FINAL

REMEDIAL INVESTIGATION REPORT OF THE NEW CUMBERLAND ARMY DEPOT'S FORMER LANDFILL (MARSH RUN FIELD) FAIRVIEW TOWNSHIP, PENNSYLVANIA

DACW45-88-D-0009
Order 5008

Prepared for:

U.S. Army Corps of Engineers
Omaha District

Prepared by:

EA Mid-Atlantic Regional Operations
EA Engineering, Science, and Technology, Inc.

January 1990

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1. INTRODUCTION

1.1 PURPOSE OF REPORT

EA Engineering, Science, and Technology, Inc. has been contracted as the Architect-Engineer with the U.S. Army Corps of Engineers, Omaha District, to perform a Remedial Investigation (RI) and to prepare an RI report of the New Cumberland Army Depot's former landfill, Marsh Run Field, in Fairview Township, Pennsylvania. This RI is part of the Defense Environmental Restoration Program (DERP) administered by the U.S. Army Corps of Engineers (COE).

This project was conducted under Delivery Order 5008 associated with Indefinite Delivery Contract Number DACW45-88-D-0009.

Previous investigation of the approximately 14-acre site (i.e., "Confirmation Study Report of the New Cumberland Army Depot, Fairview Township, Pennsylvania," Woodward-Clyde Consultants, March 1988) contracted by the U.S. Army Corps of Engineers, Omaha District, under the Department of Defense (DOD), Defense Environmental Restoration Account (DERA), has indicated the presence of ground-water and soil contamination at the site.

EA was selected to:

1. Evaluate the presence and extent of hazardous waste and associated contamination both vertically and horizontally at the landfill.

2. Assess the potential for contaminant migration in the surrounding environs.

3. Identify public health and environmental risks of contaminants relative to regulatory standards.

4. Define future investigations and/or actions required at the site.

1.2 SITE BACKGROUND

The New Cumberland Army Depot's former landfill, Marsh Run Field, is located in Fairview Township, York County, Pennsylvania. It is situated adjacent to and east of New Cumberland Army Depot (NCAD). The site is bounded to the south and southeast by Marsh Run Road and to the north and northeast by Conrail (formerly Penn Central) railroad tracks and the Susquehanna River. The site location is shown in Figure 1-1.

The site is approximately 14 acres in size and is situated in a relatively flat area, which was occupied by swampy wetlands prior to landfilling. The surrounding area is semirural. Single-family dwellings are located to the south and southeast of the site along Marsh Run Road.

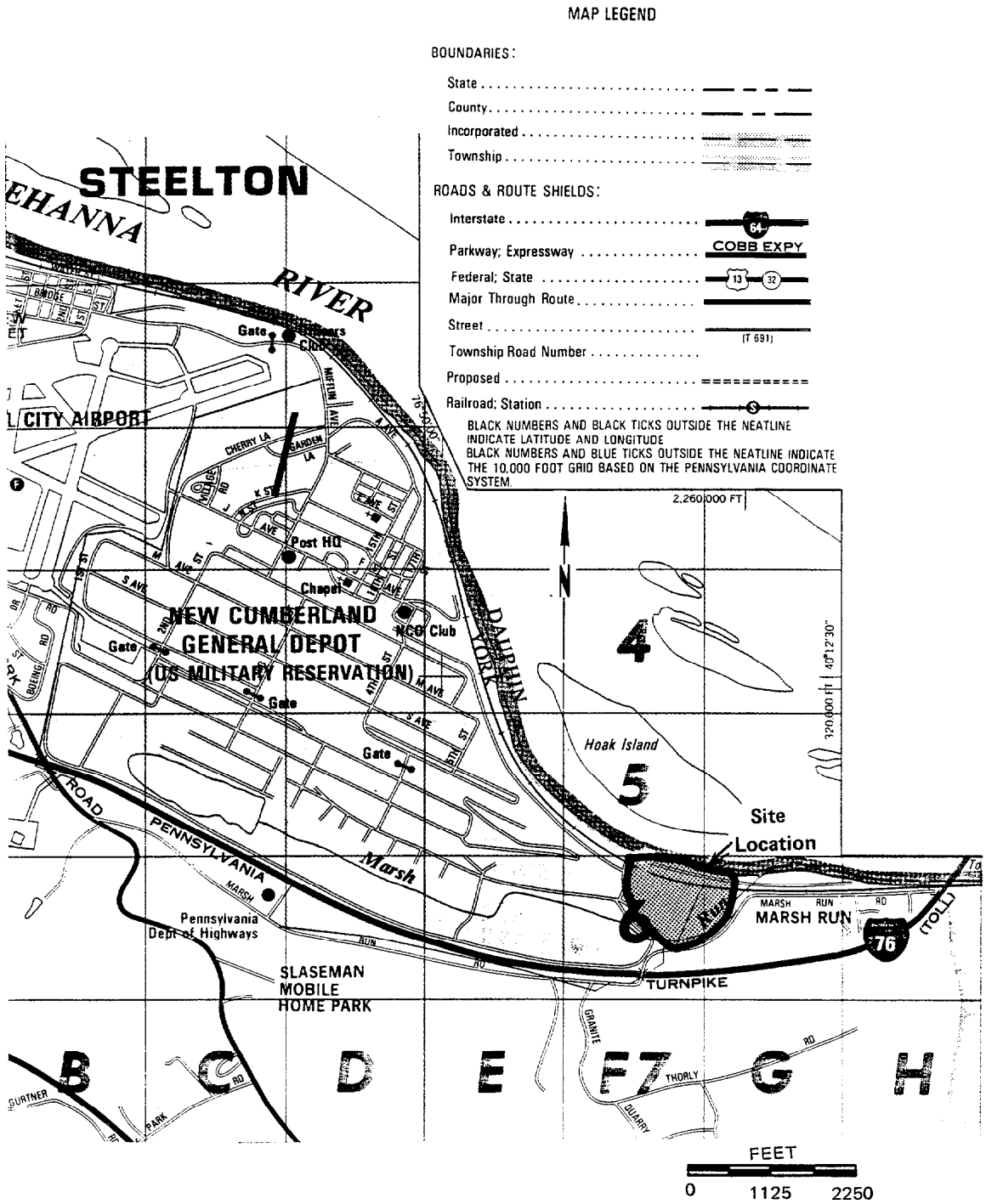


Figure 1-1. Site location.

Currently, the site exists as a filled wetland, up to 7 ft above the prefill surface. The present surface of the landfill is relatively flat with some grading (performed by Fairview Township) to facilitate drainage. The site is bordered immediately to the south by a shallow drainage ditch, which collects surface runoff and channels it into Marsh Run Creek. A NCAD access road borders the site to the east immediately outside of the Army Depot fence. This road is used by NCAD personnel during the afternoon when leaving work and by railroad personnel to service the tracks. Marsh Run Creek, which flows in a general west-to-east direction, bounds the southwest of the site (inside depot fence), passes beneath the access road, and borders the landfill immediately to the south and east (Figure 1-2). Marsh areas border the creek west and east of the site. A swale, which has been observed to contain standing water, is located immediately north of the landfill. The swale directs surface water runoff toward the marsh area east of the site.

Previously, the Marsh Run Field site was owned by NCAD, who used it as a landfill for disposal of base-derived waste materials starting in the early 1900s. The waste materials were deposited in a marshy area to a height of several feet above the standing-water level of the swampy areas. The landfill material has been mixed with soils excavated from a burrow area directly adjacent to and north of the fill. The cover soils at the site consist of reddish brown clayey and sandy silts, similar to those of the Bowmansville Series. However, the origin of the cover fill which was reportedly trucked in by Fairview Township is unknown. The thickness of the cover fill ranges from 1 to 2 ft.

Ownership of the Marsh Run Field property was transferred by the Army in 1976 to the Bureau of Outdoor Recreation, who sold the site to Fairview Township. The site was used as a soccer field until 1987 when a Confirmation Study of the site was conducted as part of DERP. Other U.S. Army investigations have addressed the problems of the adjacent solid waste management units (SWMUs) west of the Marsh Run Field area and the water quality of Marsh Run Creek since 1977; however, the Confirmation Study conducted by Woodward-Clyde was the first site-specific investigation. Findings are discussed in Section 1.2.3, Previous Investigations.

NCAD consists of 832 acres located in south-central Pennsylvania, approximately 8 km south of Harrisburg and 1.6 km east of New Cumberland in Fairview Township, York County, Pennsylvania. The depot is bounded by the Susquehanna River to the north and east, the Pennsylvania Turnpike (Interstate 76) to the south, and the Capital City Airport and residential developments to the west.

Marsh Run Storage Depot (the original name for NCAD) was constructed in 1917. The post was redesignated as an Army reserve depot with the mission to provide reserve storage for quartermaster, signal, ordnance, medical, engineer, and chemical warfare items, save toxics and chemical ammunition [Office of the Chief Chemical Warfare Services (OCCWS) 1944]. In 1918, after the end of World War I, the installation served as a receiving point for supplies returned from overseas.

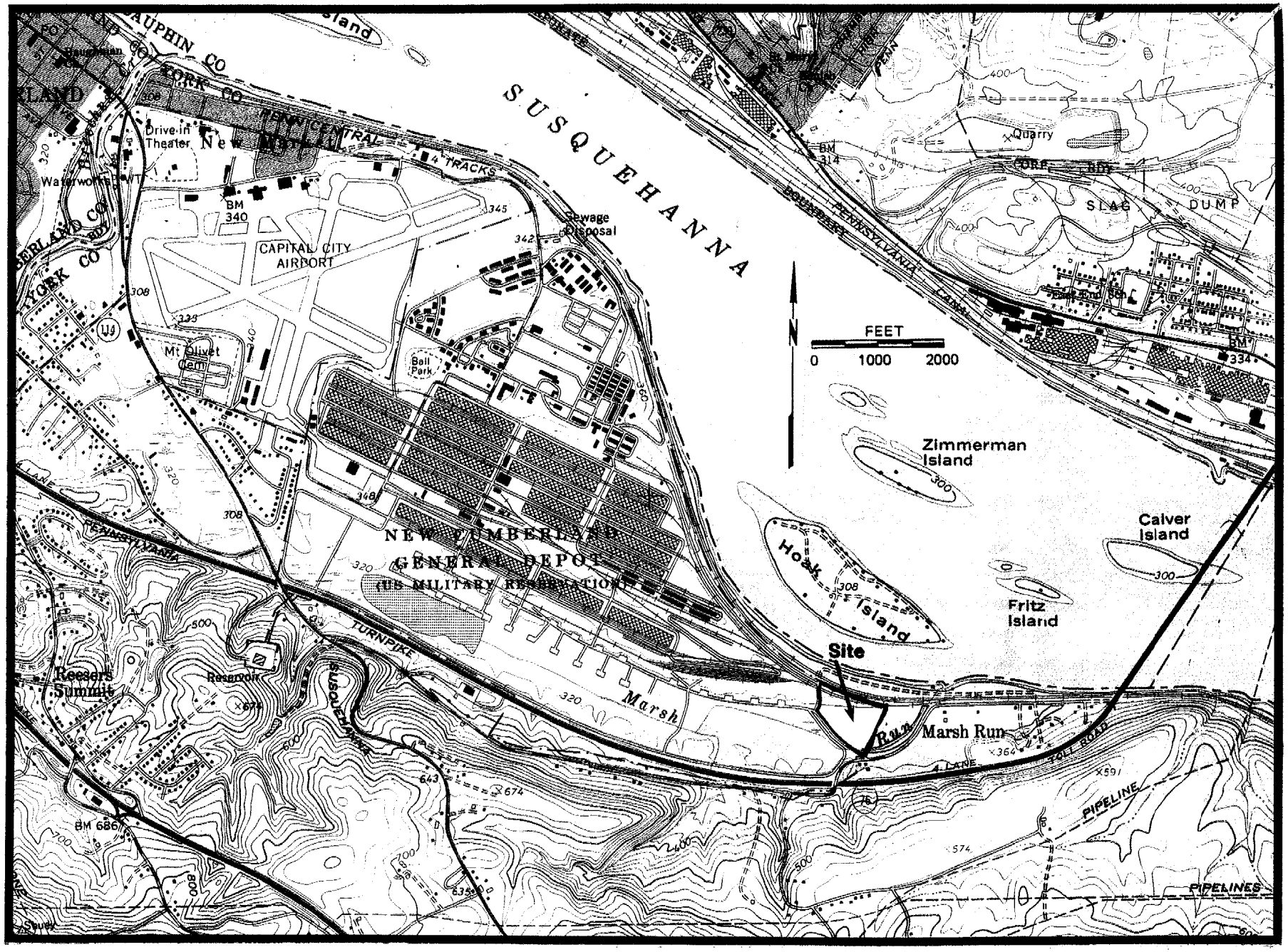


Figure 1-2. Marsh Run Field and vicinity.

Little activity occurred onpost from the end of World War I until World War II. During World War II the installation's primary mission was to serve as a filler depot to several ports of embarkation for overseas shipment. The installation also served as a reception center for newly inducted soldiers. In 1941, storage facilities onpost were doubled and a clothing impregnation plant was added to the laundry.

During the latter part of World War II, a prisoner-of-war (POW) camp for German prisoners was established onpost. Following deactivation of the POW camp and the reception center, a branch U.S. Disciplinary Barracks was activated and remained in service until March 1959.

The post was the site for receiving and disposing of excess supplies and equipment by the Quartermaster Supply Section for 13 states from the end of World War II until June 1947. Beginning in September 1946, a War Reserves Branch was established to store supplies and equipment; the branch became especially active during the Korean Conflict.

The depot became a separate installation under the Quartermaster General on 1 January 1948. During the Korean Conflict, activity increased as maintenance divisions were formed and storage space enlarged. Between 1957 and 1959 the Quartermaster Supply Section increased activities in subsistence, clothing textiles, and some Civil Defense stocks. The Quartermaster Inspector General Field Office was moved onpost in 1959, until 1962 when it was deactivated. In 1960, a million-dollar hangar and aircraft maintenance shops, connected directly to the Harrisburg-York State Airport, were constructed for maintenance of Army aircraft, especially helicopters [Chemical Systems Laboratory (CSL) 1979].

In 1962, the depot was officially named New Cumberland Army Depot and became a field installation of the U.S. Army Supply and Maintenance Command. In 1966, NCAD was placed under the jurisdiction of the U.S. Army Material Command (AMC).

In January 1967, the U.S. Army Logistics Doctrine and Systems Agency (later redesignated the U.S. Army Logistics Doctrine, Systems, and Readiness Agency) was activated onpost. Also in 1967, the Petroleum Laboratory from Schenectady Army Depot (USAGMPA) was transferred to NCAD.

Changes occurring onpost in the 1970s included location of the U.S. Environmental Protection Agency's (EPA) Pesticide Division at NCAD. In 1973, the NCAD mission was modified to include Aviation Support Command (AVSCOM). In 1974, AMC (redesignated DARCOM in January 1976 and changed back to AMC in 1984) selected NCAD as the East Coast Secondary Item Stockage and Issue Point, making the post part of a revised Distribution Plant for Secondary Items. In June 1976, the Defense Supply Agency designated NCAD as the principal distribution depot supporting U.S. Army units in the U.S. Army, Europe (USAREUR), and the Eastern Continental United States (CONUS) under Direct Support System (DSS). NCAD and other DARCOM depots were assigned to the newly designated U.S. Army Depot System Command (DESCOM), a DARCOM major subordinate command, in September 1976.

Prior to 1983, NCAD's mission was that of a supply and maintenance depot. The major maintenance operations involved overhaul and modification of Chinook helicopters and helicopter components. Since 1987, NCAD's mission has changed to that of a supply depot, and the previous maintenance facilities associated with aircraft maintenance (painting, machining, and electroplating) have been eliminated. Many hazardous chemicals associated with these operations (acids, solvents, fuels, plating solutions) are no longer stored or handled at NCAD.

1.2.1 Site Description

1.2.1.1 Regional Physiography, Soils, and Geology

The NCAD former landfill site (Marsh Run Field) is located in the extreme southern portion of the Great Valley Section of the Valley and Ridge Physiographic Province. The Great Valley Section is an area of relatively low-to-moderate relief between regions of distinctively higher average elevations. This subprovince is typified by its uniformity throughout its extent. The Great Valley Section owes its position to the erosion of a thick sequence of Cambrian and Ordovician sandstone and shale bounded by more resistant rocks to the north and south. The boundary between the Great Valley Section and the hills of the Triassic Lowland Section lies approximately 200 ft southeast of the site.

The predominant bedrock underlying the site has been mapped as the Triassic age Gettysburg Formation. The Gettysburg Formation is typically composed of maroon shales and mudstones. The mudstones are typically micaceous and silty, and may contain calcareous cement. Bedding is usually indistinct, and the rock weathers relatively easily. Tongues of pebbly sandstone and coarse-grained sandstone form uplands and ridges above the less resistant shales.

Structurally, the rock layers form a monocline having a predominantly northwest dip of about 15-35°. The northeast-southwest trending Yellow Breeches Thrust is situated approximately 3.5 mi northwest of the site. The Triassic rocks unconformably overlie Paleozoic or Precambrian rocks. The Gettysburg Formation has been estimated to be 10,000-15,000 ft thick.

A thin veneer (<10 ft) of Quaternary surficial deposits overlies the bedrock. These deposits are composed of colluvial and alluvial deposits, including terrace gravels and sands, and are typically clay, silt, sand, and gravel. Interlayering and lensing are common.

The site is relatively flat with maximum topographic relief of less than 10 ft. It is situated at an average elevation of 300 ft above mean sea level (MSL). The site topography in general slopes gradually to the southwest toward the adjacent Marsh Run Creek. The present topography is developed on fill. The cover fill and fill deposited within the confines of the site are classified by the U.S. Soil Conservation Service as Made Land. The soils of this land type are typically a mixture of reddish brown or dark brown silt loam that was originally surface soil, and silty clay that was formerly subsoil. These materials are reworked soils of

the Wheeling, Sciotoville, Penn, and Lansdale materials. Most of the soils are poorly drained and have a high water table.

1.2.1.2 Surface Water

The site is situated within the lower Susquehanna River Basin. Specifically, the site is located adjacent to and is drained by Marsh Run Creek and the adjacent swamp to the east. Marsh Run Creek discharges directly into the Susquehanna River 1,100 ft northeast of the site.

Because of past landfilling operations, the natural surface drainage has been altered. Prior to landfilling operations, the site was marsh land and was probably, in part, drained directly by the Susquehanna River. Surface topography to the south (i.e., ridges rising abruptly from the marsh to over 100 ft above the marsh) strongly preclude site incipient runoff drainage south of Marsh Run Road.

Presently, surface runoff is directed offsite toward the south and is collected by a drainage ditch which extends along the property's southwestern boundary, or is channeled by a west-east trending swale along the property's northern boundary to the adjacent swamp area east of the site.

Marsh Run Creek receives shallow ground-water discharge as base flow from the southern half of the site. It is also fed further upstream by a north-south trending perennial stream, which merges with Marsh Run Creek 2,500 ft west of the site. On the depot, Marsh Run Creek is a low-gradient stream, which connects directly with a 32-acre stormwater drainage pond on NCAD 1.3 mi west of the site. Coincidentally, this low-gradient stream on its way to the site flows eastward on the base, directly adjacent to three areas of past landfilling activities. Surface and stormwater runoff from NCAD flows to Marsh Run Creek from the warehousing and storage areas, and from heavily used streets and parking lots. The Pennsylvania Turnpike parallels Marsh Run Creek, with the highway centerline varying from 400 to 1,000 ft south of the Creek. A Turnpike maintenance facility is located approximately 1,000 ft due south of the Marsh Run Creek Dam. The highway maintenance facility surface runoff discharges into storm drainage ditches that flow into Marsh Run Creek.

Marsh Run Creek is classified as a warmwater fishery by the State of Pennsylvania. Prior to 1974, the untreated wastewaters from the paint stripping and plating facility were discharged to Marsh Run Creek. These wastes included heavy metals (cadmium, chromium, copper, iron, lead, nickel, and zinc), cyanide, solvents, paints, grease, and oil. Also, there was an active landfill on the depot in the vicinity of Marsh Run Creek. This former landfill is located approximately 3,000 ft west of Marsh Run Field on depot property. The landfill remained active until 1 April 1979. The depth of the 300 x 2,400 ft landfill has been estimated to be 8-10 ft, based on adjacent topography [U.S. Army Environmental Hygiene Agency (USAEHA) 1983].

The aforementioned landfill closure construction completed on 30 October 1979 was designed to limit the amount of leachate production and erosion. Runoff from the higher elevated areas to the northeast of the landfill was directed to a culvert constructed through a clean fill zone in the landfill to Marsh Run Creek. Clean fill, predominantly silty fine sand with little clay, was used to cap the landfill and to build a 50-ft buffer zone between the landfill and Marsh Run Creek. Before this time, erosion had exposed cells of the landfill. Slag riprap was used at the edge of the 50-ft buffer zone to minimize erosion by Marsh Run Creek and by runoff. Crushed stone has been placed over the fill area to provide temporary storage of NCAD vehicles, trailers, and depot supplies. Although the closure design appears to be successful, the landfill surface retains puddles for several days after rainfall. Subsequent to the 1979 closure, in 1983 it was reported that there were visible areas of leachate flowing from the landfill. Also, the landfill was placed on top of a bog; thus, much of the landfill material is in direct contact with the water table. It is apparent that closure activities do not completely preclude the landfill's potential contribution as an upgradient source to Marsh Run Creek with respect to Marsh Run Field.

Previous studies of Marsh Run Creek (upstream of Marsh Run Field) have found certain isomers of PCB, DDT, and chlordane, as well as lindane and malathion, from unknown sources in fish, sediment, and/or water of Marsh Run Creek (USAEHA 1983 and 1986).

1.2.1.3 Ground Water

The major aquifer in the site region is the Gettysburg Formation. Secondary porosity in the form of fractures and joints controls both the storage and flow characteristics of the aquifer. These openings provide an interconnected series of channels through which water can flow. Compression tends to close the openings; therefore, they are generally best developed near the surface, and occur less frequently and are not as large deep in the formation. Primary porosity (i.e., between grains of the formation) contributes only a minor amount of water to the formation.

In this region, ground-water flow occurs in a local to intermediate extent (i.e., recharge occurs in topographic high areas and discharge occurs in adjacent low-lying streams and springs). Investigation of the regional Gettysburg Aquifer by others (Wood 1980) indicates that the competent sandstone intervals of the Gettysburg are more extensively fractured than the relatively deformed shale beds. Consequently, it is the interlayered sandstone lithology that provides the majority of the formation water. Interconnectivity continuity is relatively well maintained in each horizon along strike, but not in the vertical direction where shale layers hydraulically segregate these units.

The greatest permeability in the Gettysburg extends in a direction nearly parallel to strike. Correspondingly, maximum aquifer response to drawdown extends in the strike direction.

Investigations by others (Wood 1980) have determined that the presence of relatively impermeable shale layers and discontinuities produced by faulting and diabase intrusions tends to promote lateral rather than vertical flow within these aquifers. Multidepth testing of wells in valleys indicated downward flow with respect to increasing depth. This was indicative that underflow at depth beneath perennial streams exists. The Gettysburg Formation is typified by a shallow water-table aquifer (i.e., several tens of feet in thickness) and grades gradually into a semiconfined aquifer with depth.

The overlying recent gravel terrace deposits are restricted in areal extent to the low-lying areas adjacent to the Susquehanna River, perennial streams, and at the foot of hills as colluvial deposits. These deposits serve as storage for subsequent recharge to the underlying bedrock aquifer.

With the exception of the overlying unconsolidated terrace deposits, storage in the bedrock aquifer is poor, usually less than 1 percent. Thus, aquifer withdrawal is directly replenished by annual rainfall recharge.

On the average, annual precipitation is 40 in. in the project area. Ground-water recharge is approximated at 12 in./year (52 mgd/mi^2) in the lower Susquehanna River basin. However, it has been reported that due to the low ground-water storage in the Triassic sandstones that an average net recharge of 6 in. per year is more appropriate (Wood 1980). The remaining precipitation is lost as surface runoff or by evapotranspiration. Ground-water baseflow to local streams has been estimated at 65 percent of total streamflow (Taylor and Werkheiser 1984).

Depth to water ranges from near-surface to 15 ft below surface within a 1,000-ft radius of the site. In the site locale, water levels are anticipated to fluctuate by 5 ft. The close proximity to the Susquehanna River has a strong influence on maximum water-level fluctuations.

In general, shallow ground-water flow at the site is under water-table conditions (unconfined). Flow is semiradial toward the south-southwest and north, toward Marsh Run Creek and the Susquehanna River, respectively. In a more regional regime, intermediate depth ground-water flow is to the east-northeast toward the Susquehanna River. Fracture orientation in the bedrock may alter the anticipated flow paths significantly when fracturing is extensive.

The residences south of the site (i.e., across Marsh Run Road) derive water from wells installed in the bedrock aquifer. These wells are hydraulically upgradient of the site.

Tables 1-1 and 1-2 list the median concentrations of inorganic parameters and trace elements, respectively, of samples collected from domestic wells in the Gettysburg Formation (Wood 1980).

TABLE 1-1 MEDIAN CONCENTRATIONS OF CHEMICAL CONSTITUENTS IN GROUND WATER OF LITHOLOGIC SUBGROUPS OF THE GETTYSBURG FORMATION (Source: Wood 1980)

	Median of indicated constituent, in milligrams per liter, except as indicated		
Constituent	Shale	Sandstone	Sandy Shale in Middletown Area
Silica (SiO_2)	20	22	21
Iron (Fe)(μg/L)	80	40	70
Manganese (Mn)(μg/L)	0	0	10
Calcium (Ca)	56	25	87
Magnesium (Mg)	11	5.4	19
Sodium (Na)	8.6	7.8	12
Potassium (K)	1.3	0.9	1.5
Bicarbonate (HCO_3)	142	81	187
Sulfate (SO_4)	28	11	118
Chloride (Cl)	7.7	5.8	11
Fluoride (F)	0.1	0.1	0.0
Nitrate (N)	3.2	2.6	2.9
Nitrite (N)	0.01	0.01	--
Ammonia nitrogen (N)	0.01	0.01	--
Organic nitrogen (N)	0.00	0.00	--
Orthophosphorous (P)	0.02	0.04	--
Dissolved solids (residue at 180 C)	256	144	400
Dissolved solids (sum of constituents)	206	142	423
Hardness (Ca, Mg)	170	110	290
Noncarbonate hardness	40	9	130
Specific conductance (micromhos)	452	230	585
pH (units)	7.3	6.6	7.5
Number of analyses for each constituent	5-17	15-23	13-15

TABLE 1-2 MEDIAN CONCENTRATIONS OF TRACE ELEMENTS IN WATER ANALYZED FROM THE GETTYSBURG AND HAMMER CREEK FORMATIONS (Source: Wood 1980)

	Dissolved aluminum (Al) (μg/L)	Dissolved arsenic (As) (μg/L)	Dissolved barium (Ba) (μg/L)	Dissolved boron (B) (μg/L)	Bromide (Br) (mg/L)	Dissolved cadmium (Cd) (μg/L)	Dissolved chromium (Cr) (μg/L)	Dissolved cobalt (Co) (μg/L)	Dissolved copper (Cu) (μg/L)	Dissolved lead (Pb) (μg/L)	Dissolved lithium (Li) (μg/L)	Dissolved mercury (Hg) (μg/L)	Dissolved nickel (Ni) (μg/L)	Dissolved selenium (Se) (μg/L)	Dissolved strontium (Sr) (μg/L)	Dissolved silver (Ag) (μg/L)	Dissolved zinc (Zn) (μg/L)
Median Concentration	10	0	100	10	0.0	1	<10	0	40	5	0	<0.5	0	0	80	0	60

1.2.2 Site History

There is limited documentation pertaining to the distribution, quantities, or types of substances deposited at the site. Reportedly, waste was piled directly over the wetland area. Trenches may have been dug for increased disposal capacity. Because of the lack of operational records, it is possible that hazardous substances may exist throughout the landfill site. It is not known how extensively the landfill was used for the disposal of hazardous substances. There is some evidence of "normal" landfill waste (i.e., household, construction debris, etc.).

This site was identified in the 1979 Installation Assessment (CSL 1979). In the early period of NCAD history, when the major depot activity was the storage of subsistence items, damaged canned goods were the major item for disposal. With the advent of the Chemical Warfare Service (CWS) storage activities, the materials sent for disposal included damaged, out-of-specification, or empty containers from such materials as napalm thickener (aluminum naphthalate soaps), decontaminating agent noncorrosive (DANC) (1,3-dichloro-5,5- dimethylhydantoin), decontaminating solution (DS-1) (diethylenetriamine), bleaches (hypochlorites), and clothing impregnating compounds (chlorinated aniline in a chlorinated paraffin binder). According to a U.S. Army CWS document (1959), approximately 713,000 ft^2 of space was appropriated at NCAD for storage of chemical warfare supplies. The primary function of NCAD with respect to the storage and distribution of chemical warfare supplies was distribution of general supplies both for Zone of Interior installation and ports of embarkment. Training ammunition was also possibly distributed. A concern of whether chemical agents were ever stored at NCAD was addressed by the review of Army documents (i.e., by EA and an independent Army archive search), which indicates that toxic chemical agents were not handled or stored at NCAD.

