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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

UMTRA Ground Water Project

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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

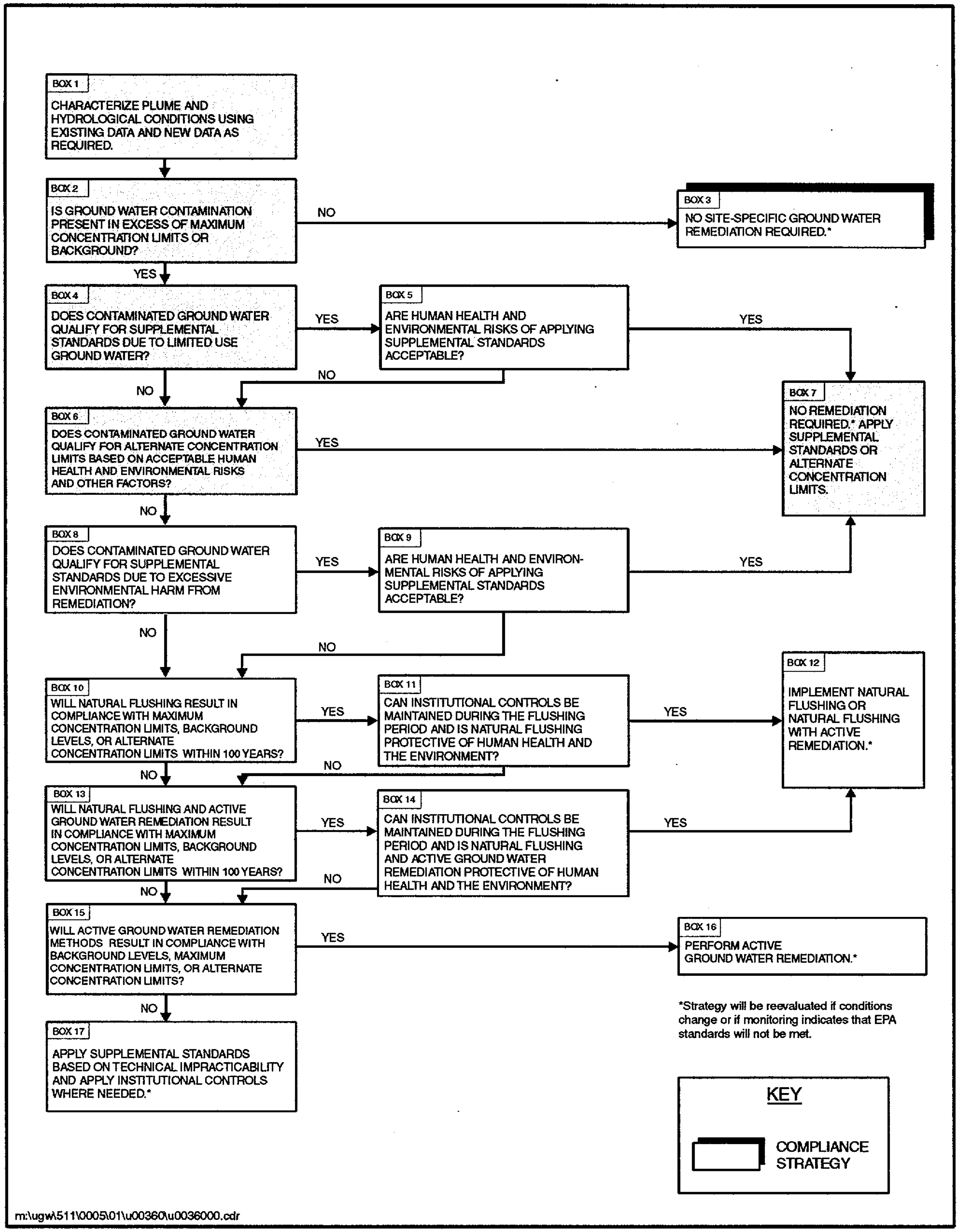

Figure 1. Compliance Selection Framework, Canonsburg, Pennsylvania, Site

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).

