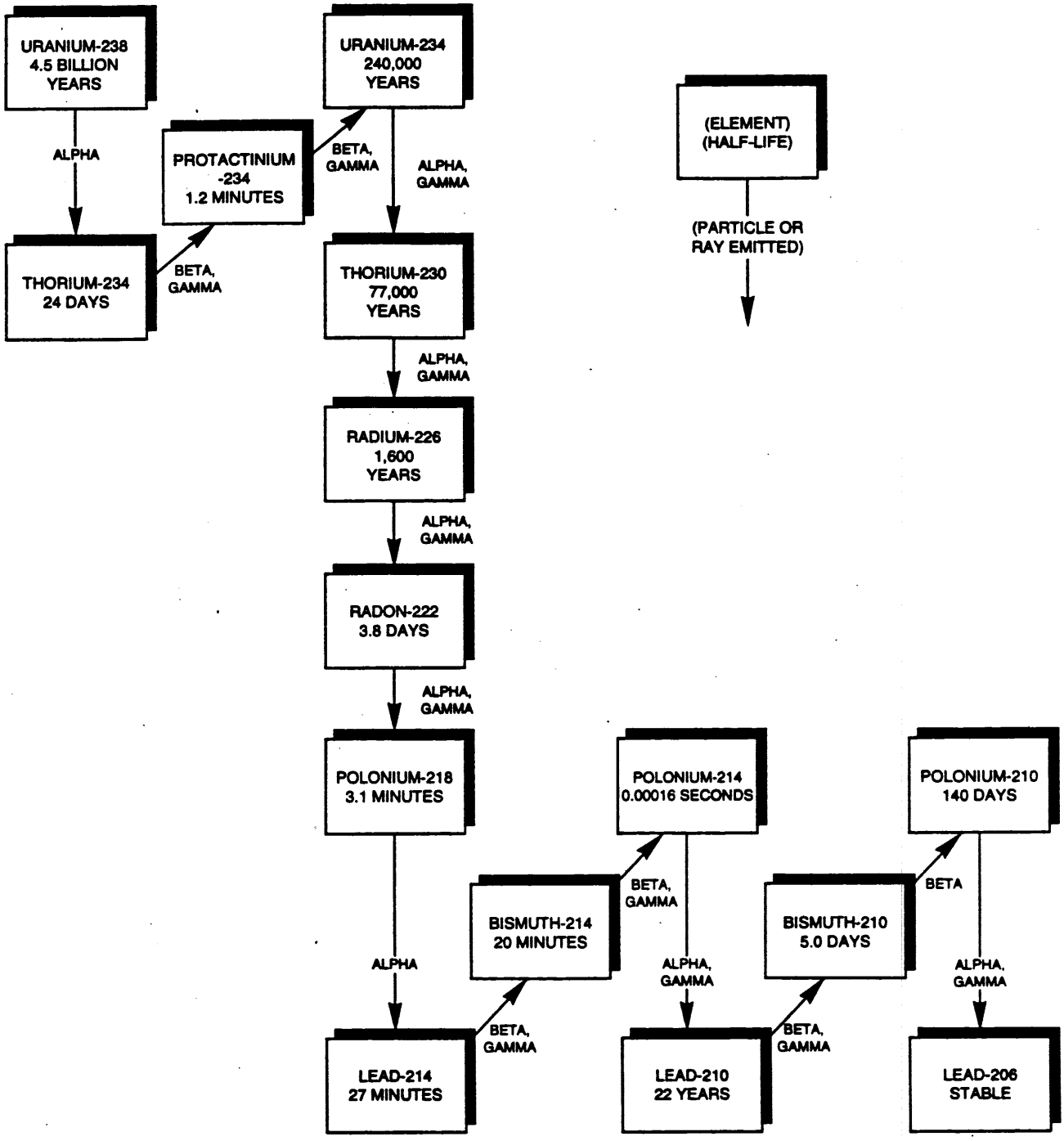



**FIGURE 5.2**
**MOLYBDENUM TOXICITY RANGES**




NOTE: ALL THE HALF-LIFE VALUES ARE ROUNDED TO THE TWO SIGNIFICANT DIGITS.

MODIFIED FROM SHLEIEN, 1992.

**FIGURE 5.3**
**HALF-LIVES AND EMISSIONS FROM DECAY CHAIN OF URANIUM-238**

MAC: SITE/CAN/BRA/HALFLIVES

decay chain of uranium-238 and uranium-234. Because all uranium isotopes in nature are radioactive, the hazards of a high uranium intake are from both its chemical toxicity and potential radiological damage. This section focuses on the chemical toxicity of natural uranium. Section 5.3 discusses the carcinogenic potential associated with exposure to radioactive isotopes of natural uranium.

Absorption

Absorption of uranium in the gastrointestinal tract depends on the solubility of the uranium compounds. The hexavalent uranium compounds, especially the uranyl salts, are water soluble, while tetravalent compounds generally are not (Weigel, 1983). Even with soluble compounds, only a small fraction is absorbed. Human gastrointestinal absorption rates of 0.76 to 7.8 percent have been determined (Wrenn et al., 1985). Uranium may absorb through skin when applied in concentrated solutions (concentration level not reported); the extent of absorption appears to be dose-dependent.

Tissue accumulation and clearance

In humans exposed to background levels of uranium, the highest uranium concentrations were found in the bone, muscle, lung, liver, and kidney (Fisenne et al., 1988). Uranium retention in bone consists of a short retention half–time of 20 days, followed by a long-retention half–time of 5000 days for the remainder (Tracy et al., 1992).

In body fluids, uranium tends to be converted into water-soluble hexavalent uranium (Berlin and Rudell, 1986). Approximately 60 percent of the uranium in plasma complexes with low-molecular-weight anions (e.g., bicarbonates and citrates), while the remaining 40 percent binds to the plasma protein transferrin (Stevens et al., 1980). Following oral exposure in humans, more than 90 percent of uranium is excreted in the feces and not absorbed in the gastrointestinal tract. Of the small percentage absorbed (typically less than 5 percent), approximately 60 percent is excreted in the urine within 24 hours whereas the remainder is distributed to the skeleton and soft tissue; 98 percent of that amount is excreted within 7 days, based on animal studies (Ballou et al., 1986; Leach et al., 1984; Sullivan et al., 1986). A small portion of the absorbed uranium is retained for a longer period.

Environmental sources of uranium

Uranium is a ubiquitous element, present in the earth's crust at approximately 4 parts per million. Uranium concentrations in ground water and surface water averaged 1 pCi/L and 3 pCi/L, respectively (NCRP, 1984). It is taken up from the soil into plant tissues to an extent depending on the plant species and the depth of its root system (Berlin and Rudell, 1986). Plant concentrations of uranium averaged 0.075 micrograms per kilogram (µg/kg) of fresh plant material in one study (Tracy et al., 1983).

The main dietary source of natural uranium for the general population is food such as potatoes, grains, meat, and fresh fish, which may contain uranium concentrations between 10 and 100 µg/kg (Prister, 1969). The total dietary uranium intake from consuming average foods is approximately 1 µg per day, approximately 20 to 50 percent of which can come from drinking water. Cereals and vegetables, particularly root crops, probably contribute most to the daily uranium intake (Berlin and Rudell, 1986).

Uranium toxicity

No human deaths definitely attributable to uranium ingestion have been reported; therefore, no lethal dose (LD) has been determined for humans. A uranium dose as low as 14 mg/kg-day resulted in the death of 50 percent of exposed laboratory animals following 23-day oral exposures ($LD_{50,23}$). The level of $LD_{50,23}$ depends on the solubility of the uranium compound tested (higher solubility compounds have greater toxicity), route of exposure, and animal species. High doses of uranium cause complete kidney and respiratory failure.

No chronic toxic effects have been reported in humans following oral exposure to uranium. Data available from populations occupationally exposed to high concentrations of uranium compounds through inhalation and information from studies in experimental animals indicate that the critical organ for chronic uranium toxicity is the kidney, specifically, the proximal tubule (Friberg et al., 1986). In humans, chemical injury reveals itself through increased catalase excretion in urine and proteinuria. Dose-response data for the toxic effect of uranium on the human kidney are limited.

The LOAEL of uranyl nitrate to cause moderate renal damage was given to rabbits in diet at 2.8 mg uranium per kg per day (Maynard and Hodge, 1949). The EPA oral reference dose of 0.003 mg/kg-day was derived based on this study (EPA, 1994a). The EPA applied an uncertaintly factor of 1000 to the LOAEL (2.8 mg/kg-day), which reflects intraspecies and interspecies variability and an uncertainty associated with the use of a LOAEL rather than the preferred use of a NOAEL. Figure 5.4 summarizes the health effects of uranium as a function of dose.

## 5.2 CONTAMINANT INTERACTIONS

Some information is available on potential interactions among contaminants found at UMTRA sites. However, discussions of potential interactions can generally be presented only qualitatively. In addition to physiological variables among individuals that can affect toxicity, uncertainties in interactions can also result from 1) differences in the relative exposure concentrations of the different contaminants compared with the concentrations tested experimentally and 2) the presence of additional ground water constituents in sufficient quantities to modify predicted toxicities even though the constituents themselves are not considered contaminants of concern for human health. Therefore, the interactions described below should be recognized as factors that can influence