A review of Army documents pertaining to storage of mustard agent at other Army facilities reports of the unstable nature of the early mustard agents (i.e., 70 percent B,B′-dichloroethyl sulfide and 30 percent of sulphur and other sulphur compounds). Early mustard agent (produced by the Levinstein Process) would sometimes build up large pressures within the containers, producing breeches of the canister. Corrosion of the canister was also a potential danger. However, from review of Army literature (CWS 1959), it appears as if the majority of chemical agents, of which mustard agent constituted half by weight, were handled by CWS branch depots. NCAD was not one of those depots.

NCAD functioned as support for CWS as indicated in a booklet prepared by the Office of the Chief, CWS, Supply Missions of Chemical Warfare Service Installations, OCCWS, Washington, D.C., 24 May 1944, in the following capacities:

1. As a Zone of the Interior distribution depot--To receive and store CWS general supplies for distribution to installations located within the First and Second service commands and the State of Pennsylvania.

2. As a Table of Organization filler depot--To receive and store CWS general supplies for shipment overseas through the Boston and New York ports of embarkment.

3. As a reserve depot--to receive and store authorized reserves of CWS general supplies for general distribution.

As a Table of Organization and reserve depot, incendiary and smoke ammunition (excluding explosive and toxic ammunition) were received, stored, and shipped overseas through ports of embarkment as directed by the Chief of Chemical Warfare Services. All items of CWS issue (except toxics and chemical ammunition) were stored and shipped by the NCAD Chemical Supply Section (Technical Services 1960).

A historical search of the archives was conducted by the U.S. Army Corps of Engineers, Office of History. The report, entitled "The New Cumberland Army Depot and Toxic Chemical Munitions" and issued 28 September 1989, concluded the following:

1. The mission statements examined do not assign the storage of toxic chemical munitions as part of the Chemical Warfare Service storage and maintenance mission at NCAD. They show that during World War II and the period 1946-1953, the Chemical Warfare Service tasked the depot's Chemical Supply Section with five major missions: (1) the construction and operation of a clothing renovation plant, (2) the storage and maintenance of industrial chemicals required for the operation of the plant, (3) the storage and maintenance of such Chemical Warfare Service items as protective clothing, gas masks, and decontamination equipment, (4) the storage and maintenance of incendiary munitions, and (5) a 1946 bomb desegregation program involving the identification and testing of incendiary bombs.

2. The records also indicate that the Chemical Warfare Service Supply Section utilized a relatively small part of the total storage space at NCAD, no more than 12 percent at any one time during 1944. Further, there is no mention of the presence there of toxic waste yards or the other special facilities present at other Chemical Warfare Service installations tasked with the storage of toxic chemical munitions.

3. There is no evidence that the Chemical Corps' plans for the post World War II period included either the storage, maintenance, or disposal of toxic chemical munitions by NCAD. The only mention of plans to store chemical munitions at New Cumberland refers to incendiary bombs. Also there is no mention in these records of the presence of chemical identification kits.

4. Official histories of Chemical Warfare Service operations at NCAD and Depot Organization and Functions Manuals make no mention of either the storage, maintenance, or disposal of toxic chemical munitions.

Beginning in April 1944, M17 cluster bombs and 100-lb incendiaries were stored in the Section Bomb Area of NCAD; this was a temporary measure imposed by the overloading of the manufacturer's storage facilities.

CWS supplies were first accepted by NCAD in December 1942, and were shipped out in the following months in total tonnages ranging from 78 to 439 tons per month between December 1942 and June 1945.

The waste disposal practices used in the landfill were the standard practices of the time period. Apparently most of the CWS supplies were protective clothing and damaged, out-of-specification, or empty containers from such materials as napalm thickener (which is only the thickener for the jelly-like napalm substance) and clothing impregnating material.

Army records indicate that a 1-lb container of potassium cyanide was buried at the site in March 1957. The container was excavated and disposed offsite by Rollins Environmental Service Company in 1978.

In 1976, the Marsh Run Field site was sold to Fairview Township. To make the site usable as a soccer field, the township graded the site and brought in topsoil to make a suitable playing surface. In 1979 and 1983, Army tests indicated that water flowing from the western edge landfill area was not adversely affecting Marsh Run Creek.

The 1979, 1983, and 1988 U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) reports of depot environmental conditions were submitted to the EPA upon issuance. Conditions of the landfills located on the depot were not considered to warrant remedial action. However, in accordance with USATHAMA reports (1979 and 1983), monitoring of Marsh Run Creek was recommended. The above-cited reports did not directly address Marsh Run Field ground-water and soil conditions. Only indirect monitoring of water quality of the adjacent Marsh Run Creek was addressed.

In August 1986, NCAD identified Marsh Run Field as an excess federal property eligible for the Defense Environmental Restoration Program, and in April 1987, the Army commenced testing of the site. In August 1987 the Army received and shared preliminary test results with Fairview Township, and closed the park. In April 1988, formal preliminary test results were received and shared with Fairview Township. Results showed that low levels of contamination existed in the subsoil and ground water. On 9 May 1988 the Pennsylvania Department of Environmental Resources (PaDER) tested the wells of Marsh Run Park neighbors for trace metals and volatile organic compounds. On 10 May 1988 results confirmed that the wells were not contaminated. As a result of the low levels of contamination found by the preliminary Marsh Run Field investigation, the Army recommended that a follow-up study be performed to determine the extent of the contamination. On 11 May 1988 the Army released funds to perform the follow-up environmental studies of Marsh Run Park. At the

same time, the Army initiated the sampling and analysis of the cover fill topsoil to determine whether contamination existed and if there were any risk to the children playing soccer on the field.

On 25 May 1988 the U.S. Army Corps of Engineers, Omaha District, had a total of eight surficial soil samples collected and analyzed at the Marsh Run Field site. The purpose of this sampling was to prepare a report addressing the contaminants present in the surface soils and to evaluate the risk to public health from exposure to these soils. An offsite sample, SS-7, was collected outside of the site boundaries. However, this sample was near the site boundaries and its validity as a background sample should be regarded with scrutiny.

On 22 and 23 June 1988 the Technical Assistance Team for Emergency Response Removal and Prevention under contract to EPA, Region III (Philadelphia), collected 15 surficial soil samples, including one background sample (#11).

On 29 June 1988 the Army disclosed the results of the topsoil sampling by the EPA and U.S. Army Corps of Engineers. The results indicated that the surface soils at Marsh Run Park did not present any apparent health hazards to the children exposed to the soils. The report indicated that the children were never at an unacceptable risk.

The environmental conditions at Marsh Run Field, although directly related to past NCAD disposal history, may also have been impacted by disposal activities of other identified SWMUs located on NCAD. Previous environmental studies of Marsh Run Creek and other SWMUs on the depot immediately adjacent to Marsh Run Creek, which flows through these areas, have indicated contamination. Other NCAD environmental concerns which may impact Marsh Run Field environs, although remote, include the solvent release at the Tank 950 area and past chromium storage at the area presently occupied by the Eastern Distribution Center. Numerous investigations have studied the environmental impact of these sites separately and in some cases cumulatively. However, the cumulative effect of all sites in the vicinity with respect to the Marsh Run Field environmental status has not been addressed. Table 1-3 summarizes the relevant usage, environmental conditions, and present status of sites that may potentially impact the site-specific environmental conditions of Marsh Run Field. In particular, impacts on the surface water quality of Marsh Run Creek and ground-water quality of the bedrock (regional) aquifer are considered. Figure 1-3 shows the location of these sites.

From examination of Table 1-3 it is apparent that other sites in the vicinity may individually or cumulatively augment any site-specific derived contamination. The recurrence of volatile and semivolatile compounds has been documented in the Marsh Run Creek surface water upgradient of Marsh Run Field, in soils and in ground water, on or beneath this depot facility. Other relevant concerns have not been fully addressed--in particular, the extent of contamination in the local bedrock aquifer. The presence of sites such as the Firefighting Training Area (Site 5, Figure 1-3) and landfills adjacent to Marsh Run Creek (Sites 2 and 4) presents an enhanced probability that ground water and surface water

TABLE 1-3 RELEVANT USAGE, ENVIRONMENTAL CONDITIONS, AND PRESENT STATUS OF SOLID WASTE MANAGEMENT UNITS ADJACENT TO THE MARSH RUN SITE

Site Name	Type	Usage	Present Condition/Status	Potential Impact to Marsh Run Field
Site 1 Chromium Sump	Subsurface sump which was corroded badly	Chromium-contaminated soil and ground water resulting from a buried concrete sump used to contain plating solutions from former plating shop. Used until fall of 1985. Soil was stained and contaminated with chromium to 8 ft. Shallow ground water also high in chromium. Subsequent deep wells installed outside of chromium-contaminated area revealed TCE contamination of bedrock wells 70-172 ft deep. This indicated regional ground-water contamination.	After results of test borings indicated contamination of soil, 1,440 yd^3 of soil were removed and shipped offsite. A ground-water collection system was also installed to collect local ground water for transportation offsite.	Low-to-moderate ground-water abatement may control shallow migration of chromium. The TCE, whether related to this site or not, is probably not influenced by recovery operation. Regional ground-water flow may trend toward Marsh Run Field if fractures influence flow paths.
Site 2 Abandoned Landfill	Landfill--approx. dimensions 300 x 900 ft	Operated between 1950s and 1971. Used primarily as truck dispatch area. Bleaching powder was discovered in this area. Apparently 100-ft-long 6-ft trenches were dug and 3 to 4 5-ton truck loads of bleaching powder were landfilled. Surface water leachate seeps were sampled and analyzed in 1988. 1,1,2-2-Tetrachloroethane was detected at 100 $\mu g/L$ in ponded water onsite. Low levels of BNAs were found in a storm drain culvert proximal to the site. Other possible waste disposal includes sewage treatment plant sludge and mess hall waste.	Potential contamination of shallow water table and adjacent Marsh Run Creek may occur. Regional aquifer ground-water quality impact due to site unknown.	Low-to-moderate potential impact on Marsh Run Creek due to shallow water-table base flow to stream.
Site 3 Refuse Transfer Area	Refuse transfer area and wood debris site 450 x 450 ft	Utilized as a fill site for inert materials. Site is operating as a refuse transfer. No evidence of hazardous materials or waste storage.	Currently in operation for refuse transfer.	Low

TABLE 1-3 (Cont.)

Site Name	Type	Usage	Present Condition/Status	Potential Impact to Marsh Run Field
Site 4 Closed Sanitary Landfill	Landfill approximately 15 acres	Used between 1952 and 1979. Domestic solid waste, cardboard, wood, and dried sewage sludge were disposed by common method of landfilling. Site closed in 1979 because it could not be permitted under existing State landfill requirements. Site lies within 100-year floodplain. Leachate seeps occur near boundary adjacent to Marsh Run Creek. Numerous aquatic and water quality studies conclude leachate seeps are diluted upon entering Marsh Run Creek. Leachate was found to contain low-level PCBs and volatile organics.	Site is closed. No recommendations for further sampling were made as a result of the latest 1986 water quality study.	Low potential for shallow water-table discharge to Marsh Run Creek. Potential for deeper bedrock aquifer impact, however, has not been evaluated by previous investigation.
Site 5 Firefighting Training Area	Open area used for firefighting training 80 x 200 ft	Currently used. First use is not known. Various types of waste oils, solvents, and chemicals were stored in the past in this location. These materials were subsequently burned during fire training exercises. The use of solvents and waste oils to start fires is no longer practical. One soil sample was found to contain semivolatile compounds: phenanthrene, flouranthene, pyrene, benzo(a) anthracene, chrysene, benzo(b) flouranthene, and benzo(a) pyrene. Surficial soil samples were not analyzed for volatile organic compounds.	Presently used. The Interim Final Report, Ground-Water Contamination Survey No. 38-26-0872-89 NCAD (1987-1988), recommended that further sampling be conducted in the unsaturated zone and at least one monitoring well be installed in the area. To date no well has been installed. Volatile and semivolatile contamination to the water table has not been addressed.	Moderate. This site is close to Marsh Run Field (i.e., <200 ft). The presence of semivolatile compounds and the absence of volatile organic data present the potential for ground-water contamination of the shallow water table and bedrock regional aquifer near Marsh Run Field. Marsh Run Creek (water quality) may also be impacted by this site.

TABLE 1-3 (Cont.)

Site Name	Type	Usage	Present Condition/Status	Potential Impact to Marsh Run Field
Site 6 Sewage Sludge Disposal Area	Sewage sludge disposal area	From 1977 to 1979, digested sewage sludge was applied to the area along the southern boundary of NCAD, south of Marsh Run Creek.	Land application of sludge ceased in 1979.	Low

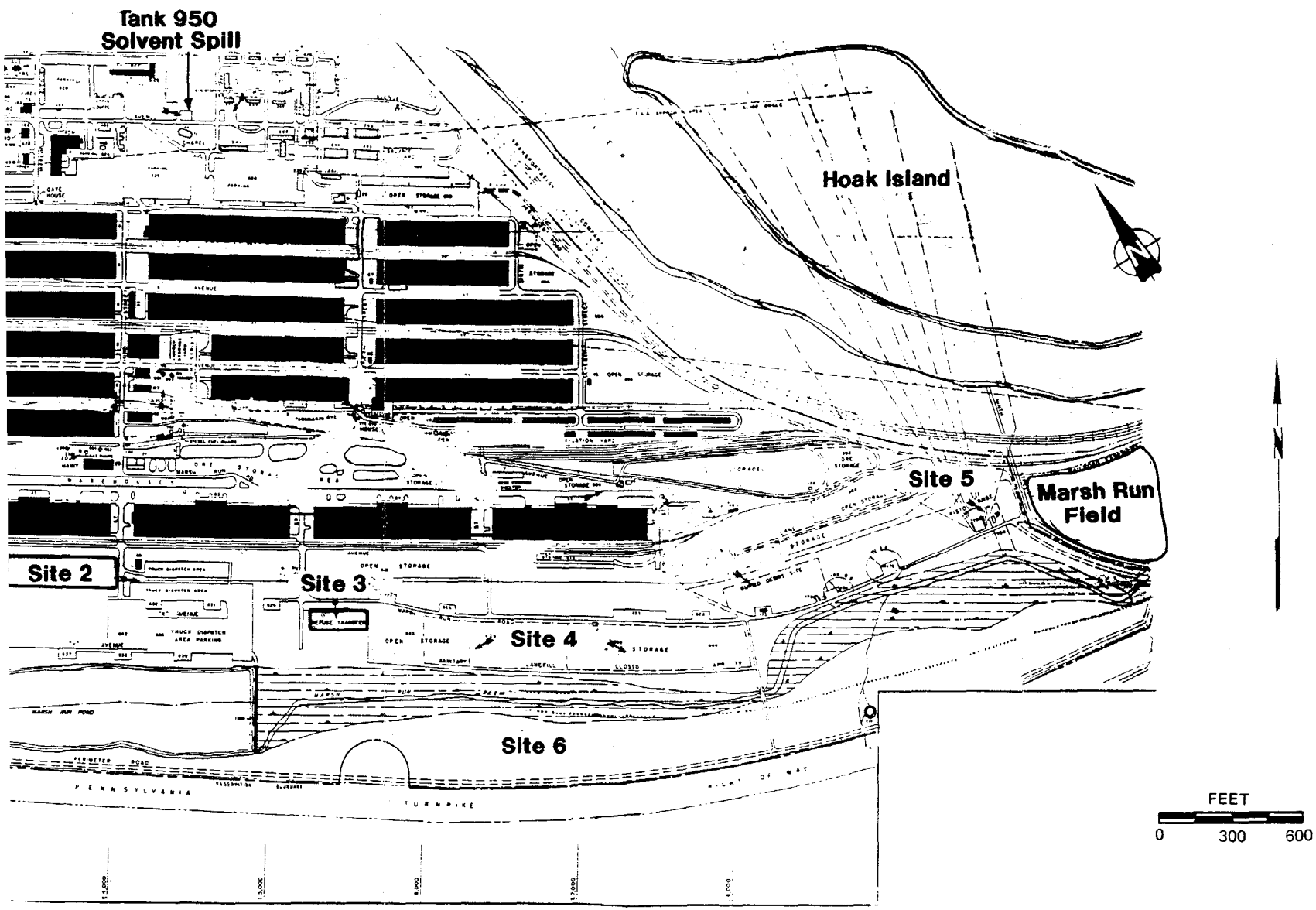


Figure 1-3.

Location map of adjacent solid waste management units. (Source: Interim Final Report, Ground Water Contamination

beneath and adjacent to Marsh Run Field, respectively, may be impacted as a result of singular or cumulative effects of one or more of these sites.

Appendix A summarizes the history of response actions and relevant site investigations. The results of relevant site investigations conducted are discussed in Section 1.2.3.

1.2.3 Previous Investigations

Previous investigations relevant to the site but not site specific were conducted as early as 1977. These early investigations primarily addressed the water quality of Marsh Run Creek, but also evaluated the ground-water quality beneath the depot along the south and southwest portions of NCAD.

The New Cumberland Army Depot has been investigated on several occasions regarding environmental problems and solutions. Results and conclusions of these reports as early as 1979 (CSL 1979) alluded to the potential of contamination introduction into the environment as a result of past disposal practices at the Marsh Run Field landfill. During the Installation Assessment of the New Cumberland Army Depot (CSL 1979), the Marsh Run Field site was identified as a potential candidate for future site-specific environmental impact investigations.

One of the more serious depot-related contaminant releases to the environment occurred in 1981 when an estimated 1,000-2,000 gal of solvents and oil leaked from an underground storage tank (Tank 950). The tank was subsequently removed and a series of monitoring wells were installed to evaluate the extent and magnitude of contamination. The Tank 950 site is situated in the central portion of the depot approximately 1 mi northwest of Marsh Run Field. Results of previous investigations of the Tank 950 spill indicate a south-southeast migration direction of volatile contamination in the overburden [USAEHA 1986; Environmental Science and Engineering, Inc. (ESE) 1987]. Figure 1-3 shows the location of the Tank 950 spill in relation to Marsh Run Field.

Other reports (USAEHA 1986; ESE 1987) indicate a contaminant plume resulting from the Tank 950 leak moving south-southeast. In 1986, volatile chemical compounds, including trans-1,2-dichloroethene, trichloroethene, and toluene, were detected in monitoring wells in excess of several thousand µg/L within 100 ft of the tank spill, and several hundred µg/L 500 ft from the tank spill. This site is presently in a remediation phase of ground-water extraction and treatment. Although based on the inferred ground-water flow path from the Tank 950 leak site investigation report, there is a remote possibility that contamination may migrate along bedrock fracture lineaments under the influence of residential well withdrawal. Movement of ground water from the Tank 950 site in the direction of Marsh Run Field is considered remote, and prior to this RI no confirmation of this scenario was available.

Nearer the site (within 3,500 ft) or along sensitive migration pathways (proximal to eastward flowing Marsh Run Creek), six sites on the depot

property have previously been investigated. These sites may also have an indirect or direct environmental impact on the environs proximal to Marsh Run Field.

Based on previous investigations, it is speculated that the water quality of Marsh Run Creek is affected to some degree by the closed sanitary landfill (Site 4) where leachate emanating from the landfill and discharging to Marsh Run Creek has been found to contain low level PCBs, pesticides, and volatile organics (USAEHA 1978 and 1983). The USAEHA 1978 investigation sampled Marsh Run Creek along sampling points which are depicted in Figure 1-4. Pesticides were detected in sediments adjacent to the Marsh Run Field Site (Sampling Point 7) and further upstream as far as Marsh Run Pond (Figure 1-4). Both reports concluded that Marsh Run Creek was receiving low-level pesticides from the adjacent sanitary landfill on the depot (Site 4) and from previously spread sewage treatment sludge (Site 6).

Figure 1-5 shows the sampling locations from the USAEHA 1983 investigation. Table 1-4 summarizes the compounds detected from those sampling locations. The results of this investigation suggested that pesticide was still being contributed to the stream sediments from adjacent sources. Several volatile organic compounds were also detected in surface water and leachate samples collected during this investigation. The closed sanitary landfill on the depot was identified as a potential source of volatile constituents.

A 1986 water quality study (USAEHA 1986) concluded that the leachate was sufficiently diluted in Marsh Run Creek and had little effect on the water quality of Marsh Run Creek.

Another site of particular interest is the Firefighting Training Area (Site 5). This area, which is shown in Figure 1-3, is on the depot property immediately to the northwest of Marsh Run Field. This site was previously sampled in August 1988 in preparation for the Interim Final Report, Ground-Water Contamination Survey No. 38-26-0872-89 NCAD, 14-17 December 1987 and 4-5 August 1988. One soil sample revealed low levels of several semivolatile compounds, including phenanthrene, flouranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)flouranthene, and benzo(a)pyrene. No analysis for volatile constituents was conducted. Subsequently, no investigative activities were targeted toward potential shallow ground-water quality. Coincidentally, the 1988 report recommended the installation of at least one monitoring well. The Firefighting Training Area is considered to present a low-to-moderate potential for adverse environmental impact on the Marsh Run Field site environs.

The environmental investigations conducted in the past 12 years on areas adjacent to Marsh Run Field, but not specific to Marsh Run Field, are summarized below.

U.S. Army Environmental Hygiene Agency (USAEHA). 1977. Solid Waste Management Consultation No. 61-0149-78, Sanitary Landfill Evaluation, New Cumberland Army Depot, New Cumberland, Pa. Aberdeen Proving Ground, Md.

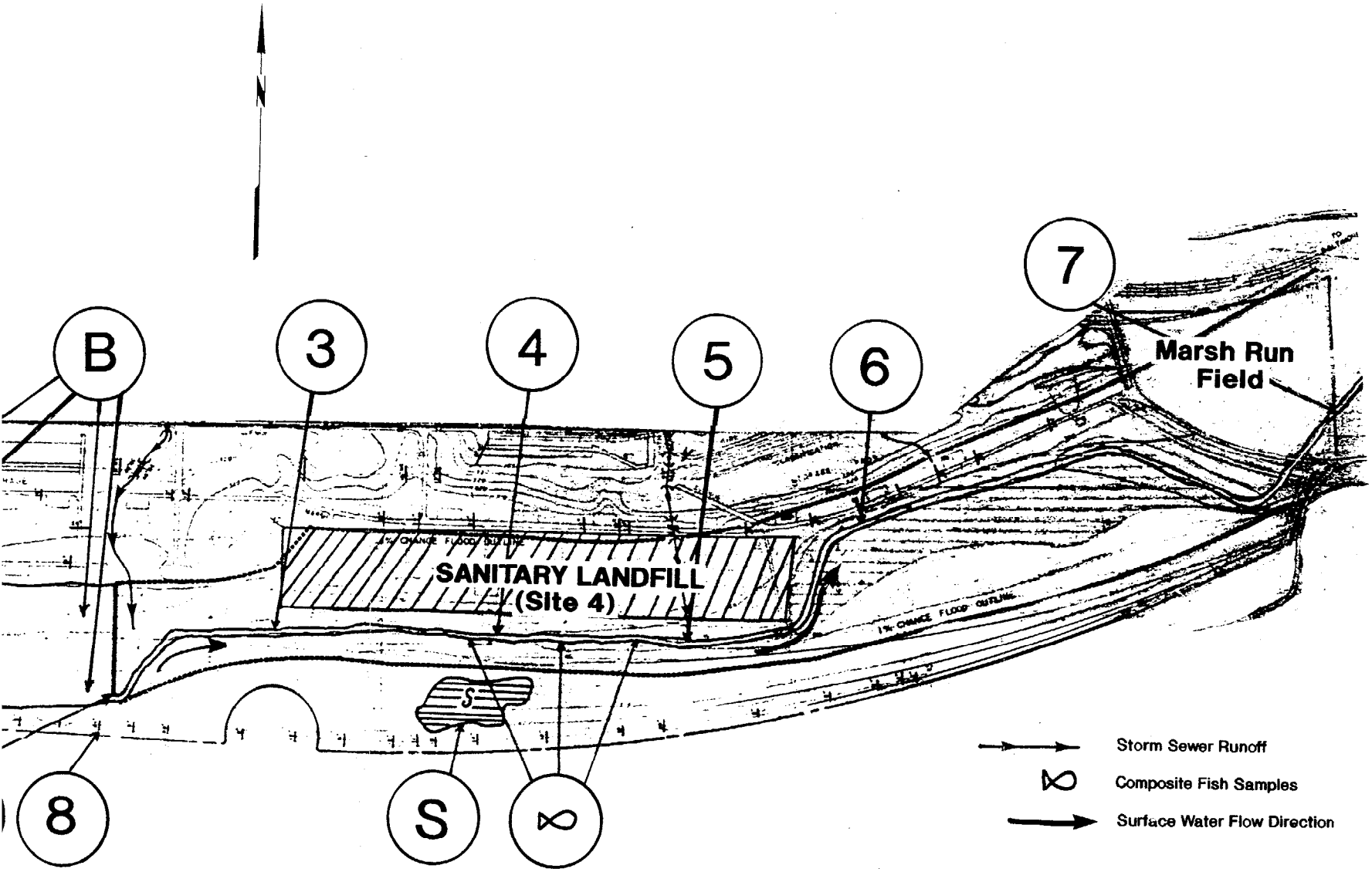


Figure 1-4.

Marsh Run Creek sediment/surface water sample points during water quality engineering Sp Study No. 32-61-073-79, NCAD, New Cumberland, PA, 23 December 1978.

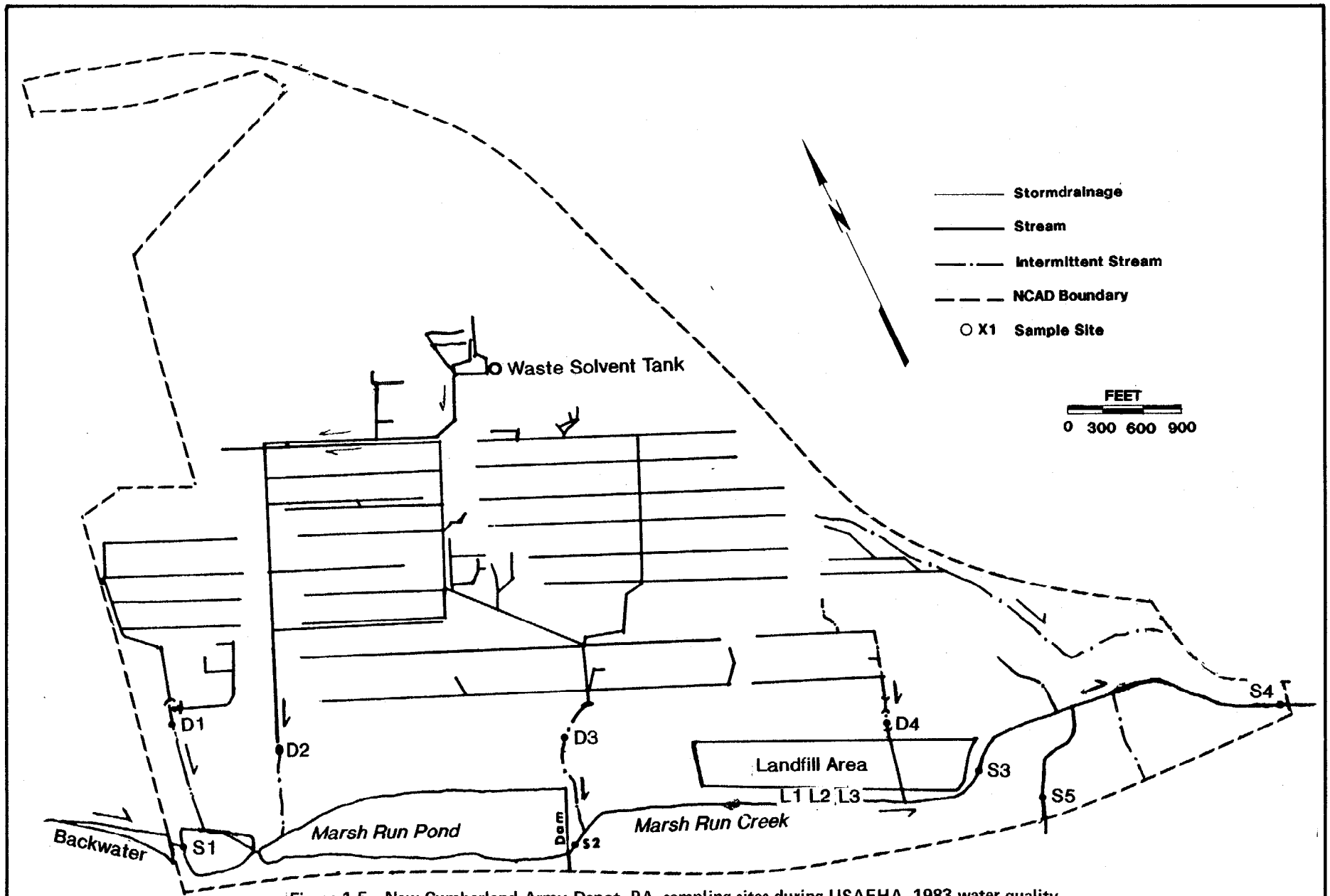


Figure 1-5. New Cumberland Army Depot, PA, sampling sites during USAEHA, 1983 water quality biological study investigation. (Source: USAEHA, 1983).