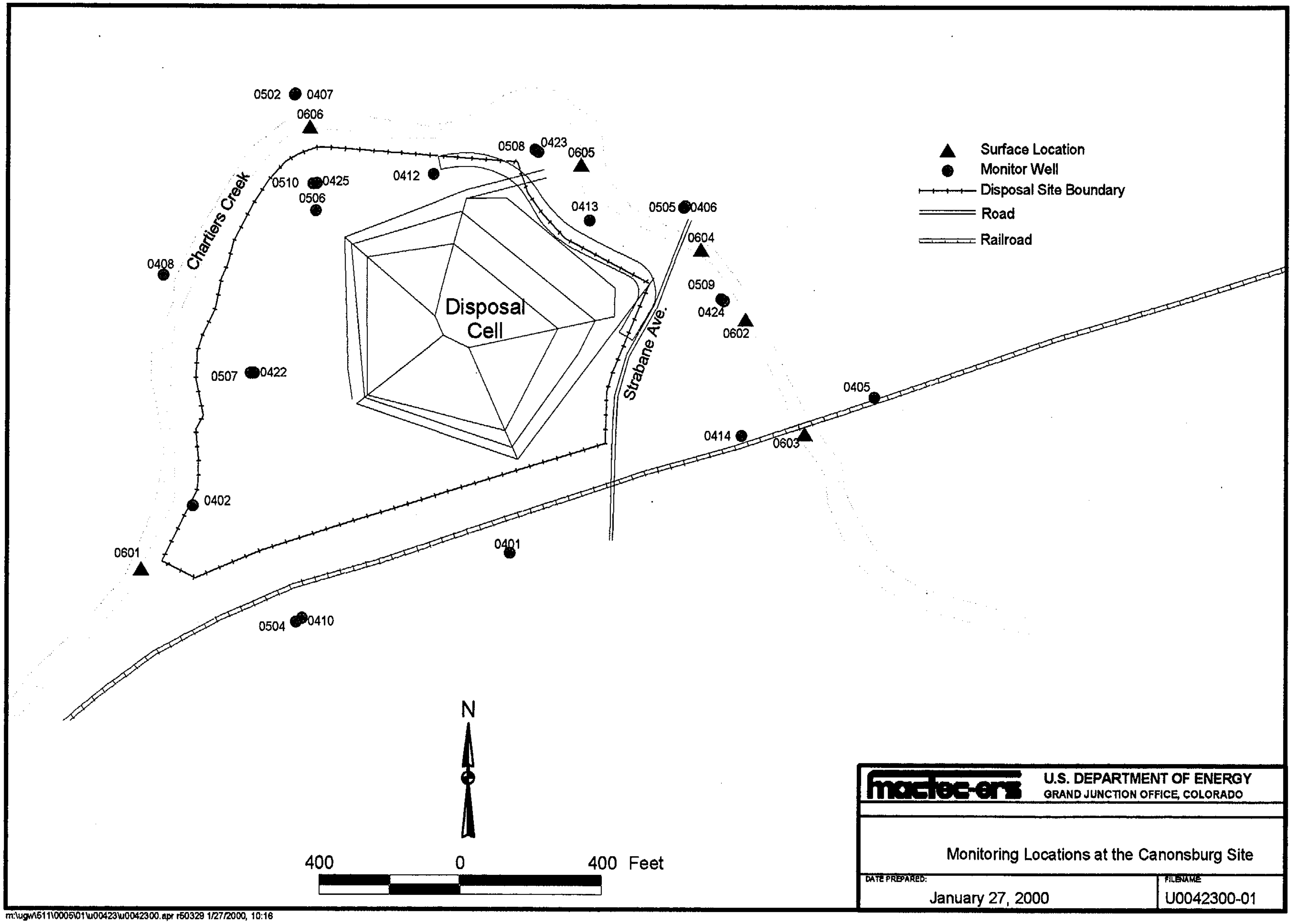

Figure 2. Monitoring Locations at the Canonsburg, Pennsylvania, Site

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,*

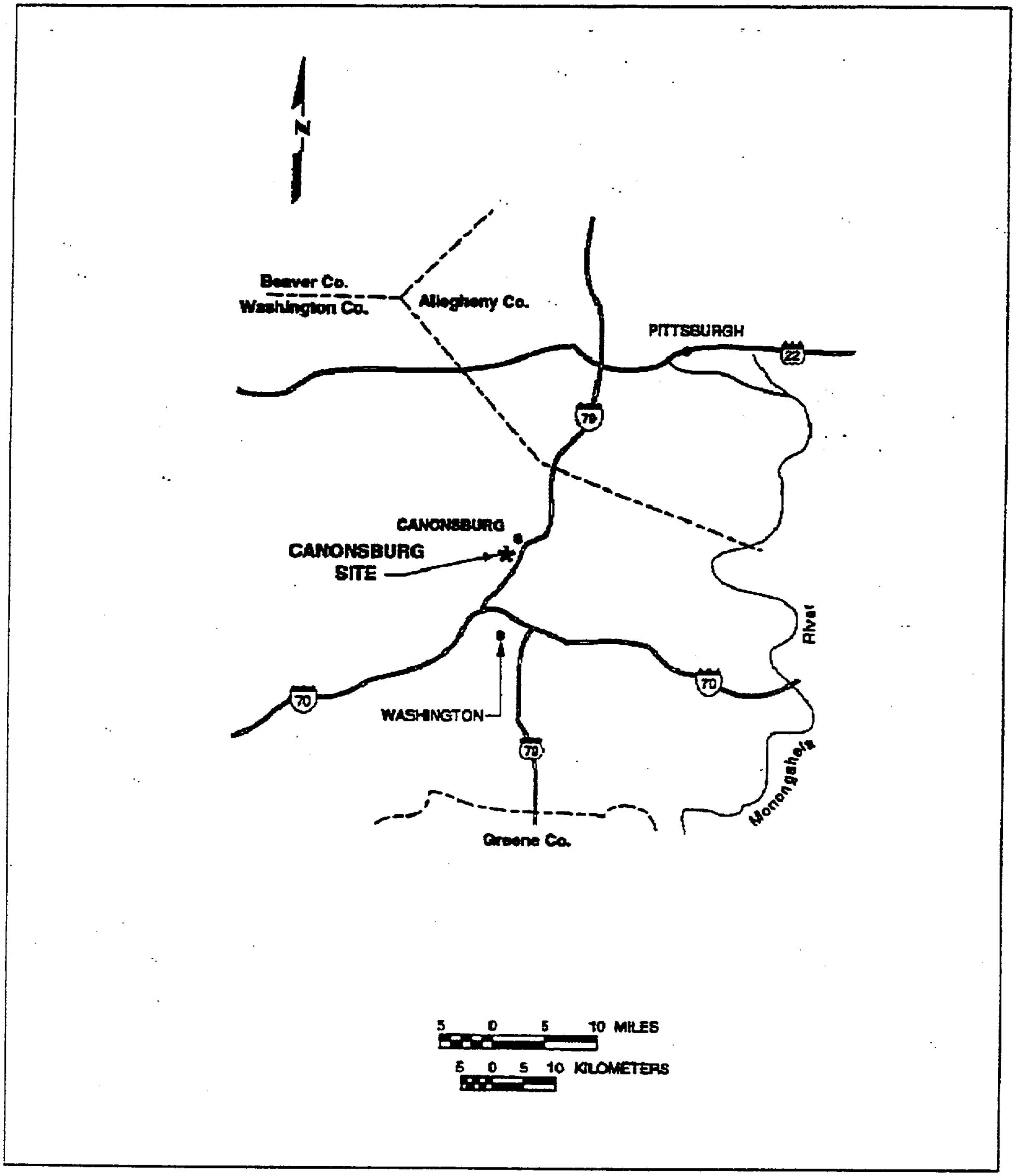

Figure 1–1. Canonsburg, PA UMTRA Mill Tailings Facility Site Location Map

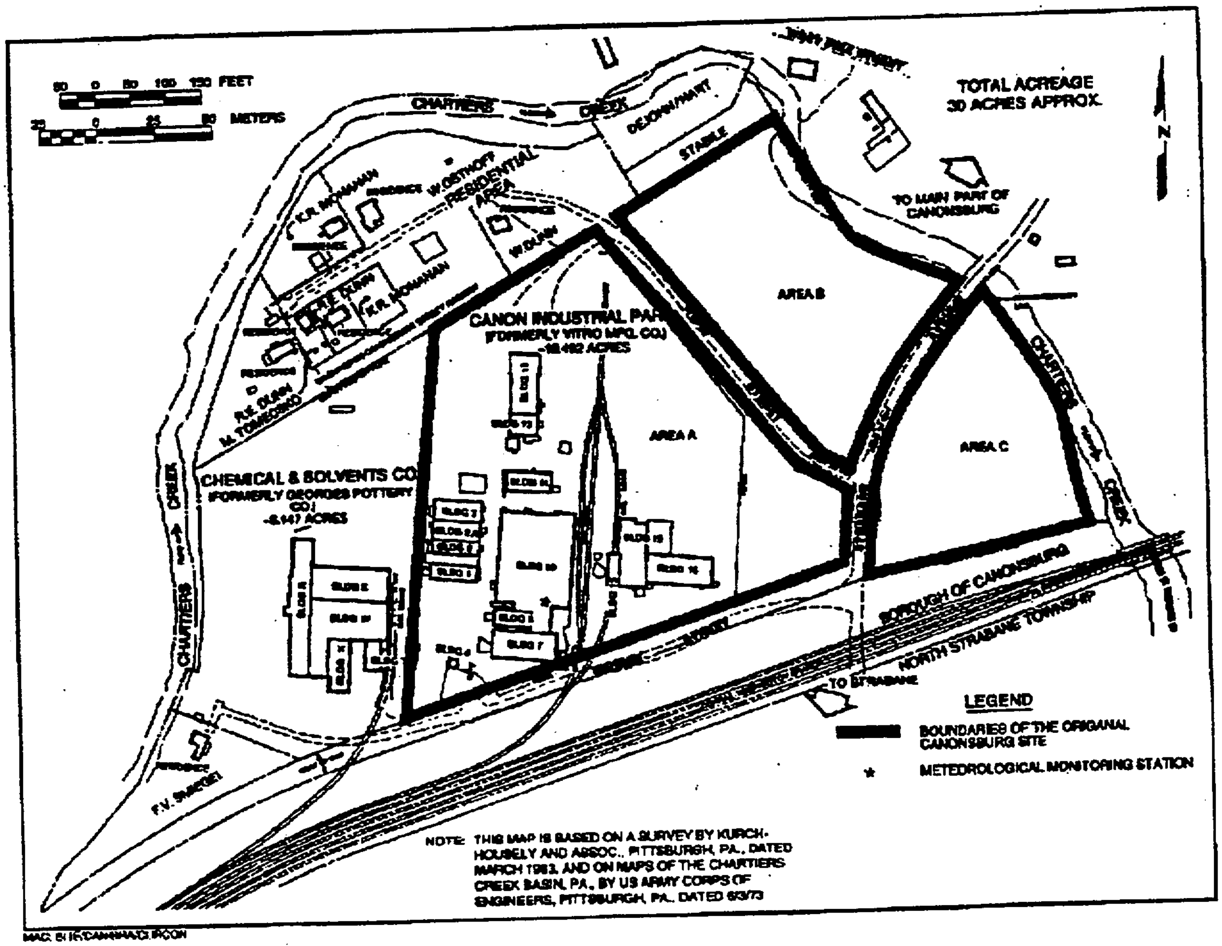

Figure 1–2. Historical Site Layout for the Canonsburg UMTRA Mill Tailings Facility

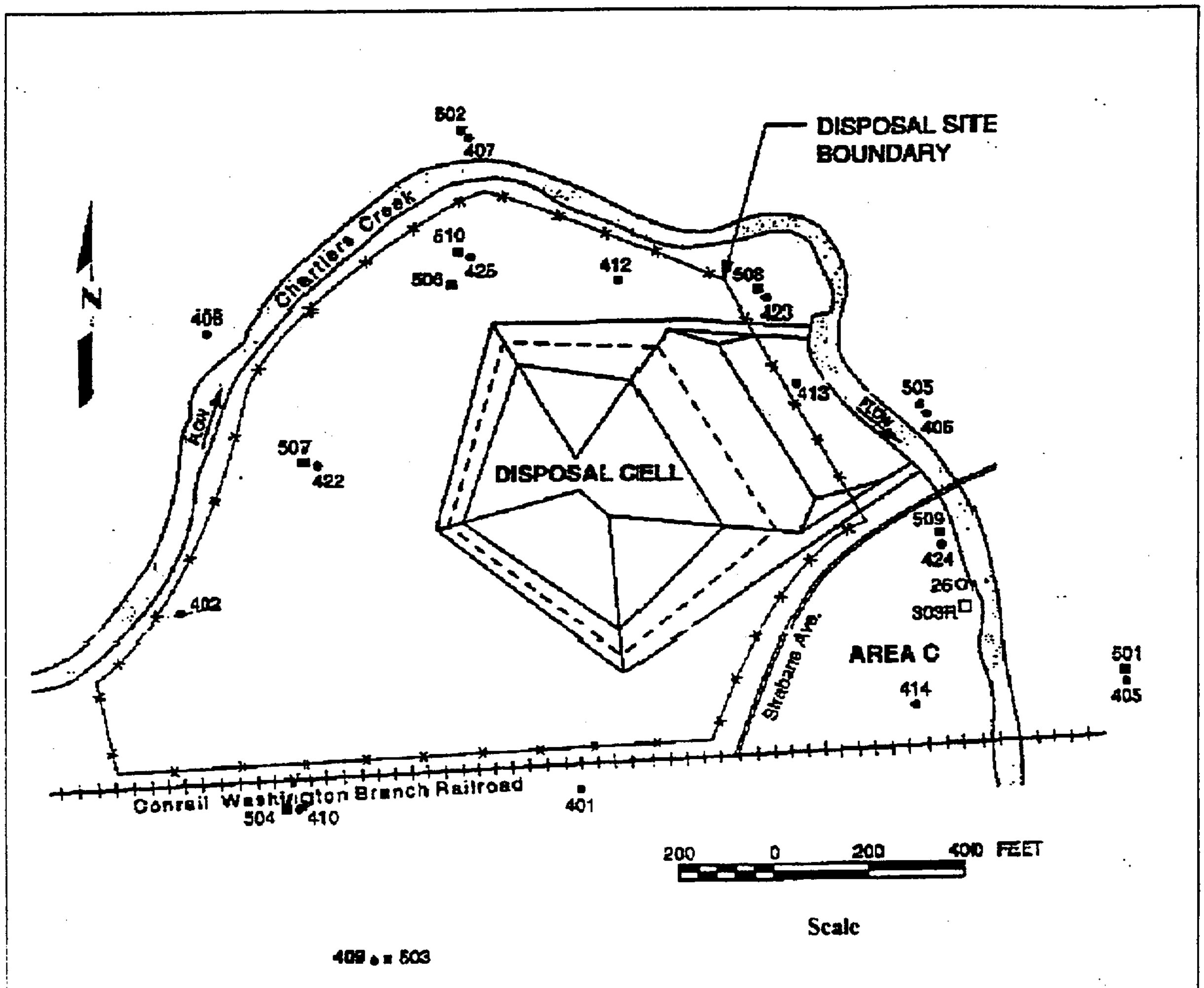

Figure 1–3. Present Day Site Layout for the Canonsburg UMTRA Mill Tailings Facility

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 (1.4×10^{-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 (4.3×10^{-5} to 1.0×10^{-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.

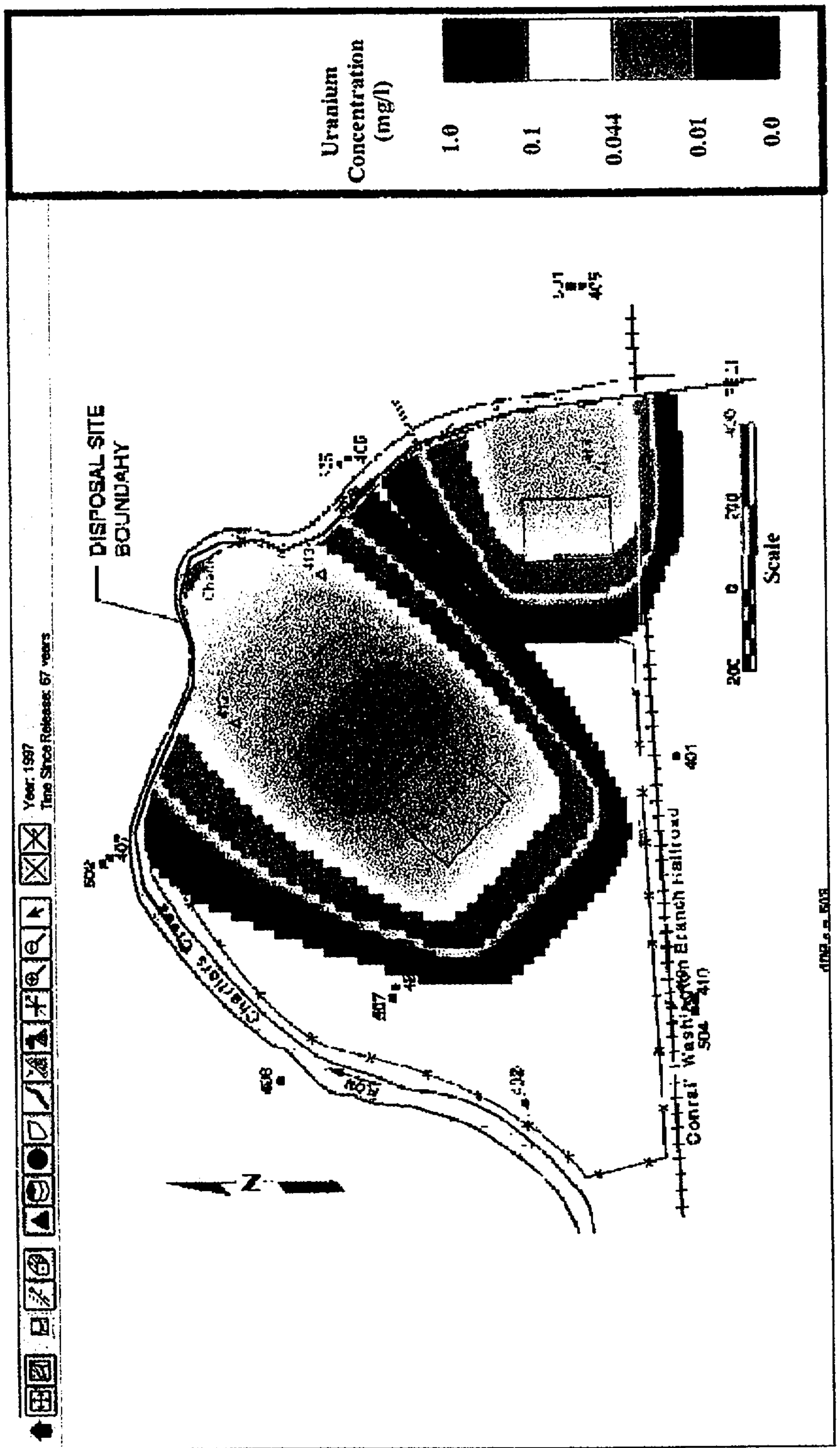

Figure 1–4. Mean Concentration Distribution for Uranium at Conditioning Time (1997)