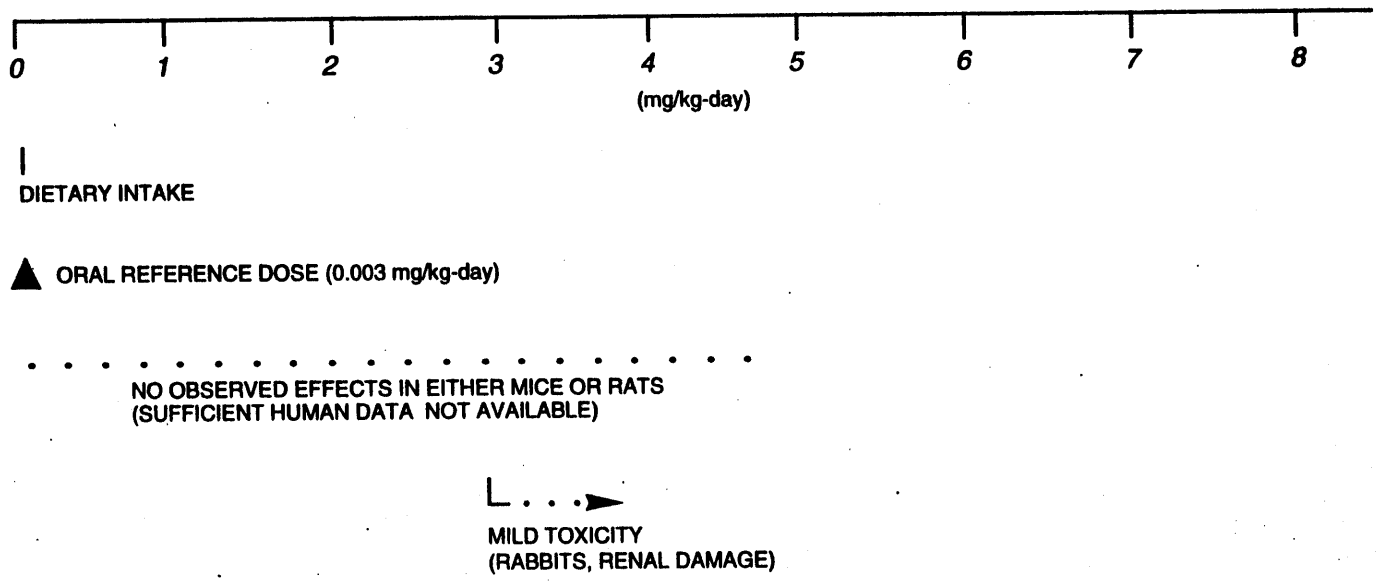



**FIGURE 5.4**
**URANIUM TOXICITY RANGES**

predicted toxicity, although the precise nature and magnitude of that influence cannot be determined.

Iron and other metals influence the rate of manganese absorption. In states of iron deficiency, manganese is actively absorbed from the intestine. In states of excess iron, manganese absorption is by diffusion only (Saric, 1986). Because iron levels in ground water at the site are at naturally high levels, the amount of manganese absorbed by a person ingesting ground water at the site may be reduced. This, in turn, may reduce the potential for toxic effects to occur from manganese ingestion. Furthermore, high levels of dietary calcium and phosphorus increase the requirements for manganese in several species (Lönnerdal et al., 1987). Thus, intake of these elements may alter the potential for absorption and potential toxicity of manganese.

The primary toxicity of molybdenum is related to its interactions with copper leading to altered excretion patterns for this element. Ruminants seem to be the most susceptible species to imbalances among these elements. In ruminants, copper has been shown to prevent the accumulation of molybdenum in the liver and may antagonize molybdenum absorption. Molybdenum can produce a functional copper deficiency. The antagonism of molybdenum to copper is augmented by sulfate (Casarett and Doull, 1991). In laboratory animal studies, molybdenum toxicity is more pronounced in situations where dietary copper intake is low (EPA, 1994a).

In animal studies iron status affected the gastrointestional absorption of uranium; however, the reported results were inconclusive (EPA, 1989e). No other information was available on uranium interactions with other metals.

## 5.3 CONTAMINANT RISK FACTORS

The EPA Office of Research and Development has calculated acceptable intake values, or RfDs, for long-term (chronic) exposure to noncarcinogens. These values are estimates of route-specific exposure levels not expected to cause adverse effects when exposure occurs for a substantial portion of the lifetime. Some of the chronic RfDs are adopted as subchronic RfDs. The RfDs include safety factors to account for uncertainties associated with limitations of the toxicological data base, including extrapolating animal studies to humans and accounting for variability in response from sensitive individuals and accounting for uncertainties associated with extrapolation from a LOAEL to a NOAEL, and from shorter term or subchronic exposures to chronic exposures. These values, updated quarterly, are published in the Health Effects Assessment Summary Tables (HEAST). They are also provided through the EPA's IRIS data base. Table 5.1 summarizes the most recent oral RfDs for the noncarcinogenic contaminants of concern.

The EPA currently classifies all radionuclides as Group A, or known human carcinogens, based on their property of emitting ionizing radiation and on the

Table 5.1 Toxicity values: potential noncarcinogenic effects

| Chemical | Chronic oral RfD[a] (mg/kg-day) | Confidence level | Critical effect/organ | RfD basis/RfD source | Uncertainty factor |
|---|---|---|---|---|---|
| Manganese | 0.005 | NA | Central nervous system | Water/IRIS[b]<br>Food/IRS[b] | 1<br>1 |
| Molybdenum | 0.005 | Medium | Increased uric acid levels in the blood, decreased copper levels | Diet/IRIS[b] | 30 |
| Uranium (soluble salts) | 0.003 | Medium | Nephrotoxicity, decreased body weight | Diet/IRIS[b] | 1000 |

[a]These doses are adopted as subchronic oral reference doses, except for uranium.
[b]EPA, 1994a.

NA – not applicable.

evidence provided by epidemiological studies of radiation-induced cancer in humans. At sufficiently high doses, ionizing radiation acts as a complete carcinogen (both initiator and promoter), capable of increasing the probability of cancer development. However, the actual risk is difficult to estimate, particularly for the low doses encountered in the environment. Most of the reliable data were obtained under conditions of high doses delivered acutely. It is not clear whether cancer risks at lower doses are dose-proportional (i.e., the linear dose-response hypothesis) or whether the risk is greatly reduced at low doses (the threshold hypothesis) (Latarjet, 1992; Shadley and Wiencke, 1989; Rigaud et al., 1993; Lazo, 1994; Oftedal, 1989; Casarett and Doull, 1991). A conservative assumption rejects the threshold hypothesis and assumes that any dose adds to the risk of cancer.

Risk factors are published in HEAST and IRIS for correlating the intake of carcinogens over a lifetime with the increased excess cancer risk from that exposure. Table 5.2 provides the most recent cancer slope factors for the uranium-234/-238 radioactive decay series.

Table 5.2 Toxicity values: potential carcinogenic effects

| Parameter | Oral slope factor $(pCi)^{-1}$, $(mg/kg\text{-}day)^{-1}$ | Weight of evidence classification | Type of cancer | Slope factor basis/slope factor source[a] |
|---|---|---|---|---|
| Lead-210[b] | 1.01E-09 | A | Bone | HEAST |
| Polonium-210 | 3.26E-10 | A | Liver, kidney, spleen | HEAST |
| Radium-226[b] | 2.96E-10 | A | Bone | HEAST |
| Thorium-230 | 3.75E-11 | A | c | HEAST |
| Uranium-238[b] | 6.20E-11 | A | d | HEAST |
| Uranium-234 | 4.44E-11 | A | d | HEAST |

[a]EPA, 1994b.
[b]Oral SF includes the contributions from short-lived decay products, assuming equal activity concentrations (i.e., secular equilbrium) with the principle nuclide in the environment.
[c]Target organs systems have not been identified for oral exposure to thorium.
[d]No human or animal studies have shown a definite association between oral exposure to uranium and development of cancer.

A – known human carcinogen.
SF – slope factor.
HEAST – Health Effects Assessment Summary Tables.

# 6.0 HUMAN HEALTH RISK EVALUATION

To evaluate human health risks to an individual or population, the results of the exposure assessment and toxicity assessment are combined. As discussed in Section 5.0, potential adverse health effects are a function of how much of the contaminant an individual takes into his or her body. At lower levels, many of the contaminants associated with the mill tailings are essential nutrients that are beneficial to health. At higher levels, these same elements can cause adverse health effects.

In this section, expected intake ranges for possible ground water ingestion from the unconsolidated material is correlated to potential health effects.

## 6.1 POTENTIAL NONCARCINOGENIC HEALTH EFFECTS

### 6.1.1 Ground water

The potential for noncarcinogenic health effects was evaluated for the 1- to 10-year-old child. Children were evaluated for noncarcinogenic effects because they have a higher intake-to-body weight ratio than adults and, thus, would be expected to receive a larger daily dose than adults. Potential noncarcinogenic effects were assessed for the following chemical contaminants of potential concern: manganese, molybdenum, and uranium.

As shown in Figure 6.1, potential adverse health effects may result from manganese intake if ground water from the unconsolidated material in Area C is used for drinking. More than 99 percent of the exposure distribution falls above the EPA oral RfD derived from drinking water consumption studies and above the threshold of mild neurological symptoms in adults. In addition, approximately 15 percent of the intakes exceeded 0.4 mg/kg-day, which is an estimated drinking water intake associated with symptoms of intoxication, including a mask-like face, muscle rigidity and tremors, and mental disturbances. Two cases of death were reported in the literature among the individuals ingesting manganese at this level. For comparison purposes, child exposure to manganese was calculated using the maximum detected value (4.05 mg/L) in background well 410. As shown in Figure 6.1, the estimated average exposure dose is 0.12 mg/kg-day, which falls within the range of early neurological symptoms. This estimate, however, is based on a maximum detection from only one upgradient well and may not be representative of long-term background conditions.

Molybdenum levels in ground water from the unconsolidated material in Area C are not expected to result in any adverse health effects, as shown in Figure 6.2. All estimated intake levels fall within nutritional or dietary intake levels. The estimated intakes are also well below the EPA oral RfD.