TABLE 1-4 LIST OF CHEMICAL COMPOUNDS DETECTED IN MARSH RUN CREEK AND ADJACENT AREA DURING SURVEY OF MARSH RUN CREEK (Source: USAEHA 1983)

Compound Detected	Highest Concentration of Compound Detected in Environmental Samples
Benzene	3 ppb (Leachate Sample L2)
Chloroethane	5 ppb (Leachate Sample L2)
Chlorobenzene	3 ppb (Leachate Sample L3)
Chloroform	15 ppb (Marsh Run Creek S1)
1,2-Dichloroethene (Trans)	3 ppb (Leachate Sample L2)
Ethyl Benzene	8 ppb (Leachate Sample L2)
1,1,2,2-Tetrachloroethane	12 ppb (Storm Drainage D4)
Tetrachloroethylene	4 ppb (Storm Drainage D4)
Trichloroethylene	22 ppb (Storm Drainage D1)
Toluene	7 ppb (Leachate Sample L2)
Vinyl Chloride	5 ppb (Leachate Sample L2)
O,P'-DDD	0.05 ppm (Leachate Sample L3)
P,P'-DDD	0.17 ppm (Leachate Sample L3)
P,P'-DDE	0.08 ppm (Leachate Sample L3)
P,P'-DDT	0.1 ppm (Leachate Sample L3)

New Cumberland Army Depot, Facilities Engineering Division. 1978. Installation Environmental Impact Assessment for New Cumberland Army Depot. New Cumberland, Pa.

U.S. Army Environmental Hygiene Agency (USAEHA). 1978. Water Quality Engineering Special Study No. 32-61-0173-79, New Cumberland Army Depot, New Cumberland, Pa. Aberdeen Proving Ground, Md.

Chemical Systems Laboratory (CSL). 1979. Installation Assessment of New Cumberland Army Depot, Pa. Aberdeen Proving Ground, Md. (USATHAMA).

U.S. Army Environmental Hygiene Agency (USAEHA). 1982. Geohydrologic Study No. 38-26-0202-82, New Cumberland Army Depot, New Cumberland, Pa. Aberdeen Proving Ground, Md.

Environmental Science and Engineering, Inc. (ESE). 1983. Installation Reassessment of Headquarters, NCAD, Pa. Gainesville, Fl. Report No. 131R.

U.S. Army Environmental Hygiene Agency (USAEHA). 1983. Water Quality Biological Study No. 32-24-0406-84, Survey of Marsh Run Creek, NCAD, Pa. 25 July - 5 August 1983.

U.S. Army Environmental Hygiene Agency (USAEHA). 1986. Follow-up on Water Quality Biological Study 32-24-0406-84, NCAD, Pa. 8 April 1986.

U.S. Army Environmental Hygiene Agency (USAEHA). 1986. Groundwater Contamination Migration Study No. 38-26-0550-87, NCAD, New Cumberland, Pa. 2-9 June 1986.

Environmental Science and Engineering, Inc. (ESE). 1987. Update of the Installation Reassessment of New Cumberland Army Depot.

U.S. Army Environmental Hygiene Agency (USAEHA). 1988. Interim Final Report, Ground-Water Contamination Survey No. 38-26-0872-89, NCAD, New Cumberland, Pa. 14-17 December 1987 and 4-5 August 1988.

Although these investigations addressed areas adjacent to the Marsh Run Field site, no site-specific data were developed from these reports. It can therefore be assumed that there is at least a potential that the singular or cumulative effect of these sites may adversely impact the Marsh Run Field environmental conditions. However, in order to evaluate the singular or cumulative effect, if any, of the peripheral sites and the contribution of contamination to the environment from Marsh Run Field, an initial site-specific study (i.e., Confirmation Study) was conducted as part of DERP. The study was conducted in 1987 by Woodward-Clyde and a final report was completed in March 1988. Until the performance of

this Remedial Investigation, the Woodward-Clyde Confirmation Study constituted the only Marsh Run Field site-specific database.

The Confirmation Study consisted of the installation of three shallow (overburden) monitoring wells, five test pits excavated within the property boundaries (three inside the fill and two outside obvious fill material), and soil and stream sediment samples collected from Marsh Run Creek. Figure 1-6 shows the sampling points from the Confirmation Study.

All soil and sediment samples from the Marsh Run Field site were analyzed for petroleum hydrocarbons, total metals, and volatile organics. Soil samples obtained from test pits were also analyzed in addition to the above parameters for base/neutral and acid (BNA) extractable organics and cyanide.

Results from sample analyses show that soils collected from test pits located within the landfill (TP-3, TP-4, and TP-5) (Figure 1-6) and sediment samples from areas surrounding the landfill all contained detectable levels of petroleum hydrocarbons, with concentrations varying from 120 ppm in TP-5 to 470 ppm in SD-1. BNA extractable organics, mainly chlorinated solvents and polyaromatic hydrocarbons (PAHs), were detected in test pit samples from within the landfill. Concentrations ranged from 4.1 ppm of 1,2,3,5-tetrachlorobenzene to 55.0 ppm of phenanthrene. Trace concentrations of volatile organics (24 ppb of chloroform) were found in only one sample, TP-3. Stream sediment samples (i.e., SD-1 through SD-4) exhibited no detectable concentrations of volatile or semivolatile compounds, with the exception of the laboratory artifacts methylene chloride and acetone.

In summary, findings of the Confirmation Study indicated the presence of semivolatile compounds, cyanide, and petroleum hydrocarbons in soil samples collected within the landfill confines. Arsenic, barium, copper, mercury, zinc, cadmium, lead, and silver were also detected in several soil samples collected onsite (i.e., test pit samples).

The ground-water samples from the monitoring wells were analyzed for petroleum hydrocarbons, volatile organics, and dissolved metals. A ground-water sample collected from MW-1A was found to contain 26 ppm trans-1,2-dichloroethane and 5 ppb trichloroethene. Elevated levels of dissolved barium, manganese, copper, cobalt, magnesium, lead, and nickel were also detected in monitoring well samples collected from MW-2A and MW-3A. Monitoring well ground-water samples were not analyzed for semivolatile compounds; consequently, the presence or absence of these compounds in the ground water was not determined. Table 1-5 lists the various chemical compounds detected in sample matrices collected during the 1987 Confirmation Study.

As a follow-up to the Confirmation Study, 23 discrete surficial soil samples were collected by the U.S. Army Corps of Engineers and the EPA on 25 May and 22, 23 June 1988, respectively. These samples were collected for the purpose of evaluating human health risk associated with

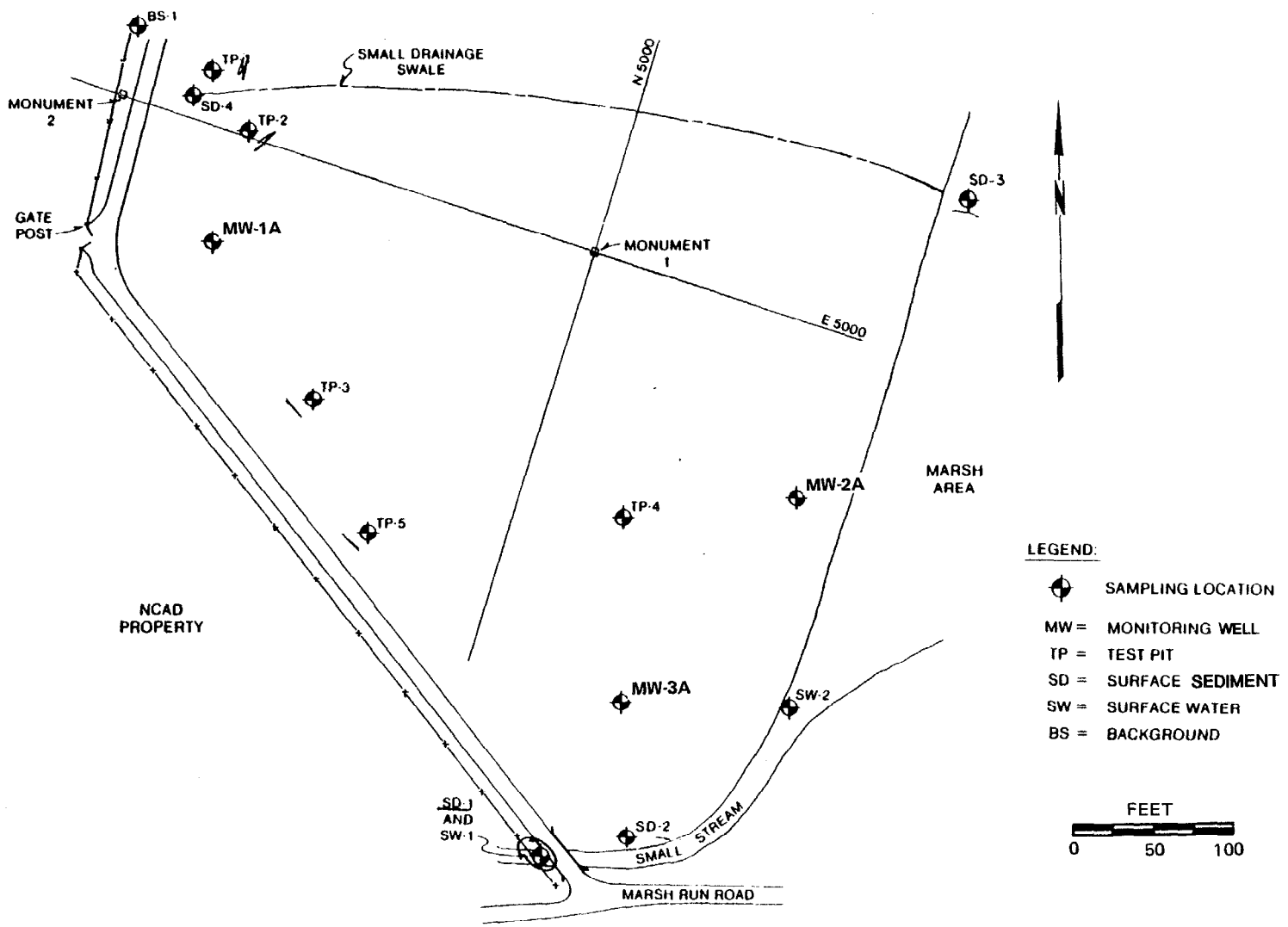


Figure 1-6. Confirmation study sampling points. (Source: Woodward–Clyde, 1987)

TABLE 1-5 LIST OF CHEMICAL COMPOUNDS DETECTED AT MARSH RUN FIELD DURING THE CONFIRMATION STUDY (Source: Woodward-Clyde 1988)

Compound	Highest Concentration of Compound Detected in Environmental Samples
Arsenic	20 ppm (test pit #5) 10 ppm (surface sediment, SD-3)
Barium	663 ppm (test pit #5) 101 ppm (surface sediment, SD-3)
Cadmium	6.9 ppm (ground water, MW-1A) 6.3 ppm (test pit #3) 0.92 ppm (surface sediment, SD-3)
Chloroform	24 ppb (test pit #3)
Copper	128 ppb (ground water, MW-3A) 261 ppm (test pit #5)
Cyanide	0.32 ppm (test pit #5)
Dibenzofuran	2 ppm (test pit #5)
1,3-Dichlorobenzene	250 ppb (test pit #3)
Trans-1,2-dichloroethene	26 ppb (ground water, MW-1A)
Trichloroethene	5 ppb (ground water, MW-1A)
Hexachlorobenzene	470 ppb (test pit #3)
Lead	66 ppb (ground water, MW-3A) 4,060 ppm (test pit #5) 72 ppm (surface sediment, SD-3)
Mercury	0.68 ppm (test pit #4)
Naphthalene	1,900 ppb (test pit #5)
Pentachlorobenzene	670 ppb (test pit #3)
Pentachlorophenol	2,800 ppb (test pit #3)
PAHs (coal tar pitch volatiles)	341 ppm (test pit #5)
Silver	67 ppm (test pit #4)

TABLE 1-5 (Cont.)

Contaminant	Highest Concentration of Contaminant Detected in Environmental Samples
1,2,4,5-Tetrachlorobenzene	41 ppm (test pit #3)
1,2,4-Trichlorobenzene	650 ppb (test pit #3)
Zinc	2,380 (test pit #5) 60 ppb (ground water, MW-3A) 101 ppm (surface sediment, SD-3)

the surface soils on the field. Tables 1-6 and 1-7 summarize the compounds detected in these surficial samples. Figure 1-7 shows the appropriate location of the surficial samples.

TABLE 1-6 RESULTS OF CHEMICAL ANALYSIS OF SURFACE SOILS COLLECTED BY USACE AT MARSH RUN FIELD, ON 25 MAY 1988
[all values in mg/kg (ppm)]

Analyte	CRDL[a]	SS1	SS2	SS2D	SS3	SS4	SS5	SS6	SS7	SS8	SS8D
Fluoranthene	0.33					0.16	0.85	0.78		8.10	4.84
Pyrene	0.33					0.14	1.16	0.64		6.86	4.10
Phenanthrene	0.33					0.16	0.51	0.45		7.15	3.63
Naphthalene	0.33						0.06			0.41	0.08
2-Methylnaphthalene	0.33						0.08			0.26	0.06
Anthracene	0.33					0.03	0.03			1.49	0.70
Chrysene	0.33						0.52	0.39		3.97	1.93
Benzo(a)anthracene	0.33						0.39	0.35		4.20	1.97
Indeno(1,2,3-c-d)pyrene	0.33							0.16		1.93	0.75
Benzo(g,h,i)perylene	0.33							0.18		2.05	0.80
Acenaphthene	0.33									0.96	0.38
Fluorene	0.33									0.98	0.42
Benzo(b)fluoranthene	0.33									2.04	0.90
Benzo(a)pyrene	0.33									3.33	1.41
Benzo(k)fluoranthene	0.33									1.77	0.89
Dibenzo(a,h)anthracene	0.33									0.78	
Dibenzofuran	0.33									0.58	0.22
Diethylphthalate	0.33	0.10	0.17	0.011	0.08	0.19	0.08			0.08	0.07
Di-n-butylphthalate	0.33	0.56	0.84	0.63	0.38	1.12	0.47	0.91	0.99	0.62	0.57
Bis(2-ethylhexyl)phthalate	0.33			0.61		0.69	1.27	1.60	1.89		0.94
Antimony	12.										
Arsenic	2.	4.23	6.93	6.79	6.36	2.77	6.81	3.93	4.19	6.22	5.63
Beryllium	1.										
Cadmium	1.										
Chromium	2.	9.03	8.88	9.28	3.33	14.60	4.23	13.40	14.80	8.36	16.60
Copper	5.	10.90	18.70	19.70	16.60	12.80	13.40	5.29	9.38	39.90	37.50
Lead	1.	10.80	12.50	14.10	130.00	25.10	73.70	21.90	15.30	44.00	32.70
Mercury	0.04	0.34	0.08	0.15	0.13	0.14	0.36	0.19	0.13	0.40	
Nickel	8.	10.30	14.00	15.10	4.82	12.40	4.74	10.60	10.80	8.87	11.70
Selenium	1.				0.18	0.12	0.17	0.08	0.16	0.10	0.11
Silver	2.										
Thallium	2.										
Zinc	4.	36.70	48.20	50.20	77.90	56.60	80.10	45.70	39.90	57.70	73.50
Cyanide	0.25[b]										

(a) Contract Required Detection Limit
(b) Actual Detection Limit
Source: U.S. ACE 1988

TABLE 1-7 SUMMARY OF ANALYTICAL RESULTS FROM SURFICIAL SOIL SAMPLES COLLECTED BY EPA TAT AT MARSH RUN FIELD ON 22, 23 JUNE 1988
[all values in mg/kg (ppm)]

Compound	Detection Limit	mg/kg (ppm)														
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S51	S52	S61	S62
1,2-Dichloroethene	0.5													9.4		
Trichloroethene	0.5												0.66	2.6		
Tetrachloroethene	0.5													2.6		
Toluene	0.5													0.20		
Xylenes, total	0.5													0.13		
2-Methylnaphthalene	0.33			0.22												
Naphthalene	0.33			0.40												
Acenaphthene	0.33			0.92												
Phenanthrene	0.33			1.9												
Fluoranthene	0.33			7.3			0.36	1.1								
Pyrene	0.33			6.6			0.32	0.79								
Chrysene	0.33			4.6												
Benzo(b)fluoranthene	0.33			8.3												
Benzo(k)fluoranthene	0.33			7.3												
[1,2-B] Pyridine 5H-Indeno	0.33			0.72												
Beryllium	2.5															
Cadmium	0.5	5.5	4.6	5.6	3.6	3.8	3.09	5.05	1.02	3.6	5.7	3.6	5.1	7.7	5.05	3.6
Chromium	1.0	3.5	4.1	33	3.06	1.5	5.7	7.6	2.6	5.7	7.4	8.7	9.7	49	5.05	5.7
Copper	1.0	17	15	797	11	26.6	5.15	29	1.5	8.8	16	12	98	185	11	8.8
Nickel	2.0	12	8.8	13	8.2	4.0	2.0	12	4.08	7.2	9.6	12	12	14	6.6	7.2
Lead	1.0	36	48	1,080	32	175	38	44	28	35	66	55	68	1,020	68	35
Zinc	0.5	49	48	1,510	35	116	29	55	19	32	46	75	209	399	28	32
Arsenic	0.5	1.5	0.67	2.4	0.83	1.3	0.70	1.3	0.58	1.0	1.5	0.57	1.2	2.6	0.56	0.95
Silver	0.5			5.6				1.5								
Antimony	10.0															
Selenium	0.5	2.3	0.81	3.8	0.60	1.4	0.95	1.2	0.63	2.4	1.9	0.81	1.5	1.9	1.7	1.5
Thallium	5.0	12		13		16						17		11	9.6	
Mercury	0.05		0.05	0.07						0.32	0.05	0.07		0.09	0.09	0.06
Cyanide	0.35			1.75								0.45		1.0		

Source: U.S. EPA 1988

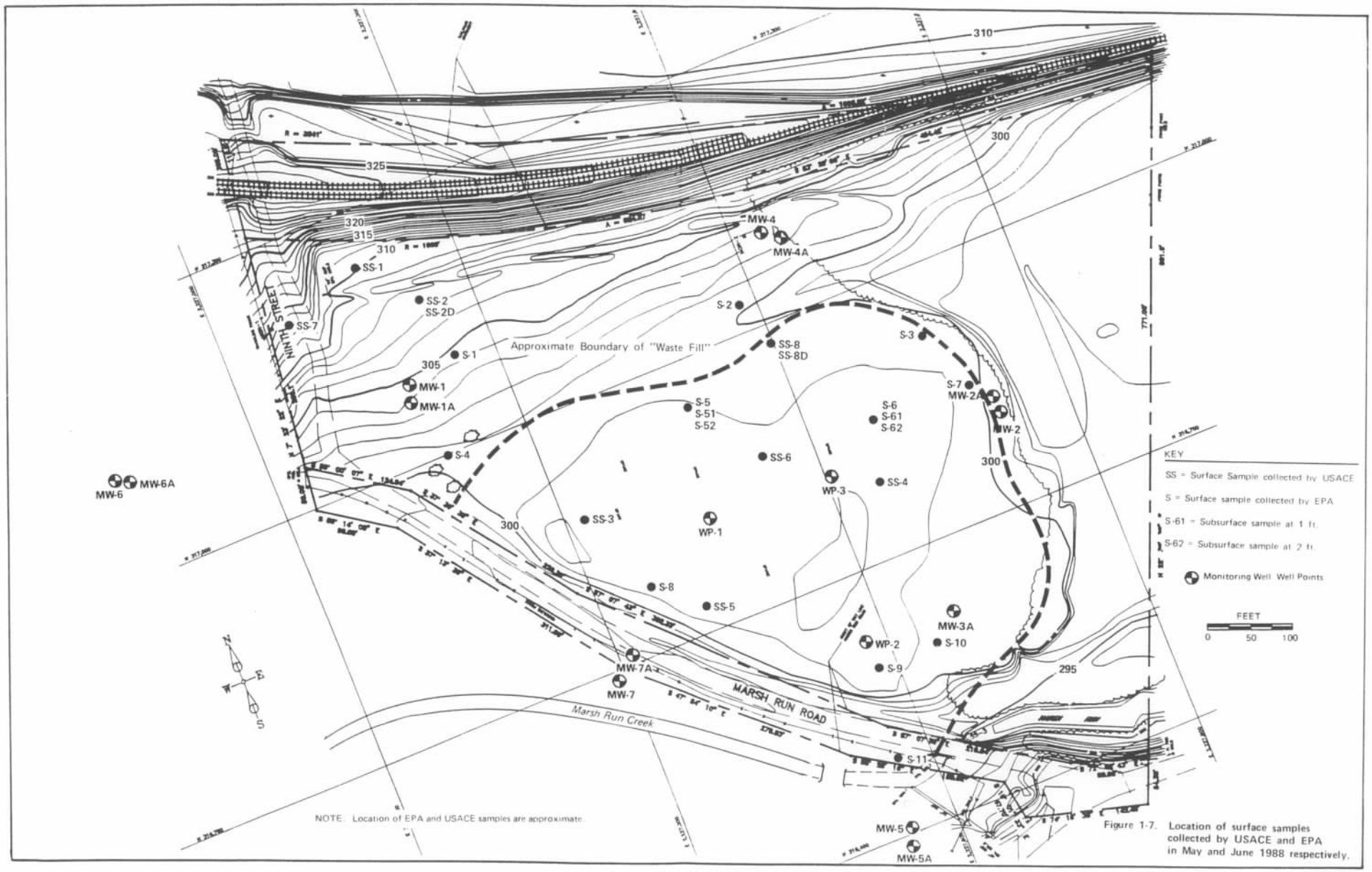


Figure 1-7. Location of surface samples collected by USACE and EPA in May and June 1988 respectively.

2. STUDY AREA INVESTIGATION

2.1 FIELD INVESTIGATION ACTIVITIES

The Remedial Investigation (RI) of the New Cumberland Army Depot's former landfill, Marsh Run Field, employed a variety of field investigative techniques in the performance of the site investigation. These techniques included geophysical surveying, monitoring well installation, monitoring well sampling, well point installation, in situ hydraulic conductivity analysis by slug test method, household supply well sampling, and surface water and sediment sampling.

The site investigation was conducted in two phases. The first phase was initiated by the geophysical investigation and followed by subsequent installation of five new monitoring wells to supplement the existing three site wells installed during a 1987 Confirmation Study. In addition, stream surface water/sediment samples, and monitoring well soil and ground-water samples were collected and analyzed. The first phase was conducted between October 1988 and February 1989. Pursuant to the examination of the preliminary chemical analysis of ground water at the site and a review of previous investigations, a second phase of monitoring well installation and environmental sampling was conducted between July and August 1989.

The second phase of the site investigation consisted of the installation of an additional five perimeter monitoring wells and three well points installed within the landfill waste material. A second sampling event included these new monitoring wells, two of the three well points, four selected household supply wells adjacent to the site, the first phase monitoring wells, and three existing Confirmation Study wells. One additional sediment/surface water sample was collected further upstream of the site in Marsh Run Creek.

Prior to the performance of the RI, minimal data existed for the Marsh Run site. EA's planned approach was to assess and build upon the available database. A description of the various field techniques employed and the rationale for their use are discussed in this Chapter. Figure 2-1 (site sampling plan) depicts the sampling locations across the site.

2.1.1 Geophysical Survey

As part of the Marsh Run RI, a geophysical investigation was performed in October 1988. The primary objectives of the geophysical survey were to:

1. Assess the electromagnetic conductivity of the fill for purposes of waste characterization, relative depth determinations, and areal extent of fill.

2. Identify conductivity anomalies situated along the site perimeter that could be associated with potential inorganic (i.e., metals, salts) contamination in the shallow ground water.

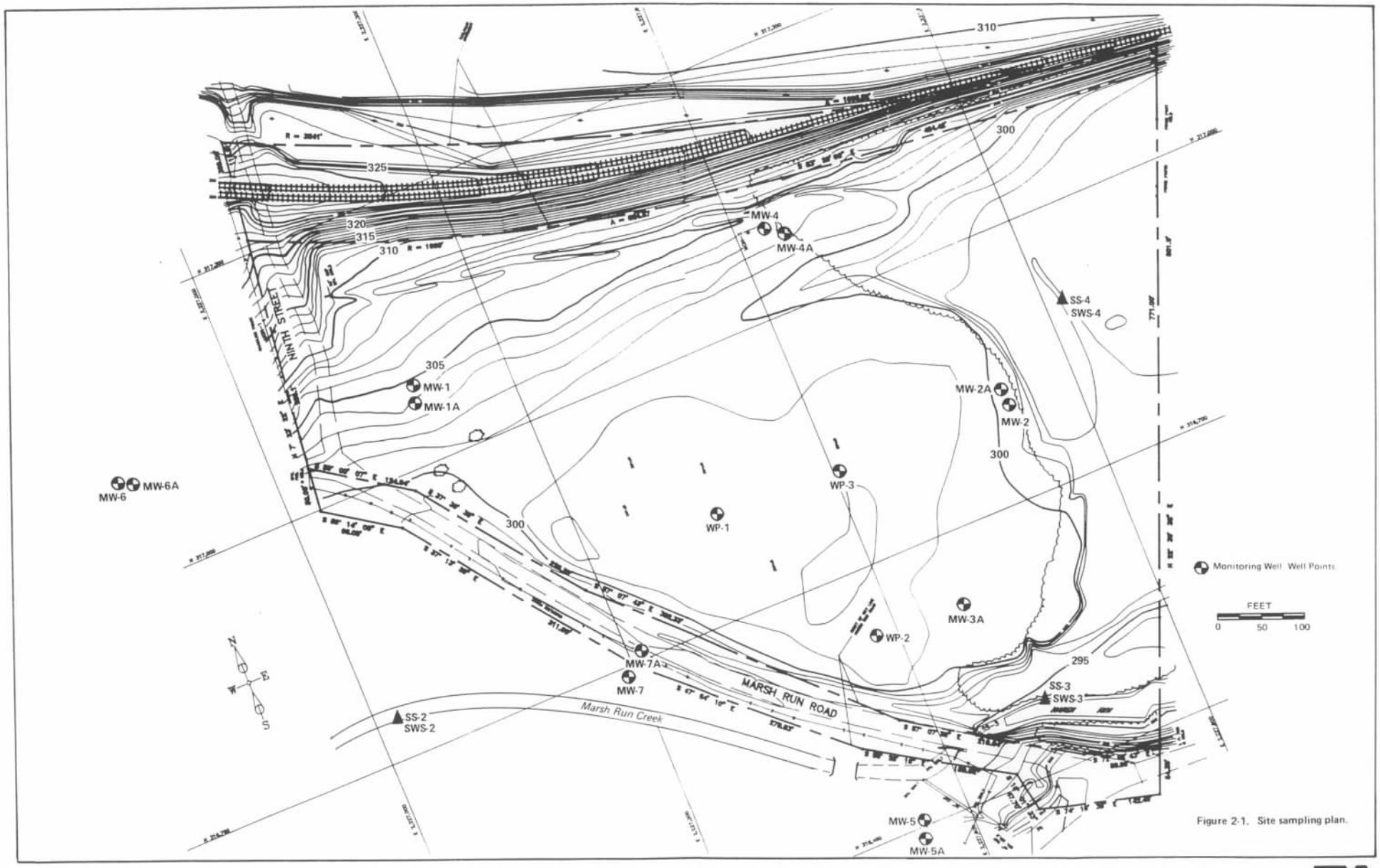


Figure 2-1. Site sampling plan.

3. Contrast fill thickness and electrical properties with those of local *in situ* geologic materials.

In an effort to meet the above-stated objectives, electromagnetic terrain conductivity (EM) survey was employed. The Geonics Ltd. EM-34-3L Terrain Conductivity instrument was chosen for the EM survey because of its relative ease of operation as well as its suitability for anticipated depths of penetration needed for shallow-depth (i.e., <50 ft) aquifer analysis.