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

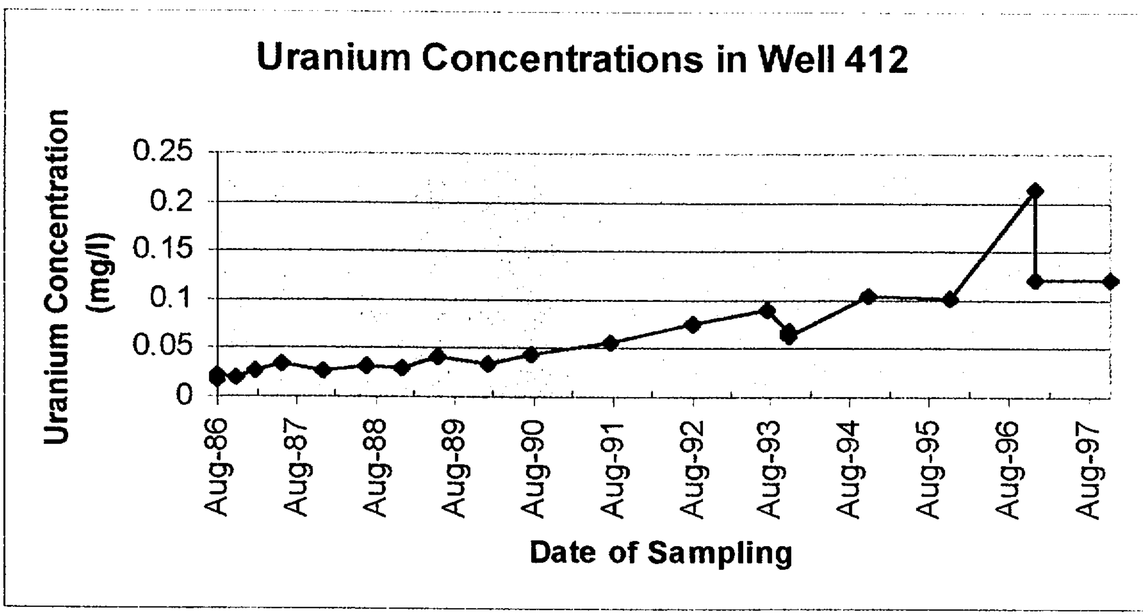

Figure 2–1. Uranium Concentration Versus Time for Monitor Well 412

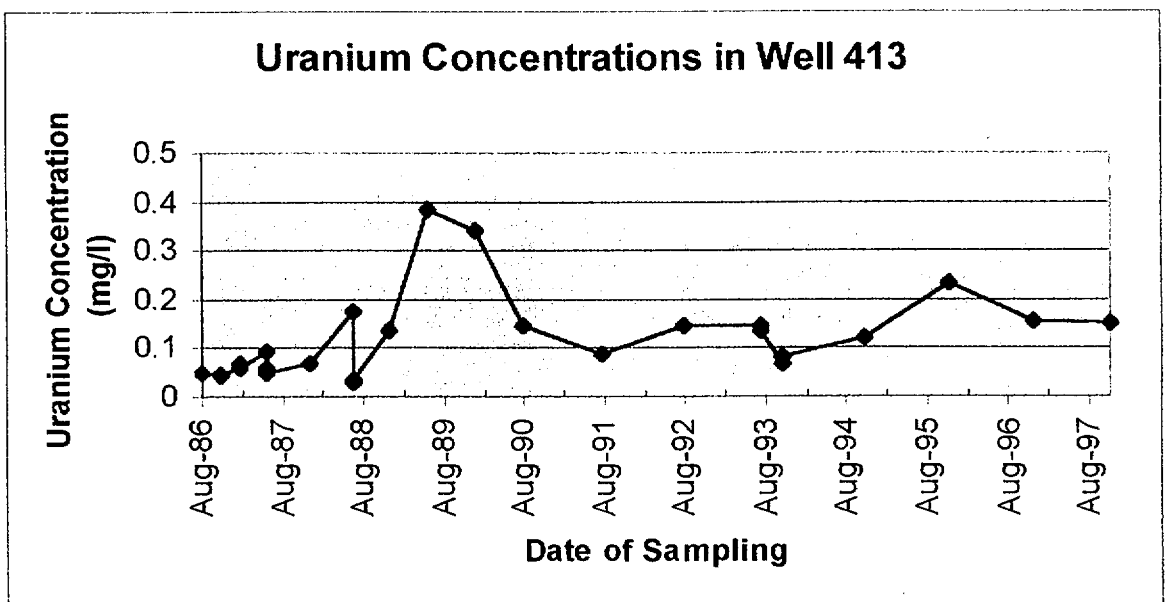

Figure 2–2. Uranium Concentration Versus Time for Monitor Well 413

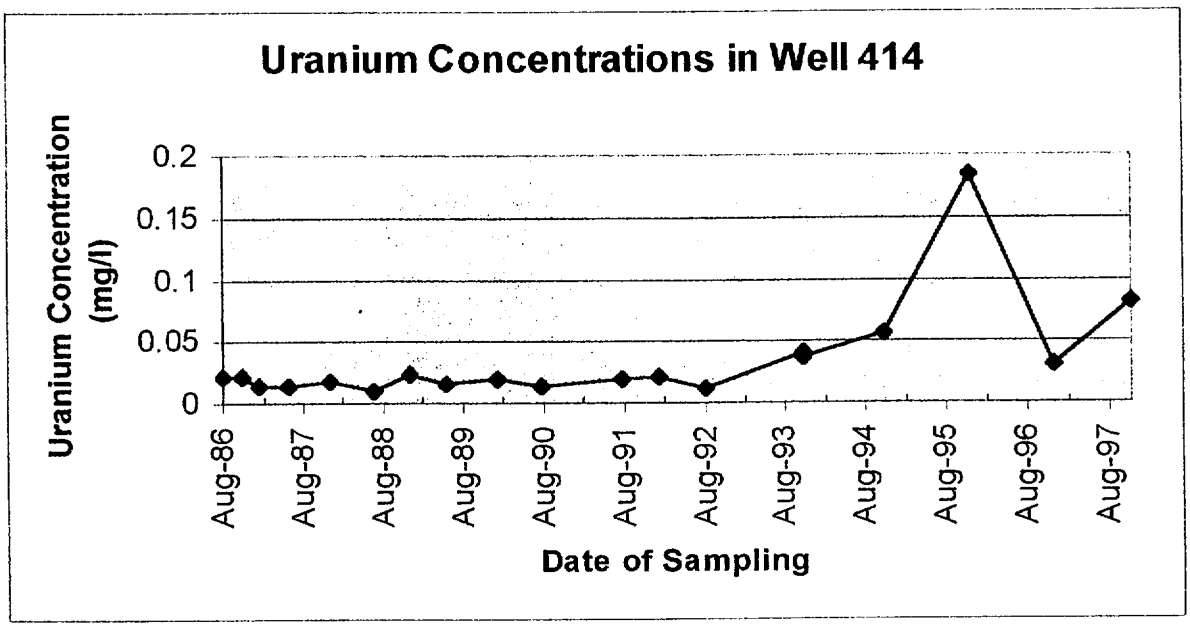

Figure 2–3. Uranium Concentration Versus Time for Monitor Well 414

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

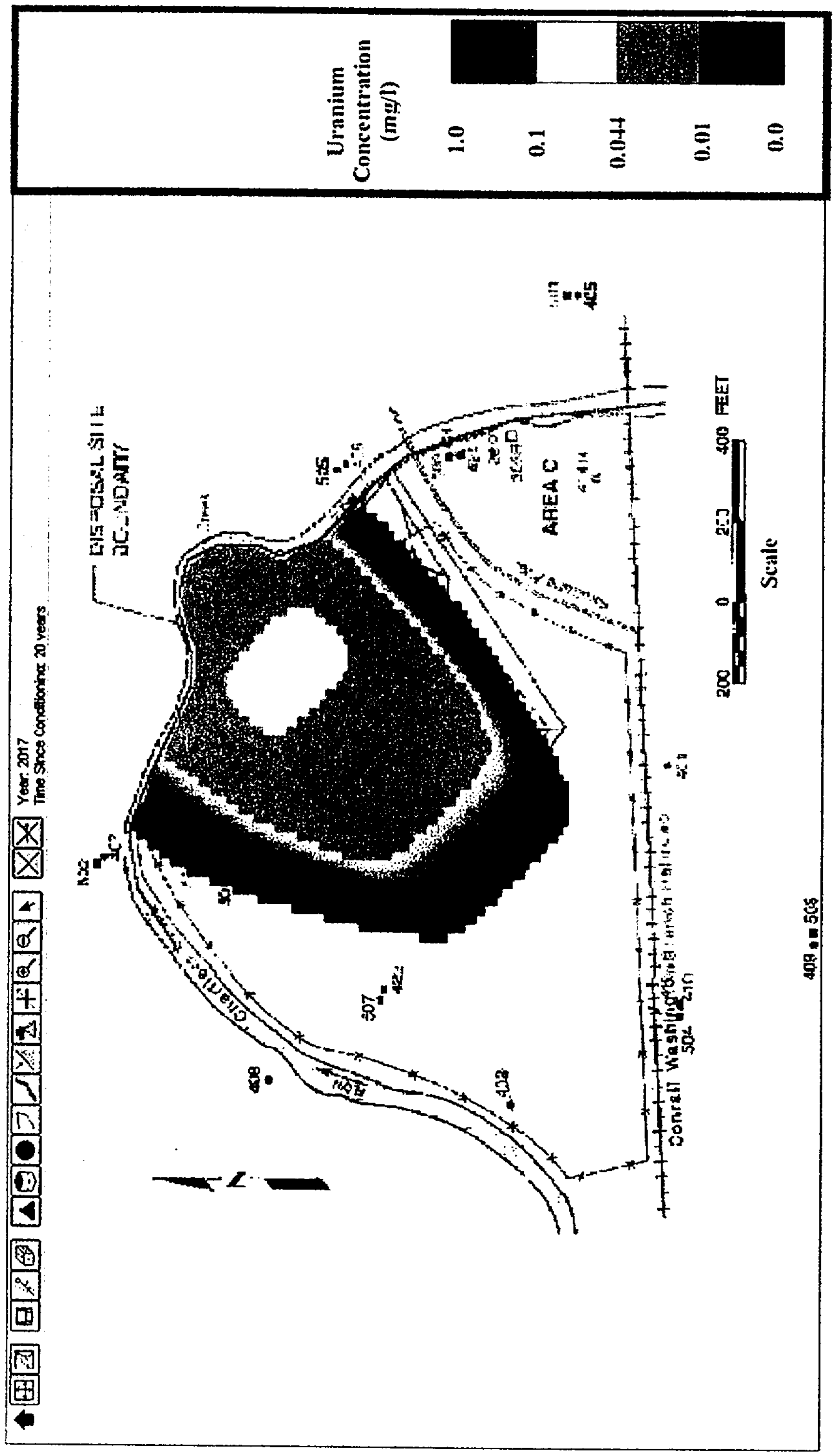

Figure 2–4. Mean Concentration Distribution for Uranium 20 Years after Conditioning Time (2017)

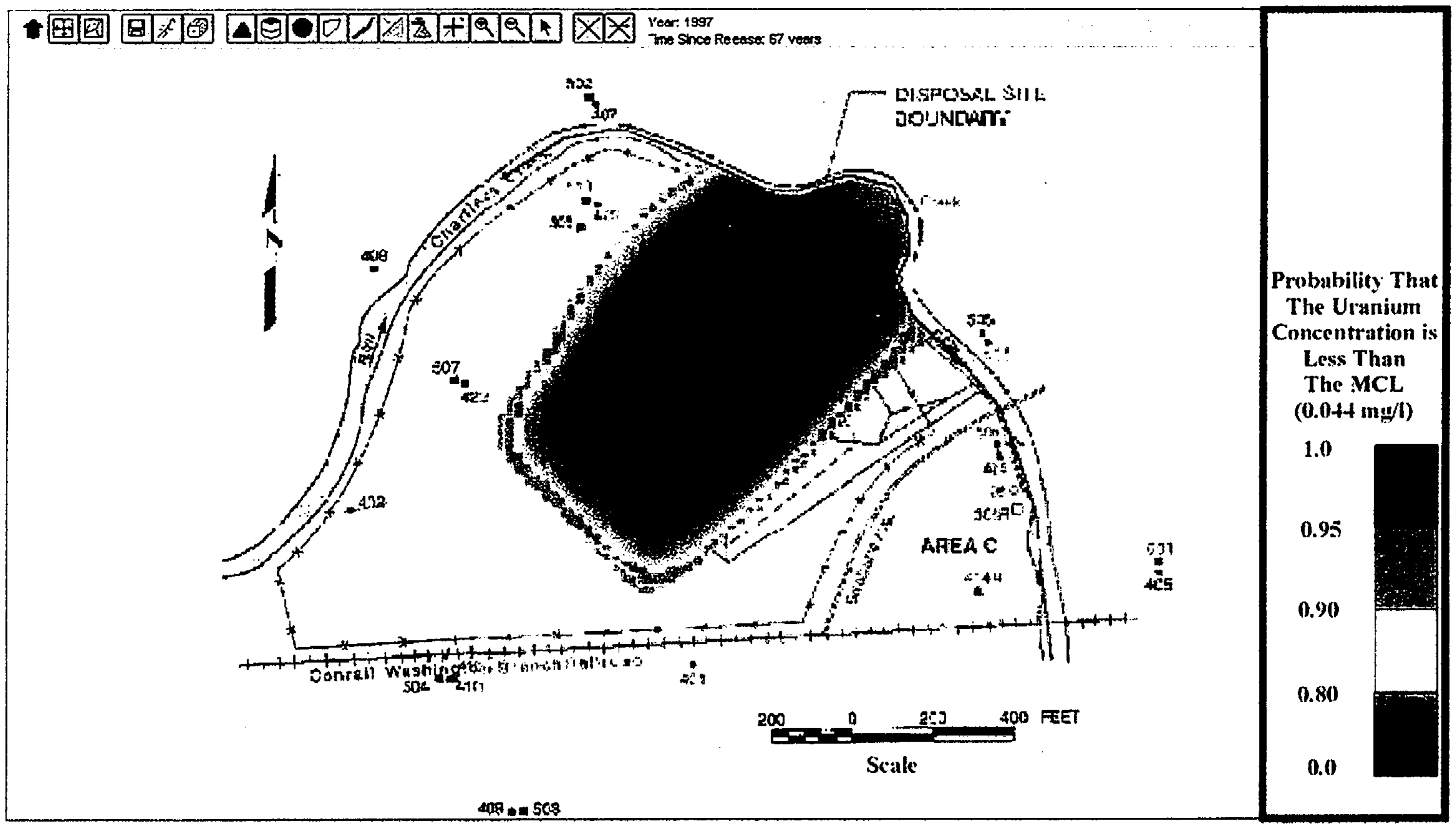

Figure 2–5. Probability of Concentration Being Less Than the MCL for Uranium at Conditioning Time (1997)