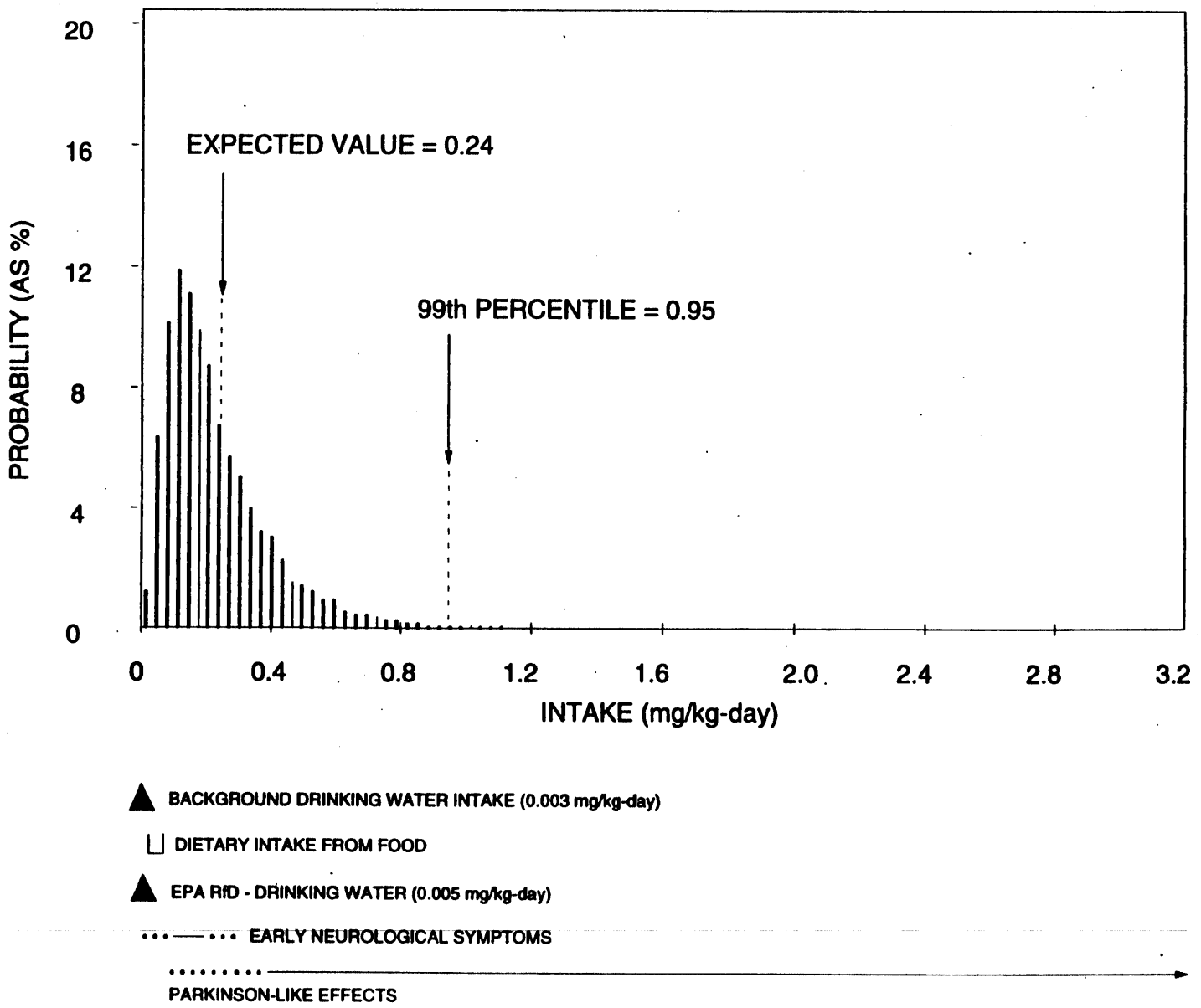



**FIGURE 6.1**
**HEALTH EFFECTS OF POTENTIAL MANGANESE EXPOSURE RANGES TO CHILDREN**
**CANONSBURG, PENNSYLVANIA, SITE**

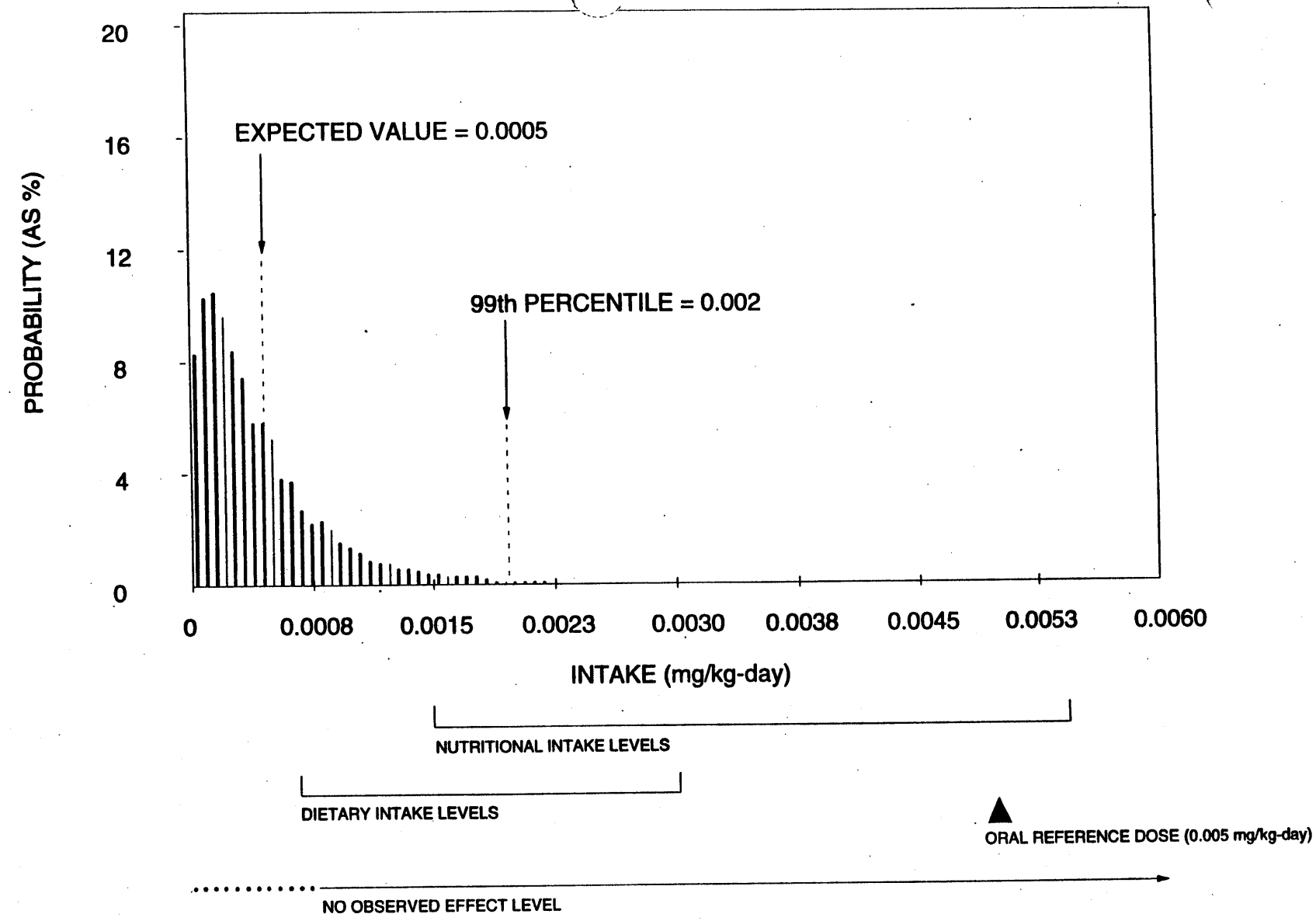



**FIGURE 6.2**
**HEALTH EFFECTS OF POTENTIAL MOLYBDENUM EXPOSURE RANGE TO CHILDREN**
**CANONSBURG, PENNSYLVANIA, SITE**



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As shown in Figure 6.3, only 1 percent of the exposure range for uranium exceeds the EPA oral RfD. The estimated intakes for uranium fall well below any toxic effects observed in humans or in animal studies.

### 6.1.2 Surface water/sediment

Potential noncarcinogenic health effects were evaluated for 6- to 12-year-old children who may be exposed to contaminants while playing in Chartiers Creek. Doses were estimated in Section 4.0 for incidental surface water ingestion, dermal contact with surface water, and incidental sediment ingestion. Doses were also estimated for adults who may ingest fish caught from Chartiers Creek. These doses are presented again in Table 6.1 for comparison with relevant toxicity data from Section 5.0. As seen in Table 6.1, the estimated doses for a child playing in the creek are at levels that would not be expected to result in adverse effects. All doses for the child fall below the EPA oral RfD and are below dietary and nutritional intake levels. Also, the estimated manganese dose for adults from fish ingestion is well below the EPA oral RfD for manganese in food sources.

## 6.2 POTENTIAL CARCINOGENIC HEALTH EFFECTS

The contaminants considered for potential carcinogenic risk include uranium as well as all uranium isotopes. These constituents are radioactive and, as such, are considered potential carcinogens. Figure 6.4 shows the exposure distribution for uranium-234 and uranium-238 ground water exposure doses and their potential lifetime carcinogenic risks. Although natural uranium has not been demonstrated to cause cancer in humans or animals following ingestion exposures, these estimates of excess lifetime cancer risk are based on the cancer slope factor developed by the EPA. The majority of the exposure distribution for ground water ingestion of uranium falls within the range of 1 in a million (1E-06) to 1 in 100,000 (1E-05). This falls within the National Contingency Plan (NCP) guidance for acceptable excess risk of 1 in a million (1E-06) to 1 in 10,000 (1E-04). The expected exposure dose results in an excess lifetime cancer risk of 9 in a million, and the upper 99th percentile exposure is expected to result in an excess lifetime cancer risk of 3 in 100,000. The distribution presented here is considered conservative because it is based on a cumulative 30-year exposure duration. As discussed previously, this exposure duration is probably appropriate, but ground water uranium concentrations resulting from uranium processing at this site are expected to decline after the tailings are stabilized; therefore, this exposure distribution may overestimate risk.