The electromagnetic survey measures the apparent electrical conductivity-induced magnetic field of the subsurface materials below the survey line. The individual secondary magnetic field of the subsurface material is measured along with the primary magnetic field produced by the instrument itself. When traversing relatively open terrain with few cultural interferences (e.g., utilities, power lines, and buildings) or interference from open terrain over landfills and disturbed earth, high electromagnetic conductivity anomalies are typically associated with one of the following scenarios: (1) concentrations of ionic constituents (i.e., metals or salts) above ambient levels in ground water, (2) an assemblage of metals or metal-rich material (i.e., drums, metal debris, ash, etc.), (3) increased clay content or water content from increased porosity, and/or (4) increased thickness of any of the above.

The geophysical survey and all subsequent RI investigations were referenced to a 100 x 100 ft grid established onsite. The grid was oriented parallel and perpendicular to Monument 1 and Monument 2, which were previously established by Woodward-Clyde Consultants during the Confirmation Study. The Marsh Run Field site was traversed along northeast-southwest traverse lines which were spaced parallel to each other at 50-ft intervals. Two readings were obtained at each station. Each station was located 33 ft apart along each traverse line. Readings were obtained with coil separation running parallel to the traverse lines. The survey was conducted over the fill utilizing a 10-m intercoil spacing in both the horizontal and vertical dipole modes yielding effective depths of penetration of 7.5 m and 15 m, respectively. Where possible, the survey was conducted offsite, in particular to the north where the fill/no-fill boundary was indefinite, and to the south and southwest onto the base in the vicinity of Marsh Run Creek. Figure 2-2 shows the site grid and orientation of geophysical traverse lines.

Pursuant to the field survey, the data were reduced in the form of lateral profiles, contour maps, and three-dimensional net graphs.

2.1.2 Geologic Investigation

The local geology in the vicinity of the site was characterized by soil samples and rock cores obtained from monitoring well borings conducted during the RI. Monitoring well boring logs are provided in Appendix A.

Rock coring was performed with a 10-ft-long NX wire-line double, split-barrel coring device. Core runs were continuously obtained at 10-ft intervals. Upon retrieval, each core was logged and placed in a secure container.

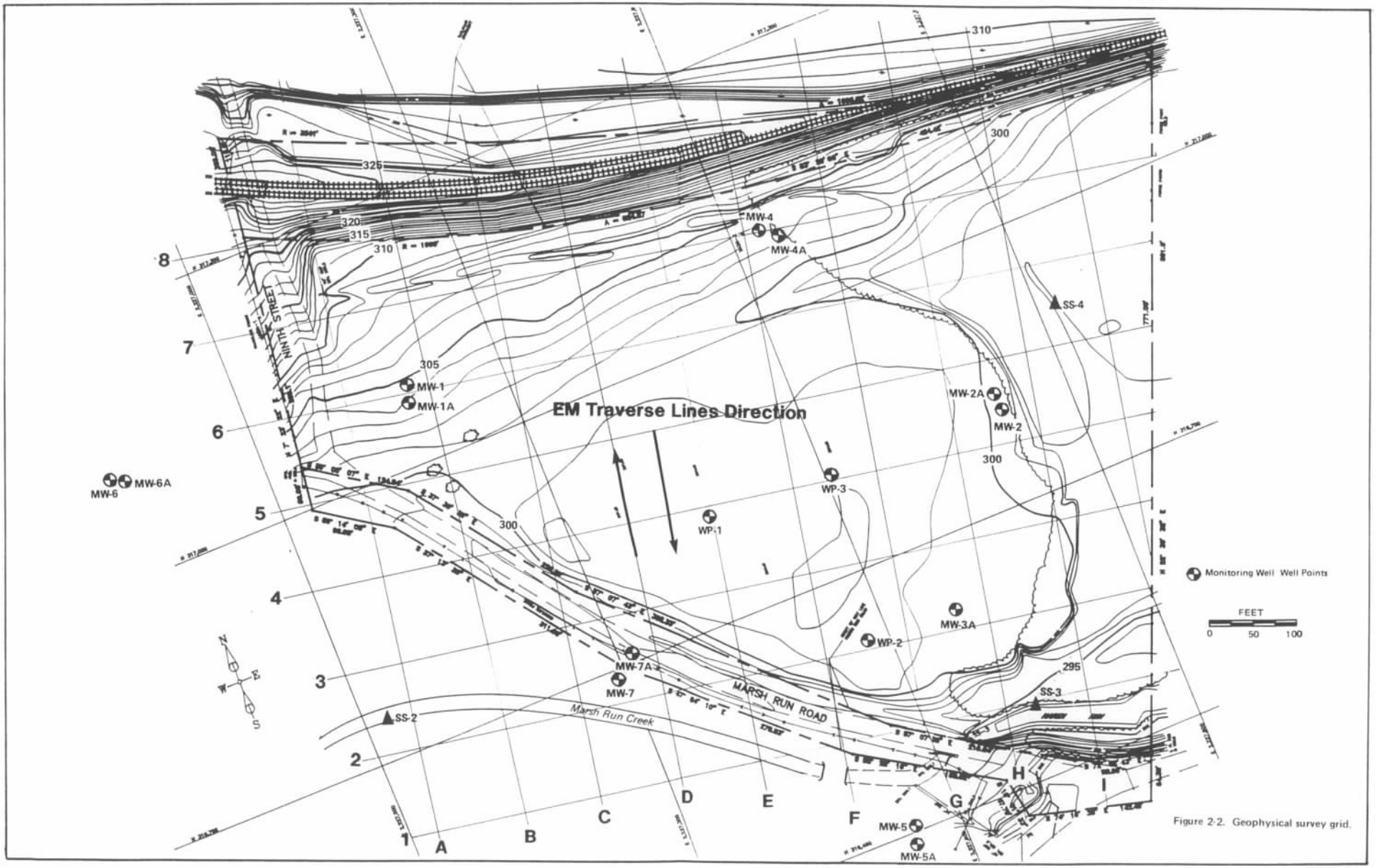


Figure 2-2. Geophysical survey grid.

In addition to collected rock cores, subsurface fractures in the bedrock were identified by the relative increases in drilling rates, and by the observation of additional formation water discharging from the boring during air rotary drilling.

In situ soils were characterized by the shallow portion (i.e., overburden drilling) of the monitoring well borings. Samples were collected with a 2-in. OD, 1.37-in. ID, split-spoon sampler.

2.1.3 Ground-Water Investigation

The history of site activities has given rise to concern for contamination of ground water within the unconsolidated zone (overburden) and the bedrock aquifer beneath the site. The ground-water monitoring program was designed to assess whether and to what degree toxic or hazardous materials have contaminated the ground water as a result of past facility operation. The monitoring well installation consisted of a two-phase approach (Phase I and Phase II).

2.1.3.1 Monitoring Well Installation

The first phase of monitoring well installation was conducted between 11 and 20 January 1989. A total of five monitoring wells (MW-1, MW-4, MW-4A, MW-5, and MW-5A) were installed onsite as depicted in the site plan (Figure 2-1). Two overburden (shallow) wells, MW-4A and MW-5A, were installed to a depth of 15 ft. These two new wells were installed to compliment the three existing shallow site monitoring wells (MW-1A, MW-2A, and MW-3A), and to define the water-table surface and assess the ground-water quality of the shallow unconsolidated overburden. Additionally, three deep bedrock wells (MW-1, MW-4, and MW-5) were installed as cluster companions of three shallow wells (MW-1A, MW-4A, and MW-5A) to assess the vertical hydraulic gradient between the saturated overburden and bedrock aquifer, to determine the potentiometric configuration of the bedrock aquifer at a nominal depth of 50 ft, and to provide samples for assessment of ground-water chemical quality of the bedrock aquifer-derived ground water. Phase I monitoring well placement was based on the assumption that bedrock aquifer flow patterns were from south to north following the regional topography toward the Susquehanna River. Shallow overburden ground-water flow patterns were less predictable and were anticipated to be radial or semiradial (as indicated by the Woodward-Clyde Confirmation Study) and controlled somewhat by Marsh Run Creek and the Susquehanna River.

In light of the preliminary assessment of Phase I geologic and ground-water chemical data, a second phase of monitoring well installation proceeded in July 1989. The suspected flow patterns used to justify the Phase I monitoring wells were somewhat confirmed by the Phase I monitoring well data. Further refinement of the site hydrogeologic scenario was to be accomplished by the Phase II well placement. Five additional monitoring wells were installed. Bedrock wells MW-2, MW-6, and MW-7 were installed at a 50-ft depth each. Overburden wells MW-6A and MW-7A were

installed as cluster companions of MW-6 and MW-7, respectively. These additional wells were located as a result of the Phase I preliminary conceptualization of local ground-water flow patterns to best supplement the existing data.

Other contributing factors to the Phase II well placement were the suspected influence from potential offsite sources on the chemical characteristics of the ground water beneath the site. The impact of these potential sources (discussed in Section 1.2.3, Previous Investigations) to the site environs were addressed by the additional upgradient bedrock wells MW-1 and MW-6. Overburden monitoring well MW-7A was placed to intercept shallow ground water prior to its discharging into Marsh Run Creek. MW-6A was placed to assess shallow ground water at the closest identified potential offsite source (Fire Fighting Training Area, Site 5).

Additionally, three well points (WP-1, WP-2, and WP-3) were placed in the landfill waste material; locations are shown in Figure 2-1. The purpose of the well points was twofold. First, the mounding configuration of shallow ground water within the fill confines was to be refined; and second, the shallow ground-water quality of water directly beneath and in contact with the fill material could be analyzed. With these objectives in mind, all three well points were located in the waste material; specifically, WP-1 and WP-3 were situated within high geophysical anomalies. Only WP-1 and WP-3 were sampled. WP-2 was strictly used as a water-level data point.

A total of four overburden monitoring wells were installed during Phase I and Phase II drilling activities. The overburden monitoring well construction and monitoring well-boring soil sampling protocols were as follows:

1. The boring was a minimum of 8 in. in diameter to permit at least 2 in. of annular space between the boring wall and all sides of the centered riser and screen. Unconsolidated overburden was sampled continuously to 10 ft, and at 5 ft thereafter with split-spoon sampler. Samples of the overburden were collected for chemical and physical analysis in the following manner.

   From each shallow well, three soil samples were collected for chemical analysis. A discrete sample was taken of the cover fill material (i.e., 0-2 ft). A second discrete sample was collected from the landfill or other fill material. In the cases of MW-5A, MW-6A, and MW-7A, which were outside the landfill's boundary, no landfill material was encountered; however, some road fill was encountered and collected as a fill sample. In the landfill proper, the MW-4A boring penetrated only 4 ft of relatively inert fill (i.e., clay and gravel). Consequently, at this location a discrete sample was collected of the fill material, and a third discrete sample of the natural <u>in situ</u> residual material below the landfill or

other fill was collected in all overburden monitoring well borings. Samples were screened for volatiles with an Hnu-PID. In addition, at least one sample was collected and analyzed from each Phase I monitoring well for physical characteristics. Table 2-1 summarizes the sampling scheme and analytical parameters for the shallow overburden monitoring well soil samples collected during Phase I and Phase II.

2. The well riser was constructed of new, threaded, 2-in. inside diameter, Schedule 40, flush joint, polyvinyl chloride (PVC) pipe.

3. The well screen was 10 ft in length and was constructed of the same size and strength PVC material as the well riser. The screen consisted of noncontaminating No. 10 slot (0.010 in.), factory constructed. The screen was positioned in the borehole on top of the bedrock-overburden interface so that any nonaqueous phase that might occur on top of the water table would be intercepted.

4. Filter-pack material was placed around and 2 ft above the screened portion of each well. Filter pack was composed of clean, washed, bagged, No. 2, graded fine, silica sand (40 mesh).

5. A 2-ft seal, consisting of tamped bentonite pellets, was placed into the annular space between the riser and boring wall immediately above the filter pack. The placed pellets were hydrated with aquifer water obtained from the borehole prior to grouting. Cement grout was placed from the top of the bentonite seal to the ground surface. The cement grout consisted of a mixture of portland cement (ASTM C 150) and water in the proportion of not more than 7 gal of clean water per bag of cement (1 ft^3 or 94 lb). Additionally, 3 percent of bentonite powder by weight was added.

6. Coordinates and elevations were established for each monitoring well. The horizontal coordinates were to the closest 0.1 ft and referenced to Monument 1 or Monument 2, which were established in the final Confirmation Study, and to the Pennsylvania State Planar Coordinate System. A ground elevation to the closest 0.01 ft and an elevation for the top of the casing to the closest 0.01 ft were surveyed at each well. These elevations were referenced to the National Geodetic Vertical Datum of 1929.

7. A 6-in. outer, protective steel casing was installed a minimum of 3 ft below the surface and 2.5 ft above the surface. It was surrounded by a 3 x 3 ft, 4-in.-thick concrete pad with three protective posts embedded in it.

TABLE 2-1 SUMMARY OF SOIL SAMPLES COLLECTED FOR CHEMICAL AND PHYSICAL ANALYSIS DURING MONITORING WELL INSTALLATION

Phase 1 Installation

Sample Designation	Laboratory Accession Number	Interval (ft)	Overburden Shallow/Bedrock Well	Corps Field Split	Matrix	Date Collected
CHEMICAL ANALYSIS						
MW-1, S-1	0138	0.5-2.0	Bedrock		Cover fill	16 JAN 89
MW-1, S-2	0139	2.0-4.0	Bedrock	Field Split	Fill	16 JAN 89
MW-1, S-3	0140	4.0-6.0	Bedrock		Fill	16 JAN 89
MW-1, S-4	0141	6.0-8.0	Bedrock		In situ soil	16 JAN 89
MW-1, S-6	0142	15.0-16.0	Bedrock		In situ soil/saprolite	16 JAN 89
MW-4A, S-1	0213	0-2.0	Overburden		Cover fill	12 JAN 89
MW-4A, S-3	0214	4.0-6.0	Overburden		Fill	12 JAN 89
MW-4A, S-6	0215	15.0-16.0	Overburden		In situ soil/saprolite	12 JAN 89
MW-4, S-1	0216	0-2.0	Bedrock		Cover fill	12 JAN 89
MW-4, S-2	0217	2.0-4.0	Bedrock		Fill	12 JAN 89
MW-4, S-3	0218	4.0-6.0	Bedrock		Fill	12 JAN 89
MW-4, S-4	0219	6.0-8.0	Bedrock		In situ soil	12 JAN 89
MW-4, S-6	0220	15.0-16.0	Bedrock		In situ soil/saprolite	12 JAN 89
MW-4, S-3 (duplicate)	0221	4.0-6.0	Bedrock		Fill	12 JAN 89
Rinsate Blank 2	0222	NA	NA		Water	12 JAN 89
Trip Blank 2	0223	NA	NA		Water	12 JAN 89
MW-5, S-1	0117	0-2.0	Bedrock		Cover fill	11 JAN 89
MW-5, S-2	0118	2.0-4.0	Bedrock		Road fill	11 JAN 89
MW-5, S-3	0119	4.0-6.0	Bedrock		Road fill	11 JAN 89
MW-5, S-4	0120	6.0-8.0	Bedrock	Field Split	In situ soil	11 JAN 89
MW-5, S-5	0121	8.0-10.0	Bedrock		In situ soil/saprolite	11 JAN 89
MW-5A, S-1	0122	0-2.0	Overburden		Cover fill	11 JAN 89
MW-5A, S-3	0123	4.0-6.0	Overburden		Road fill	11 JAN 89
MW-5A, S-5	0124	8.0-10.0	Overburden		In situ soil	11 JAN 89
MW-5A, S-5 (duplicate)	0125	8.0-10.0	Overburden		In situ soil	11 JAN 89
Rinsate Blank 1	0126	NA	NA		Water	11 JAN 89
Trip Blank 1	0127	NA	NA		Water	11 JAN 89
PHYSICAL ANALYSIS						
MW-1, S-5	89141	8.0-10.0	Bedrock	NA	In situ soil	16 JAN 89
MW-4, S-4	89138	6.0-8.0	Bedrock	NA	In situ soil	12 JAN 89
MW-4, S-5	89139	8.0-10.0	Bedrock	NA	In situ soil	12 JAN 89
MW-4A, S-2	89140	2.0-4.0	Overburden	NA	Fill	12 JAN 89
MW-5, S-2	89142	2.0-4.0	Bedrock	NA	Fill	11 JAN 89
MW-5, S-6	89144	15.0-16.0	Bedrock	NA	In situ soil/saprolite	11 JAN 89
MW-5A, S-6	89143	15.0-16.0	Overburden	NA	In situ soil/saprolite	11 JAN 89

TABLE 2-1 EXTENDED

Sample Designation	Analytical Parameters
CHEMICAL ANALYSIS	
MW-1, S-1	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-1, S-2	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-1, S-3	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-1, S-4	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-1, S-6	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-4A, S-1	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-4A, S-3	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-4A, S-6	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-4, S-1	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-4, S-2	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-4, S-3	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-4, S-4	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-4, S-6	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-4, S-3 (duplicate)	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
Rinsate Blank 2	Volatiles, semivolatiles, pest/PCB, TPH, total metals
Trip Blank 2	Volatiles
MW-5, S-1	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-5, S-2	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-5, S-3	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-5, S-4	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-5, S-5	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-5A, S-1	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-5A, S-3	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-5A, S-5	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-5A, S-5 (duplicate)	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
Rinsate Blank 1	Volatiles, semivolatiles, pest/PCB, TPH, total metals
Trip Blank 1	Volatiles
PHYSICAL ANALYSIS	
MW-1, S-5	Atterberg limits, moisture, grain size
MW-4, S-4	Atterberg limits, moisture, grain size
MW-4, S-5	Atterberg limits, moisture, grain size
MW-4A, S-2	Atterberg limits, moisture, grain size
MW-5, S-2	Atterberg limits, moisture, grain size
MW-5, S-6	Atterberg limits, moisture, grain size
MW-5A, S-6	Atterberg limits, moisture, grain size

TABLE 2-1 (Cont.)

Phase 2 Installation

Sample Designation	Laboratory Accession Number	Interval (ft)	Overburden Shallow/Bedrock Well	Corps Field Split	Matrix	Date Collected
MW-2, S-1	3158	0-2.0	Bedrock		Cover fill	19 JUL 89
MW-2, S-1 (duplicate)	3159	0-2.0	Bedrock		Cover fill	19 JUL 89
MW-2, S-2	3160	2.0-4.0	Bedrock		Fill	19 JUL 89
MW-2, S-3	3161	4.0-6.0	Bedrock		Fill	19 JUL 89
MW-2, S-4	3162	6.0-8.0	Bedrock	Field Split	In situ soil	19 JUL 89
MW-2, S-5	3163	8.0-10.0	Bedrock		In situ soil	19 JUL 89
Trip Blank 7	3164	NA	NA		Water	19 JUL 89
MW-6A, S-1	3222	0-2.0	Overburden		Fill	20 JUL 89
MW-6A, S-3	3223	4.0-6.0	Overburden		In situ soil	20 JUL 89
MW-6A, S-4	3224	6.0-8.0	Overburden		In situ soil	20 JUL 89
MW-6, S-1	3225	0.-2.0	Bedrock		Fill	21 JUL 89
MW-6, S-2	3226	2.0-4.0	Bedrock		In situ soil	21 JUL 89
MW-6, S-3	3227	4.0-6.0	Bedrock		In situ soil	21 JUL 89
MW-6, S-4	3228	6.0-8.0	Bedrock		In situ soil	21 JUL 89
Trip Blank 8	3229	NA	NA		Water	21 JUL 89
MW-7A, S-1	3219	0-2.0	Overburden			20 JUL 89
MW-7A, S-3	3220	4.0-6.0	Overburden			20 JUL 89
MW-7A, S-4	3221	6.0-8.0	Overburden			20 JUL 89
MW-7, S-1	3253	0.2.0	Bedrock		Fill	25 JUL 89
MW-7, S-2	3254	2.0-4.0	Bedrock		In situ soil	25 JUL 89
MW-7, S-3	3255	4.0-6.0	Bedrock		In situ soil	25 JUL 89
MW-7, S-2 (duplicate)	3256	2.0-4.0	Bedrock		In situ soil	25 JUL 89
MW-7, S-4	3257	6.0-8.0	Bedrock		In situ soil	25 JUL 89
MW-7, S-5	3258	8.0-10.0	Bedrock		In situ saprolite	25 JUL 89
Trip Blank 9	3259	NA	NA		Water	25 JUL 89

TABLE 2-1 (Cont.) EXTENDED

Sample Designation	Analytical Parameters
MW-2, S-1	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-2, S-1 (duplicate)	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-2, S-2	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-2, S-3	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-2, S-4	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-2, S-5	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
Trip Blank 7	Volatiles
MW-6A, S-1	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-6A, S-3	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-6A, S-4	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-6, S-1	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-6, S-2	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-6, S-3	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-6, S-4	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
Trip Blank 8	Volatiles
MW-7A, S-1	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-7A, S-3	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-7A, S-4	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-7, S-1	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-7, S-2	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-7, S-3	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-7, S-2 (duplicate)	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-7, S-4	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
MW-7, S-5	Volatiles, semivolatiles, pest/PCB, cyanide, TPH, total metals
Trip Blank 9	Volatiles

8. A permanent marking, which clearly identified the well number, the U.S. Army Corps of Engineers, Omaha District, and the adjusted top of inner PVC casing elevation, was affixed to the outer casing of each well. The shallow monitoring well-borings construction diagrams are provided in Appendix B. Additionally, the well construction diagrams of existing site monitoring wells MW-1A, MW-2A, and MW-3A are also provided in Appendix B.

Six bedrock monitoring wells were installed during Phase I and Phase II. MW-1, MW-2, MW-4, MW-5, MW-6, and MW-7 were installed as cluster companions to the corresponding shallow overburden monitoring wells MW-1A, MW-2A, MW-4A, MW-5A, MW-6A, and MW-7A. Bedrock well construction and monitoring well boring soil sampling protocols are as follows:

1. Hollow-stem auger drilling and split-spoon sampling through overburden to bedrock was continuous to 10 ft and at 5-ft intervals thereafter. Five soil samples were collected from each bedrock monitoring well for chemical analysis. A discrete sample was taken of the cover fill (i.e., 0-2 ft). As discussed previously for the shallow wells soil sampling protocol, very little fill (i.e., 2-4 ft of soil and gravel) or no fill was encountered during the bedrock monitoring well boring; therefore, discrete samples were taken at each bedrock well boring over the depth of the boring. In all instances, overburden boring and split-spoon samples terminated at a depth below surface of 15 ft or less. Table 2-1 summarizes the sampling scheme and analytical parameters for the bedrock well soil samples.

2. Once bedrock was encountered (i.e., auger refusal), the augers were left in the ground as temporary casings. An NX wire-line, split-core barrel was then used to core a minimum of 5 ft into competent rock.

3. Upon retrieval of the core sample, logging of the core, and confirmation of competent bedrock, the core hole was reamed to 8 in. by air rotary method. (Compressor was outfitted with an in-line oil/air separator filter.)

4. The augers were removed and a 6-in., Schedule 5 steel casing was placed to seal off the overburden, grouted into place, and allowed to set for a minimum of 16 hours.

5. Coring was continued to 50 ft after outer casing grout had been allowed to cure.

6. Once the targeted depth of 50 ft was reached, the core hole was reamed to 50 ft with a 6-in. air rotary bit.

(Compressor was outfitted with an in-line oil/air separator filter.)

7. The well riser consisted of new, threaded, 2-in. diameter, Schedule 40, flush-joint PVC pipe.

8. The well screen was 10 ft in length and was constructed of the same size and strength PVC material as the well riser. The screen was noncontaminating No. 10 slot (0.010 in.), factory constructed. The screened portion was placed at the bottom of the borehole.

9. Filter-pack material was placed around and 2 ft above the screened portion of each well. Filter pack was composed of clean, washed, and bagged No. 2, graded fine silica sand.

10. A 2-ft seal, consisting of tamped bentonite pellets, was placed into the annular space between the riser and boring wall immediately above the filter pack. The placed pellets were hydrated with aquifer water obtained from the borehole prior to grouting. Cement grout was placed from the top of the bentonite seal to the ground surface. The cement grout consisted of a mixture of Portland cement (ASTM C 150) and water in the proportion of not more than 7 gal of clean water per bag of cement (1 ft^3 or 94 lbs). Additionally, 3 percent of bentonite powder by weight was added.

11. Coordinates and elevations were established for each monitoring well. The horizontal coordinates were to the closest 0.1 ft and referenced to Monument 1 or Monument 2, which were established in the final Confirmation Study, and to Pennsylvania State Planar Coordinates. A ground elevation to the closest 0.01 ft and an elevation for the top of the casing to the closest 0.01 ft were surveyed at each well. These elevations were referenced to the National Geodetic Vertical Datum of 1929.

12. A 6-in. outer, protective steel casing was installed a minimum of 2.5 ft above the surface. It was surrounded by a 3 x 3 ft, 4-in.-thick concrete pad with three protective posts embedded in it.

13. A permanent marking, which clearly identifies the well number, the U.S. Army Corps of Engineers, Omaha District, and the adjusted top of casing elevation, was affixed to each well's outer casing. Bedrock monitoring well-boring construction diagrams are provided in Appendix B.

2.1.3.2 Well Point Installation

Three 2-in. I.D., stainless-steel well points were installed in the landfill during the Phase II site activities (WP-1, WP-2, and WP-3). The screen and riser were constructed of stainless steel. The screen size openings were factory slotted, 0.01 in. The well points were pushed into the fill by hydraulic force of the drill rig. Penetration of the well point was ceased upon well-point refusal. Depth of penetration ranged from 10 to 12 ft below the surface, presumably into weathered bedrock or saprolite. A protective outer casing was also pushed 2.5 ft into the ground and surrounded with a 3 x 3 ft, 4-in.-thick concrete pad with three protective posts embedded in it. Well point locations are shown in Figure 2-1.

2.1.3.3 Ground-Water Sampling of Existing and New Monitoring Wells

During the course of the investigation, one ground-water sampling event of Phase I monitoring wells occurred on 8 February 1989. A total of eight monitoring wells were sampled (i.e., five new and three existing wells). A second sampling event of the existing site monitoring wells and the monitoring wells installed during Phase I and Phase II occurred on 16 and 17 August 1989.

Upon arrival at each well, the condition of the well and surrounding area was noted. This inspection included security (well locked), evidence of tampering, evidence of physical damage, well integrity, and evidence of breakage or heaving of concrete pad.

After the physical inspection was completed, static water levels were determined. Water level relative to the surveyed reference was determined in all wells to be sampled prior to initiation of any purging and sampling activities. All water-level determinations were made to the nearest 0.01 ft. Measurements were referenced to the previously surveyed reference point. An electronic sounder was used to determine water levels. Penetration of water is indicated by activation of a light or meter. No nonaqueous phase liquid (NAPL) was encountered.

To ensure that cross-contamination via water-level sounding equipment did not occur, sounding equipment was decontaminated between each well. Decontamination was accomplished by wiping the sounding device with a paper towel saturated with methanol as retrieved. Probes were methanol-rinsed and fully immersed in clean water between soundings.

Prior to sample acquisition, the monitoring wells were purged in order to ensure that the sample collected was as representative as possible of the aquifer water. Purging was accomplished by bailing with a dedicated Teflon bailer. The volume purged (four static casing volumes) was measured by filling a 5-gal bucket. Upon completion of purging, all purge water was containerized in 55-gal drums for temporary storage. In the event a well dewatered prior to evacuation of the required volume, the well was allowed 15 minutes to recover and purging was reinitiated. If the well dewatered a second time, the volume purged was recorded.

Ground-water sampling was accomplished with dedicated bottom-filling Teflon bailers. All bailers were laboratory cleaned prior to use. A clean piece of line was attached to the bailer and the bailer was lowered into the well until it filled and was then retrieved. The water was discarded. This process was repeated two times. The first sample aliquot was used to fill the volatile organics parameter bottles. Samples for volatile organics were collected in a manner that would minimize aeration and the containers were kept free of bubbles and headspace. The bailer was then filled and the sample transferred to the pre-preserved sample containers. Containers that contained preservative were not filled to overflowing and were mixed after filling. After the containers were filled, they were labeled, security sealed, an entry was made on the chain-of-custody form, and they were placed in a cooler on ice. When a field split or duplicate was taken, similar aliquots for each sample were alternately filled. Table 2-2 summarizes the sampling scheme for ground-water samples collected during February and August. Wells were sampled so that the suspected least contaminated were sampled first and the suspected most contaminated last.

Temperature, pH, dissolved oxygen, and specific conductance were determined in the field. These determinations were made using a pH meter and a YSI salinity-conductivity-temperature meter. All instrumentation was calibrated prior to transport to the field and standardized in the field prior to each use using a two-buffer technique. Tables 2-3 and 2-4 summarize the purging, sampling, and physical parameter determinations for the ground-water samples collected during February and August, respectively. During the second round of ground-water sampling, samples were analyzed for total (nonfiltered) and dissolved (filtered) trace metals. Dissolved trace metal aliquots were vacuum filtered in the field using 0.45-µm membrane filters prior to preservation. Monitoring well samples collected during the first round were not analyzed for dissolved trace metals.