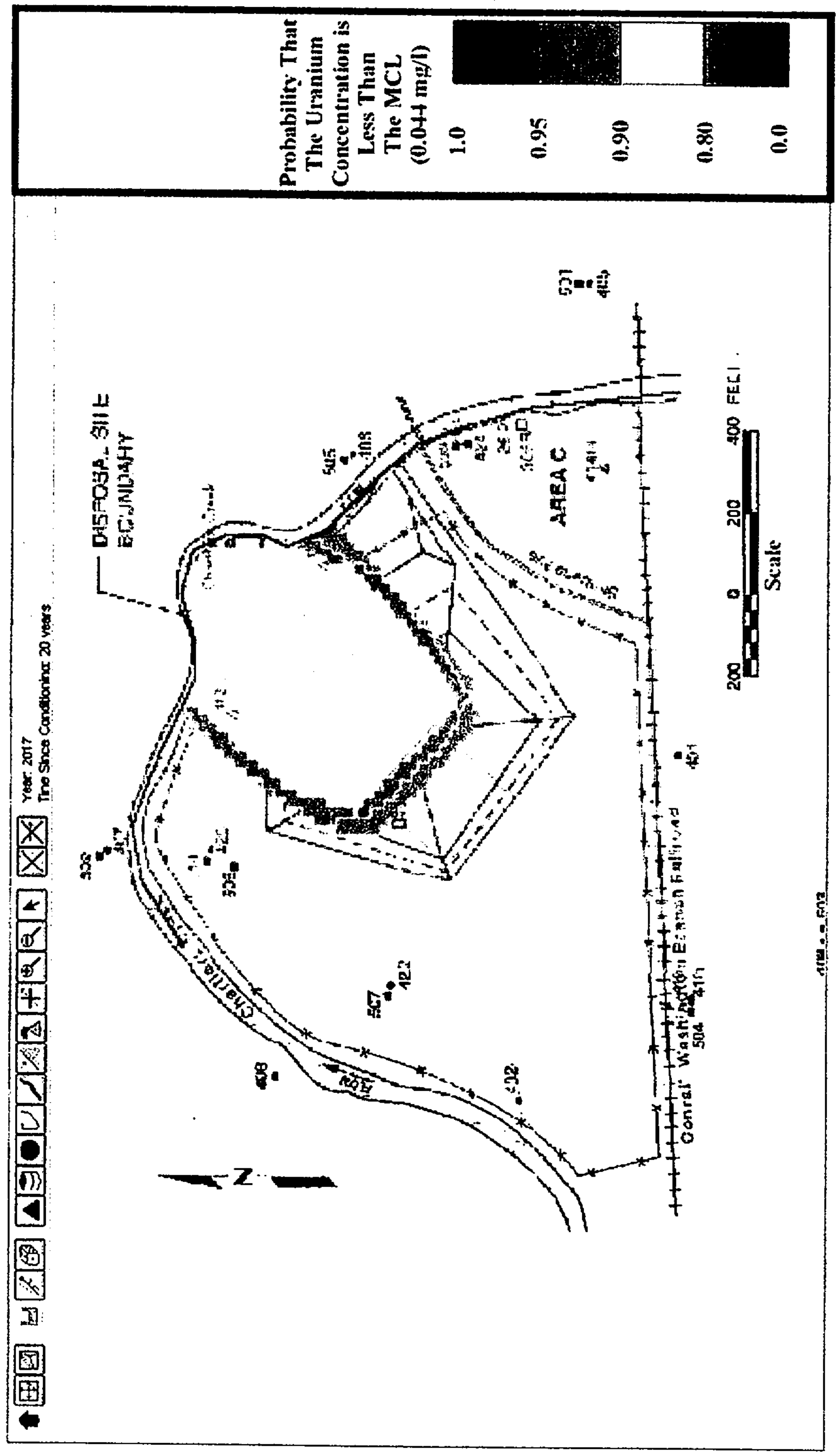

Figure 2–6. Probability of Concentration Being Less Than the MCL for Uranium 20 Years after Conditioning Time (2017)

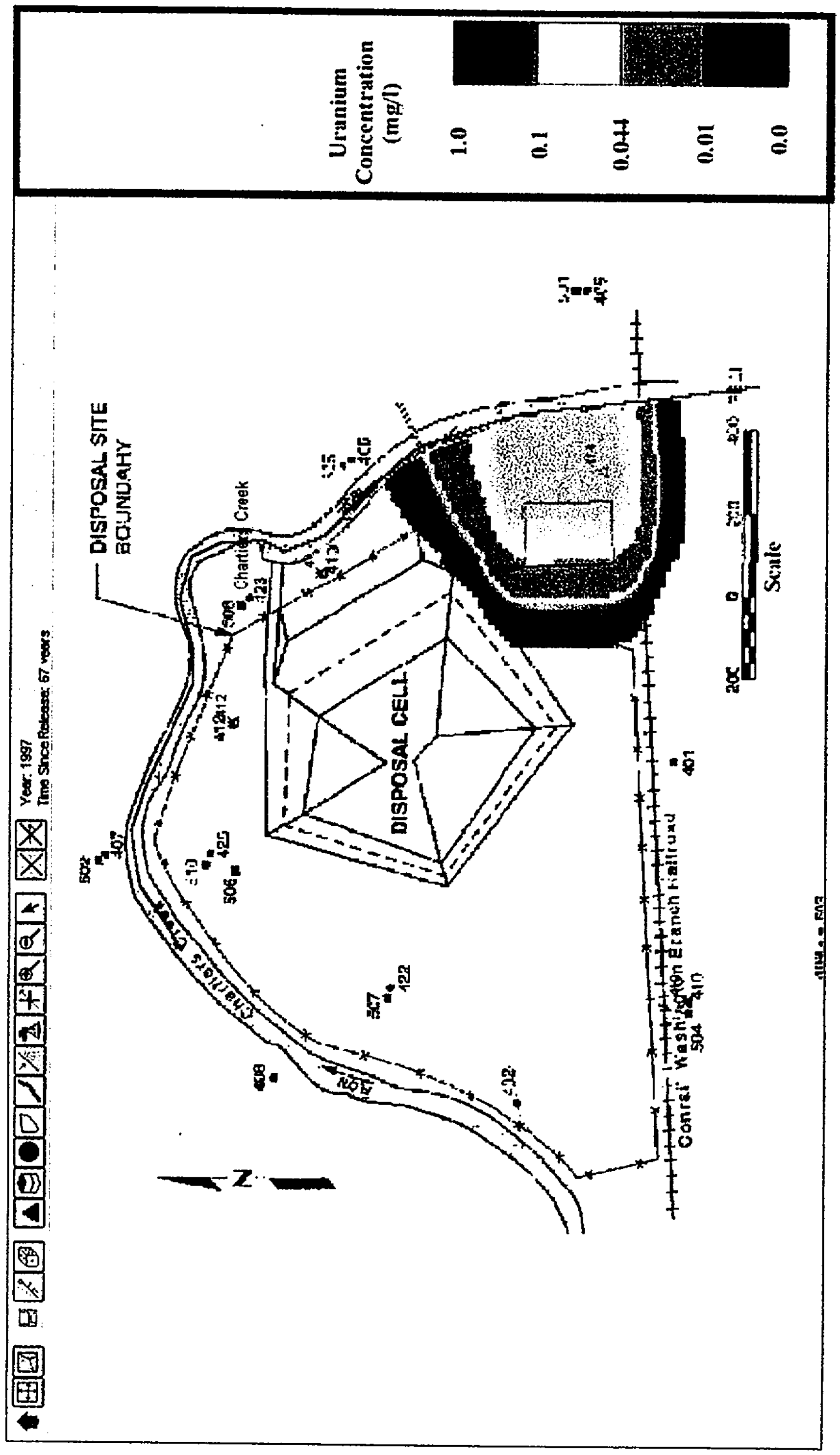

Figure 2–7. Mean Concentration Distribution for Uranium at Conditioning Time (1997)

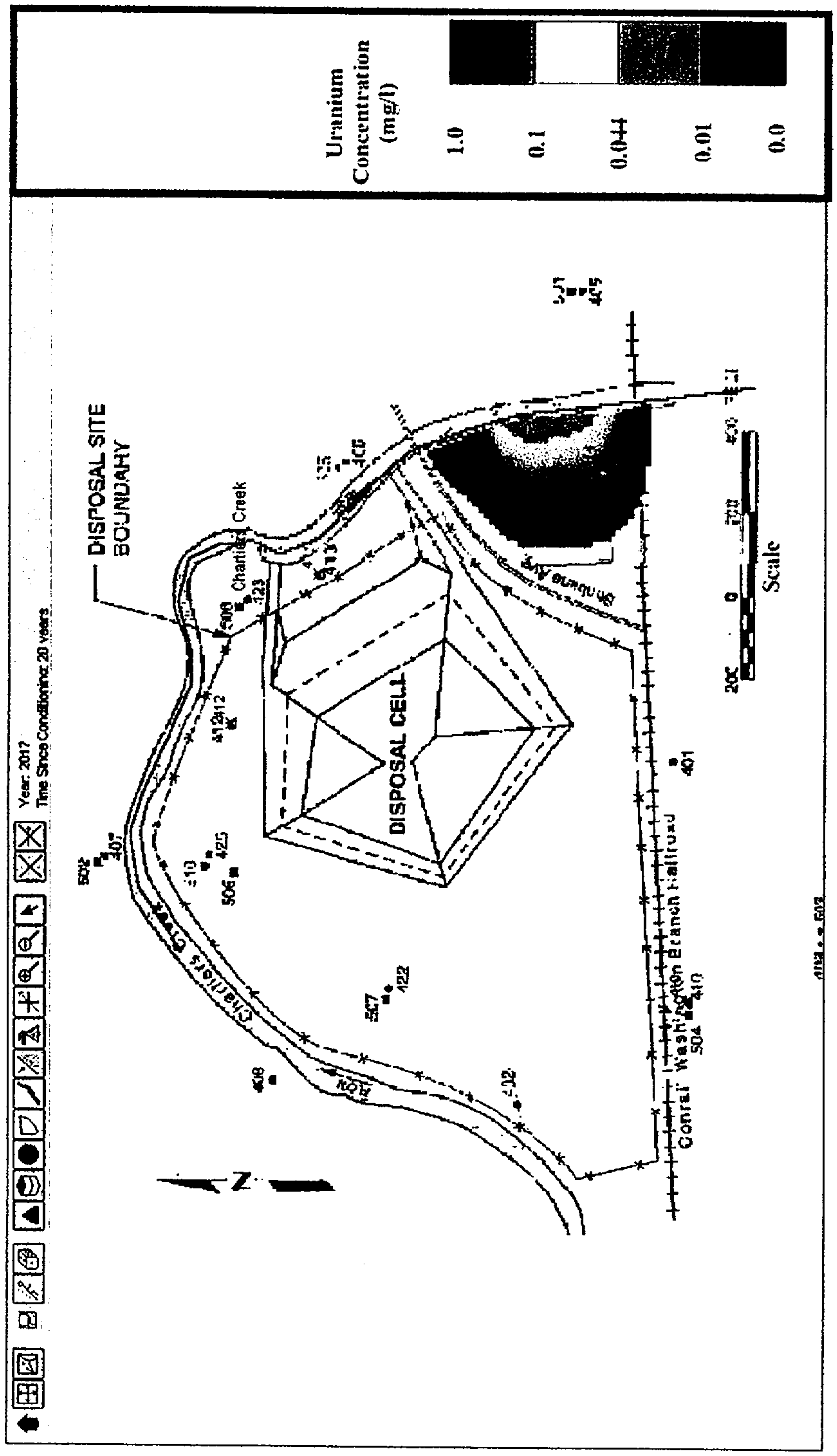

Figure 2–8. Mean Concentration Distribution for Uranium 20 Years after Conditioning Time (2017)

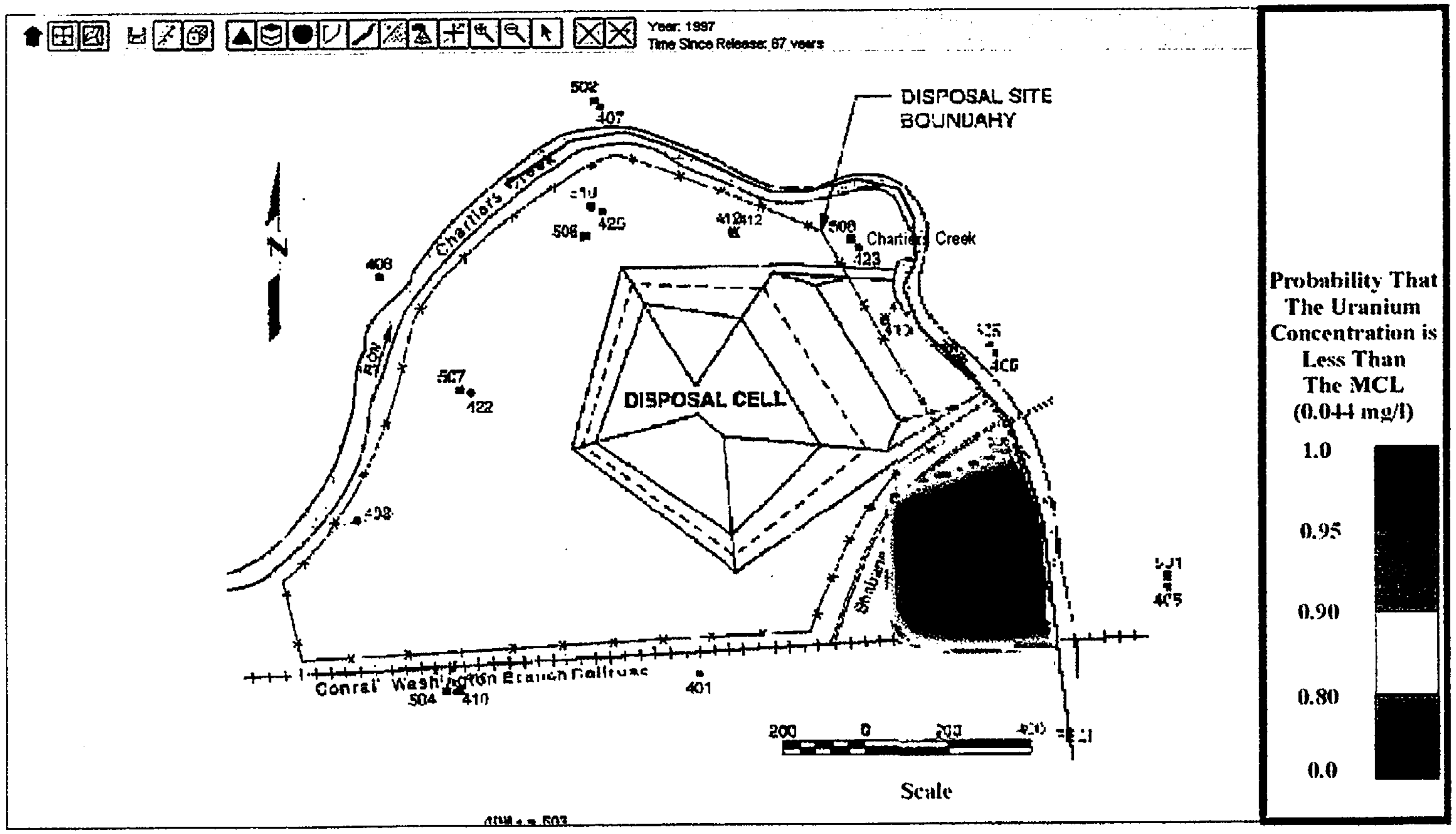

Figure 2–9. Probability of Concentration Being Less Then the MCL for Uranium at Conditioning Time (1997)