Uranium is the only radionuclide statistically above background in the unconsolidated material ground water at the Canonsburg site. However, because uranium decays to radioactive progeny, longer-lived radioactive progeny of the uranium decay series were evaluated for carcinogenic risk. Thus, the carcinogenic risk of radium-226, lead-210, polonium-210, and thorium-230

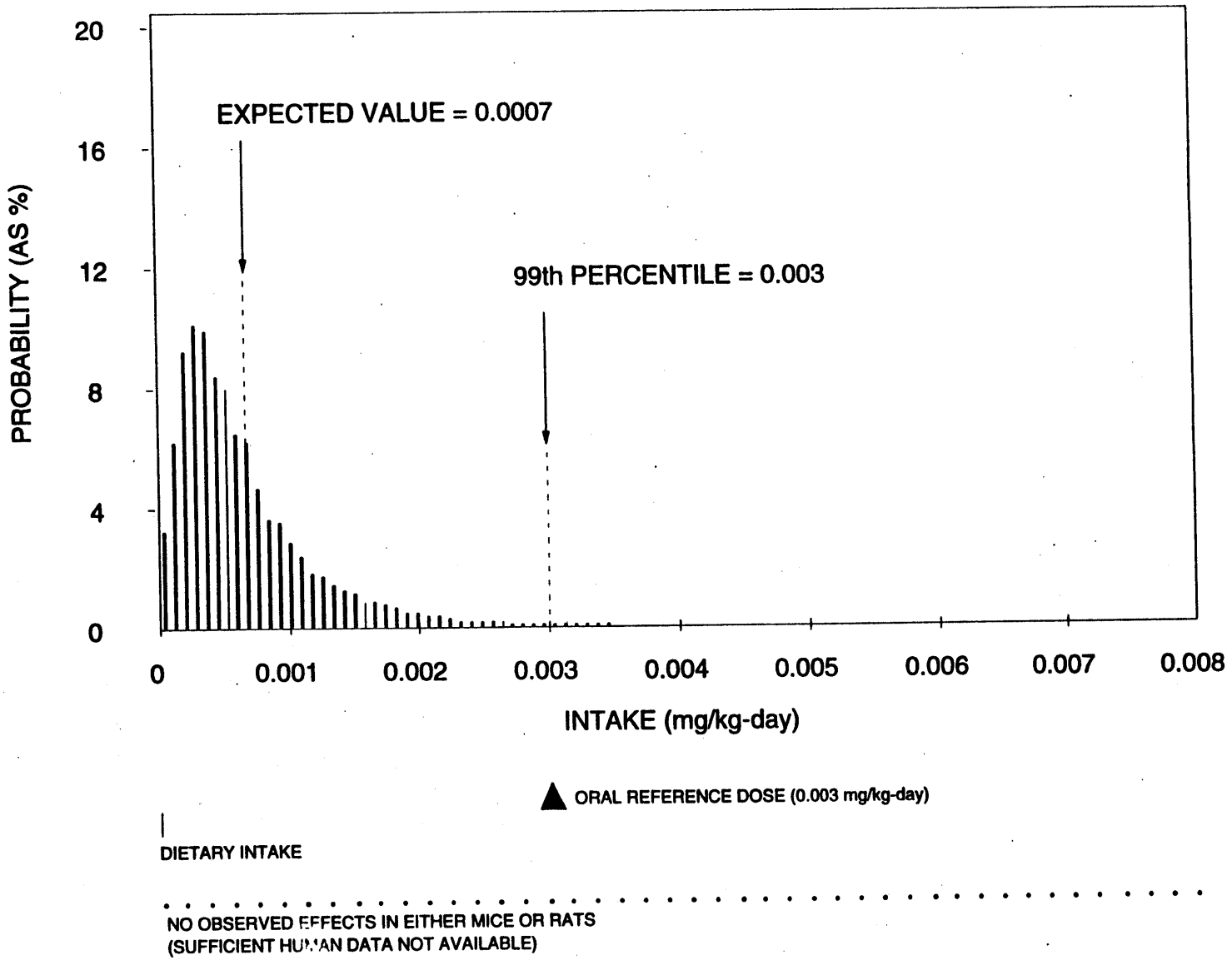


**FIGURE 6.3**
**HEALTH EFFECTS OF POTENTIAL URANIUM EXPOSURE RANGES TO CHILDREN**
**CANONSBURG, PENNSYLVANIA, SITE**

**Table 6.1 Estimated doses and toxicity values for the surface water and sediment exposure pathways in Chartiers Creek, Canonsburg, Pennsylvania, site**

| | Exposure doses (mg/kg-day) | | | | Toxicity values (mg/kg-day) | |
|---|---|---|---|---|---|---|
| Contaminant of potential concern | Surface water ingestion | Dermal contact with surface water | Sediment ingestion | Fish ingestion | EPA oral RfD | Dietary intake level |
| Manganese | 0.00005 | 0.00001 | 0.002 | 0.009 | 0.005[a]<br>0.14[b] | NA |
| Molybdenum | 0.00005 | 0.00001 | 0.00006 | NC | 0.005 | 0.0007-0.003 |

[a]EPA oral RfD for manganese in water.
[b]EPA oral RfD for manganese in food.

NA – not applicable.
NC – could not be calculated.

were evaluated, based on ground water ingestion from the unconsolidated material in Area C. As shown in Table 6.2, the estimated increased carcinogenic risk from these radionuclides is about 1 in 10,000 (1E-04). This risk level is at the upper end of the acceptable range of the 1E-06 to 1E-04 as recommended in the NCP for Superfund sites. If the cancer risk estimated for these radionuclides is added to the range of carcinogenic risk estimated for uranium, the total excess cancer risk could also be at the upper end of the NCP risk range.

## 6.3 LIMITATIONS OF THE HUMAN HEALTH RISK EVALUATION

The following potential limitations apply to the interpretation of this human health risk evaluation:

- Subpopulations with increased sensitivity are not specifically addressed on the graphs. Expected sensitivities in certain groups were discussed in the text to the extent possible.

- Some individuals may be more sensitive to the toxic effects of certain constituents for undetermined reasons; therefore, adverse health effects may occur in sensitive individuals at lower exposure levels.

- Data available to interpret potential adverse health effects may not always be sufficient to allow accurate determination of all health effects due to lack of testing in humans or testing of dose ranges other than those expected at the site.

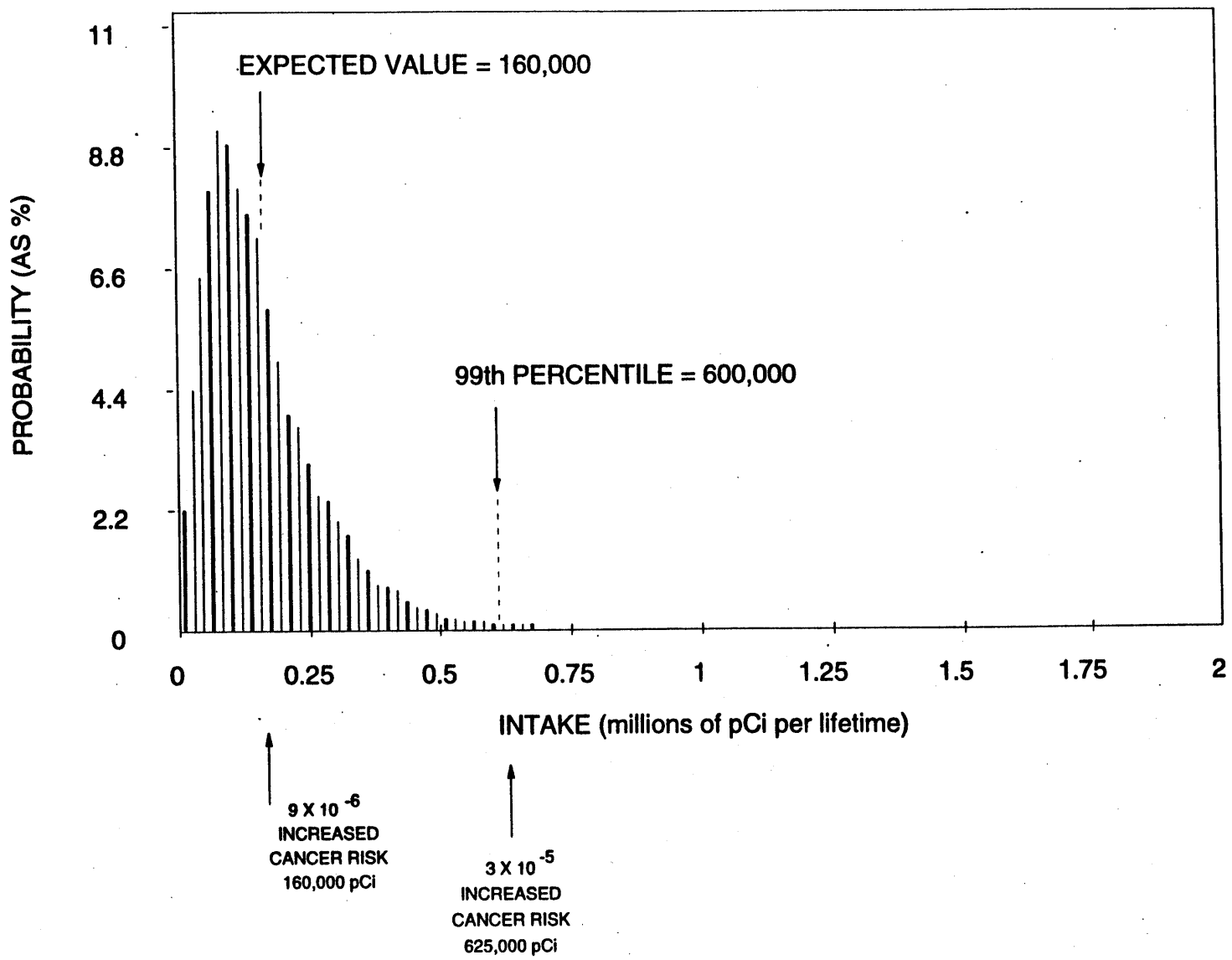


**FIGURE 6.4**
**EXCESS LIFETIME CANCER RISK FROM POTENTIAL URANIUM -234/238 EXPOSURE RANGES**
**CANONSBURG, PENNSYLVANIA, SITE**



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**Table 6.2 Carcinogenic risk for the unconsolidated layer ground water ingestion pathway, Canonsburg, Pennsylvania, site**

| Contaminant of potential concern | Exposure point concentration (pCi/L) | Intake (pCi per lifetime) | Oral slope factor $(pCi)^{-1}$ | Lifetime risk |
|---|---|---|---|---|
| **Radionuclides** | | | | |
| Lead-210 | 5.0[a] | 105,000 | 1.01E-09 | 1E-04 |
| Polonium-210 | 0.2[a] | 4,200 | 3.20E-10 | 1E-06 |
| Radium-226 | 0.7[b] | 14,700 | 2.96E-10 | 4E-06 |
| Thorium-230 | 0.7[a] | 14,700 | 3.75E-11 | 6E-07 |
| | | | **Total:** | 1E-04 |

[a]Maximum observed concentration in filtered or unfiltered water samples, 1986-1993.
[b]Maximum observed concentration in filtered or unfiltered water samples, 1988-1993.

- Although the areal extent of ground water contamination and its movement have been evaluated hydrologically and geochemically, the monitoring locations sampled may not include the most contaminated areas. In addition, concentrations may decrease substantially over time.