2.1.3.4 Well Point Sampling

During the second round of ground-water sampling on 16 and 17 August 1989, two well points (WP-1 and WP-3) were purged, sampled, and analyzed in the same manner as the monitoring wells. The well points were sampled for purposes of evaluating the shallow ground-water quality immediately below and in direct contact with landfill waste materials. The sampling scheme is summarized in Table 2-4.

2.1.4 Surface Water Sampling

During the Phase I field activities, two upgradient surface water samples (SWS-1 and SWS-2) and two downgradient surface water samples (SWS-3 and SWS-4) were collected from the adjacent Marsh Run Creek and marsh land. One upgradient sample (SWS-1) was collected upgradient of NCAD and the other (SWS-2) was collected upgradient of the Marsh Run Field landfill. The downgradient samples consisted of one sample adjacent to the Marsh Run Field landfill in Marsh Run Creek (SWS-3) and the other downgradient sample taken in the adjacent marsh land east of the site (SWS-4).

TABLE 2-2 SUMMARY OF GROUND-WATER SAMPLING SCHEME FOR SAMPLES COLLECTED 8 FEBRUARY (Phase I) AND 16,17 AUGUST (Phase II) 1989

Phase 1 Sampling

Sample Designation	Laboratory Accession Number	Corps Field Split	Matrix	Date Collected (M/D/Y)	Analytical Parameters
MW-1	0459	Field split	Water	2/8/89	Volatiles, semivolatiles, pest/PCB, total metals, TPH, nitrate/ nitrite, nitrogen, phosphorous, SO_4, Cl, F, TDS, alkalinity
MW-1A	0460		Water	2/8/89	Volatiles, semivolatiles, pest/PCB, total metals, TPH, nitrate/ nitrite, nitrogen, phosphorous, SO_4, Cl, F, TDS, alkalinity
MW-2A	0463		Water	2/8/89	Volatiles, semivolatiles, pest/PCB, total metals, TPH, nitrate/ nitrite, nitrogen, phosphorous, SO_4, Cl, F, TDS, alkalinity
MW-2A (duplicate 1)	0461		Water	2/8/89	Volatiles, semivolatiles, pest/PCB, total metals, TPH, nitrate/ nitrite, nitrogen, phosphorous, SO_4, Cl, F, TDS, alkalinity
MW-3A	0462	Field split	Water	2/8/89	Volatiles, semivolatiles, pest/PCB, total metals, TPH, nitrate/ nitrite, nitrogen, phosphorous, SO_4, Cl, F, TDS, alkalinity
MW-4	0464		Water	2/8/89	nitrite, nitrogen, phosphorous, SO_4, Cl, F, TDS, alkalinity nitrite, nitrogen, phosphorous, SO_4, Cl, F, TDS, alkalinity
MW-4 (duplicate 2)	0465		Water	2/8/89	Volatiles, semivolatiles, pest/PCB, total metals, TPH, nitrate/ nitrite, nitrogen, phosphorous, SO_4, Cl, F, TDS, alkalinity
MW-4A	0466		Water	2/8/89	Volatiles, semivolatiles, pest/PCB, total metals, TPH, nitrate/ nitrite, nitrogen, phosphorous, SO_4, Cl, F, TDS, alkalinity
MW-5	0477		Water	2/8/89	Volatiles, semivolatiles, pest/PCB, total metals, TPH, nitrate/ nitrite, nitrogen, phosphorous, SO_4, Cl, F, TDS, alkalinity
MW-5A	0478		Water	2/8/89	Volatiles, semivolatiles, pest/PCB, total metals, TPH, nitrate/ nitrite, nitrogen, phosphorous, SO_4, Cl, F, TDS, alkalinity
Rinsate Blank 6	0457		Water	2/8/89	Volatiles, semivolatiles, pest/PCB, total metals, TPH, nitrate/ nitrite, nitrogen, phosphorous, SO_4, Cl, F, TDS, alkalinity
Trip Blank 6	0458		Water	2/8/89	Volatiles

TABLE 2-2 (Cont.)

Phase 2 Sampling

Sample Designation	Laboratory Accession Number	Corps Field Split	Matrix	Date Collected (M/D/Y)	Analytical Parameters
MW-1	3743	Field split	Water	8/16/89	Volatiles, semivolatiles, pest/PCB, total metals, dissolved metals, TPH, nitrate/nitrite, phosphorous, SO_4, Cl, F, TDS, alkalinity
MW-1A	3706		Water	8/16/89	Volatiles, semivolatiles, pest/PCB, total metals, dissolved metals, TPH, nitrate/nitrite, phosphorous, SO_4, Cl, F, TDS, alkalinity
MW-2	3740		Water	8/16/89	Volatiles, semivolatiles, pest/PCB, total metals, dissolved metals, TPH, nitrate/nitrite, phosphorous, SO_4, Cl, F, TDS, alkalinity
MW-2 (duplicate)	3741		Water	8/16/89	Volatiles, semivolatiles, pest/PCB, total metals, dissolved metals, TPH, nitrate/nitrite, phosphorous, SO_4, Cl, F, TDS, alkalinity
MW-2A	3738		Water	8/16/89	Volatiles, semivolatiles, pest/PCB, total metals, dissolved metals, TPH, nitrate/nitrite, phosphorous, SO_4, Cl, F, TDS, alkalinity
MW-3A	3745		Water	8/17/89	Volatiles, semivolatiles, pest/PCB, total metals, dissolved metals, TPH, nitrate/nitrite, phosphorous, SO_4, Cl, F, TDS, alkalinity
MW-4	3705	Field split	Water	8/16/89	Volatiles, semivolatiles, pest/PCB, total metals, dissolved metals, TPH, nitrate/nitrite, phosphorous, SO_4, Cl, F, TDS, alkalinity
MW-4A	3739		Water	8/16/89	Volatiles, semivolatiles, pest/PCB, total metals, dissolved metals, TPH, nitrate/nitrite, phosphorous, SO_4, Cl, F, TDS, alkalinity
MW-5	3700		Water	8/16/89	Volatiles, semivolatiles, pest/PCB, total metals, dissolved metals, TPH, nitrate/nitrite, phosphorous, SO_4, Cl, F, TDS, alkalinity
MW-5A	3704		Water	8/16/89	Volatiles, semivolatiles, pest/PCB, total metals, dissolved metals, TPH, nitrate/nitrite, phosphorous, SO_4, Cl, F, TDS, alkalinity
MW-6	3703		Water	8/16/89	Volatiles, semivolatiles, pest/PCB, total metals, dissolved metals, TPH, nitrate/nitrite, phosphorous, SO_4, Cl, F, TDS, alkalinity

TABLE 2-2 (Cont.)

Phase 2 Sampling (Cont.)

Sample Designation	Laboratory Accession Number	Corps Field Split	Matrix	Date Collected (M/D/Y)	Analytical Parameters
MW-6 (duplicate)	3699		Water	8/16/89	Volatiles, semivolatiles, pest/PCB, total metals, dissolved metals, TPH, nitrate/nitrite, phosphorous, SO_4, Cl, F, TDS, alkalinity
MW-6A	3702		Water	8/16/89	Volatiles, semivolatiles, pest/PCB, total metals, dissolved metals, TPH, nitrate/nitrite, phosphorous, SO_4, Cl, F, TDS, alkalinity
MW-7	3701		Water	8/16/89	Volatiles, semivolatiles, pest/PCB, total metals, dissolved metals, TPH, nitrate/nitrite, phosphorous, SO_4, Cl, F, TDS, alkalinity
MW-7A	3742		Water	8/16/89	Volatiles, semivolatiles, pest/PCB, total metals, dissolved metals, TPH, nitrate/nitrite, phosphorous, SO_4, Cl, F, TDS, alkalinity
WP-1	3746		Water	8/17/89	Volatiles, semivolatiles, pest/PCB, total metals, dissolved metals, TPH, nitrate/nitrite, phosphorous, SO_4, Cl, F, TDS, alkalinity
WP-3	3747		Water	8/17/89	Volatiles, semivolatiles, pest/PCB, total metals, dissolved metals, TPH, nitrate/nitrite, phosphorous, SO_4, Cl, F, TDS, alkalinity
Field Blank	3744		Water	8/17/89	Volatiles, semivolatiles, pest/PCB, total metals, dissolved metals, TPH, nitrate/nitrite, phosphorous, SO_4, Cl, F, TDS, alkalinity
Trip Blank	3717		Water	8/16/89	Volatiles

TABLE 2-3 RECORD OF PURGING AND SAMPLING OF SITE MONITORING WELLS AT NEW CUMBERLAND ARMY DEPOT'S FORMER LANDFILL, MARSH RUN FIELD, 8 FEBRUARY 1989

	Well No.							
	MW-1	MW-1A	MW-2A	MW-3A	MW-4	MW-4A	MW-5	MW-5A
Well depth (ft)[a]	52.2	17.88	15.44	16.88	52.0	17.27	52.2	17.37
Reference elevation (ft MSL)	306.58	306.02	302.50	303.42	305.85	305.04	302.75	304.31
Well diameter (ft)	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Depth to water (ft)[a]	12.32	10.90	6.61	7.95	14.66	10.81	7.68	7.30
date/time	2-8-89/0817	2-8-89/0821	2-8-89/0858	2-8-89/0904	2-8-89/0832	2-8-89/0835	2-8-89/0952	2-8-89/0949
Water level elevation (ft MSL)	294.26	295.12	295.89	295.47	291.19	294.23	295.07	297.01
Casing volume (gal)	6.4	1.1	1.4	1.4	6.0	1.0	7.1	1.6
Purge volume (gal)	25.0	5.0	5.5	5.5	25.0	5.0	17.0[b]	3.8[b]
Purge method	Teflon Bailer	Teflon Bailer	Teflon Bailer	Teflon Bailer	Teflon Bailer	Teflon Bailer	Teflon Bailer	Teflon Bailer
Sampling--date/time	2-8-89/1020	2-8-89/1015	2-8-89/1115	2-8-89/1110	2-8-89/1240	2-8-89/1230	2-8-89/1524	2-8-89/1546
Sampling method	Teflon Bailer	Teflon Bailer	Teflon Bailer	Teflon Bailer	Teflon Bailer	Teflon Bailer	Teflon Bailer	Teflon Bailer
Specific conductance (μmhos/cm)	280	290	780	800	420	180	710	590
Dissolved oxygen (mg/L)	6.2	7.5	5.8	3.9	4.8	7.9	4.9	5.2
Temperature (C)	9.8	12.2	9.7	8.5	10.4	10.2	9.5	7.2
pH (units)	7.35	6.5	6.65	6.7	6.3	6.25	6.75	6.15

(a) Depth referenced to top of PVC casing.
(b) Denotes well was purged dry twice.

TABLE 2-4 RECORD OF PURGING AND SAMPLING OF SITE MONITORING WELLS AT NEW CUMBERLAND ARMY DEPOT'S FORMER LANDFILL, MARSH RUN FIELD, 16, 17 AUGUST 1989

	Well No.							
	MW-1	MW-1A	MW-2	MW-2A	MW-3A	MW-4	MW-4A	MW-5
Well depth (ft)[a]	52.2	17.88	51.54	15.44	16.88	52.0	17.27	52.2
Reference Elevation (ft MSL)	306.58	306.02	301.70	302.50	303.42	305.85	305.04	302.75
Well diameter (ft)	0.16	0.16	0.16	01.6	0.16	0.16	0.16	0.16
Depth to water (ft)[a]	11.55	10.65	6.70	6.35	6.25	11.80	9.50	6.90
date/time	8-16-89/0750	8-16-89/0754	8-16-89/0810	8-16-89/0813	8-16-89/0818	8-16-89/0758	8-16-89/0800	8-16-89/0900
Water level elevation (ft MSL)	295.03	295.37	295.00	296.15	297.17	294.05	295.54	295.85
Casing volume (gal)	6.5	1.2	7.2	1.5	1.7	6.4	1.2	7.3
Purge volume (gal)	26	5	29	6	7	26	5	18[b]
Purge method	Teflon bailer	Teflon bailer	Teflon bailer	Teflon bailer	Teflon bailer	Teflon bailer	Teflon bailer	Teflon bailer
Sampling--date/time								
Sampling method	Teflon bailer	Teflon bailer	Teflon bailer	Teflon bailer	Teflon bailer	Teflon bailer	Teflon bailer	Teflon bailer
Specific Conductance (μmhos/cm)	385	275	380	850	1,100	422	195	970
Dissolved oxygen (mg/L)	5.9	7.1	6.3	5.8	4.4	4.8	6.1	4.7
Temperature (C)	12.1	13.0	11.9	12.7	13.0	11.4	11.9	12
pH (units)	7.1	5.7	7.6	6.3	6.6	7.2	5.8	6.8

(a) Depth referenced to top of PVC casing.
(b) Denotes well was purged dry twice.

TABLE 2-4 EXTENDED

	Well No.							
	MW-5A	MW-6	MW-6A	MW-7	MW-7A	WP-1	WP-2	WP-3
Well depth (ft)[a]	17.37	51.95	17.0	52.12	17.08	13.83	12.24	12.09
Reference Elevation (ft MSL)	304.31	301.11	303.34	302.02	301.92	304.53	304.71	304.34
Well diameter (ft)	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Depth to water (ft)[a]	6.55	8.30	7.85	6.25	6.40	6.25	6.40	7.90
date/time	8-16-89/0905	8-16-89/0920	8-16-89/0916	8-16-89/0910	8-16-89/0835	8-16-89/0830	8-16-89/0822	8-16-89/0827
Water level elevation (ft MSL)	297.76	292.81	295.49	295.77	295.52	298.28	298.31	296.44
Casing volume (gal)	1.7	7.0	1.5	7.3	1.7	1.2	0.9	0.7
Purge volume (gal)	5[b]	28	6	30	7	5	NA	3.5
Purge method	Teflon bailer	Teflon bailer	Teflon bailer	Teflon bailer	Teflon bailer	Teflon bailer	NA	Teflon bailer
Sampling--date/time								
Sampling method	Teflon bailer	Teflon bailer	Teflon bailer	Teflon bailer	Teflon bailer	Teflon bailer	NA	Teflon bailer
Specific Conductance (μmhos/cm)	700	322	2,150	850	1,500	1,350	NA	1,420
Dissolved oxygen (mg/L)	6.2	4.1	6.9	5.5	3.9	2.2	NA	3.5
Temperature (C)	13.2	13.1	12.7	11.4	13.3	13.8	NA	13.5
pH (units)	6.4	7.6	6.5	7.3	7.1	6.5	NA	6.6

Pursuant to preliminary analysis of the chemical data from surface water samples collected during the first round, the need for an additional sampling point on the depot was assessed. Consequently, during Phase II field activities a surface water sample (SWS-5) was collected further upgradient of previous samples and upstream of the confluence of west-east and south-north flowing stream segments. Figure 2-3 depicts surface water sampling locations. Table 2-5 summarizes the sampling scheme and analytical parameters.

Surface water samples were collected as subsurface grabs using laboratory-cleaned devices constructed of material appropriate to the analysis being performed (e.g., plastic for trace metals and glass for semivolatiles and volatiles).

2.1.5 Sediment Sampling

Three upgradient (SS-1, SS-2, and SS-5) and two downgradient (SS-3 and SS-4) sediment samples were collected in the same place as the corresponding surface water samples, along the bank of the stream, at the water's edge, or in the marsh. Sediment samples were collected with dedicated laboratory-cleaned, stainless-steel sampling triers. The sampling station location rationale was the same as that for the surface water samples. Figure 2-3 depicts the sediment sample locations. Table 2-5 summarizes the sampling scheme and analytical parameters.

2.1.6 Residential Well Sampling

Four residences near the site were selected for domestic supply well sampling. The wells selected were situated south and east of the site. Locations of the residences sampled are depicted in Figure 2-3. Table 2-6 lists relevant information for each household well sampled. From a topographic perspective, these wells are apparently upgradient of the site. They derive ground water from approximately the same depth interval of the bedrock aquifer, as do the site monitoring wells.

Each well sampled was accessed by the kitchen cold-water tap. None of the residences sampled were outfitted with a water treatment system. Prior to obtaining a sample, the tap was allowed to purge for approximately 15 minutes. Upon completion of the required purging time, sample aliquots were filled directly from the tap. Temperature, specific conductivity, and pH measurements were obtained for each sample.

2.1.7 In-Situ Permeabilities

In situ permeabilities of the overburden and bedrock water-bearing strata were calculated for all of the newly installed wells. Monitoring wells MW-1, MW-2, MW-4, MW-5, MW-6, and MW-7 were installed in the upper portion of the bedrock aquifer. Monitoring wells MW-4A, MW-5A, MW-6A, and MW-7A were installed in the unconsolidated overburden. Hydrogeologic characterization was conducted utilizing a slug injection test developed by Bouwer and Rice (1978). This procedure is applicable to fully or partially penetrating wells within a water-table (unconfined) aquifer.

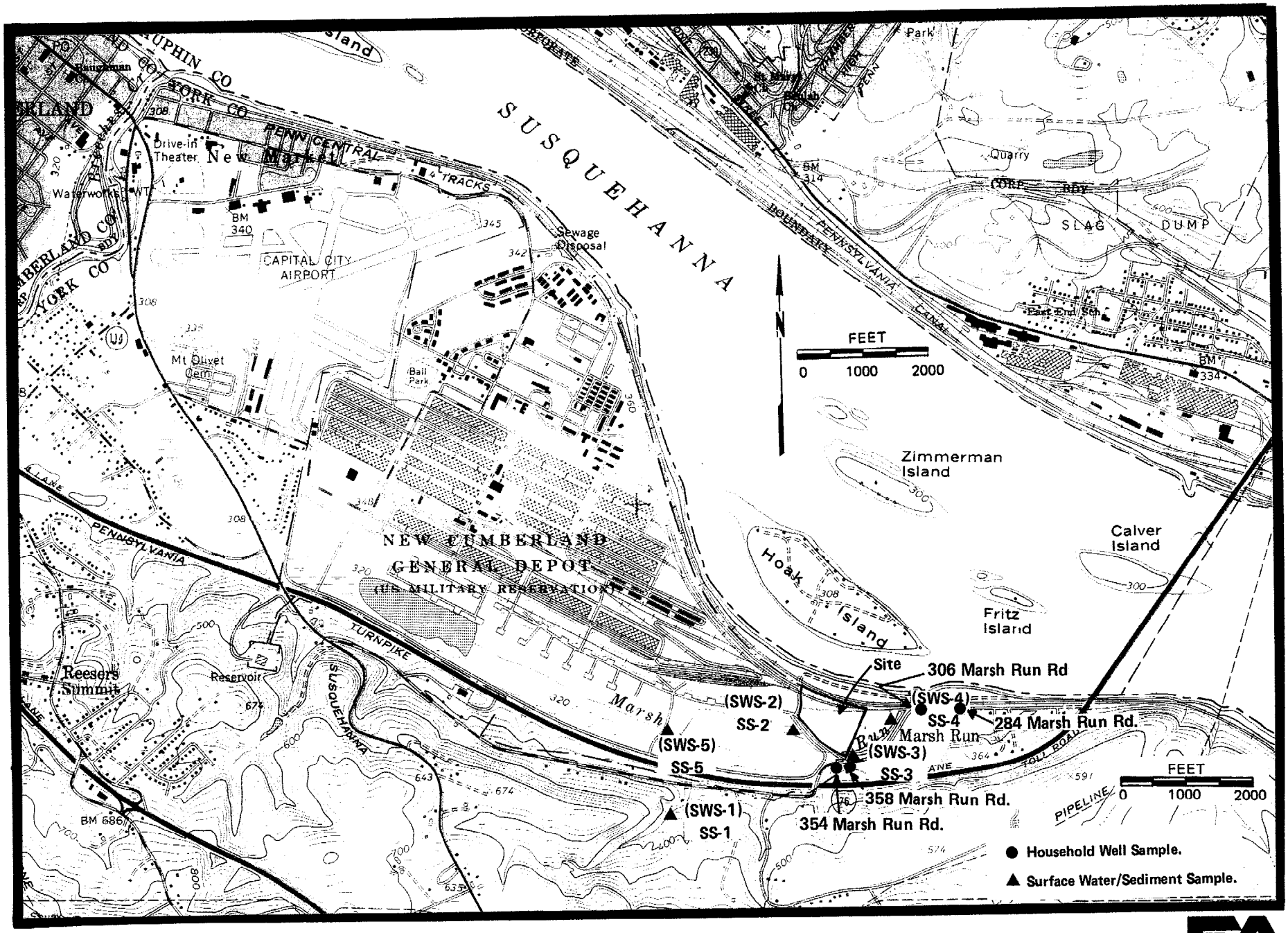


Figure 2-3. Location of storm surface water/sediment and household well samples.

TABLE 2-5 SUMMARY OF SAMPLING SCHEME FOR SURFACE WATER AND SEDIMENT SAMPLES

Phase 1 Sampling

Sample Designation	Laboratory Accession Number	Corps Field Split	Sample Location	Date Collected (M/D/Y)	Analytical Parameters
Surface Water Samples					
SWS-1	0247		Upstream (base & site)	1/19/89	Volatiles, semivolatiles, cyanide, TPH, pest/PCB, total metals
SWS-1 (duplicate 1)	0248		Upstream (base & site)	1/19/89	Volatiles, semivolatiles, cyanide, TPH, pest/PCB, total metals
SWS-2	0249		Upstream (site)	1/19/89	Volatiles, semivolatiles, cyanide, TPH, pest/PCB, total metals
SWS-2 (duplicate 2)	0250		Upstream (site)	1/19/89	Volatiles, semivolatiles, cyanide, TPH, pest/PCB, total metals
SWS-3	0246	Field split	Downstream (site)	1/19/89	Volatiles, semivolatiles, cyanide, TPH, pest/PCB, total metals
SWS-4	0251	Field split	Marsh	1/19/89	Volatiles, semivolatiles, cyanide, TPH, pest/PCB, total metals
Rinsate Blank 5	0244		N/A	1/19/89	Volatiles, semivolatiles, cyanide, TPH, pest/PCB, total metals
Trip Blank 5	0245		N/A	1/19/89	Volatiles
Sediment Samples					
SS-1	0233		Upstream (base & site)	1/18/89	Volatiles, semivolatiles, cyanide, TPH, pest/PCB, total metals
SS-1 (duplicate 1)	0234		Upstream (base & site)	1/18/89	Volatiles, semivolatiles, cyanide, TPH, pest/PCB, total metals
SS-2	0235		Upstream (site)	1/18/89	Volatiles, semivolatiles, cyanide, TPH, pest/PCB, total metals
SS-3	0236	Field split	Downstream (site)	1/18/89	Volatiles, semivolatiles, cyanide, TPH, pest/PCB, total metals
SS-4	0237	Field split	Marsh	1/18/89	Volatiles, semivolatiles, cyanide, TPH, pest/PCB, total metals
SS-4 (duplicate 2)	0238		Marsh	1/18/89	Volatiles, semivolatiles, cyanide, TPH, pest/PCB, total metals
Rinsate Blank 3	0241		N/A	1/18/89	Volatiles, semivolatiles, TPH, pest/PCB, total metals
Rinsate Blank 4	0242		N/A	1/18/89	Volatiles, semivolatiles, TPH, pest/PCB, total metals
Trip Blank 3	0239		N/A	1/18/89	Volatiles
Trip Blank 4	0240		N/A	1/18/89	Volatiles

TABLE 2-5 (Cont.)

Phase 2 Sampling Sample Designation	Laboratory Accession Number	Corps Field Split	Sample Location	Date Collected (M/D/Y)	Analytical Parameters
Surface Water Samples					
SWS-5	3715	Field split	Upstream (base & site)	8/16/89	Volatiles, semivolatiles, TPH, pest/PCB, total metals
SWS-5 (duplicate)	3716		Upstream (base & site)	8/16/89	Volatiles, semivolatiles, TPH, pest/PCB, total metals
Sediment Samples					
SS-5	3165	Field split	Upstream (base & site)	7/19/89	Volatiles, semivolatiles, TPH, pest/PCB, total metals
SS-5 (duplicate)	3166		Upstream (base & site)	7/19/89	Volatiles, semivolatiles, TPH, pest/PCB, total metals

TABLE 2-6 LISTING OF HOUSEHOLD SUPPLY WELLS AND PHYSICAL PARAMETERS IN VICINITY OF MARSH RUN FIELD

Sample Designation	Laboratory Accession Number	Date Collected	Approximate Well Depth (ft)	Treatment System	Pipe Material	pH (units)	Specific Conductivity (μmhos/cm)	Temperature (C)
354 Marsh Run Rd.	4112	8/31/89	105	none	copper	6.1	680	11.5
358 Marsh Run Rd.	4113	8/31/89	45	none	copper	6.6	460	12
306 Marsh Run Rd.	4114	8/31/89	28	none	copper	5.8	370	12
284 Marsh Run Rd.	4115	8/31/89	60	none	copper	6.4	550	11.8

A synopsis of the slug test method developed by Bouwer and Rice (1978) follows. An initial static water level of the well was taken. A slug of water was quickly injected, at which time an elapsed time count began. Water levels were recorded by a Hermit 1000-B automated water-level recorder at the following logarithmic interval:

Cycle	Elapsed Time	Log Sample Interval
1	0-2 sec	0.2 sec
2	2-20 sec	1 sec
3	20-120 sec	5 sec
4	2-10 min	30 sec
5	10-100 min	2 min
6	100-1,000 min	10 min
7	1E3-1E4 min	100 min
8	1E4 min	500 min

Residual drawdown vs. elapsed time was recorded until the water level in the well had fallen to not less than 90 percent of the original static level. The elapsed time vs. residual drawdown data are provided in Appendix C. Elapsed time vs. residual drawdown was then graphed on semilog paper.

The hydraulic conductivity (K) was calculated from the equation:

$$K = \frac{r_c^2 \ln (R_e/r_w)}{2L_e} \frac{1}{t} \ln \frac{Y_o}{Y_t}$$

where

R_e = effective radial distance over which the head difference y is discharged

r_w = radial distance between well center and undisturbed aquifer (r_c plus thickness of gravel envelope or developed zone outside casing)

L_e = height of perforated, screened, encased, or otherwise open section of well through which ground water enters

Y_o = y at time zero

Y_t = y at time t

t = time since y_o

r_c = radial distance of well casing

Table 2-7 summarizes the calculated hydraulic conductivities and transmissivities of the overburden and upper bedrock saturated zones. Slug test data results from monitoring wells MW-1A, MW-2A, and MW-3A, which were installed during the Confirmation Study, are also provided.

Slug test data were used in calculating aquifer transmissivities and linear ground-water velocity in both the overburden and bedrock aquifers. Comparisons between overburden, landfill waste, and bedrock hydraulic conductivities were used for subsequent contaminant transport and fate modeling and analysis.

TABLE 2-7 SUMMARY OF AQUIFER HYDRAULIC CONDUCTIVITY DETERMINED FROM SLUG TEST CONDUCTED ON SITE MONITORING WELLS 9 FEBRUARY AND 17 AUGUST 1989

Well No.	Aquifer Interval Tested	Hydraulic Conductivity (cm/sec)	Hydraulic Conductivity (ft/day)
MW-1	Shallow bedrock	8.6×10^{-4}	2.4
MW-4	Shallow bedrock	6.8×10^{-4}	1.9
MW-5	Shallow bedrock	1.79×10^{-5}	0.05
MW-4A	Unconsolidated overburden	2.8×10^{-5}	0.08
MW-5A	Unconsolidated overburden	1.3×10^{-4}	0.37
MW-2	Shallow bedrock	1.3×10^{-3}	3.6
MW-6	Shallow bedrock	2.5×10^{-5}	0.07
MW-6A	Unconsolidated overburden	4.3×10^{-5}	0.12
MW-7	Shallow bedrock	1.5×10^{-3}	4.32
MW-7A	Unconsolidated overburden	5.5×10^{-5}	0.14
WP-1	Landfill waste/fill	$>1 \times 10^{-2}$ (a)	>28.3
MW-3A (b)	Landfill fill	4.5×10^{-3}	13
MW-2A (b)	Landfill fill	7×10^{-4}	1.98
MW-1A (b)	Reworked fill	2×10^{-2}	57

(a) No recorded change in initial water level WP-1 due to introduction of slug suggests high hydraulic conductivity in excess of 1×10^{-2} cm/sec (i.e., water level equilibrium reached in less than 0.1 minute).

(b) Hydraulic conductivity values reported by Woodward-Clyde Consultants.

3. PHYSICAL CHARACTERISTICS OF THE STUDY AREA

3.1 RESULTS OF FIELD INVESTIGATIONS

This Chapter describes the results of field activities conducted during the New Cumberland Army Depot (NCAD) Remedial Investigation (RI). A descriptive narrative of the current physical conditions at the site, including geology, soils, surface water, ground water, and waste characterization, is included. Additionally, the conceptual interpretation of the site hydrogeology is discussed.