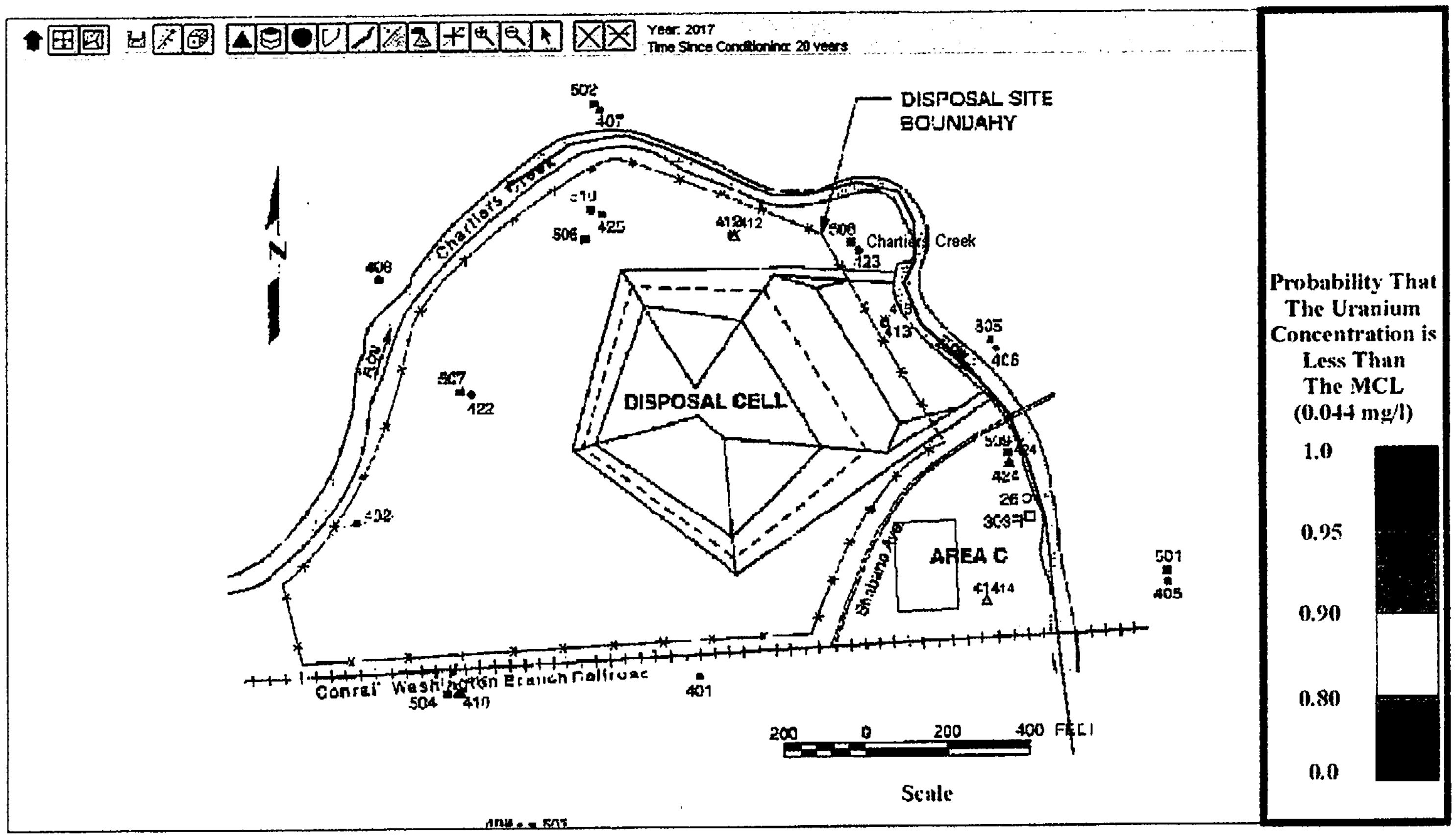

Figure 2–10. Probability of Concentration Being Less Than the MCL for Uranium 20 Years after Conditioning Time (2017)

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

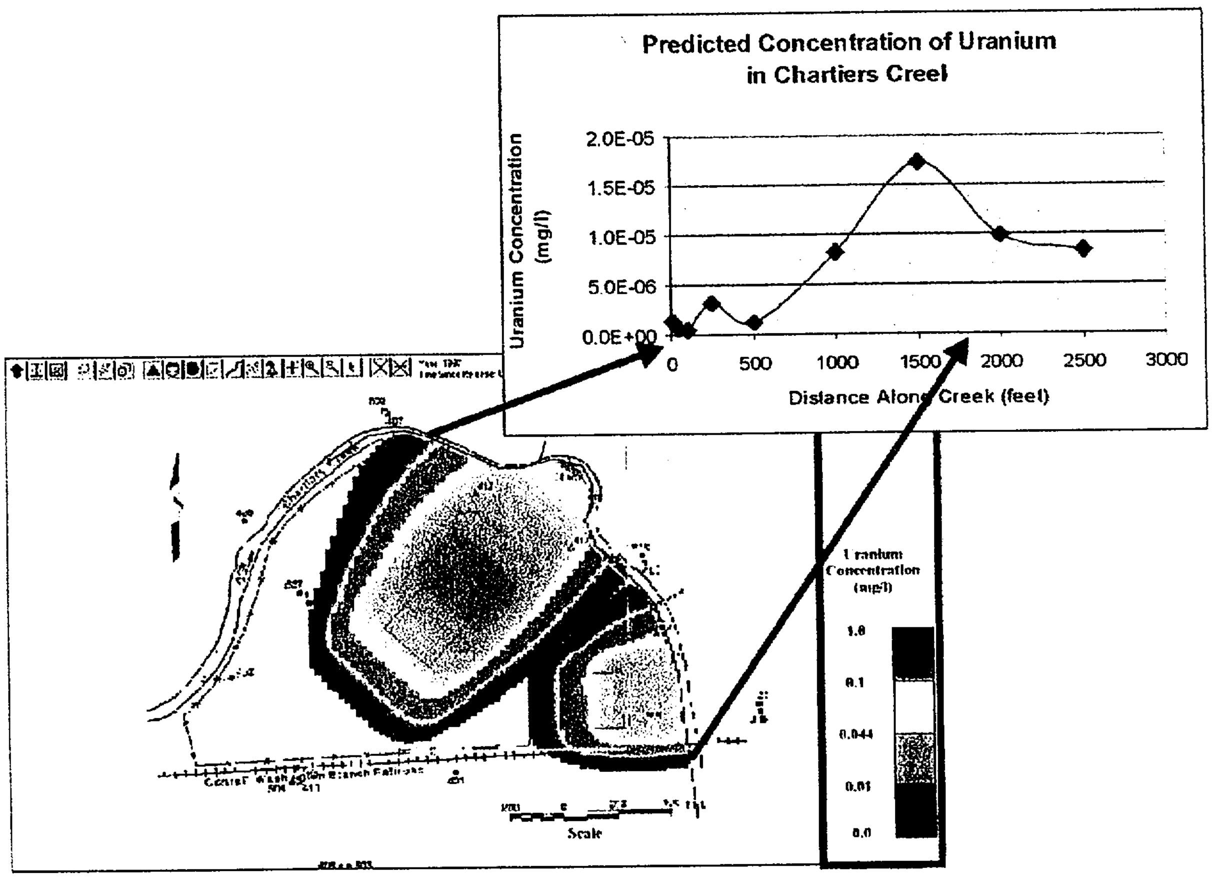

Figure 2–11. Stream-Aquifer Modeling Results Predicting Surface Water Concentrations of Uranium in Chartiers Creek