- The results of risk evaluation presented in this document are based on filtered (0.45-micron) ground water samples. Therefore, the potential loss of certain ground water constituents as a consequence of filtration represents a source of uncertainty.

- Only the drinking water exposure pathway has been considered in depth, although other pathways have been screened to determine their relative and independent contribution. However, the incremental or independent contribution from the ground water-irrigated produce ingestion pathway could not be estimated here.

- This risk assessment evaluates only risks related to inorganic ground water contamination. Potential contamination from any of the organic constituents that might be used in uranium processing has not been addressed.

The evaluation presented here has considered these limitations and compensated whenever possible by presenting toxicity ranges and probabilistic exposure assessments rather than point estimates to incorporate as much variability as could reasonably be defined. Section 8.2 details the impact of these potential limitations.

# 7.0 ENVIRONMENTAL EVALUATION

The objective of the environmental portion of the risk assessment is to determine whether contaminants detected at the site have the potential to adversely affect the existing biological community at or surrounding the site. Currently, the EPA has no guidance for quantifying potential impacts to ecological receptors, but has developed a qualitative approach generally used for ecological evaluation (EPA, 1989c). With the qualitative approach, the EPA recommends comparing ambient environmental media concentrations with water quality, sediment quality, or other relevant criteria or guidelines to determine whether the concentrations that the ecological receptors are expected to encounter exceed these values.

Although the effects of contaminants on ecological receptors are a concern, it is difficult to predict whether effects on individual populations will cause damage to the community or ecosystem. If a prey species is affected, predators may be able to feed on other species; losses of predators may be compensated for by other predators or by immigration of another predator population. Thus, it may be difficult to recognize whether adverse effects are occurring, unless there are gross impacts such as mass killings within a population or community. Evidence of gross impacts were not observed during the field survey at the Canonsburg site.

Sublethal effects may occur if contaminants are present at concentrations that may not kill organisms directly, but diminish their ability to survive or reproduce. Types of sublethal effects include behavioral changes, reduced reproductive success, or enzyme level changes, which can affect the population or community level of organization. However, it is often difficult to identify and measure the sublethal effects and establish a causal relationship to a specific environmental stressor, such as a chemical contaminant.

Thus, it is important to note that this preliminary ecological risk assessment cannot account for all potential variables. However, it does provide a qualitative evaluation of potential ecological risks at this site.

## 7.1 EXPOSURE CHARACTERIZATION

This section identifies the potential exposure pathways associated with the Canonsburg site. For risk to exist, a receptor must be exposed to contaminants. Exposure can occur only with both a source of contamination and a mechanism of transport to a receptor population or individual.

Ground water, and potentially surface water and sediment, are the only possibly impacted media at the site. Thus, soil or air exposure pathways (such as incidental ingestion of soil, dermal contact with soil, and inhalation of air containing particulates) do not represent an ecological concern and will not be evaluated in this baseline risk assessment. However, surface water-related or ground water-related exposure pathways (such as ingestion of surface water potentially affected by contaminated ground water, bioconcentration of

contaminants in surface water by aquatic organisms, and consumption of organisms that have accumulated contaminants) are possible at the site.

The main surface water body in the Canonsburg site area is Chartiers Creek (Figure 7.1). The site lies in the Chartiers Creek basin along the creek's southern bank, approximately 15 mi (24 km) upstream of its confluence with the Ohio River. In the Canonsburg area, Chartiers Creek is a meandering stream 75 to 100 ft (23 to 30 m) wide and approximately 10 ft (3 m) deep (DOE, 1983a). In the site vicinity, the stream dimensions are usually much less, ranging from approximately 25 to 40 ft (7.6 to 12 m) wide and approximately 6 ft (1.8 m) deep.

This water body is a potential exposure point for resident aquatic life and terrestrial wildlife (as well as domestic animals) that may contact surface water and/or sediments. This risk assessment evaluates these exposure pathways.

Another potential current pathway could involve plant uptake of contaminants in ground water. Due to the shallow depth to ground water (approximately 5 ft [1.5 m] or less below land surface), plant roots may reach contaminated ground water. This risk assessment evaluates plant uptake, assuming that the plant roots reach soil saturated with ground water.

Another potential pathway involves use of ground water as a water source for irrigating garden plants. For this baseline risk assessment, it was assumed that a domestic well, at some point in the future, could be installed in Area C, which is the site area being considered for public use. The water from this hypothetical well could be used for irrigating garden plants.

## 7.2 ECOLOGICAL RECEPTORS

This section identifies the ecological resources present at the site and vicinity that potentially may be exposed to site-related contaminants.

The following information on ecological receptors is based primarily on surveys performed before the tailings encapsulation process was initiated and is provided as a historical perspective. Limited observations of aquatic organisms (at the surface water and sediment sampling locations) and of terrestrial flora and fauna were made during a 19 and 20 October 1993 field survey.

### 7.2.1 Terrestrial resources

The Canonsburg disposal cell and surrounding land was planted with grass after the completion of remedial action. The disposal cell and surrounding land within the site fence line is now covered with a dense growth of grass, as well as occasional herbaceous species such as yellow hop clover, red clover, yarrow, Queen Anne's lace, curled dock, and alfalfa. This land is mowed once or twice a year which serves to maintain the grass and herb cover; very few woody plant species occur in this mowed area (TAC, 1990; 1993).

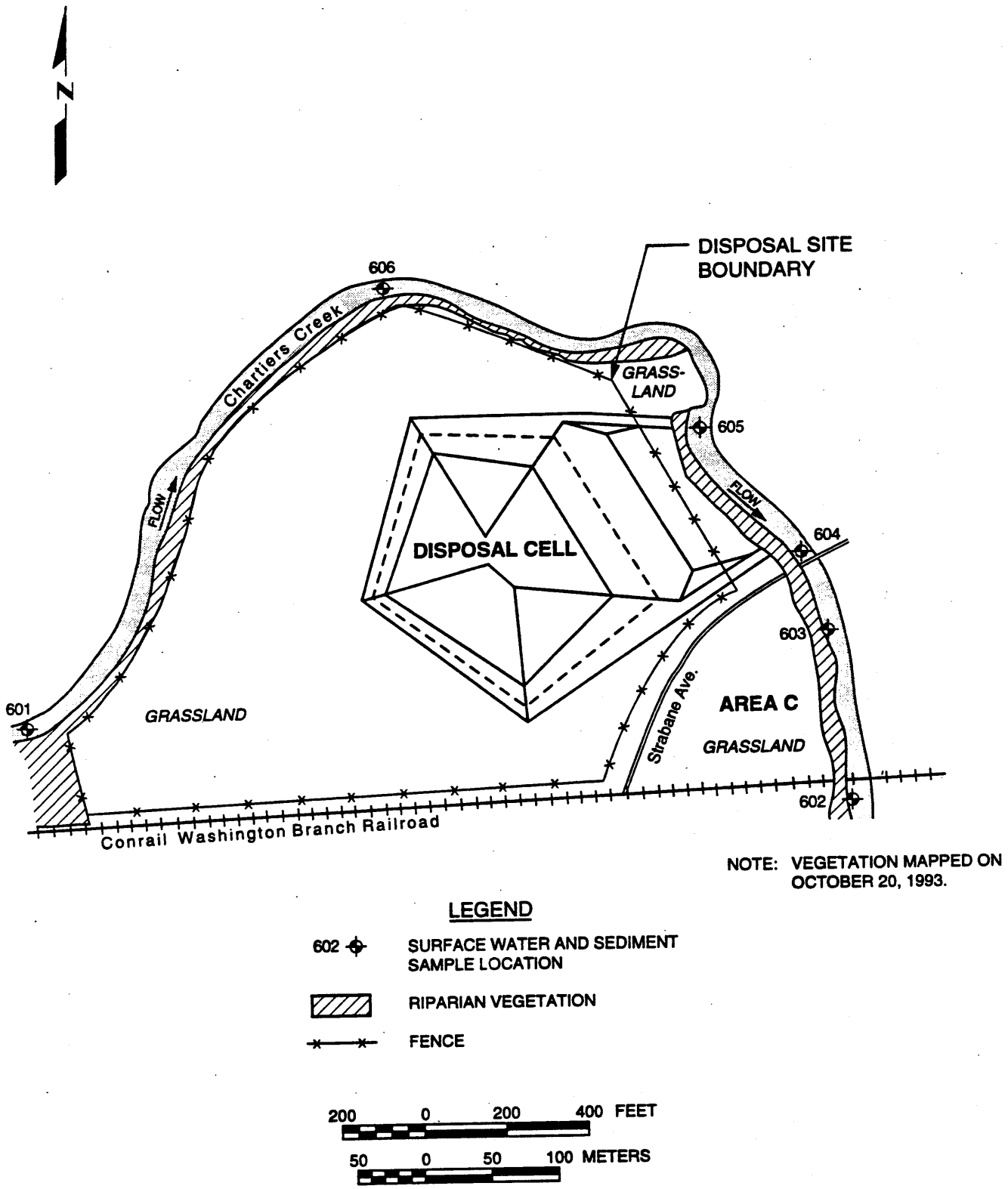


**FIGURE 7.1**
**LOCATION OF RIPARIAN VEGETATION GROWING ALONG CHARTIERS CREEK CANONSBURG, PENNSYLVANIA, SITE**

Chartiers Creek borders the site on the north, west, and east and a wooded riparian zone occurs between the site fence line and the creek (Figure 7.1). This vegetation grows in a thin band along the eastern site boundary and forms a wider band on the north and west sides of the site. The wooded riparian plant community on the north and west sides of the site occurs on a bank 3 to 15 ft (1 to 5 m) above the creek. The majority of the site is covered by a grass-dominated plant community, which typically grows up to the creek bank.

Within the riparian community along the creek, sycamore was the most frequently observed canopy tree. A few large black willows were also observed. Other large trees observed in lesser numbers were box elder, basswood, black locust, and silver maple. Box elder was clearly the most common understory species observed. Other species noted in the understory were basswood, sugar maple, black cherry, red oak, black locust, and apple. Wild grape vines were commonly observed growing in the trees. Ground cover was dominated by herbaceous species. Some grass and *Carex* sp. were observed. Black snakeroot was also very common, along with poison ivy, *Aster* sp., and *Rubus* sp. (TAC, 1993).