3.1.1 Electromagnetic Terrain Conductivity Survey

An electromagnetic (EM) terrain conductivity survey was conducted over the fill and the immediately adjacent areas and referenced to the 100 x 100 ft grid previously established onsite. Initially, the fill area was surveyed using a 10-m intercoil spacing. The effective depths of penetration were approximately 7.5 m (24.8 ft) and 15 m (49.5 ft) for the horizontal and vertical dipole configurations, respectively. Conductivity measurements were obtained in both the horizontal and vertical dipole configuration at each station located at 33-ft intervals along northeast-southwest trending traverse lines. The traverse lines were spaced 50 ft apart and parallel to each other.

The EM-34-3L was calibrated at the base station located west of the site once each morning and at the end of each day. Additionally, instrument calibration was performed after each instrument shutoff.

EM terrain conductivity data were analyzed by initially determining terrain conductivity ranges associated with background (ambient) levels. Secondly, all external cultural interferences that could potentially affect terrain conductivity were identified, such as fences, underground utilities, and above-ground metal objects. Once these two conditions were satisfied, conductivity values in excess of background terrain conductivity were identified as anomalous.

Terrain conductivity can be increased by the following natural or artificial conditions: (1) increase in electrolytic constituents in the ground water or partially saturated zone (i.e., salts, dissolved metallic ions), (2) increase in metallic debris in an otherwise low conductivity matrix (i.e., drums or metal objects in soil or fill), or (3) increased clay content in the soil overburden because of cation exchange capacity of clay particles.

In the case of traversing a landfill, metallic debris is the predominant influencing factor on terrain conductivity. Secondly, the increased electrolytic constituents in the ground water as a result of the dissolution of metallic ions from the fill materials may also increase measured terrain conductivities.

Because the majority of the site and surrounding vicinity is covered with landfill-derived materials or road fill (i.e., to the south and east of the site), and the northern boundary is bounded by railroad tracks, it

was difficult to establish in situ background levels. The majority of the area surveyed was either waste material or disturbed borrow material. Very little of the area surveyed, except for the marsh area to the east, could be considered undisturbed or in situ. Visual inspection of the northern portion of the site as well as test pits dug in the area (Test Pits 1 and 2) during the Confirmation Study indicated that relatively inert (i.e., borrow or construction) debris underlie this area.

In light of this situation, a terrain conductivity range of 10-20 mmhos/m was selected as an ambient (background) reference based on the relatively high persistence of this range along the north and east perimeters where inert or in situ materials are most prevalent. Based on previous EM survey conducted in the Harrisburg region, a terrain conductivity of 20 mmhos/m is characteristic of saturated silty clay materials such as those encountered in the site vicinity.

In general, terrain conductivities north of the site grid 6-line and west of the B-line were relatively flat (consistent within a given range), suggesting a relatively uniform material. Monitoring well boring data in these areas confirm the presence of soil and some inert construction debris fill; therefore, no waste fill material is suspected in areas identified as "ambient" terrain conductivity.

Cultural interference was identified from the depot fence south of the site. No other dominant external features were identified that may effect conductivity readings.

Figures 3-1 and 3-2 illustrate the electromagnetic terrain conductivity distributions across the site which were generated from the 10-m horizontal and vertical dipole data, respectively. Across the site, the terrain conductivity ranges from less than 10 mmhos/m to greater than 60 mmhos/m. The area of highest terrain conductivity is situated south of the site grid 6-line, west of the I-line, and east of the B-line. As previously mentioned, values in excess of 20 mmhos/m have been interpreted as representative of above background conductivities. These higher conductivity zones have been qualified as being associated with landfill "waste fill" material. As a result of this correlation, an approximate waste fill/ inert fill boundary is depicted in Figures 3-1 and 3-2.

Examination of the horizontal dipole data (Figure 3-1) reveals moderately high conductivity nodes (i.e., >50 mmhos/m) situated within the slightly elevated terrain conductivity area (>20 mmhos/m) at grid points C.0-4.6, E.5-4.0, and F.0-4.0.

Specifically, the sharp drop-off of measured terrain conductivity over a relatively short distance (e.g., conductivity varies from >60 mmhos/m to 20 mmhos/m over lateral distance of 30 ft) in the vicinity of grid point C.0-4.6 indicates the potential for a high density assemblage of metallic constituents (i.e., drums, scrap metal, ash etc.).

Although it is exceedingly difficult to distinguish high density assemblages of metal in a heterogeneous, moderately high conductive fill such

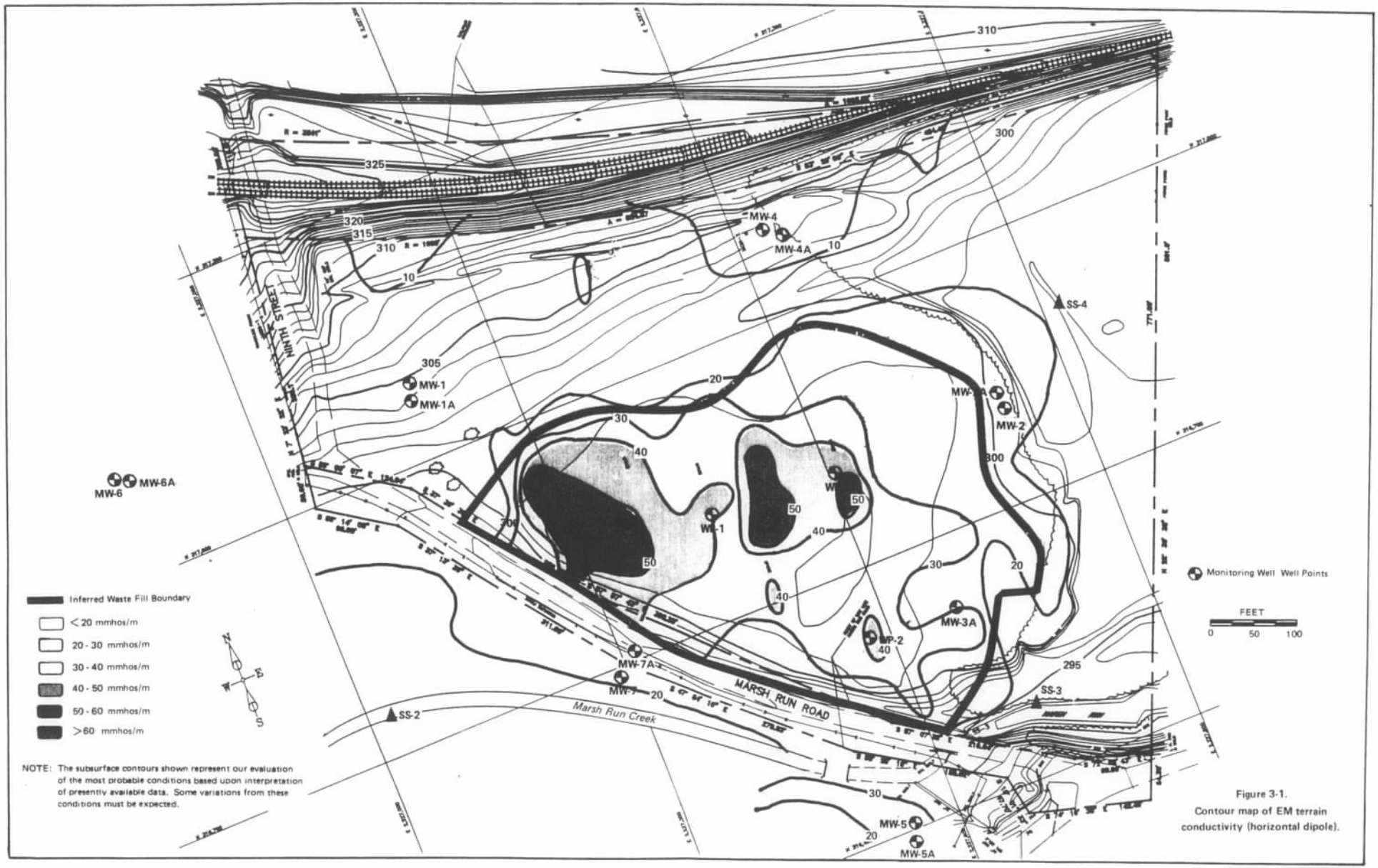


Figure 3-1.
Contour map of EM terrain conductivity (horizontal dipole).

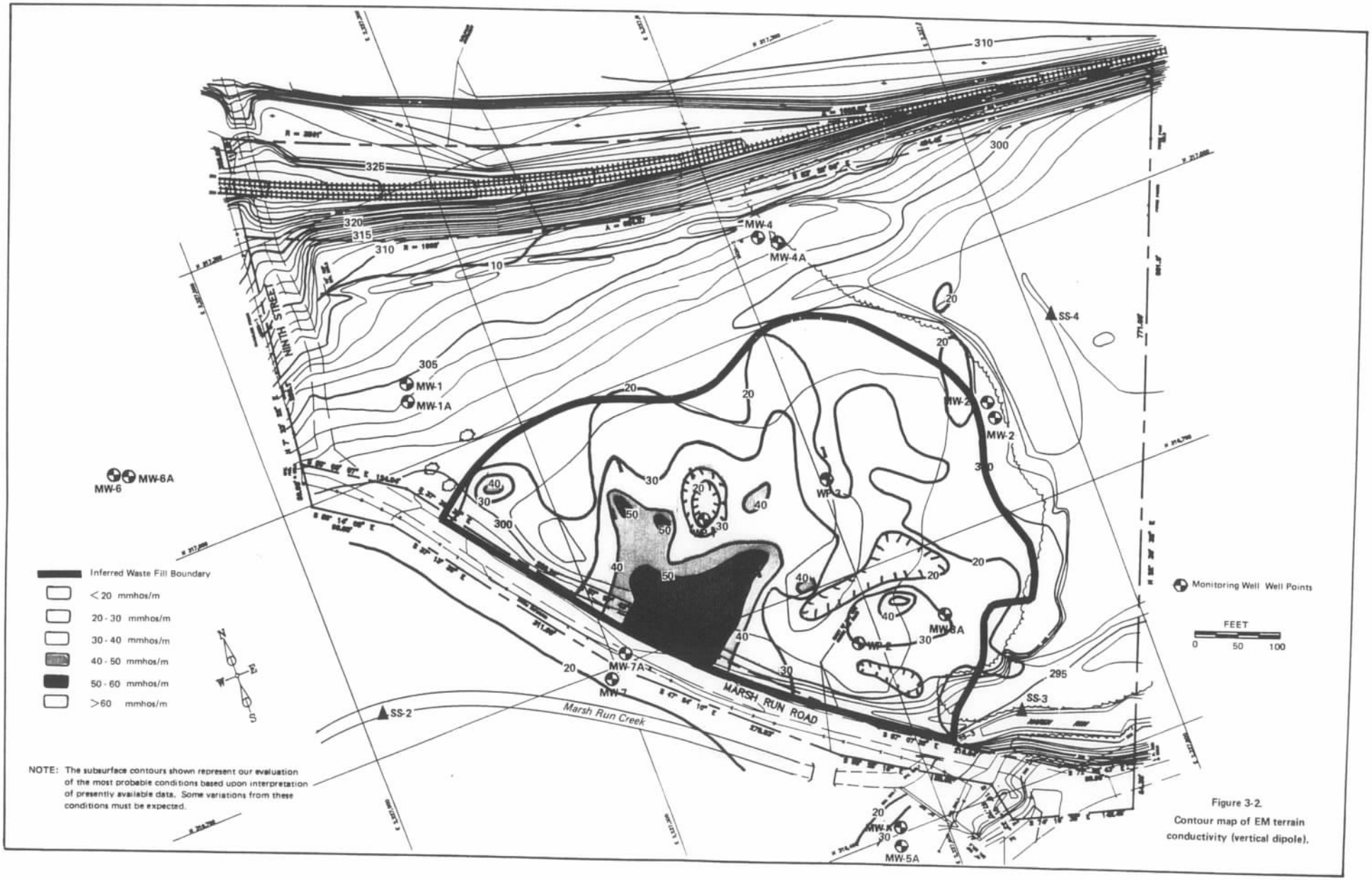


Figure 3-2.
Contour map of EM terrain conductivity (vertical dipole).

as that encountered at Marsh Run Field, anomalous conductivity perturbations within the fill may be sometimes interpreted as solid metallic assemblage (metal debris or ash). Specifically, sharp declines in conductivity (i.e., from 60 to 20 mmhos/m) over a relatively short lateral distance (i.e., <30 ft) is typically indicative of metallic assemblages, rather than a more gradual conductivity decline commonly associated with a contaminated ground-water or leachate plume.

Figure 3-3 illustrates the conductivity distribution measured in the horizontal dipole from a three-dimensional perspective. It shows the relatively marked contrast between terrain conductivity across the site and the segregation of a moderate-to-high conductivity area (south-central) and low (ambient) conductivity (north, east, and west perimeter) areas of the site.

The vertical dipole data contour map (Figure 3-2) reflects, in general, a similar conductivity distribution across the site. The highest concentration of terrain conductivity is situated south of the 6-line.

Terrain conductivities measured in the vertical mode within the area identified as above ambient are typically 10-20 percent less than terrain conductivities measured in the horizontal dipole mode. This situation is further illustrated in the EM profile comparisons of horizontal and vertical dipole measurements (Figures 3-4 through 3-8). This comparison suggests that the fill is less than 15 ft deep and that no apparent large-scale trenches were excavated during landfilling, which has also been supported by well points and monitoring well test borings. Conversely, north of the 6-line both horizontal and vertical dipole measurements are relatively similar in magnitude, which suggests no major electrical conductivity difference between the bedrock and fill material.

Of particular interest is the occurrence and distribution of reverse polarity (RP) EM response in the vertical dipole across the site. Typically, an RP instrument response is indicative of a nonconductive dike structure, the instrument's nonlinearity response to apparent conductivity above 700 mmhos/m (instrument reads 0 at conductivity higher than 700 mmhos/m), or in most cases such as in landfill investigations a manifestation of randomly dispersed debris characteristic of landfill material or instrument response. From examination of the RP distribution in Figure 3-2 it is evident that the majority of the RP readings are situated within the same portion of the site as that identified as the above-ambient conductivity zone. The coincidence of the high conductivity and the RP readings in the one portion of the site and the relative absence of RP and low conductivity in another portion of the site further supports the presence of two types of fill within the site boundaries. The first type of fill matrix represented by higher-than-ambient terrain conductivity and a higher percentage of RP is interpreted as fill of a higher density of metallic debris, most probably depot-derived waste material. The second more conductively inert material is representative of construction/demolition type debris such as soil, concrete, asphalt, and reworked borrow material. Figure 3-9, which illustrates the vertical

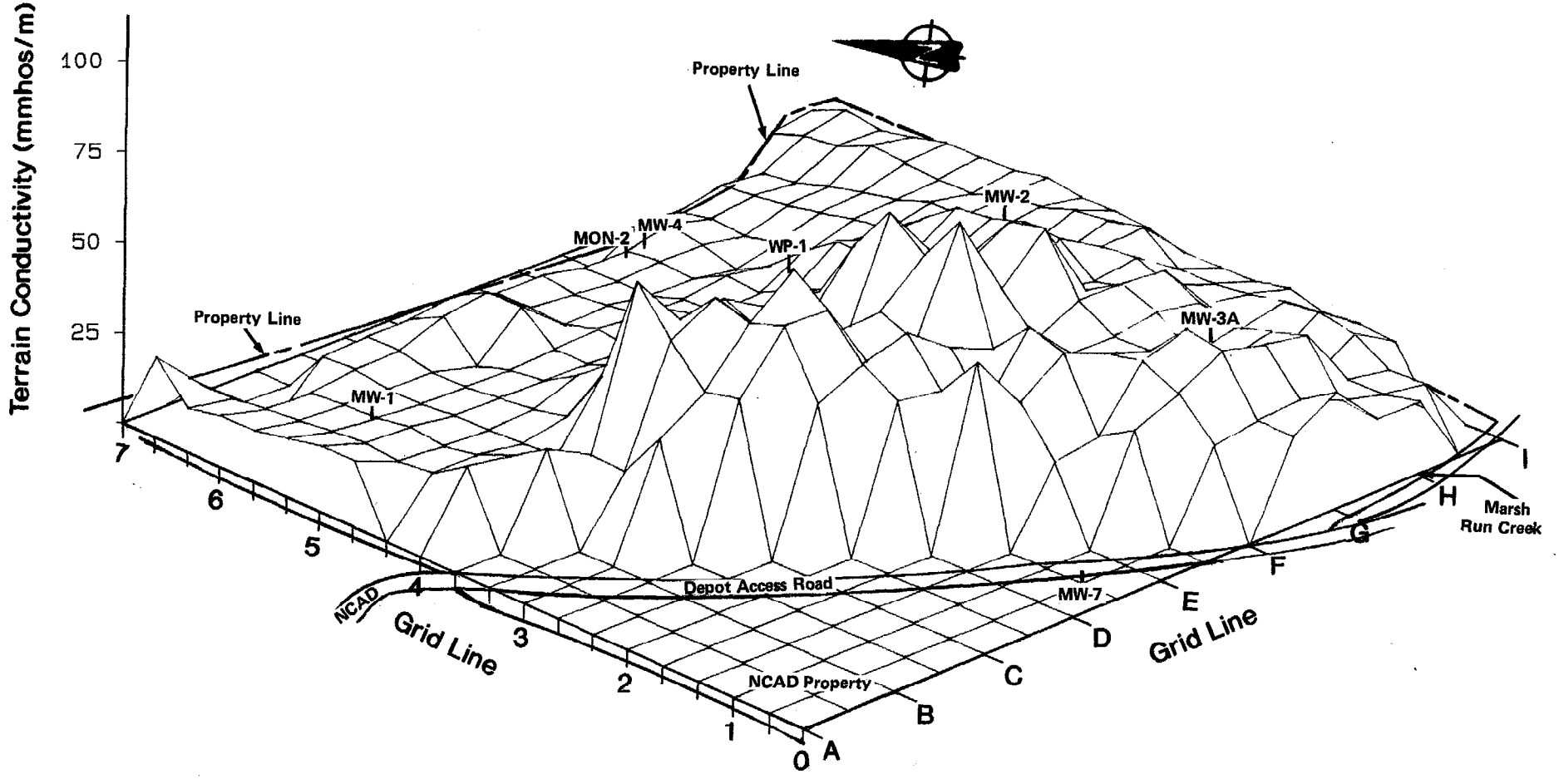


Figure 3-3. EM Survey - Horizontal Dipole (effective depth 25 ft).

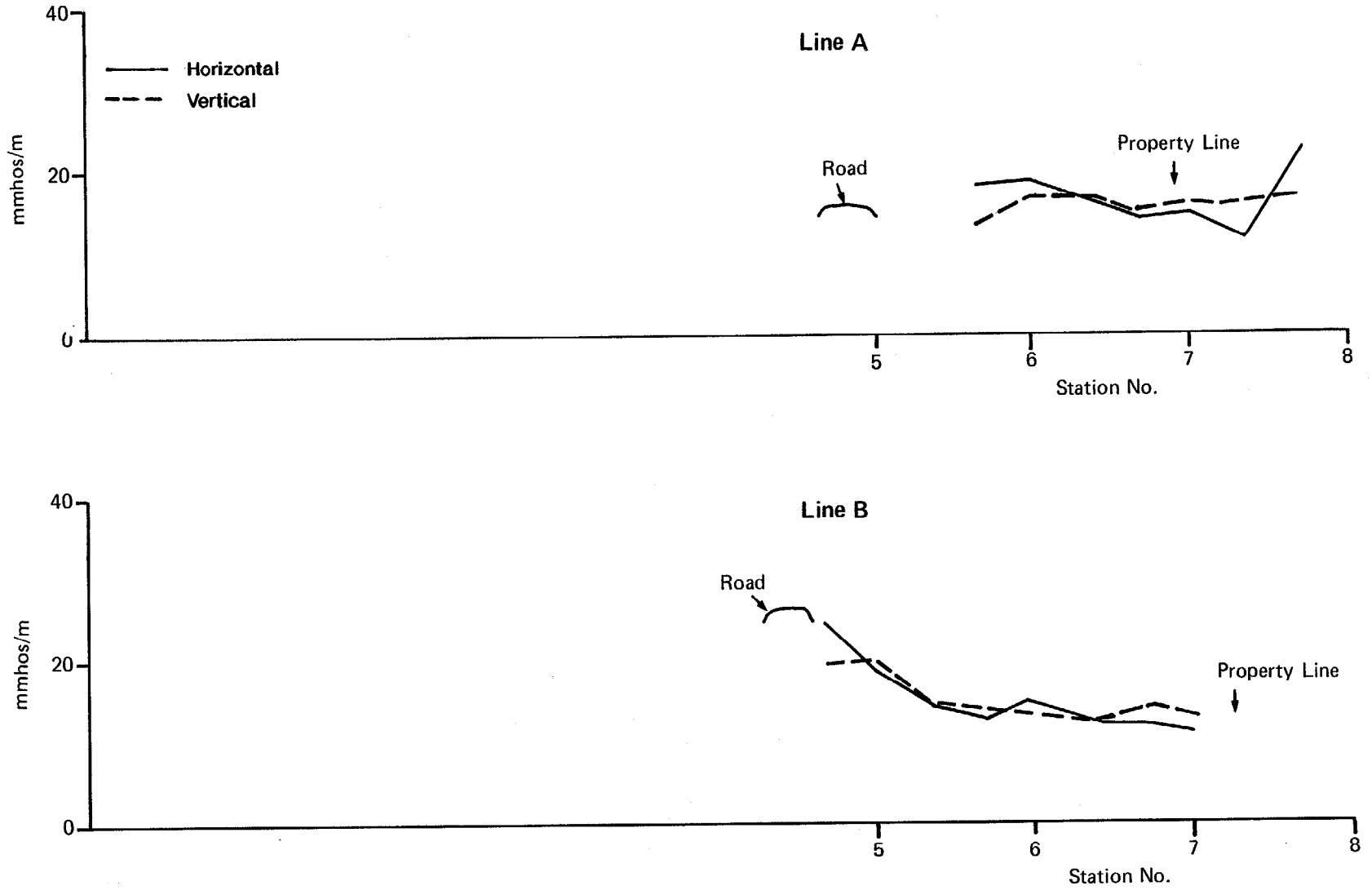


Figure 3-4. EM profiles A&B Lines.

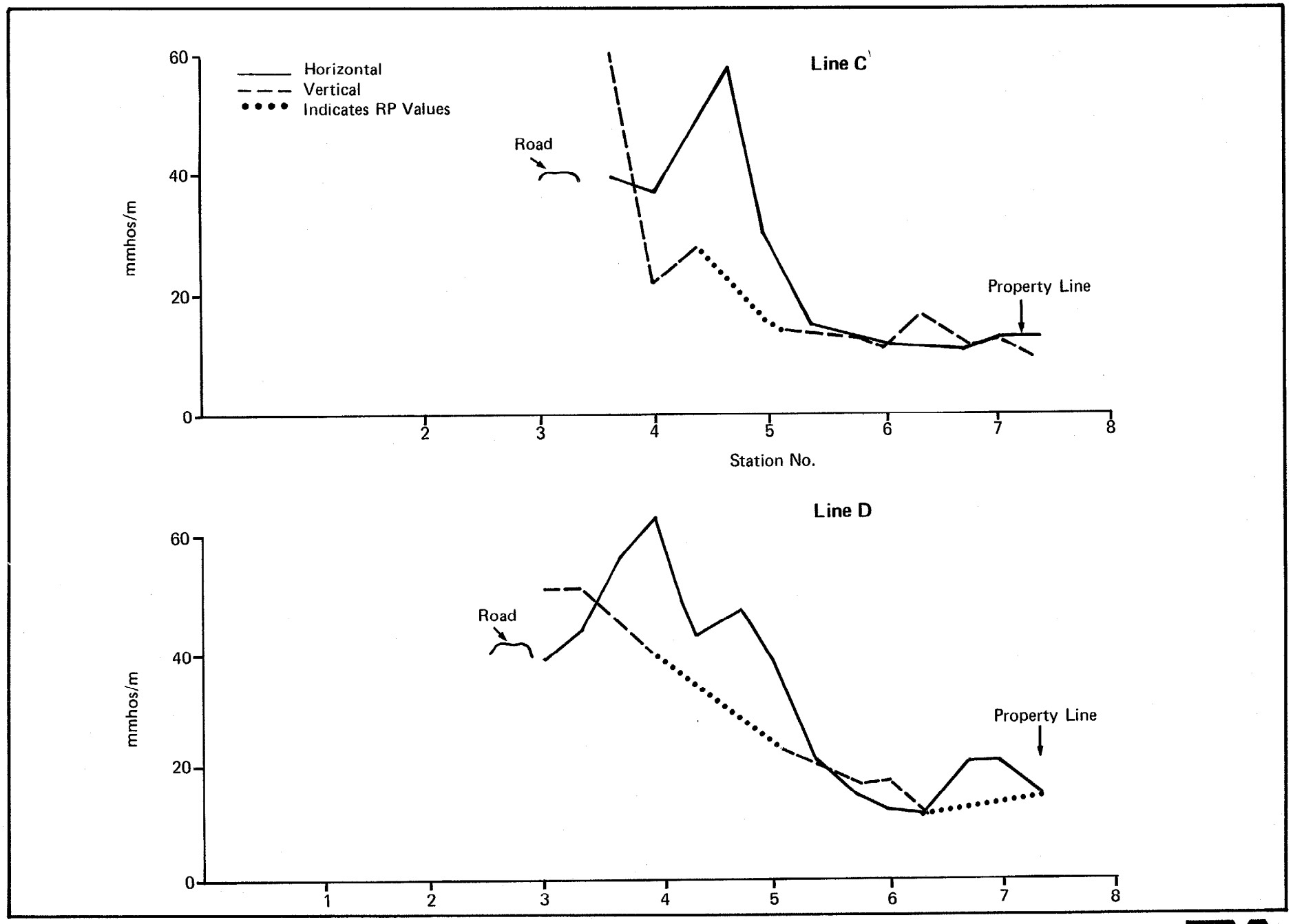
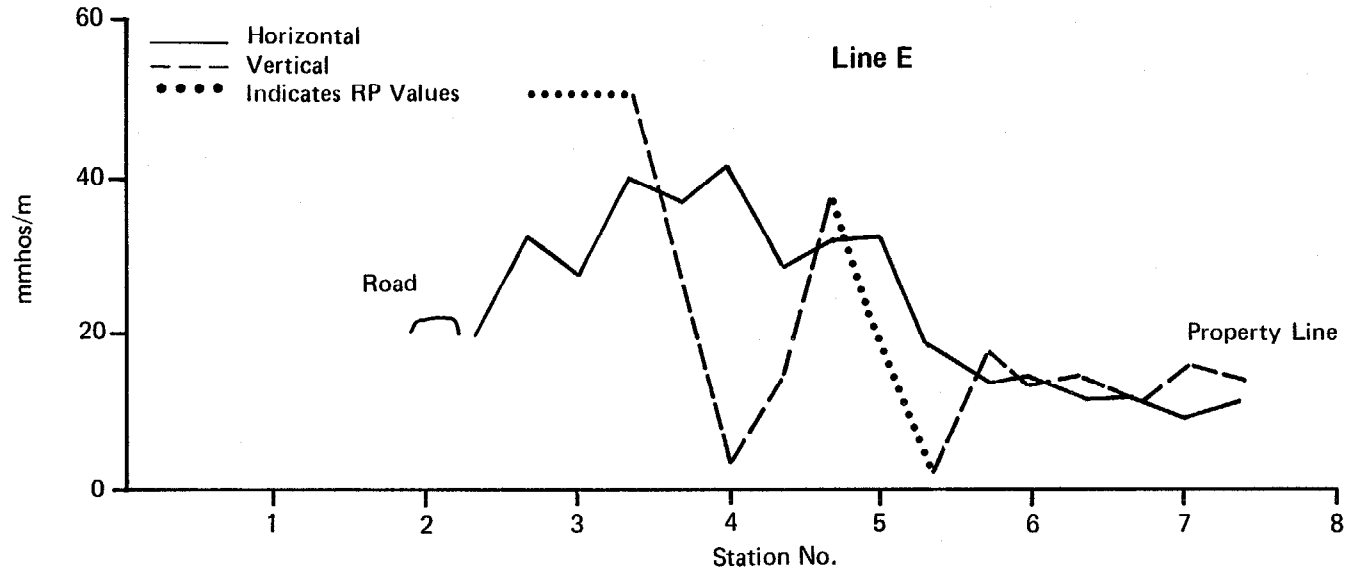


Figure 3-5. EM Profile C&D Lines.