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

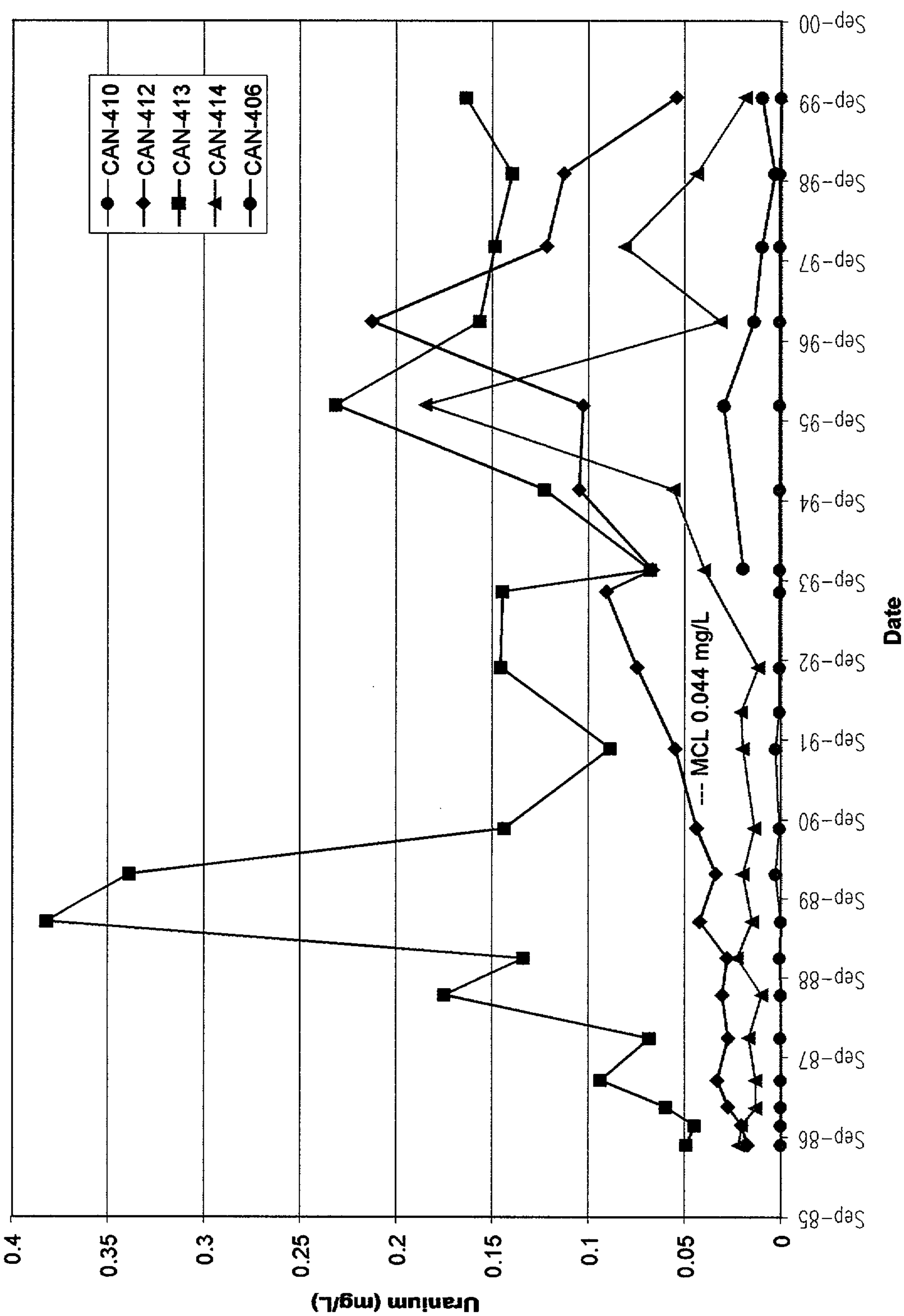

Figure 3–1. Uranium Concentrations in Ground Water

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

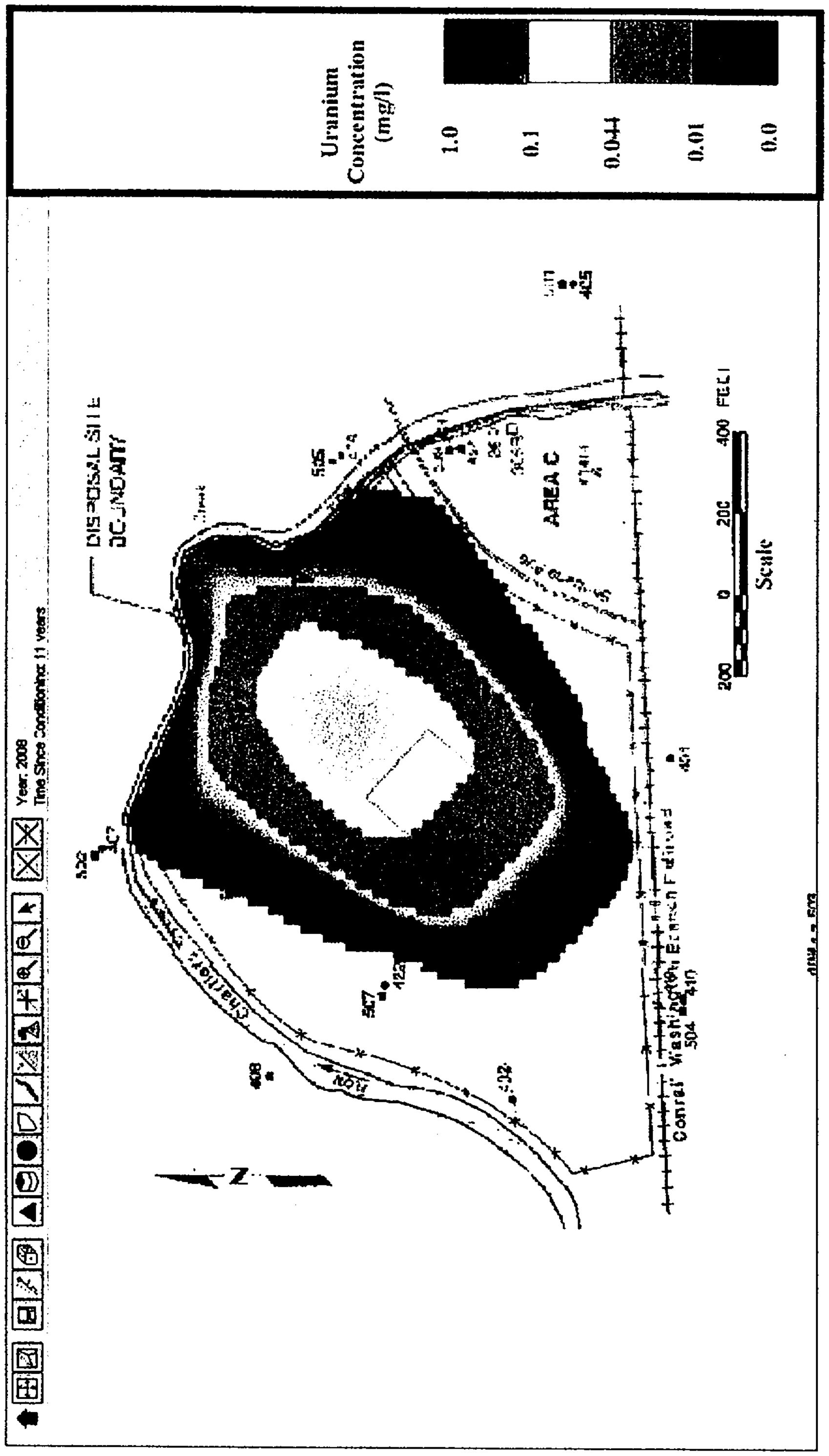

Figure 3–2. Mean Concentration Distribution for Uranium 10 Years After Start of Pump-and-Treat Scenario (y008)

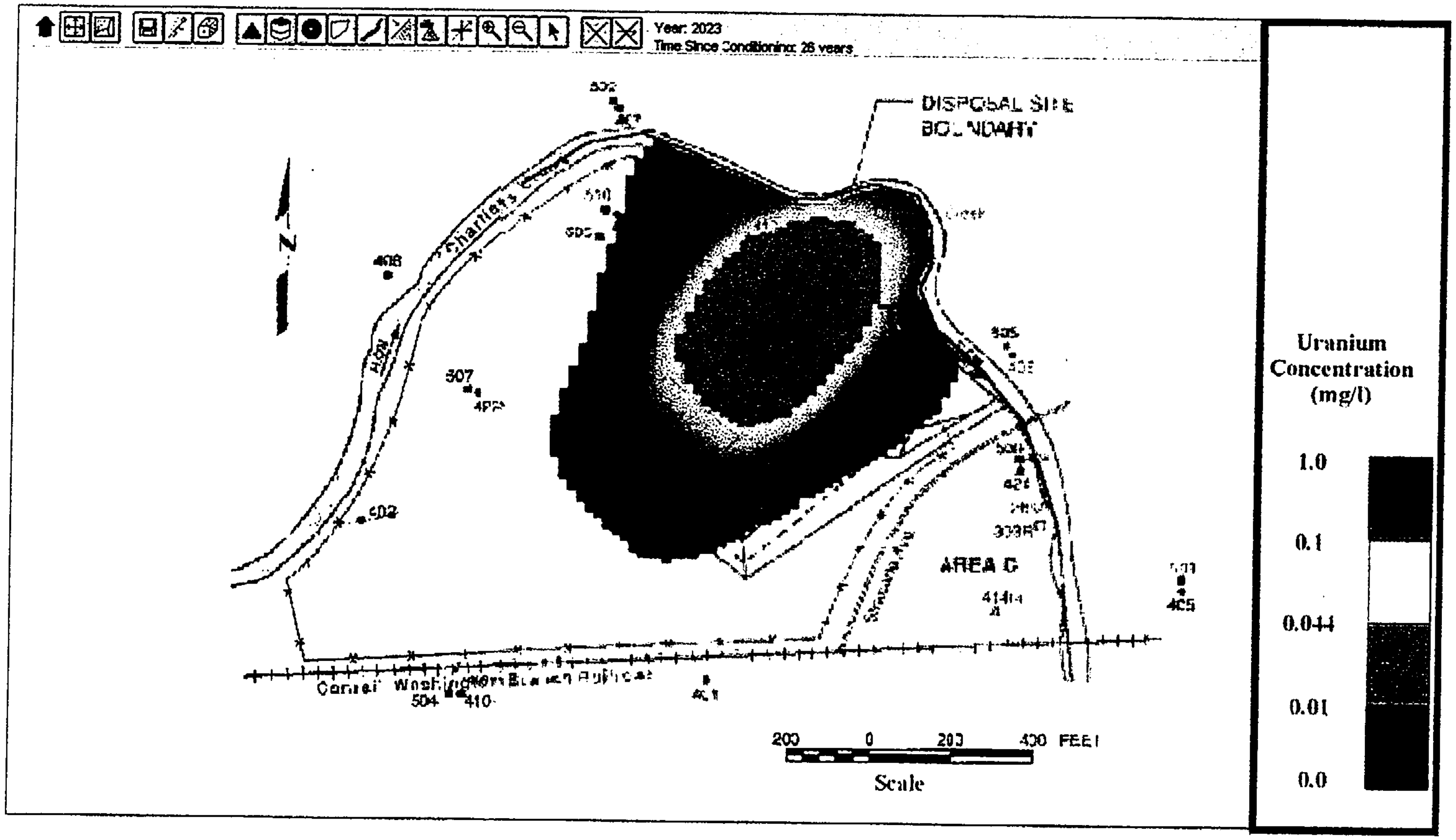

Figure 3–3. Mean Concentration Distribution for Uranium 15 Years After 10-Year Pump-and-Treat Scenario (2023)

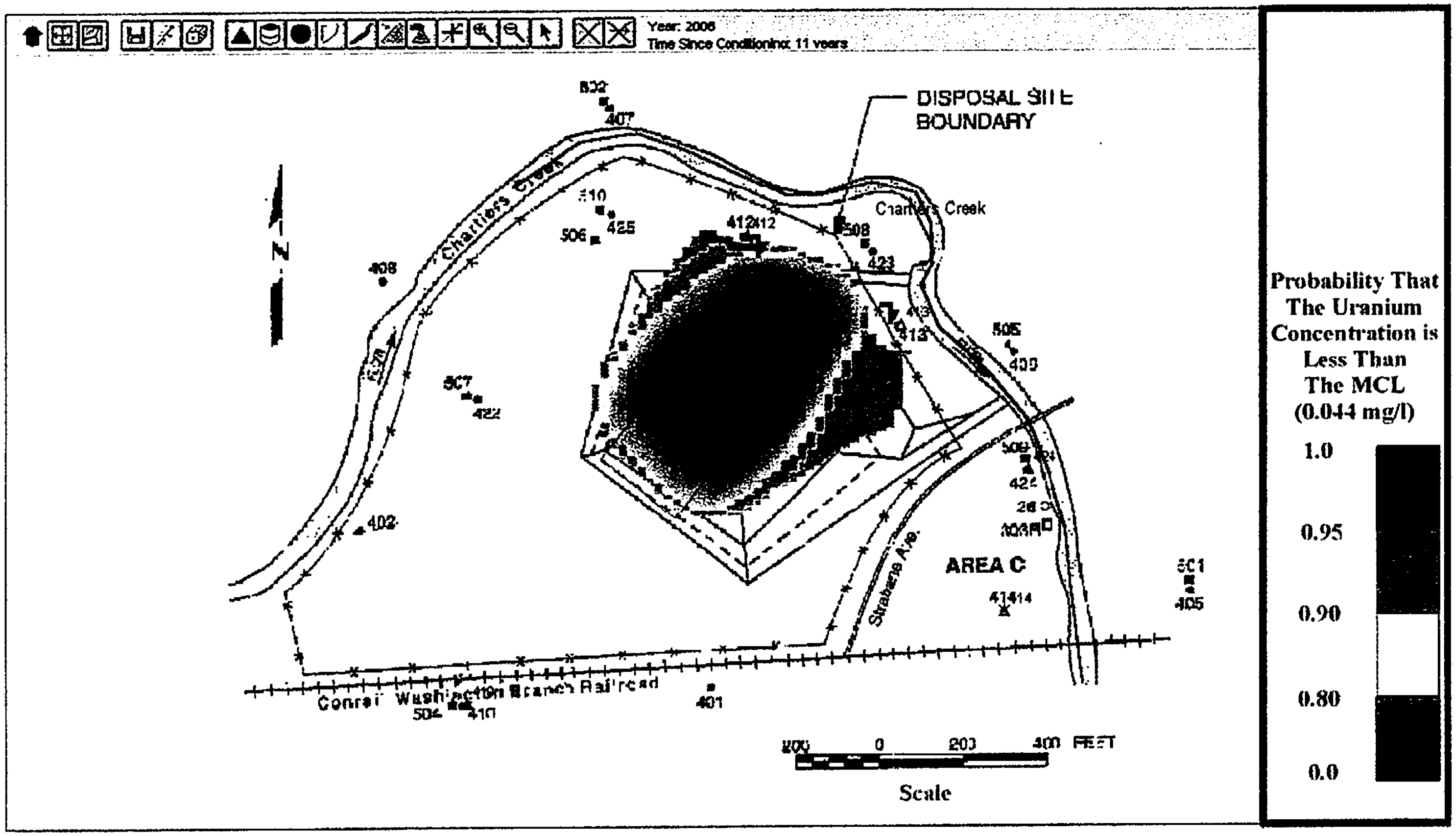

Figure 3–4. Probability of Concentration Being Less Than the MCL for Uranium 10 Years After Start of Pump-and-Treat Scenario (2008)

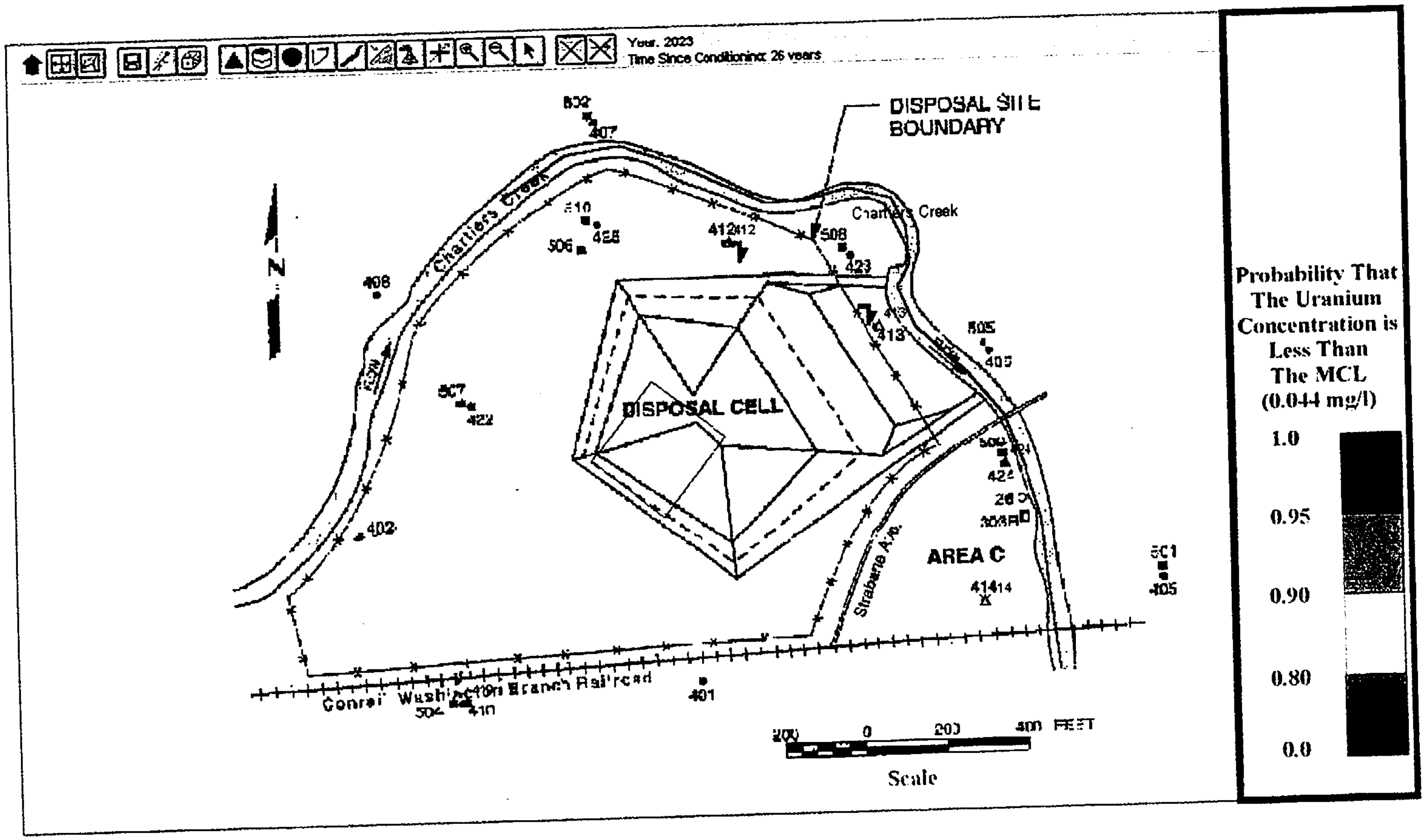

Figure 3–5. Probability of Concentration Being Less Than the MCL for Uranium 15 Years After 10-Year Pump-and-Treat Scenario (2023)