Only limited surveys for wildlife have occurred at or near the Canonsburg site. No amphibians and only one reptile (garter snake) were observed during site visits, although a variety of frog, toad, salamander, and snake species are expected to occur at the site. Surveys for nesting birds were not conducted; species recorded in the fall include the blue jay, song sparrow, crow, downy woodpecker, black capped chickadee, white-breasted nuthatch, robin, and Carolina wren. Birds of prey recorded were the kestrel and Coopers Hawk. Waterfowl such as the mallard and wood duck have been observed in the creek, as well as the green heron. Woodchuck were observed in both the grassland and wooded riparian plant communities (DOE, 1983a; TAC, 1993).

### 7.2.2 Aquatic organisms

No quantitative surveys of aquatic organisms occurring in Chartiers Creek have been conducted to date as part of the technical assistance contractor (TAC) investigation (DOE, 1994). A brief qualitative survey of the aquatic organisms in Chartiers Creek was conducted in the vicinity of the six surface water and sediment sampling locations (Figure 7.1). The bottom sediments were composed of cobble and silts. Several pools and riffles occur in the reach of Chartiers Creek in the site vicinity.

A fine-mesh dip-net and soil sieve were used to collect fish and benthic macroinvertebrates at each of the surface water sampling locations. One fish, a darter (Etheostomata), was collected in a riffle area near location 604. Several unidentified fish were observed at various points along the creek. Four crayfish were collected and numerous burrows and chimneys were observed along the stream. Numerous isopods were observed on the undersides of rocks in the riffle areas. Chironomids and oligochaetes were found in surficial sediments throughout the creek. Limpets were observed in the riffle areas attached to

attached to rocks. No apparent differences among the locations were noted during the October 1993 survey with respect to the fauna observed.

Based on previous investigations in the site vicinity, fish reported in the reach of Chartiers Creek include creek chub, white sucker, striped shiner, and carp (DOE, 1983a). Also, the following benthic macroinvertebrates were collected from the creek during previous investigations: oligochaetes, chironomids, leeches, snails, water beetles, isopods, and crayfish (DOE, 1983a).

## 7.3 CONTAMINANTS OF ECOLOGICAL CONCERN

### 7.3.1 Ground water

The list of ground water contaminants exceeding background levels in the unconsolidated unit was used as the list of contaminants of potential concern for evaluating potential plant receptors exposed to ground water (see Section 3.3). This list was developed using data from the most contaminated monitor wells finished in the unconsolidated materials at the site (412, 413, and 414). Wells 412 and 413 are downgradient of the tailings encapsulation area, and well 414 is in Area C. The list of contaminants of potential concern from these wells include the following inorganics: ammonium, arsenic, boron, calcium, chloride, magnesium, manganese, molybdenum, potassium, sodium, strontium, sulfate, and uranium. These contaminants and their associated concentrations differ from the list used for the human health risk assessment, which only assessed data from well 414, because plant roots can access ground water beneath the site at all locations. Thus, additional contaminants of concern were added to those evaluated in the human health assessment based on the additional consideration of data from wells 412 and 413.

The list of ground water contaminants exceeding background levels in the unconsolidated unit was also used as the list of contaminants of potential concern for evaluating potential receptors of irrigation water. However, the irrigation pathway only considered data from well 414, which is in Area C. As in the human health assessment, Area C was assumed to be the only area of the site potentially accessible for the installation of a well and subsequent use for irrigation. The first column of Table 3.3 provides the list of contaminants of potential concern from well 414: ammonium, boron, calcium, manganese, molybdenum, potassium, strontium, and uranium.

The exposure point concentrations used for ground water were either the upper 95 percent confidence limit of the concentration from any one well or the maximum detected value, whichever value was lower. When applicable, the well with the highest concentration for any one contaminant was used to represent the exposure point concentration for that contaminant.

### 7.3.2 Surface water/sediment

The list of contaminants of potential concern in the surface water bodies was developed from the same list of contaminants evaluated for ground water because any site-related contaminants in surface water are primarily assumed to be a result of ground water discharge. This list of contaminants was then compared with the surface water data to determine which contaminants are potentially site-related (i.e., those contaminants exceeding ground water background levels in wells 412, 413, and 414). Table 7.1 presents the surface water data for these site-related contaminants.

If a contaminant was never detected in Chartiers Creek (e.g., uranium) or the concentration detected adjacent to or downstream of the site was less than or equal to the concentration upstream of the site (e.g., ammonium, sodium, sulfate, and magnesium), it was excluded as a contaminant of potential concern for ecological receptors. Additionally, calcium, chloride, and potassium were excluded as contaminants of potential concern because the differences between the upstream and adjacent concentrations were minimal (less than 5 percent). Although arsenic, boron, and strontium were identified as statistically elevated above background in ground water from monitor wells 412, 413, and 414, no data are available for Chartiers Creek because the surface water has never been analyzed for these constituents. Based on these comparisons, manganese and molybdenum are the contaminants of potential ecological concern selected for surface waters in Chartiers Creek.

The concentrations used in these comparisons to background were from unfiltered samples. Data from unfiltered samples were used because most of the state of Pennsylvania's water quality criteria are stated as total recoverable (unfiltered) metal concentrations.

No sediment samples were collected from Chartiers Creek prior to the October 1993 sampling. The constituents analyzed in the sediments that were identified as being site-related (i.e., above background ground water quality) were evaluated in this assessment. These include the metals manganese, molybdenum, and uranium. Table 7.2 presents the sediment data for these metals by location.

## 7.4 POTENTIAL IMPACTS TO WILDLIFE AND PLANTS

### 7.4.1 Terrestrial risk

A number of potential exposure pathways were evaluated for terrestrial vegetation and wildlife. Terrestrial vegetation can be directly exposed to contaminants in ground water through uptake by the roots. Contaminants may bioaccumulate in various plant parts and exert a wide range of influences depending on the specific contaminant. Plant uptake rates vary greatly among species and are affected by soil characteristics (pH, moisture, redox potential, organic matter, etc.), plant sensitivity, and input-output balance. Another

**Table 7.1 Occurrence of constituents detected in Chartiers Creek surface water, Canonsburg, Pennsylvania, site vicinity**

| | Upstream of site Location ID | Adjacent to site[a] Location ID | | | | Downstream of site Location ID |
|---|---|---|---|---|---|---|
| Constituent | 601 | 606 | 605 | 604 | 602 | 603 |
| Ammonium[b] | 0.25 | NA | NA | NA | 0.20 | NA |
| Calcium[b] | 83 | NA | NA | NA | 87 | NA |
| Chloride[b] | 50 | NA | NA | NA | 51 | NA |
| Magnesium[b] | 19 | NA | NA | NA | 19 | NA |
| Manganese | 0.13 (0.16)[b] | 0.17 | 0.16 | 0.13 | 0.12 (0.16)[b] | 0.12 |
| Molybdenum | 0.09 (0.08)[b] | 0.17 | 0.16 | 0.10 | 0.09 (0.085)[b] | 0.10 |
| Potassium[b] | 6.5 | NA | NA | NA | 6.8 | NA |
| Sodium[b] | 62 | NA | NA | NA | 58 | NA |
| Sulfate | 280 (207)[b] | 250 | 250 | 280 | 270 (203)[b] | 270 |
| Uranium | <0.001 (<0.001)[b] | <0.001 | <0.001 | <0.001 | <0.001 (<0.001)[b] | <0.001 |

[a]Refers to sampling locations adjacent to the disposal cell or Area C.
[b]Concentrations presented are median concentrations for unfiltered data collected from 1991 through 1993.

Note: All concentrations reported in milligrams per liter. Unfiltered data collected on 19 and 20 October 1993, unless otherwise specified.

NA – not analyzed.

**Table 7.2 Occurrence of constituents detected in Chartiers Creek sediment, Canonsburg, Pennsylvania, site vicinity**

| | Upstream of site Location ID | Adjacent to site[a] Location ID | | | | Downstream of site Location ID |
|---|---|---|---|---|---|---|
| Constituent | 601 | 606 | 605 | 604 | 602 | 603 |
| Manganese | 1410 | 1550 | 2150 | 2820 | 590 | 1900 |
| Molybdenum | 33 | 13 | 96 | 25 | 2 | 16 |
| Uranium | 2.0 | 1.8 | 2.0 | 2.6 | 1.6 | 2.4 |

[a]Refers to sampling locations adjacent to the disposal cell or Area C.

Note: All concentrations reported in milligrams per kilogram dry weight. Data collected on 19 and 20 October 1993.

potential exposure route for plants is through garden irrigation by ground water. Foraging wildlife can be indirectly exposed to contaminants in ground water by ingesting plants or fruits (such as apples) that may have bioaccumulated certain contaminants. Terrestrial wildlife can also be exposed to contaminants in surface water bodies by ingesting the surface water, aquatic organisms that have accumulated contaminants, and/or sediments.

Vegetation

Based on the shallow depth to contaminated ground water at the site, some plants could have rooting zones in soils that intercept contaminated ground water. Concentrations of the contaminants of potential concern in plant tissue at harvestable maturity, based on uptake from ground water, could not be estimated but should be considered in future studies at the site.

Another potential exposure route for plants is through garden irrigation by ground water. Table 7.3 compares the ground water concentrations (represented by well 414) with the approximate concentrations in water that should be protective of plants if used as a continuous source for irrigation (EPA, 1972). The EPA developed these approximate irrigation water concentrations to protect agricultural crops from toxicity associated with buildup of a particular constituent in the soil. Two of the contaminants of potential concern, boron and manganese, have comparison values. The ground water concentration for manganese exceeds the comparison value, while boron is below the comparison value. No comparison values are available for the remainder of the contaminants of potential concern. Thus, it is not possible to evaluate the potential for these compounds to adversely affect plants when applied in irrigation water. However, based on the available information, use of the alluvial ground water near the site as a continuous source of irrigation water may result in deleterious effects to plants, due to the elevated concentration of manganese.