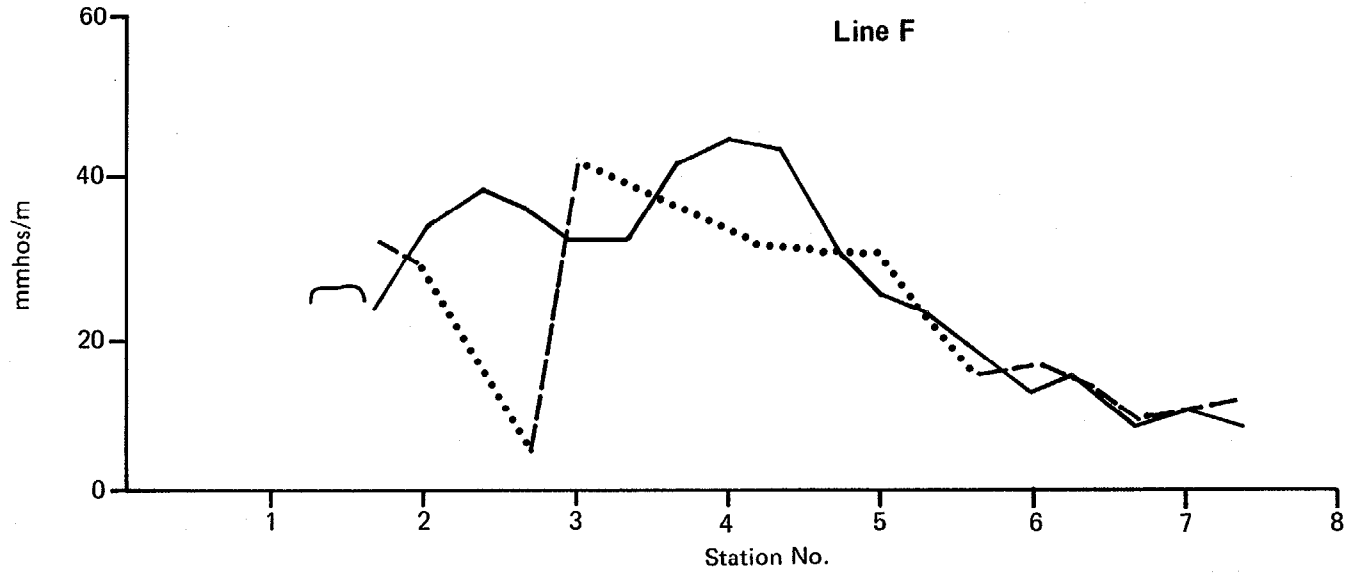


Figure 3-6. EM Profile E&F Lines.

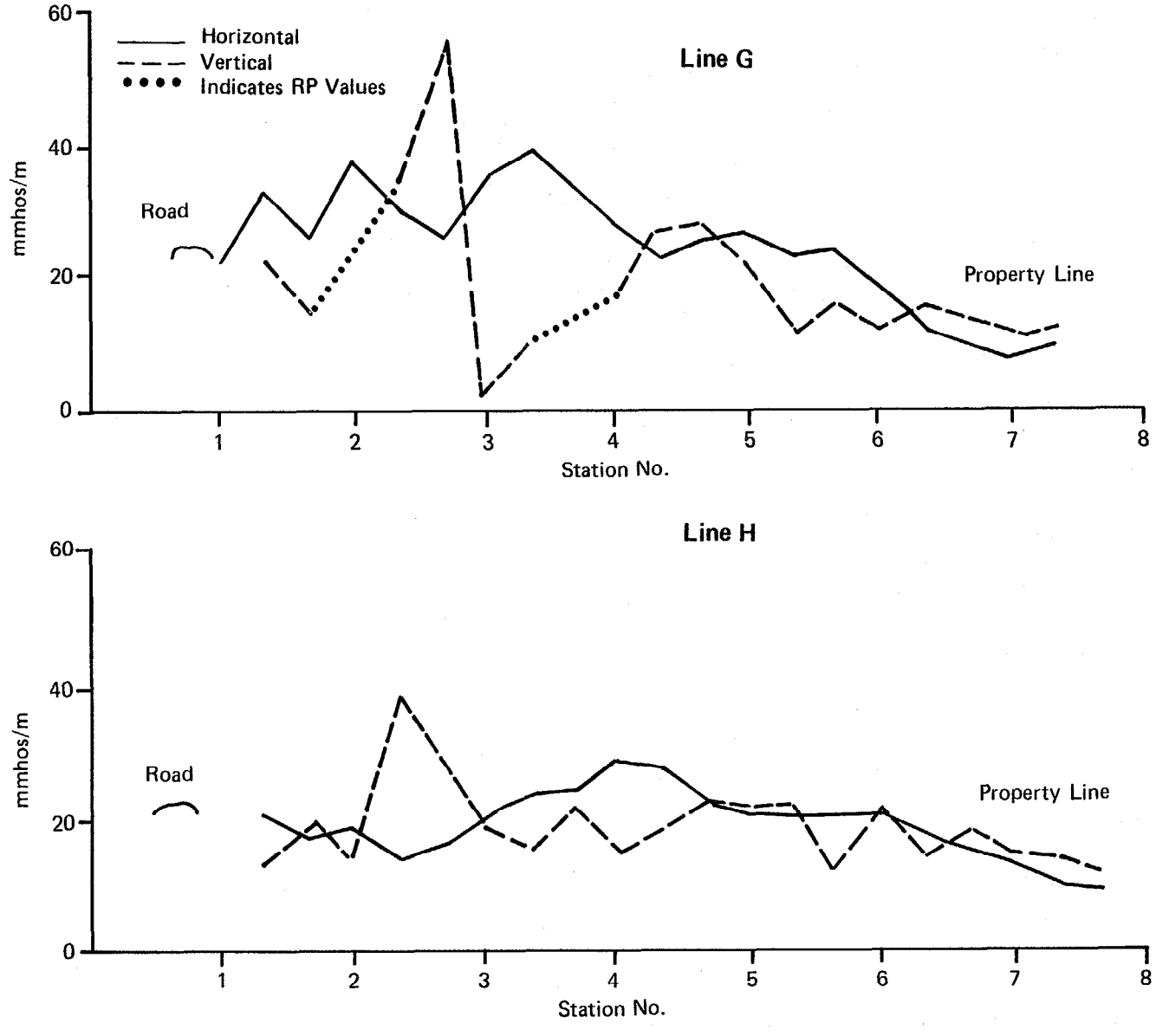


Figure 3-7. EM Profile G&H Lines.

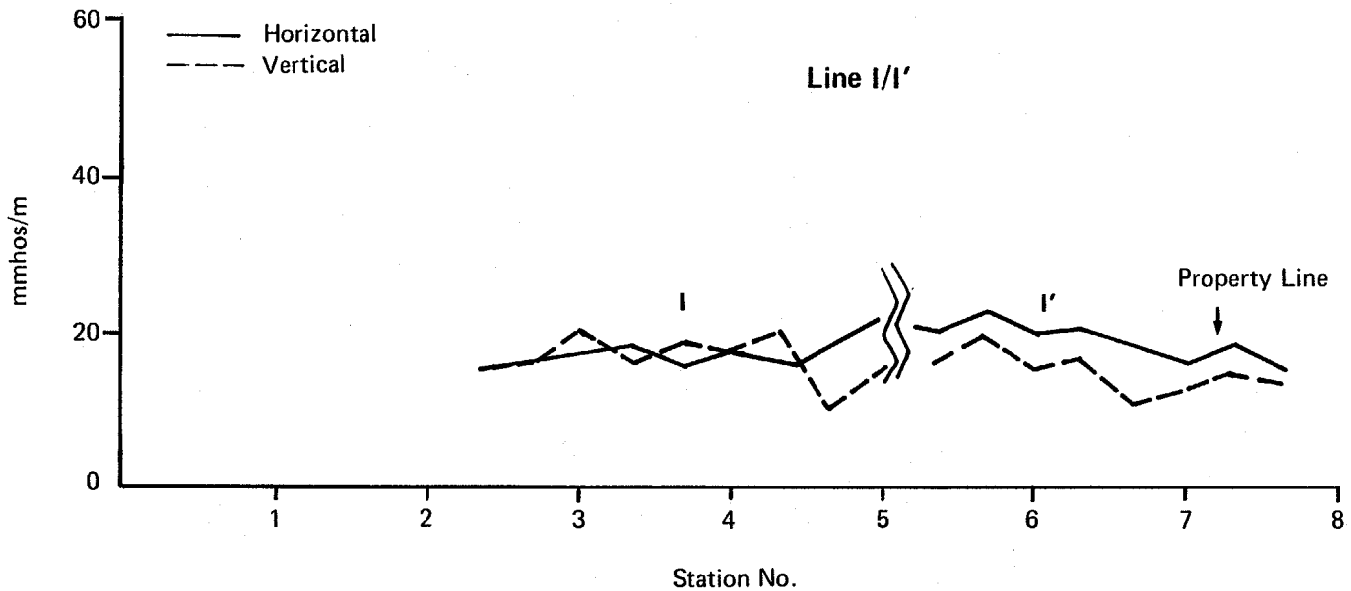


Figure 3-8. EM Profile I/I′ Line.

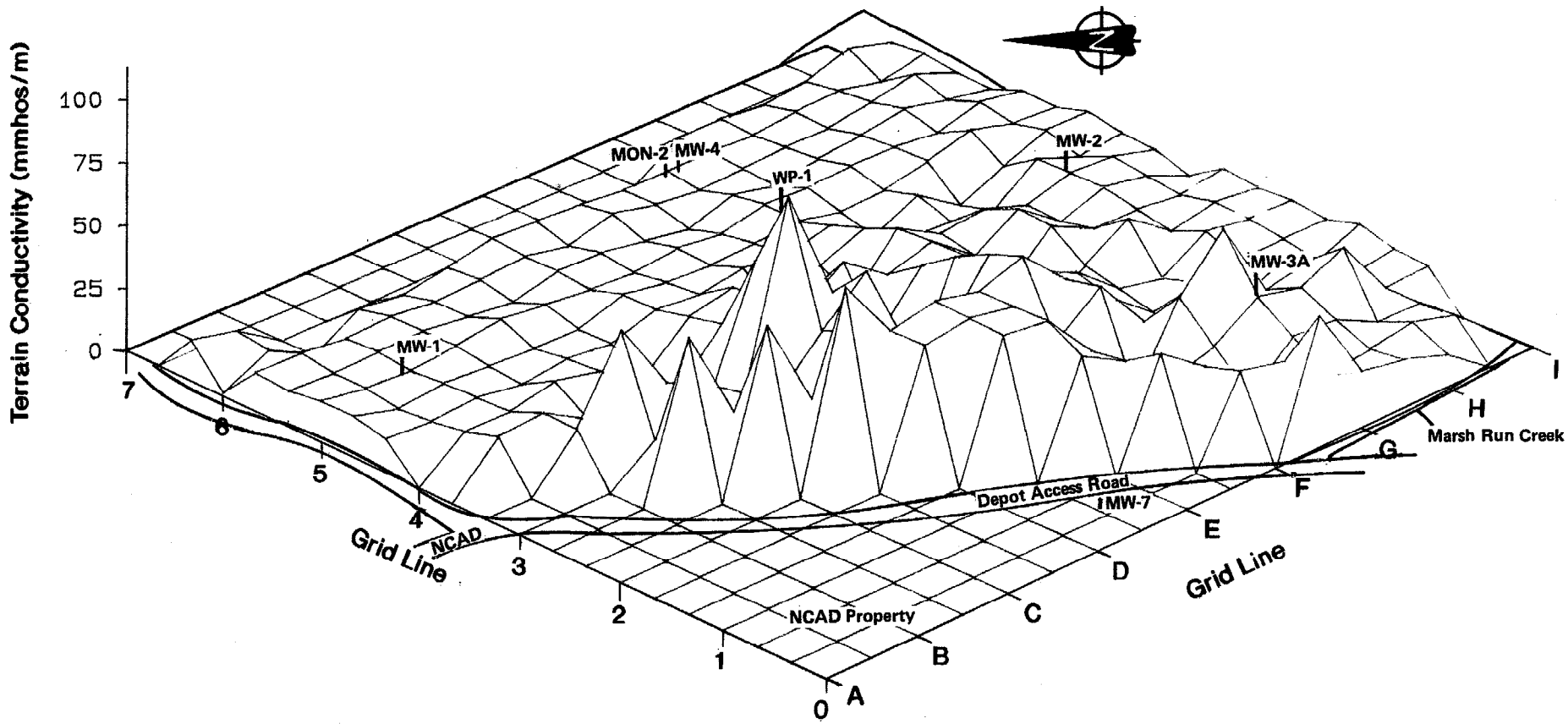


Figure 3-9. EM Survey - Vertical Dipole (effective depth 50 ft).

dipole terrain conductivity distribution from a three-dimensional perspective, illustrates the two distinct zones of terrain conductivity within the site boundaries.

One spurious occurrence of terrain conductivity above 20 mmhos/m was measured in the horizontal dipole at grid point D.0-7.0. A reverse polarity reading was also measured at this location in the vertical dipole. Consequently, this region was tentatively identified as an isolated area of potential metallic assemblage.

Based on the results of EM data, no inference was made as to the presence or absence of a shallow, high-conductivity ground-water plume. In general, the perimeter conductivity to the south (near stream) is slightly higher than that to the north (in marsh), which may be indicative of an elevated conductivity ground water emanating from the fill and migrating toward Marsh Run Creek to the south, or possibly due to deicing road salt contamination from base perimeter road clearing.

3.1.2 Waste Characterization

During the course of this RI, no direct characterization of the landfill waste material was conducted. However, indirect methods of determining waste material extent were conducted, such as the previously discussed geophysical methods and well point installation over geophysical anomalously high areas. Other indirect observations, such as surface topography, were used in conjunction with well point installation and geophysics to, at a minimum, estimate waste fill volumes. As previously discussed in Section 3.1.1, the lateral extent of what has been characterized as "waste fill" was relatively well defined by surface geophysical methods.

Waste fill in the context used for this RI can be categorized as waste materials of industrial, domestic, and other suspected and unknown types of refuse potentially deposited at the Marsh Run Site by past NCAD landfilling operations. The previous operations and use of NCAD during Marsh Run Field's active landfilling life present the potential for a wide variety of waste, including industrial solvents, metal sludges, damaged canned food items, chemical warfare impregnating agents, and general domestic refuse.

To date the most definitive evidence as to the physical nature of the waste fill has been gathered during the excavation of Test Pits 3, 4, and 5 conducted during the Woodward-Clyde Consultants (WWC) 1987 Confirmation Study. As a supplement to this data, monitoring well borings MW-2 (EA), MW-3A and MW-2A (WWC) encountered what is suspected as being waste at the extreme eastern periphery of the waste fill. Each of the borings encountered approximately 3-4 ft of domestic refuse fill intermixed with silty sand.

Test Pits 3 and 4 (WWC) (locations shown in Figure 1-6) both encountered a mixture of silty sand and gravel with metal, wood, brick, black rubber cylinders, glass, pasty white material, and white powdery material below the 1-1.5 ft of surficial topsoil. While most of the material is typical general domestic refuse, the powdery and white pasty material is suspect

and may be an industrial-related material. Test Pit 4, which is also situated within the area designated as waste fill, encountered at the same depths general refuse waste such as wood, glass, and brick fragments.

During well point installation, observation of the hydraulic force needed to advance the well point indicated that refusal (i.e., top of weathered bedrock) was encountered at depths below surface of 11.5, 9.5, and 10 ft for WP-1, WP-2, and WP-3, respectively. However, due to the confirmed presence of 5, 6, 1.5, and 4 ft of clayey silt (ML/CL) in monitoring well borings MW-2, MW-1, MW-4, and MW-3A (WWC), respectively, at depths below ground surface of 4-5 ft, it is postulated that waste fill is less than 7 ft and averages 4 ft across the site. Furthermore, examination of the sudden topography drop-off at the eastern edge of the fill and the presence of a clayey silt layer at similar depths below ground surface in monitoring well boring MW-5, a 4-5 ft average waste thickness can be assumed with reasonably good confidence. Based on an assumed average waste thickness of 4 ft (exclusive of 1-ft cover fill) and the inferred lateral extent of waste fill from geophysical data, an estimated maximum waste volume of 23,000-24,000 c.y. was disposed of at the site.

The waste material appears to be covered with an apparently continuous 1-1.5 ft layer of topsoil/silty sandy loam of moderate permeability. The cover fill is grassed or covered with small scrubs. No breech of cover fill was evident, nor was any exposed waste visible at the surface. Due to ground cover and relatively gentle topography, erosion of the cover fill is considered negligible.

In light of the soil sampling scheme conducted for monitoring well borings during this RI (Section 2.1.3.1), surficial soil samples of the cover fill were not obtained. However, as previously mentioned in Section 1.2.3, Previous Investigations, 23 surficial soil samples were collected by the U.S. Army Corps of Engineers (COE) and EPA (Tables 1-6 and 1-7) for the purpose of assessing human health risk associated with exposure to the site cover fill. EA was authorized by the COE, Omaha District, to incorporate the analytical results of the aforementioned sampling efforts into this RI baseline risk assessment.

3.1.3 Soils

The predominant soil series at the site and surrounding vicinity is mapped according to the York County Soil Survey [Soil Conservation Service (SCS) 1955] as Made Land soil series, designated by symbols Me and MdD on Figure 3-10. These miscellaneous land types consist of areas where, during the course of urban development, industrial development or landfilling operations have altered the landscape by moving or covering so that the normal *in situ* soil characteristics have been destroyed. These reworked soils have been mapped as a mixture of Penn and Landsdale surficial and subsoil materials (MdD) and Wheeling and Sciotoville materials (Me).

The north-northwestern portion of the site is comprised of the reworked Penn and Landsdale materials (MdD). This material was encountered in

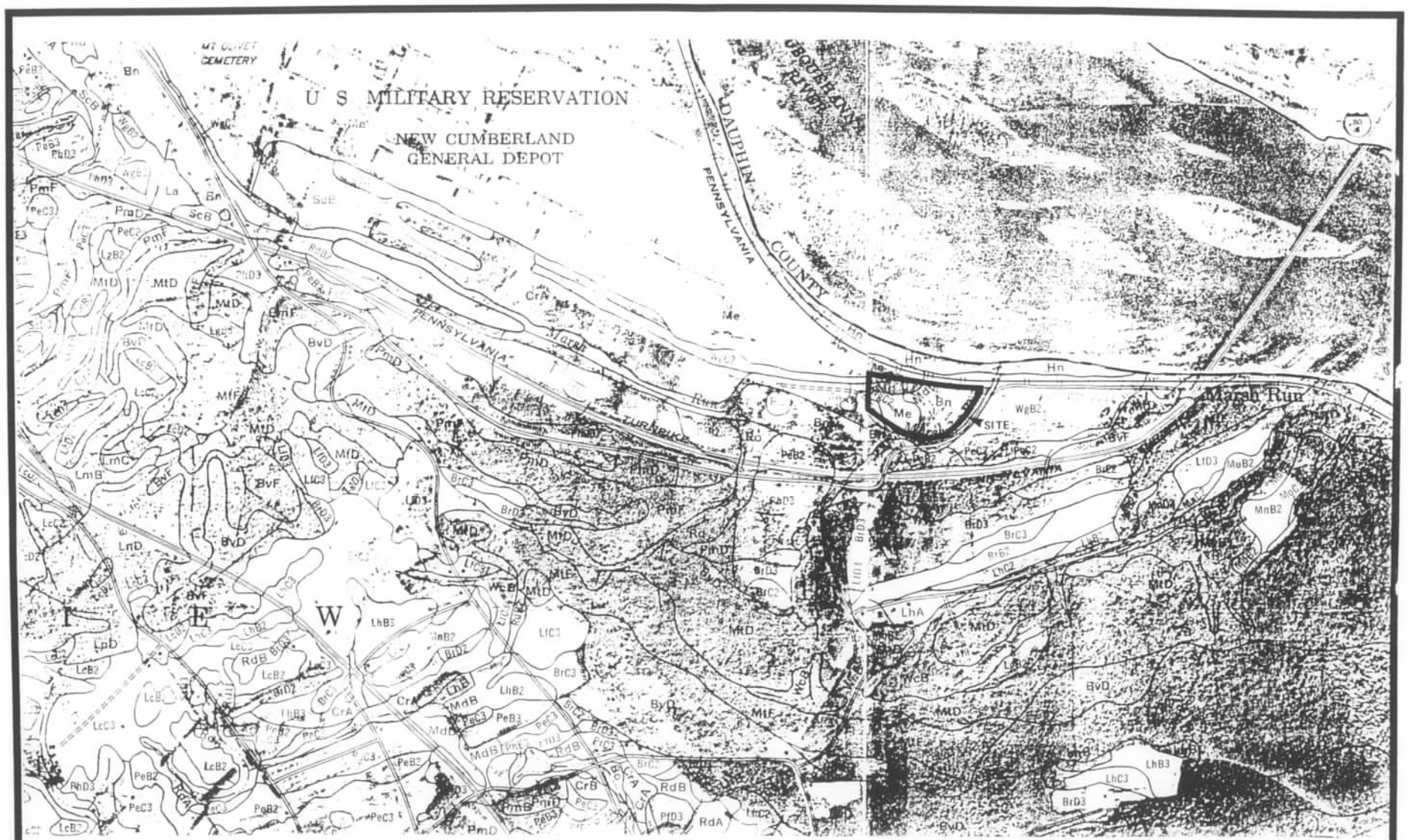


Figure 3-10. Soil series map (Source: Soil Survey of York County).

monitoring well boring MW-4 as a dark brown silty loam and clayey silt. A soil sample obtained at 2 ft from boring MW-4 was analyzed for grain size distribution, Atterburg limits, and natural water content, and is classified as ML in accordance with the Unified Soil Classification System (USCS) specifications. The soil physical analysis data are provided in Table 3-1. Grain size curves are provided in Appendix E. The "Made Land" soil series are typically residual materials of parent Triassic sandstone and red shale. In the area of monitoring wells MW-4 and MW-1 the soil appears to have been disturbed and reworked to a depth of 4-6 ft. The reworked soil interface at these depths is characterized by an indistinct transitional contact from clayey silt or silty loam to a clayey, sandy gravel (SC, GC). The characteristics of a sandy, clayey gravel subsoil at depths greater than 5 ft at MW-4 is consistent with the Soil Survey's reported gravelly subsoil material description of Landsdale and Penn soil types. A subsoil sample of the material obtained from monitoring well boring MW-1 at 9.5-ft depth was analyzed for physical characteristics and classified as a gravelly sand with silt (SC-SM) in accordance with USCS specifications. Approximately 40 percent by weight of this sample was greater in size than a coarse sand (4.5 mm diameter). It appears as if the soil series mapped MdD is the least altered (with respect to distribution) of the Made Land soil types (since the Soil Conservation Service field mapping).

The Made Land soil type designate Me appears to be distributed in areas currently identified during the geophysical survey as waste fill. The physical nature of the cover fill was most adequately assessed by the monitoring well borings MW-2 (EA), MW-2A and MW-3A (Woodward-Clyde 1987). Boring log data in these areas indicate 1 ft of topsoil loam, black, silty fine sand material apparently distributed across the waste fill area. This material was reportedly placed over the top of the fill material by Fairview Township. The origin of this surficial material is reportedly from the borrow area north of the site; however, topsoil was evidently brought in from an offsite location for the upper 4-6 in. of cover.

Underlying the surficial topsoil/black silty loam in the vicinity of MW-2, MW-3A is approximately 4-5 ft of reworked fill. It was encountered as a fine sand with silt and fine-to-coarse gravel intermixed with brick, glass, cinders, and ash. The matrix soil characteristics of the fill in the area are consistent with the Soil Conservation Service's general description of the Wheeling and Sciotoville soil series which are moderately well drained, dark brown to red, silt loam grading to a silty clay loam or sandy loam at 2 to 3 ft depth for the Sciotoville and Wheeling soil series, respectively.

Other additional direct observation of the site soils was the excavation of test pits which was performed by Woodward-Clyde Consultants during the Confirmation Study. Specifically, Test Pits 3, 4, and 5 were excavated in the area mapped as Me and identified during the RI as presumably waste fill material. These test pits (Woodward-Clyde logs provided in Appendix A) indicate the occurrence of 1 to 1.5 ft of black, fine, sandy silty loam (topsoil) which is apparently continuous across the waste fill.

TABLE 3-1 SUMMARY OF PHYSICAL PROPERTIES OF SOIL SAMPLES COLLECTED DURING MONITORING WELL INSTALLATION

Sample Designation	Matrix	Depth of Sample (ft)	Natural Water Content (%)	Liquid Limit LL (%)	Plastic Limit PL (%)	Plasticity Index	Percent Passing Sieve			USCS Classification Symbol
							No. 4	No. 10	No. 200	
MW-1, S-5	In situ soil	8-10	6.6	NA	NA	NA	60	32	10	GP-GM
MW-4A, S-2	Fill	2-4	15.8	24	17	7	100	99	77	CL-ML
MW-4, S-4	In situ soil	6-8	10.6	25	15	10	99	90	47	SC
MW-4, S-5	In situ soil	8-10	8.7	17	14	3	83	67	28	SM
MW-5, S-2	Fill	2-4	27.9	45	32	13	100	99	88	ML
MW-5, S-6	In situ soil	15-16	11.5	24	15	9	100	96	55	CL
MW-5A, S-6	In situ soil	15-16	10	26	17	9	100	98	37	SC

Underlying the topsoil is 3 to 4 ft of additional reworked soil and waste fill (i.e., brick, glass, cinders, and other industrial material) at all three test pit locations.

The major in situ soil series mapped at the eastern third of the site is comprised of the Bowmansville silt loam (Bn). This series consists of deep, poorly drained floodplain soils. Typically, the surface layer is dark grayish-brown silt loam, the upper part of the subsoil is light brownish-gray silty clay loam, and the lower part of the subsoil is a reddish-brown silty clay loam to silty clay. Most of this soil unit is undisturbed because of the heavy growth of trees, shrubs, and underbrush on this portion of the site.

At the extreme northwestern portion of the site, a spur of Wheeling silt loam (WgC2) is present. According to the Soil Survey this is suited to residential, commercial, and/or industrial development. Typically this soil is a dark brown silt loam mostly distributed in short slopes adjacent to areas of gently sloping Wheeling soil. The area on the site mapped as WgC2 may have been used for borrow placed elsewhere onsite, including on top of and mixed with other fill in the areas designated Me and/or waste fill.

Elsewhere to the immediate west of the site (i.e., on depot property) Made Land is present specifically for the base of the access and depot perimeter roads. Further west the Bowmansdale Series is present as low-lying floodplain soils adjacent to Marsh Run Creek. Further south of the site (i.e., south of Marsh Run Road), upland slope soils of the Penn and Wheeling series are present. Table 3-2 summarizes the physical properties of the surrounding in situ Bowmansdale, Wheeling, and Penn soil series as reported by the Soil Conservation Service.

In summary, the majority of the site not covered with dense underbrush and trees is comprised of reworked local soils to a depth of 4-6 ft. The central portion of the site designated Me (Made Land) in Figure 3-10 by the Soil Conservation Service and characterized by geophysical investigation as "waste fill" (Figures 3-1 and 3-2) is covered with a thin veneer, 1-1.5 ft of black, silty loam (topsoil) placed by Fairview Township. Below this thin veneer lie various local reworked soils intermixed with "waste fill" material. Outside of the area designated "waste fill" to the north lie reworked local soils that appear relatively free of any waste fill material. The northwest portion of the site retains some natural in situ soil of the Wheeling Series that was used to some extent as borrow material during landfill activities and as a final cover fill placement. All of the soil types are covered with grass and small scrubs. No areas of stressed vegetation or large-scale erosional features were observed.

The dominant in situ soils bordering the site to the east and west are those of the Bowmansville silt loam, which is a low-lying, poorly drained floodplain soil adjacent to Marsh Run Creek. This soil is covered with heavy undergrowth and trees and is relatively undisturbed.

TABLE 3-2 SUMMARY OF PHYSICAL PROPERTIES OF IN SITU SOIL TYPES IN THE VICINITY OF MARSH RUN

Map Symbol	Depth to Season Water Table (ft)	Depth to Bedrock (ft)	Classification		Percentage Passing Sieve			Permeability (in./hr)	Maximum Dry Density (lb/ft^3)
			Unified	AASHO	No. 4	No. 10	No. 200		
Bn (MW-5, S-6-Bn)[a]	0-1½	4-8	ML-CL (CL)[a]	A-4	100 (100)[a]	90-95 (97)[a]	75-90 (55)[a]	2.0-6.2	~100
PeB_2	> 4	1½-3	ML-CL	A-6	90-100	85-95	60-70	2.0-6.2	106
PeC_2	> 4	1½-3	ML-CL	A-6	80-90	70-80	55-65	2.0-6.2	105
WgB_2	> 6	5-8	CL	A-6	100	85-95	70-85	2.0-6.2	118
WgC_2	> 6	5-8	CL	A-6	90-100	85-95	70-80	2.0-6.2	116

(a) denotes results of physical analysis of soil sample collected as part of this RI.