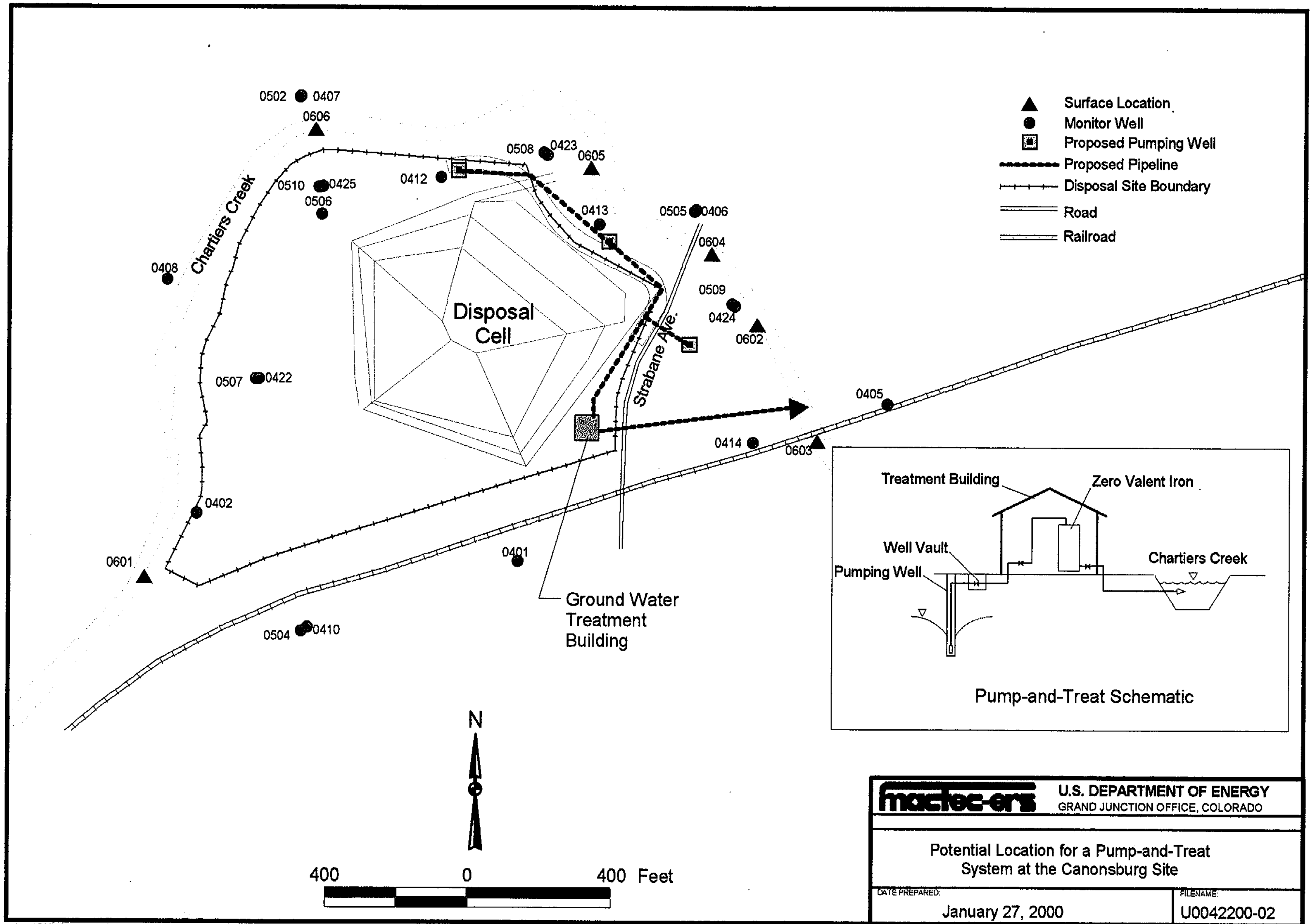

Figure 3–6. Potential Location for a Pump-and-Treat System at the Canonsburg Site

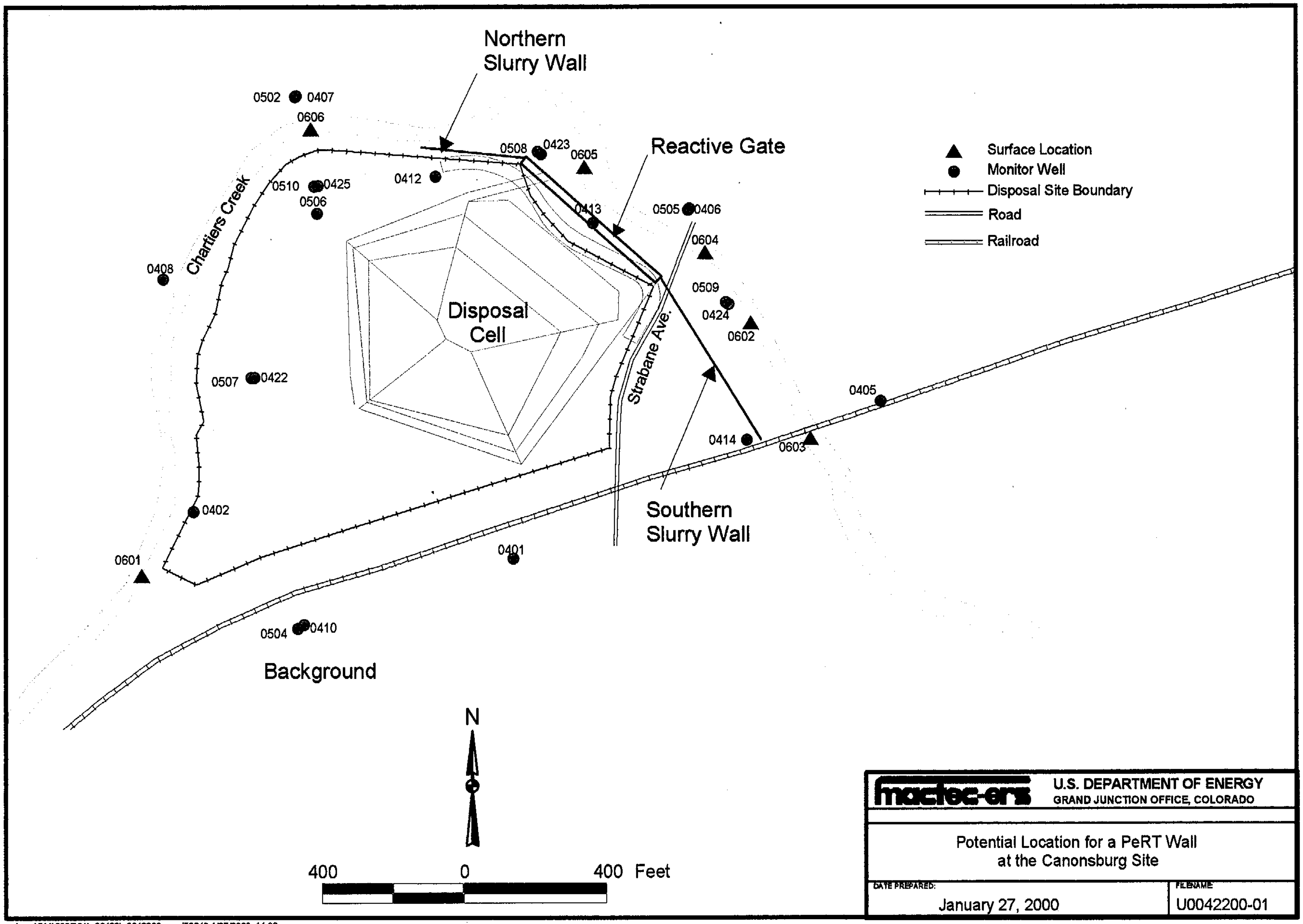

Figure 3–7. Potential Location for a PeRT Wall at the Canonsburg Site

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.

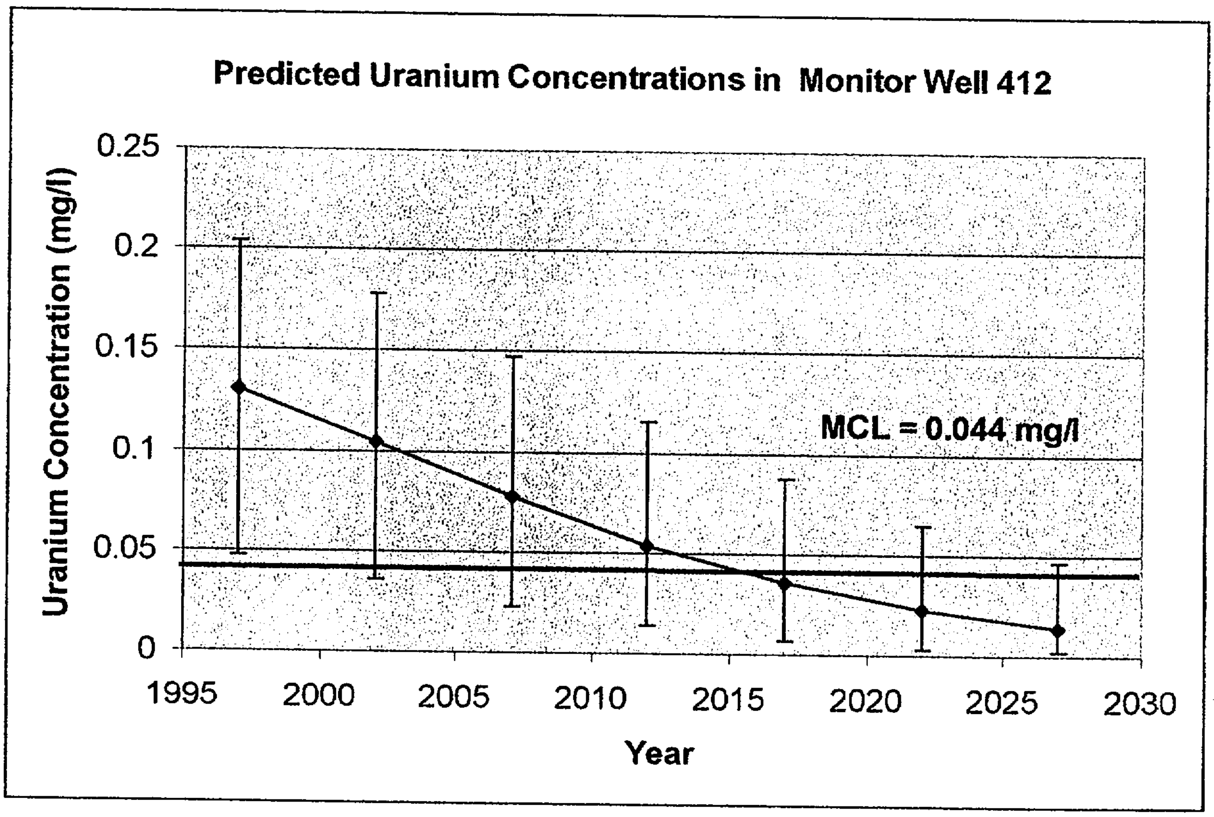

Figure 4–1. Uranium Concentration Versus Time for Verification Monitoring in Well 412