**Table 7.3 Comparison of contaminants of potential concern in ground water with available water quality values, Canonsburg, Pennsylvania, site**

| Contaminant | Concentration in ground water | Aquatic life water quality value[a] | Water concentration protective of livestock[b] | Concentration in irrigation water protective of plants[b] |
|---|---|---|---|---|
| Ammonium | 1.3 | NA | NA | NA |
| Boron | 0.39 | 1.6 | 5.0 | 0.75 |
| Calcium | 93 | NA | NA | NA |
| Manganese | 11 | 1.5 | NA | 0.20 |
| Molybdenum | 0.03 | 50 (0.79)[d] | 10[f] | NA |
| Potassium | 4.3 | NA | NA | NA |
| Strontium | 0.30 | NA | NA | NA |
| Uranium | 0.04 | 8[e] | NA | NA |

[a]Value obtained from the commonwealth of Pennsylvania, Title 25, Environmental Resources, Chapter 16.51, *Water Quality Criteria for Toxic Substances*, Pennsylvania Department of Environmental Resources (PADER, 1991), unless specified otherwise. These values are standards protective of aquatic life via chronic exposure.

[b]From EPA (1972), unless specified otherwise. Irrigation water values shown are for water used continuously on all soils.

[c]No state or federal criteria available. Value shown is the lower end of the tolerance range for freshwater organisms (EPA, 1986).

[d]No state or federal criteria available. Value presented is the current molybdenum criterion recommended by the U.S. Fish and Wildlife Service for the protection of aquatic organisms (50 mg/L), with one exception. The exception is for newly fertilized eggs of rainbow trout, which are sensitive to molybdenum concentrations above 0.79 mg/L (Eisler, 1989).

[e]No Pennsylvania or federal criteria available. Value presented is the state of Colorado's hardness dependent water quality standard for the protection of aquatic life via chronic exposure (CDPHE, 1991).

[f]Value presented is the current safe level for molybdenum in cattle drinking water recommended by the U.S. Fish and Wildlife Service (Eisler, 1989).

Concentrations reported in milligrams per liter unless otherwise noted. Concentration in ground water is the upper confidence limit or maximum detected concentration, whichever is less.

L/kg – liters per kilogram.
mg/kg DW – milligrams per kilogram dry weight.
NA – not available.

Wildlife

The exposure of terrestrial organisms from the ingestion of plants or animals that have accumulated contaminants (e.g., birds eating fish) is a potential exposure pathway at the site. Birds and other vertebrates consuming these plants and animals can bioaccumulate some of the contaminants of potential concern if the amount ingested exceeds the amount eliminated. This is often a function of the areal extent of contamination versus the areal extent of the animals feeding range. In the case of small contaminated areas, the contribution of impacted food to the total diet is usually very minute, and bioaccumulation is not a concern. Therefore, although exposure via the diet may be possible, the potential for bioaccumulation is not always a concern.

Biomagnification is potentially of greater concern and involves increased concentration of a constituent at each successive trophic level in the food chain. Of particular concern for biomagnification effects are the top predators, especially the carnivorous birds and mammals. Only a limited number of constituents have the potential for magnifying in the food chain. Most constituents are metabolized in organisms and eliminated at each level of the food chain and, thus, would not increase in concentration at each successive trophic level. Based on available information on the contaminants of concern at this site, the potential for these contaminants to represent a hazard via food chain transfer is probably low.

Other potential pathways of exposure to wildlife include ingesting water or sediments in Chartiers Creek. Animals may drink from the creek and, thus, be potentially exposed to contaminants in surface water and/or sediments. However, no available federal or state criteria or guidelines have been established to protect terrestrial wildlife from water or sediment exposure. Therefore, the potential hazards to terrestrial receptors from surface water and sediment ingestion were not evaluated.

### 7.4.2 Aquatic risk

Surface water

A potential exposure point for aquatic life is Chartiers Creek in the site vicinity. The ground water from the unconsolidated material is believed to discharge into the creek. Comparing the surface water data collected from the creek at the upstream location with those of the adjacent and downstream locations indicates that most of the constituents did not exceed upstream concentrations.

Manganese and molybdenum were identified as contaminants of potential concern in the creek water. The maximum concentrations for manganese (0.17 mg/L) and molybdenum (0.17 mg/L) were detected at sampling location 606 (Figure 7.1). No state or federal water quality criteria have been developed for these two constituents (PADER, 1991; 40 CFR Part 131). However, the EPA reported a value of 1.5 mg/L of manganese as the lower end of a tolerance

range for freshwater organisms (EPA, 1986). The maximum detected manganese concentration in Chartiers Creek falls approximately 1 order of magnitude below this value. For molybdenum, the U.S. Fish and Wildlife Service currently recommends a value of 50 mg/L to protect most aquatic organisms and 0.79 mg/L to protect newly fertilized rainbow trout eggs (Eisler, 1989). Because Chartiers Creek is a warm water habitat, protecting trout eggs is not of concern. The maximum detected molybdenum concentration in Chartiers Creek falls well below the 50 mg/L value protective of aquatic organisms. The concentrations for manganese and molybdenum at sampling locations 606 and 605 were only slightly higher than those at the upstream location (Table 7.1). This suggests that ground water discharge to the creek has not affected the water quality, although the limited sampling is not conclusive.

Sediment

Surficial sediment (approximately 0 to 4 inches below sediment surface) was collected from six locations (Figure 7.1) during the 19 and 20 October 1993 sampling event. No sediment samples had been collected prior to this sampling event. The sediment data for manganese and molybdenum varied among sampling locations (Table 7.2). The highest concentration for each contaminant of potential concern was detected at a location adjacent to the site: location 604 for manganese and uranium and location 605 for molybdenum. The lowest concentration for each constituent was detected at location 602.

No established state or federal sediment quality criteria or guidelines exist to protect aquatic life from the contaminants of potential concern at this site (EPA, 1988; NOAA, 1990). The EPA is evaluating a methodology based on the three-phase sorption model for free metal ion activity and is assessing its applicability for determining the bioavailable fraction within sediments (EPA, 1989d). Currently, a number of other predictive models and methods are being investigated for metals, but no single approach has been accepted to adequately develop sediment-based metals criteria (Shea, 1988; Chapman, 1989; EPA, 1989d; NOAA, 1990; Di Toro et al., 1991; Burton, 1991).

Because no sediment quality values currently exist for manganese, molybdenum, and uranium, the potential for detected sediment concentrations to adversely affect biota could not be addressed. It is difficult to draw any conclusions concerning sediment quality conditions in Chartiers Creek due to the limited data set (i.e., one sampling event) and the variability of the data.

## 7.5 LIMITATIONS OF THE ECOLOGICAL RISK ASSESSMENT

The qualitative evaluation of potential ecological risks presented here is a screening level assessment of the risks associated with potential exposure of plants and animals to contaminated ground water, surface water, and sediment at the Canonsburg site. Sources of uncertainty in any ecological assessment arise from the monitoring data, exposure assessments, toxicological information, and the inherent complexities of the ecosystem. In addition, methods of

predicting nonchemical stresses (e.g., drought), biotic interactions, behavior patterns, biological variability (i.e., differences in physical conditions, nutrient availability), and resiliency and recovery capacities are often unavailable. In general, limitations for the Canonsburg ecological risk assessment include the following:

- Only a small amount of ecological data were collected during this screening.
- Little is known about site-specific intake rates for wildlife or amounts of contaminants taken up by plants. General literature values were used in many cases.
- Only limited ecotoxicological reference data are available.
- Considerable uncertainty is associated with the toxicity of mixtures of contaminants.

## 7.6 SUMMARY

Surface water data from Chartiers Creek in the site vicinity indicate the presence of slightly higher concentrations for two constituents (manganese and molybdenum) at some downgradient locations. However, it is not known whether site-related constituents have affected the water quality of the Chartiers Creek.

A limited data set (one sampling round) currently exists of the sediment quality in Chartiers Creek in the site vicinity. Although a statistical analysis cannot be conducted with the limited data, no trends are apparent in the data. Sediment concentrations for the contaminants of potential concern were highest at two locations adjacent to the site. However, insufficient data are available to determine if this is related to releases from the site or due to natural variability. Sediment quality values to protect aquatic life are not available for the contaminants of potential concern; thus, it is not possible to evaluate the potential for these concentrations to represent an ecological concern.

Based on available data and criteria, no ecological threat exists to plants at harvestable maturity that may have roots in contact with soil saturated with the most contaminated ground water in the alluvial aquifer. Due to manganese levels, this ground water would not be suitable for continuous long-term irrigation for plants.

The potential for the contaminants of potential concern detected in media at the site to represent a food chain hazard (via bioaccumulation and biomagnification) is considered low, based on available surface water and sediment data. However, no tissue analysis from potential ecological receptors (e.g., wildlife and plants) has been conducted.

Insufficient water quality and sediment quality values were available to allow a comprehensive evaluation of the impact of surface water, sediments, and contaminated ground water on ecological receptors. However, based on available data, it does not appear that former site activities have impacted surface water and sediments in the site vicinity.

# 8.0 INTERPRETATION AND RECOMMENDATIONS

## 8.1 RISK SUMMARY

The UMTRCA requires the UMTRA Project to protect public health and the environment from radiological and nonradiological hazards associated with the uranium mill sites. This baseline risk assessment was conducted for the Canonsburg site to evaluate the presence of these hazards. This risk assessment is conservative in that it evaluates residential exposure by drinking water from the most contaminated well at the site. Because contaminated ground water is currently not used by area residents, human health is currently not at risk. This situation will continue if land and water use at the site remain the same. Changes of land use may or may not create future risks. Specific future land uses should be evaluated to identify potential health and environmental risks from the contaminated ground water in the unconsolidated materials (uppermost aquifer).

Future drinking water use of contaminated ground water could be associated with adverse health effects. However, it is unlikely that such use will occur in the future because the natural quality of the uppermost aquifer water is poor and this water has not been used for human consumption in the site area. Note also that in the future hypothetical residential scenario, only the people who drill a well in the most contaminated portion of the uppermost aquifer could experience the health problems discussed below. Furthermore, the ground water contaminant concentrations will decline over time.

The primary human health risk associated with ground water contamination in the uppermost aquifer at the Canonsburg site could be from manganese ingestion. Using ground water from the uppermost aquifer in Area C for drinking purposes could result in ingesting manganese at levels that could most likely produce adverse effects to the nervous system. The estimated doses fall above the threshold for mild neurological symptoms in adults. Doses based on the natural background manganese levels detected in one well in the uppermost aquifer could also result in mild neurological symptoms. Manganese in ground water was also at levels that could be potentially harmful to ecological receptors. Ground water would not be suitable for continuous long-term irrigation for plants.