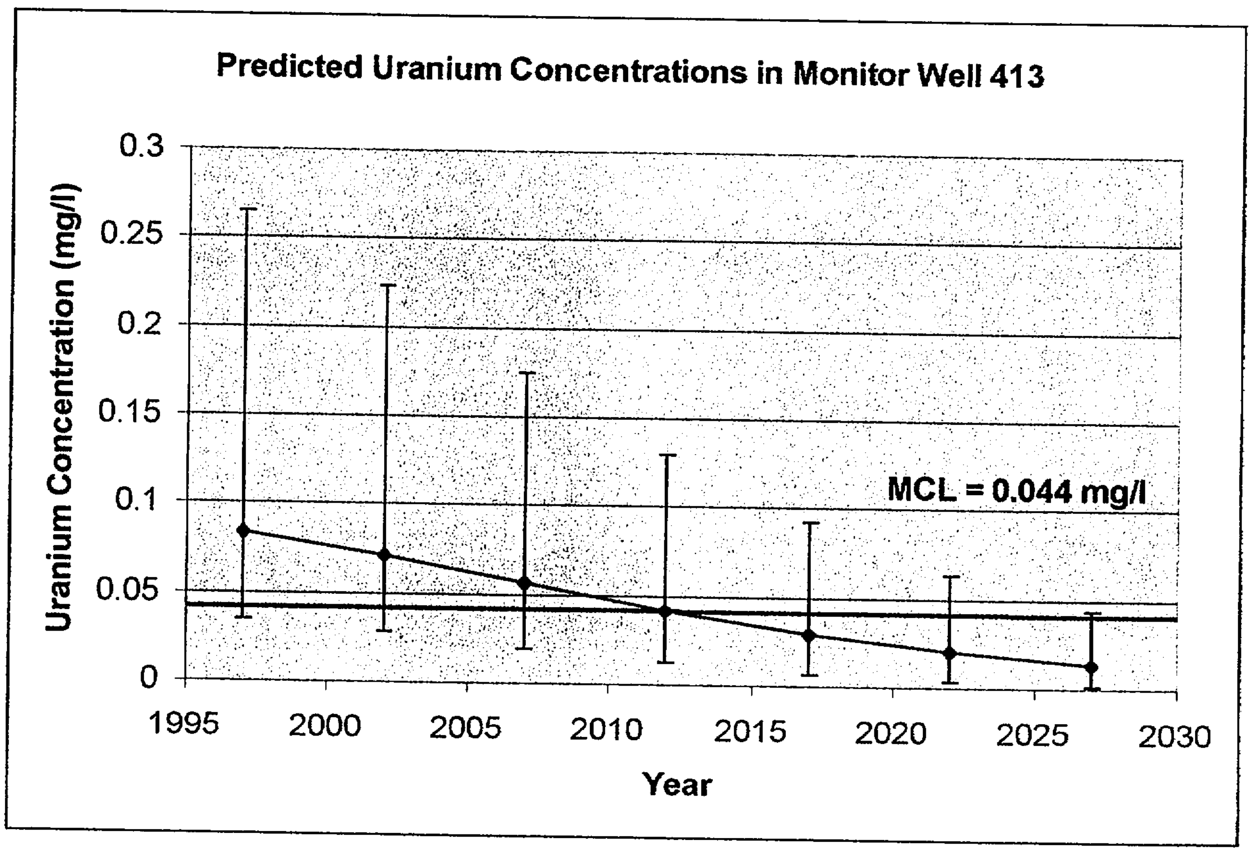

Figure 4–2. Uranium Concentration Versus Time for Verification Monitoring in Well 413

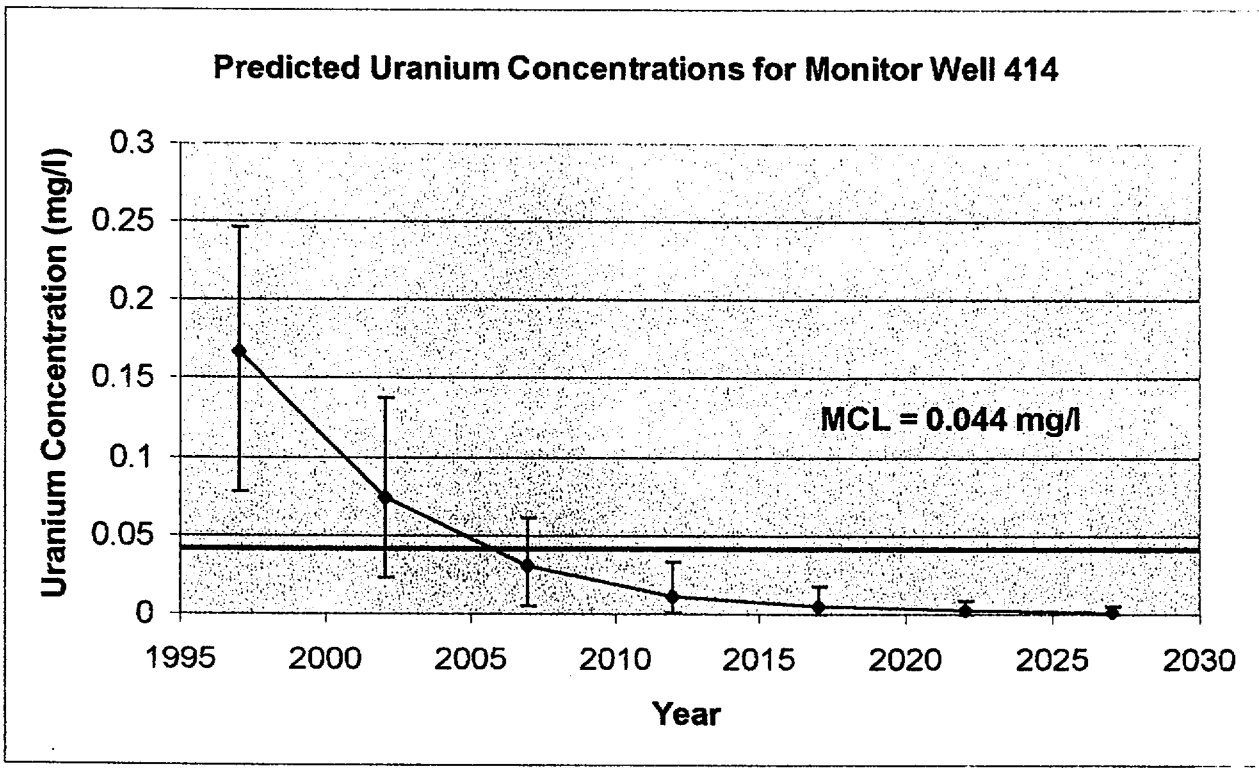

Figure 4–3. Uranium Concentration Versus Time for Verification Monitoring in Well 414

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 (1.4×10^{-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.

6.0 References

American Society for Testing Materials (ASTM), 1995. "Standard Guide for Documenting a Ground-Water Flow Model Application," D5718-95.

Anderson, M.P., and W.W. Woessner, 1992. *Applied Groundwater Modeling, Simulation of Flow and Advective Transport,* publisher.

Colorado Department of Health and Environment (CDPHE), 1991. *Basic Standards and Methodologies for Surface Water*, 3.1.0, Water Quality Control Commission, Denver.

Deutsch, C.V., and A.G. Journel, 1992. *Geostatistical Software Library and User's Guide*, Oxford University Press.

Faust, C.R., P.N. Sims, C.P. Spalding, P.F. Andersen, B.H. Lester, M.G. Shupe, and A. Harrover, 1994. *FTWORK: Groundwater Flow and Solute Transport in Three Dimensions*, GeoTrans, Inc.

Freeze, R.A., 1969. "The Mechanism of Natural Ground-Water Recharge and Discharge, One-Dimensional, Vertical, Unsteady, Unsaturated Flow Above a Recharging or Discharging Groundwater Flow System," Water Resources Research, 5:153–171.

Freeze, R.A., and J.A. Cherry, 1979. *Groundwater*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Haan, C.T., 1977. *Statistical Methods in Hydrology*, The Iowa State University Press.

Iman, R.L., and M.J. Shortencarrier, 1984. A *FORTRAN 77 Program and User's Guide for the Generation of Latin Hypercube and Random Samples for Use with Computer Models*, NUREG/CR-3624, SAND83-2362 Sandia National Laboratory, Albuquerque, New Mexico.

Knowlton, R.G., D.M. Peterson, D. Walker, H. Zhang, J. White, in press. R*eference Manual for Groundwater Analysis and Network Design Tool, or GANDT*, Sandia National Laboratory, Albuquerque, New Mexico.

McDonald, M.G., and A.W. Harbaugh, 1988. "A Modular Three-Dimensional Finite-Difference Ground-water Flow Model," *Techniques of Water-Resources Investigations*, Book A6.

McLaughlin, D., L.B. Reid, S.G. Li, J. Hyman, 1993. "A Stochastic Method for Characterizing Ground-Water Contamination", *Ground Water*, 31(2)237–249.

Metzler, D., R, Plieness, R. Knowlton, D. Peterson, H. Zhang, and J. Knott, 1997. "Implementing the Natural Flushing Strategy: An Approach to Meeting the EPA Ground Water Standards at Select Uranium Mill Tailings Sites," *Tailings and Mine Waste* '97, Balkema, Rotterdam.

MK-Ferguson, 1986. *Canonsburg, Pennsylvania Uranium Mill Tailings Site Remedial Action Completion Report*, prepared by MK-Ferguson for the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

Narasimhan, T.N., A.F. White, and T. Tokunaga, 1986. "Groundwater Contamination From an Inactive Uranium Mill Tailings Pile, Application of a Dynamic Mixing Model," *Water Resources Research*, 22(13)1820–1834.

Oak Ridge National Laboratory (ORNL), 1996. *Screening Benchmarks for Ecological Risk Assessment,* Version 1.6 (database), Environmental Sciences Division and Health Sciences Research Division, October. Accessible at www.hsrd.ornl.gov/ecorisk/benchome.html

Pannatier, Y., 1996. V*ariowin, Software for Spatial Data Analysis in 2D*, Springer-Verlag, New York.

Peck, A., S. Gorelick, G. de Marsily, S. Foster, V. Kovalevsky, 1988. *Consequences of Spatial Variability in Aquifer Properties and Data Limitations for Groundwater Modeling Practice*, Chapter 5, "Satisfying Data Requirements for Modeling," and Chapter 7, "Evaluating the Uncertainty of Groundwater Model Results," International Association of Hydrological Sciences (IAHS) Publication No. 175.

Pennsylvania Department of Environmental Resources (PADER), 1992. *Water Quality Standards*, Chapter 93, Title 25, Environmental Resources, Pennsylvania Code.

Pennsylvania Geologic Survey (PGS), 1994. "Information Concerning the Pennsylvania Geologic Survey's Water Well Inventory Data," UPDCC File Location No. 1.19.7, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

Peterson, D.M., and J.L. Wilson, 1988. *Variably Saturated Flow Between Streams and Aquifers*, Technical Completion Report WRRI No. 233, New Mexico Water Resources Research Institute.

Templeton, D., 1993. "Trash, Debris, Slabs at Creek Pose Safety Hazard, Agency Told," *Pittsburgh Post-Gazette*, Sunday, March 28.

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.

———, 1984. *Processing Site Characterization Report, Canonsburg, Pennsylvania*, UMTRA–DOE/AL–0041.

———, 1993. *Adsorption Isotherm Special Study*, DOE/AL/62350–17F, prepared by Jacobs Engineering Group, Inc.

———, 1995a. *Long-Term Surveillance Plan for the Canonsburg, Pennsylvania, Disposal Site*, DOE/AL/62350–203, Rev. 0.

———, 1995b. *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.

———, 1998. *Annual Site Inspection and Monitoring Report for Uranium Mill Tailings Radiation Control Act Title I Disposal Sites, Interim Annual Report for the Period October 1, 1997 through December 31, 1997,* prepared by MACTEC Environmental Restoration Services, Grand Junction, Colorado, April.

U. S. Environmental Protection Agency (EPA), 1987. *Alternate Concentration Limit Guidance, Part I: ACL Policy and Information Requirements, Interim Final* EPA/530-SW-87-017, Office of Solid Waste, Waste Management Division, Washington, D.C., July.

———, 1989. *Risk Assessment Guidance for Superfund, Vol. I, Human Health Evaluation Manual* (Part A), EPA/540/1-89/002, Office of Emergency and Remedial Response, Washington, D.C.

U. S. Nuclear Regulatory Commission, 1982. *A Collection of Mathematical Models for Dispersion in Surface Water and Groundwater*, NUREG–0868, written by R.B. Codell, K.T. Key, and G. Whelan.

———, 1996. *Alternate Concentration Limits for Title II Uranium Mills*, Staff Technical Position, January.

———, 1995. R*eassessment of NRC's Dollar Per Person-Rem Conversion Factor Policy* NUREG–1530.

Van Rooy, D. and D. Rosbjerg, 1988. "The Effect of Conditioning Transport Simulations on Transmissivity, Head and Concentration Data," *Consequences of Spatial Variability in Aquifer Properties and Data Limitations for Groundwater Modelling Practice*, by Peck, A., S. Gorelick, G. de Marsily, S. Foster, and V. Kovalevsky, report prepared by a working group of the International Commission on Groundwater, International Association of Hydrological Sciences, IAHS Publication 172:163–177.

Walker, D.D., H. Zhang, R.G. Knowlton Jr., and D.M. Peterson, 1996. "Probabilistic Screening Model of Volatile Contaminant Transport in the Unsaturated and Saturated Zones," *Calibration and Reliability in Groundwater Modeling*, IAHS Publication, 237:599-606, proceedings of the ModelCARE 96 Conference, Golden, Colorado, September.

Washington County Board of Commissioners, 1993. *Industrial Directory of Washington County, Pennsylvania, 1992–1993.*

Washington County Planning Commission, 1993. *Washington County Profile.*

Whelan, G., and J.P. McDonald, 1996. T*he Multimedia Environmental Pollutant Assessment System (MEPAS): Riverine Pathway Formulations*, PNNL–11176, Pacific Northwest National Laboratory, prepared for DOE.

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