## 8.2 LIMITATIONS OF THIS RISK ASSESSMENT

Limitations to this evaluation of health risks follow:

- Most of the results presented here are based on 0.45-micrometer filtered ground water samples. The effects of filtration differ for different elements. Filtered samples generally have lower concentrations of a given constituent than unfiltered samples because suspended particles are removed during filtration. However, constituents bound to these suspended particles can

still produce toxic effects if ingested and broken down in the acid environment of the stomach.

- Potential exposure to and subsequent toxicity of a contaminant will vary from individual to individual. By using the probability distributions for potential exposure and presenting ranges of exposures that can produce toxic effects, this assessment attempts to emphasize that variability. However, it is not possible to account for all sources of variability and still present useful and meaningful analyses. Using ranges for expected toxic effects and distributions for expected exposures should provide the reader with a better understanding of the likelihood of toxic effects to occur.

- To assess toxicity, standardized reference values developed by various agencies, as well as toxicity data in the literature, were used. These data have limitations, including the following:

  - Not all constituents elevated above background levels at a given site have comprehensive toxicity data available.

  - In some cases, data obtained from laboratory animal testing at exposure doses different from those expected at the site were used to determine toxicity. The relationship between dose and response is not always linear, and humans do not always exhibit toxic effects similar to those seen in animals.

  - Data used to determine toxicity are generally based on exposure to only one chemical. In reality, exposure to multiple chemicals occurs simultaneously. The interactive effects of multiple constituents and the impact of these interactions on expected toxicity generally cannot be accurately assessed from existing data.

- This document evaluates risks associated with exposures only to organic contaminants of ground water at the UMTRA Project site at Canonsburg. Potential organic contaminants related to uranium processing have not been considered.

- To assess potential intake via the fish ingestion exposure route, assumptions were made regarding uptake of contaminants into fish tissue. Uncertainties are associated with the BCFs used to make these estimates because these factors are taken from the literature and do not consider site-specific conditions. In addition, data on the bioconcentration of molybdenum in fish were not available. Therefore, the fish ingestion pathway could not be quantitatively assessed for molybdenum.

- Although considerable effort has been directed at determining contaminant movement and placing monitor wells in locations that capture maximum contamination, variability in physical systems and models used to determine

contaminant migration could still result in well placements that do not measure the highest contaminant concentrations or determine the fullest extent of contamination. On the other hand, because the major source of contamination (the tailings and contaminated soils) at the Canonsburg site has been removed, the assumption of a constant source used in this risk assessment may lead to an overestimation of risks. Because the contaminant concentrations could be higher or lower than those used in the analysis, the net effect of these uncertainties on future risk estimates cannot be predicted at this time.

- The drinking water pathway has been used as the major determinant of exposure. Although other pathways have been screened and determined not to contribute considerably to the total exposure, the additivity of exposure from these pathways should be kept in mind. Section 6.0 considers cases where a measurable contribution from other pathways could increase expected exposure enough to alter the predicted toxicity.

- The limitations for the Canonsburg ecological risk assessment include a limited amount of ecological data collected during this screening; little knowledge about site-specific intake rates for wildlife or amounts of contaminants taken up by plants; limited availability of ecotoxicological reference data; and considerable uncertainty associated with the toxicity of mixtures of contaminants.

By presenting ranges of toxic effects, probable exposure distributions, summaries of available data on health effects and interactions, and outlines of potential limitations, this document should provide a realistic interpretation of potential health risks associated with ground water contamination at this site. This assessment is designed to present a picture of contamination and risk as accurately as possible based on the available data, and to convey fields where uncertainties exist.

## 8.3 GROUND WATER CRITERIA

In 1983, the EPA established health and environmental protection standards for the UMTRA Project (40 CFR Part 192). The standards were revised and the final rule was published on 11 January 1995 (60 FR 2854). The ground water standards consist of ground water protection standards to evaluate disposal cell performance and ground water cleanup standards for existing contamination at processing sites. Concentration limits for constituents at the site are summarized in Table 8.1. Because maximum concentration limits (MCL) are not established for every contaminant, for contaminants without MCLs, background levels must be met. The standards also allow for supplemental standards or alternate concentration limits (ACL) where appropriate.

In general, the EPA ground water standards are sufficient to protect humans and the environment. However, some risk assessments may identify site-specific factors that suggest these standards are not appropriate. When standards are

**Table 8.1 Concentration limits of constituents**

| Constituent | EPA MCL for UMTRA 40 CFR 192.02 | Health advisories 10-kg child, 10-day[a] | Health advisories 70-kg adult lifetime[a] |
|---|---|---|---|
| | (mg/L) | | |
| **Chemicals (inorganic)** | | | |
| Antimony | NA | 0.01 | 0.003 |
| Arsenic | 0.05 | NA | NA |
| Barium | 1.0 | NA | 2 |
| Boron | NA | 0.9 | 0.6 |
| Cadmium | 0.01 | 0.04 | 0.005 |
| Chromium | 0.05 | 1.0 | 0.1 |
| Lead | 0.05 | NA | 0.015[b] |
| Mercury | 0.002 | NA | 0.002 |
| Molybdenum | 0.1 | 0.04 | 0.04 |
| Nickel | NA | 1.0 | 0.1 |
| Nitrate (as $NO_3^-$) | 44[c] | 44[c] | NA |
| Selenium | 0.01 | NA | NA |
| Silver | 0.05 | 0.2 | 0.1 |
| Strontium | NA | 25.0 | 17 |
| Zinc | NA | 6.0 | 2 |
| **Radionuclides** | | | |
| Radium-226/-228 | 5 pCi/L | NA | NA |
| Uranium (U-234/-238) | 30 pCi/L (0.044 mg/L) | 0.03 mg/L[d,e] | 0.1 mg/L[d] |

[a]EPA, 1995.
[b]Action level.
[c]Equals 10 mg/L nitrate as nitrogen.
[d]Proposed values (EPA, 1989e), under review; expected revision 1995.
[e]Longer-term health advisory.

NA – not available.

too restrictive (for example, when there may be no potential for exposure), a less restrictive ACL may be sought. In other cases, the standards may not be sufficiently protective (for example, if many contaminants near the MCL have additive or synergistic adverse health effects).

While these standards apply only to the UMTRA Project, the EPA has also published drinking water health advisory levels for both long- and short-term exposures (EPA, 1995). Table 8.1 presents these advisories.

Contaminant concentrations in ground water from well 414 in Area C, which was used to assess potential risk in this assessment, do not exceed any of the EPA MCLs based on data since 1988. However, the uranium health advisory for children was exceeded once in the last sampling round in October 1993.

Due to permanent land use restrictions, no current or future point of potential exposure exists in the disposal site area (see Figure 2.2 for location). However, the three monitor wells 412 (unconsolidated unit), 413 (unconsolidated unit), and 506 (bedrock), all located within or just next to the restricted area, show uranium concentrations in excess of MCL.

The molybdenum MCL was exceeded several times in downgradient wells, and the MCL was also exceeded in background wells. The lead MCL was exceeded a few times in both the unconsolidated and bedrock wells in 1987 and 1988. However, molybdenum and lead concentrations measured in subsequent years did not exceed their respective MCLs. The chromium MCL was also exceeded in unconsolidated and bedrock wells; however, this only occurred in 1988, and the MCL was also exceeded in a background well.

## 8.4 RISK MITIGATION MEASURES

Ground water from a deep bedrock aquifer which is not affected by the UMTRA Project site is used in the area for domestic purposes including drinking. No affected ground water is known to be used for any purposes. However, potential for adverse health effects to occur exists following long-term use of contaminated ground water from the uppermost aquifer below Area C of the former Canonsburg uranium processing site. Although the cities of Canonsburg and Houston, North Strabane Township, and Chartiers Township are close to the processing site in Washington County, Pennsylvania, they are not expected to be influenced by ground water flow from the site. Ground water discharges into Chartiers Creek, which borders the western, northern, and eastern boundaries of the site. However, no site-related releases are known to affect the creek. The commonwealth of Pennsylvania water law is discussed below.

The Department of Environmental Resources Ground Water Quality Protection Strategy of the commonwealth of Pennsylvania describes the principles that the department intends to follow in implementing its ground water quality protection program through regulations, policies, and technical guidance. It states that the owner/operator of a property of concern is responsible for detecting and

remediation and other applicable measures will be required. Applicable measures will include, but may not be limited to, treatment/containment of contaminated ground water as necessary to restore the ground water or to protect human health and the environment. The ultimate goal of ground water remediation is to reduce contamination levels to background quality. An owner/operator who restores contaminated ground water to its background quality will be released from further liability for remediation of those contaminants. If achieving background quality is not possible, the owner/operator will not be released from liability.

## 8.5 RECOMMENDATIONS

Ground water use is restricted on the majority of the Canonsburg site, with the potential exception of Area C which is being considered for public use. Based on the risk assessment results, the manganese levels in Area C could result in potential adverse health effects following chronic exposures. Therefore, it is recommended that the contamination be better characterized prior to any future use of ground water beneath Area C.

Monitoring of ground water from the unconsolidated material, shallow bedrock, and potential surface expression points should continue until detailed characterization of the site ground water is complete. Such additional characterization will be discussed in future Canonsburg ground water documents.

Plant uptake studies are being conducted for the UMTRA Ground Water Project. Results of these studies will be used to evaluate the irrigated-produce and wild-fruit-ingestion exposure pathway meaningfully. The results will be included in the NEPA document and ground water strategy planning for this site.

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The following individuals contributed to the preparation of this report.

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## CODE OF FEDERAL REGULATIONS

10 CFR Part 40, *Domestic Licensing of Source Materials*, U.S. Nuclear Regulatory Commission.

40 CFR Part 131, *Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants; States' Compliance*; Final Rule, U.S. Environmental Protection Agency.

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## FEDERAL REGISTER

60 FR 2854, *Groundwater Standards for Remedial Actions at Inactive Uranium Processing Sites*, final rule, U.S. Environmental Protection Agency, 11 January 1995.

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42 USC §7901 *et seq.*, *Uranium Mill Tailings Radiation Control Act*, 8 November 1978.

42 USC §7922 *et seq.*, *Uranium Mill Tailings Remedial Action Amendments Act*, 5 November 1988.