With respect to potential future use of onsite soils for regrading or other use, the northwest portion of the site north of Pennsylvania State planar coordinate N 317,000 and west of coordinate E 2,227,600 could be accessed. Based on Woodward-Clyde test pit data from TP-1 and TP-2 (Appendix A) and the Soil Conservation Service's Soil Series map, this area is relatively undisturbed. In general, depths to the seasonal water table are greatest in this area (>6) ft due to the higher elevation and the relative undisturbed nature of the soil. Conceivably, a conservative estimate of 3,000-4,000 c.y. of usable fill material could be excised from this area while maintaining a grade suitable for incipient runoff drainage.

3.1.4 Geology

3.1.4.1 Physiography

The Marsh Run Field site is situated at the southern extreme of the Great Valley Section of the Valley and Ridge Physiographic Province and is bordered immediately to the south (i.e., south of Marsh Run Road) by the higher elevated and more resistant Triassic Lowland Physiographic Province. The Great Valley Section is characterized by relatively low-to-moderate relief. The relatively flat topography in the vicinity of the site is developed on Quaternary and Tertiary floodplain and alluvial silt, clay, and sand sediments. Topographic relief across the site is low (<10 ft). Alteration of the natural topography has been made over the years by landfilling activities, road fill placement, and railroad track embankment construction to the north.

Structurally, the site is situated at the extreme north boundary of the Triassic Newark-Gettysburg Basin. The Newark-Gettysburg Basin extends along a southwest-northeast trend principally in Pennsylvania and New Jersey. This relatively extensive basin dips monoclinally to the northwest. It was formed as a result of erosion and subsequent deposition of detritus derived from Paleozoic and Precambrian metamorphic highlands during a tectonic uplifting south of the basin. These sediments were carried by streams from the highlands and deposited as a wedge of thickening sediments away from the source. The basin is parallel to the Appalachian Highlands. Faulting within the basin is prevalent in the thicker sedimentary sequences.

3.1.4.2 Descriptive Geology

As previously discussed in Section 3.1.3, the majority of the site not covered with trees has been filled with various types of depot-derived landfill waste intermixed with borrow material from adjacent areas and cover topsoil was reportedly trucked in by Fairview Township. The origin of the cover fill is not known. The waste material was placed over what was originally a low-lying floodplain marsh area adjacent to the Susquehanna River. The original marsh area was and still is traversed by the west-to-east flowing Marsh Run Creek. In general, the topographically flat marsh silt, clay, peat, and sand deposits of Quaternary age are situated at the base of the hills which rise abrubtly in elevation several hundreds of feet to the south of the site. The hills south of the site

as well as the underlying bedrock beneath the site are Triassic-age, fine-grained sandstone, siltstone, and shale of the Gettysburg Formation.

The surficial and shallow subsurface geology in the vicinity of Marsh Run Field is characterized by a thin veneer (approximately 5-7 ft thick) of Quaternary alluvium. The alluvial deposits underlying the site are typically unconsolidated clays, silts, and thick interbeds or lenses of fairly well-sorted, subrounded to rounded, fine sand and gravel. These detrital sediments are floodplain sediments which border the Susquehanna River and its tributaries. They were deposited as a result of cyclic river flooding and overwash deposition. Figure 3-11 shows the location of two idealized cross-sectional views of the site. Figures 3-12 and 3-13 illustrate the idealized subsurface geology of the site.

The entire landfilled portion of Marsh Run Field is directly underlain by Quaternary sediments. A varicolored, brown to gray, medium stiff clayey silt with a trace of sand and fine gravel underlies fill material in the portion of the site south of site grid line-6. It is apparently continuous across this area of the site. The fill characterized as waste fill is almost entirely underlain by this clayey silt layer. A soil sample of this clay layer was collected from MW-5 at a depth of 15 ft and was classified as a lean clay (CL) in accordance with USCS specifications. Based on grain-size distribution data, the permeability of this material is estimated to be less than 1×10^{-6} cm/sec. Thickness of this clayey silt material ranges from 2 ft at MW-6 to 8 ft at MW-5, and averages 4 ft where present across the site.

The clayey silt layer encountered is representative of Quaternary alluvial deposits. Its extent to the west and south is uncertain; however, based on topography and the presence of low-lying marsh sediments adjacent to Marsh Run Creek, the silty clay layer is suspected to be present west of the site below the fill. To the south where the lowlands transgress to the upland region, the clay silt layer most probably laterally grades into the residual silts of the Triassic siltstone and shales. Figure 3-14 (isopachous map of clay/silt layer) illustrates the inferred thickness (based on boring data) of clay beneath the site. One major margin for error in inferring the clay is continuous across the site is the lack of data beneath the "waste fill" over the entire site. It is not certain whether or not the clay layer is absent over a portion of the site due to a coarse-grained lens or other depositional factors. However, based on the reported marshy nature of the area prior to landfilling and the observed clay layer east, west, and immediately south of the site, the presence of a continuous clay layer is likely.

Further to the north-northeast, the clayey silt laterally grades to a reddish-brown clayey sand and rounded gravel (Figures 3-12 and 3-13). This lithology was encountered in boring MW-4 at a thickness of 7 ft. It is comprised of a larger percentage of sand and gravel-sized particles than the clayey silt sediments to the southeast. Therefore, the permeability of the clayey sand is estimated, based on area size and density, to be correspondingly higher by approximately one magnitude (i.e., 1×10^{-5} cm/sec) than that of the clayey silt.

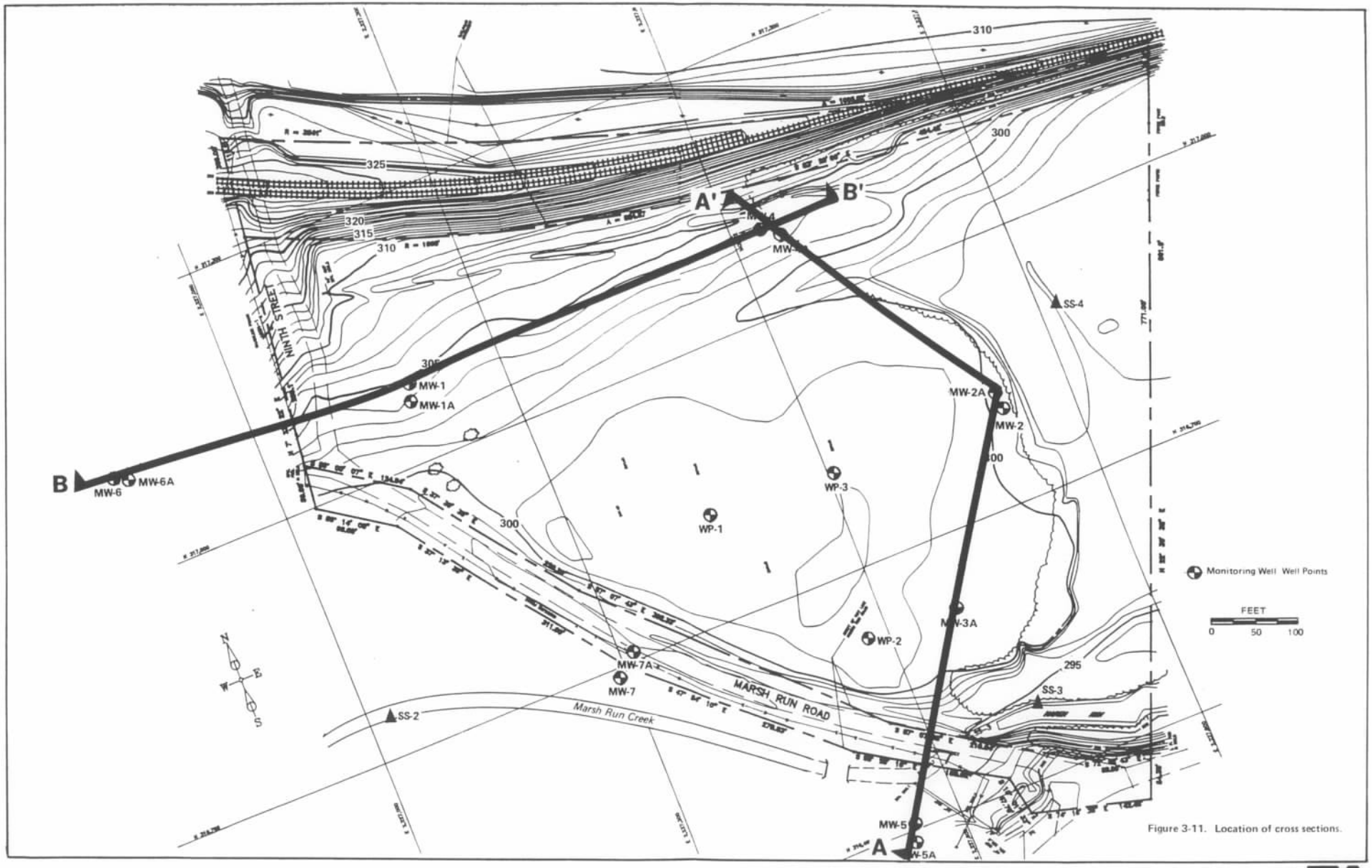
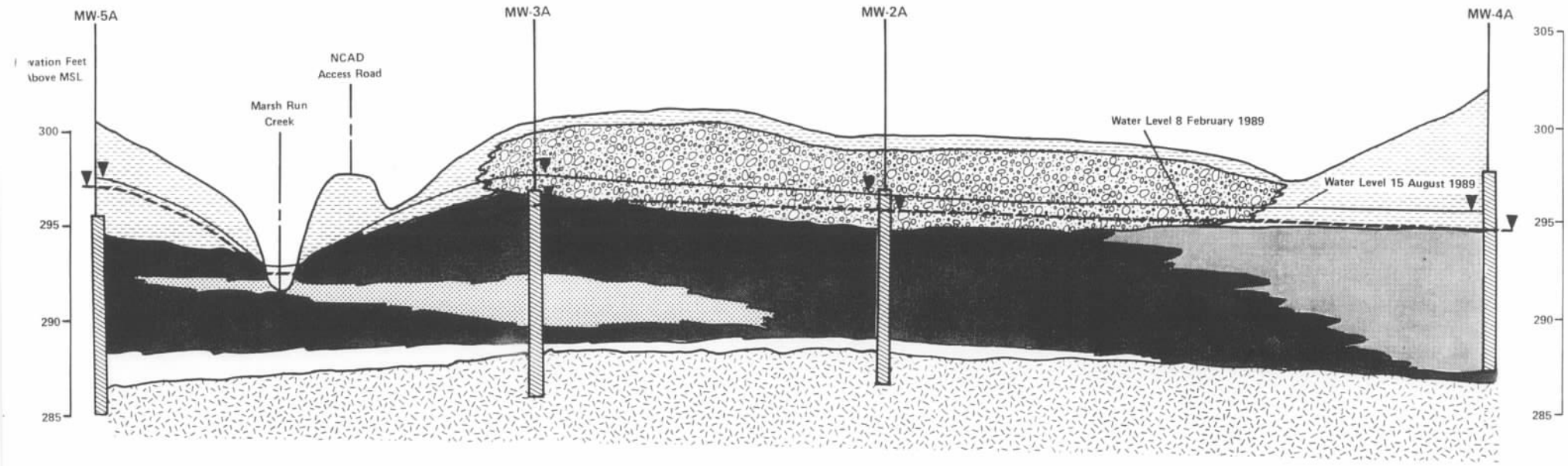


Figure 3-11. Location of cross sections.



Monitoring Well Screened Interval

Waste Fill

Residual Overburden/Reworked Overburden

Clay/Silt Flood Plain Deposits

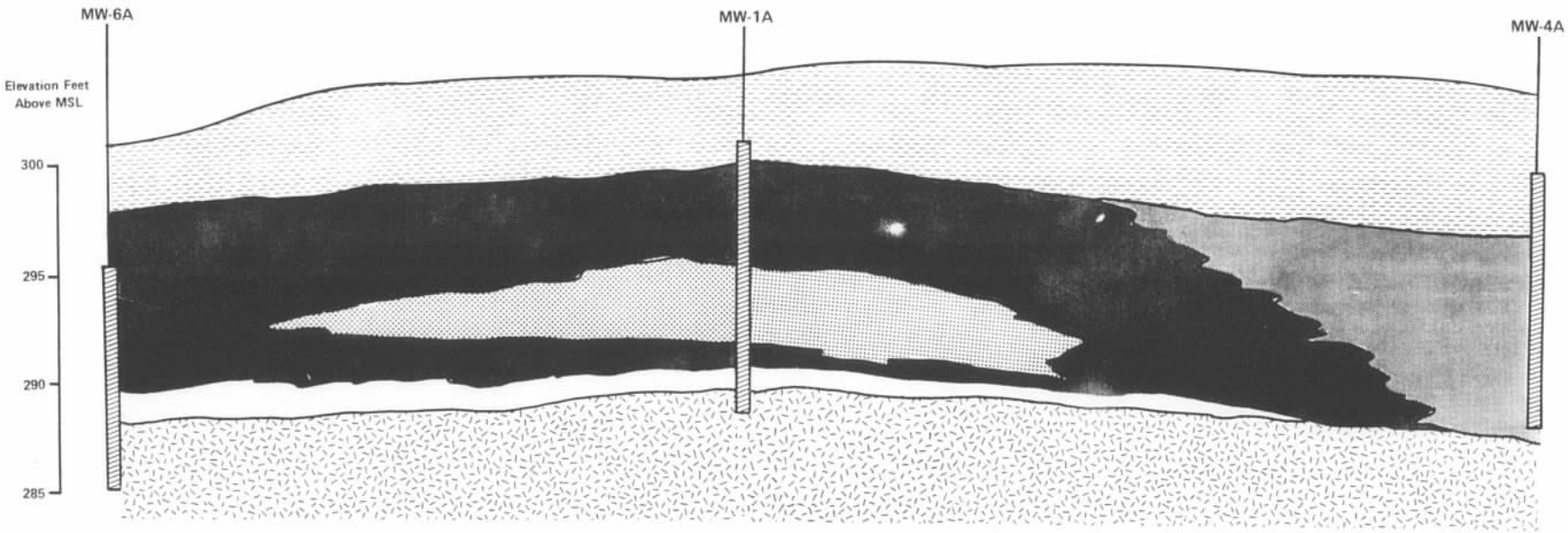
Clayey Sand

Highly Weathered Bedrock (Saprolite)

Sand and Gravel

Bedrock (Gettysburg Formation)

Figure 3-12.
Idealized view of subsurface geology at Marsh Run Field, Cross Section A–A'.



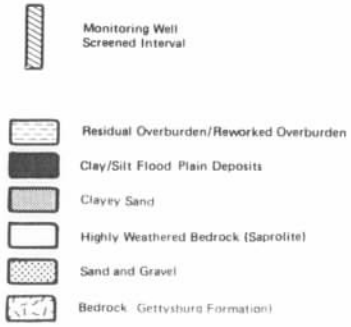


Figure 3-13.
Idealized view of subsurface geology
at Marsh Run Field, Cross Section B–B'.

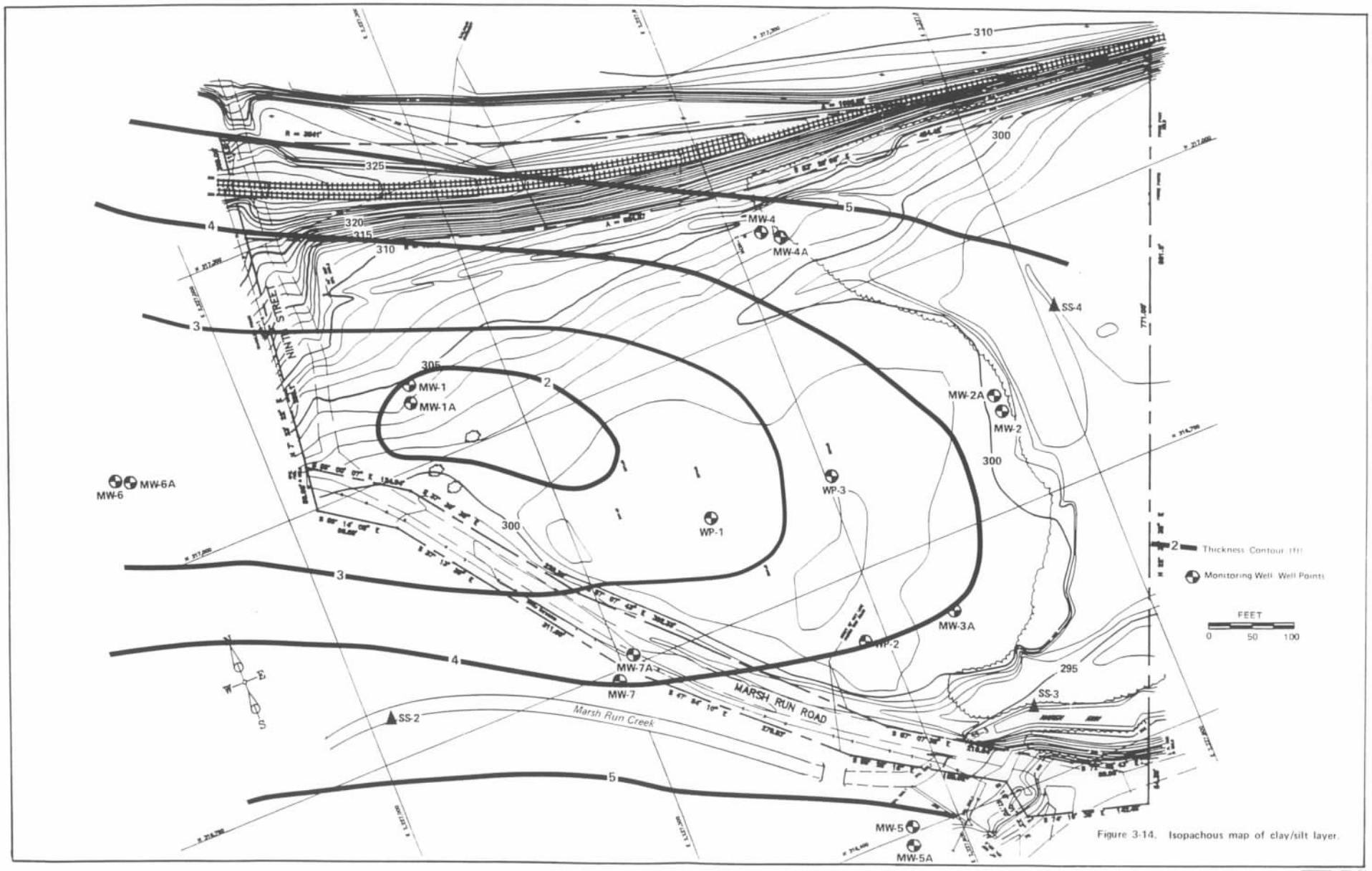
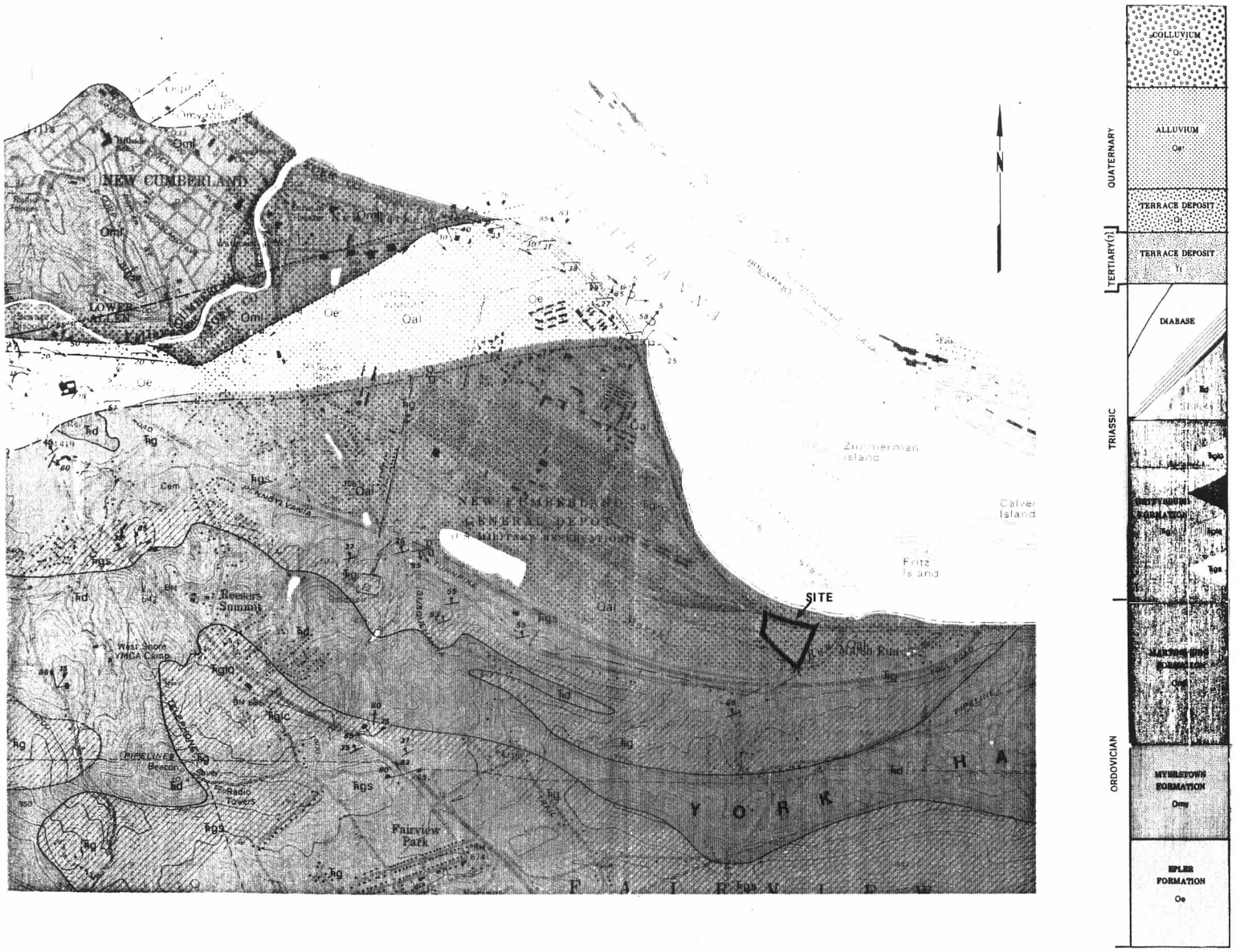


Figure 3-14. Isopachous map of clay/silt layer.

Two representative samples of the clayey sand material were collected from MW-4 at depths of 7.5 and 9.5 ft; these samples were classified as clayey sand (SC) and silty sand (SM), respectively, in accordance with USCS specifications. Although physical analysis of these soil samples indicates a larger percentage of coarse-grained sediments, fines (clay, silt) make up approximately 25-45 percent of the material by weight. Therefore, based on this grain size distribution, this material could be characterized as having moderate to moderately low permeability. There is an apparent decrease in fines with increasing depth, indicating a slight downward coarsening of sediments. It is speculated that further lateral coarsening of shallow subsurface sediments may occur approaching the banks of the Susquehanna River.

Interlayered or lensoidal sands and gravel were encountered in borings MW-3 and MW-1 at thicknesses of 3 and 4 ft, respectively. The sand-gravel layer was encountered below the clayey silt layer in both of these borings. Based on boring log data, the sand-gravel layer is suspected of being restricted to the southeastern portion of the site (i.e., it was not encountered in boring MW-2 and MW-4) and may be continuous in a roughly east-west orientation across the southeastern portion of the site. The sand lithology is typically a medium brown, moderately well sorted, fine-to-coarse sand and fine gravel with a trace of rounded cobbles, weathered sandstone, and shale rock fragments. A grain- size analysis of this material was conducted on a sample collected at a depth of 9.5 ft from MW-1. This material is classified as a sandy gravel with silt (GP-GM) in accordance with USCS specifications. Based on the grain size distribution of this material, permeability is expected to be moderately high, estimated in the range of 1×10^{-3} cm/sec.

The unconsolidated sediments of the site are underlain by the Gettysburg Formation of Triassic age. The general site geology is shown in Figure 3-15. Locally the Gettysburg Formation was encountered at a depth of 11-15 ft below ground surface. It is typically a maroon, silty, fine-to-medium grained sandstone interlayered with fissile shale. Infrequent lenses of subrounded vein quartz and rock fragment clasts in a silty matrix usually less than 8 in. thick were also encountered. The relative percentage of shaley horizons to siltstone/sandstone horizons varied from 10 to 50 percent. The higher percentage of shale horizons was evident in the upper few tens of feet of rock. All bedrock monitoring well borings encountered a gradational change from silty fine sandstone, siltstone, and shale (upper section) to a more evenly graded fine-to-medium grained sandstone with less silt and fewer shale horizons (lower section). The matrix cement is high in iron oxides, resulting in the characteristic maroon color. This gradational lithologic change at increased depth was generally reflected by a corresponding increase in the rock quality determination (RQD) percentage of rock cores. In general, a low RQD value indicates a higher degree of rock fracturing; however, in this case the RQD of the shale layers was low due to the relative brittleness (fissilty) of the shale. Consequently, the low RQD value for the shale/ siltstone does not imply extensive fracturing or fracturing connectivity. The nature of the fine-grained mudstone and shale is that of plastic deformation when subjected to tectonic-related stress; as a consequence, fracture interconnectivity is assumed to be low in shale horizons.



Contact

Dashed where approximately located; dotted where inferred.

Steep (reverse) — Low-angle

Thrust fault

Sawteeth on upper plate. Dashed where approximately located; dotted where concealed.

U — D

High-angle fault

U, upthrown side; D, downthrown side. Dashed where approximately located; dotted where concealed.

Facing direction known		Facing direction unknown	
Inclined	20	Inclined	47
Vertical		Approximate	30
Horizontal		Vertical	
Crumpled	22	Crumpled	57
Overturned	20		

Strike and dip of beds

Note: In all cases, the strike-and-dip symbol is on the exact location where data were obtained. Other structural symbols based on readings at the same point are grouped as near as possible to the bedding symbol location.

Inclined (75) — Vertical — Multiple joint system (85, 40)

Strike and dip of joints

FEET

0 1000 2000

Figure 3-15. General geologic map with key.

Boring data indicate that the upper section siltstone/shale lithology thickens from west to east. Depth to the bottom of the siltstone/shale horizon ranges from 20 to 41 ft below ground surface at elevations of 279 to 259 ft MSL, respectively. Bedding in the siltstone/shale horizon is characterized as massive and nondescript. However, bedding inclination, where discernible, was found to be consistent with regional trends, dipping uniformly 20-30° to the north-northwest. The high percentage of shale in the siltstone/shale (upper section) tends to facilitate weathering at a faster rate than the more resistant sandstone of the lower section.

Because of the lower section sandstone rigidity and its inability to deform with stress, fracturing, although no more common in the lower section, exhibits better openness and development. Fractures tend to be larger, and most likely more laterally extensive. Therefore, it is speculated that these fractures are the primary transmissive conduits for ground water in the upper 50 ft.

The dominant orientation of fracturing is low angle (~20°) and oblique to bedding. Fracture density of both the upper and lower bedrock sections measured perpendicular to fracture planes ranges from one per 5 to 10 ft.

In summary, the site investigation has characterized the geologic conditions to a depth of 50 ft. The geologic conditions encountered at the site have been evaluated based on the data collected. All of the geological data developed during this investigation are consistent with data generated by previous investigations. The supplemental data obtained during this RI have furthered the knowledge of hydrostratigraphic unit interconnectivity and consequently the geologic impact on ground-water flow patterns. The presence and extent of the shallow subsurface clayey silt and its lateral gradations are potentially important with respect to vertical and lateral contaminant migration and available remedial options such as ground-water cutoff trenches and slurry walls. Its continuity beneath the site is suspected but not confirmed. Depth to bedrock is shallow (11-15 ft). The upper 10 to 30 ft of bedrock is comprised of shale and siltstone while a deeper section is comprised of a more evenly grained sandstone. The sandstone section is anticipated to be the primary ground water-bearing zone.

3.1.5 Surface Water

The Marsh Run Field site is located within the central portion of the lower Susquehanna River Basin. Specifically, the site is located adjacent to and is drained by Marsh Run Creek. Marsh Run Creek discharges directly into the Susquehanna River, 1,100 ft northeast of the site.

Marsh Run Creek enters NCAD at the southwest corner of the depot and flows into Marsh Run Pond, which is approximately 32 acres in area. Upstream of the pond, the stream runs through a large marsh encircled by homes and commercial properties. Below the pond, Marsh Run Creek flows east through the depot and is surrounded by marshy mud flats. Much of the marshy mud flats through which it flows have been previously used as

land disposal areas for depot waste, while other marsh areas along the creek were used for sewage sludge disposal.

Approximately 2,550 ft west of the site, an unnamed north-flowing stream, which flows out of the relatively undeveloped hills south of the site, merges with Marsh Run Creek.

Surface water and stormwater runoff from NCAD flow into Marsh Run Creek from the warehousing and storage areas. The Pennsylvania Turnpike parallels Marsh Run Creek with the highway centerline varying from 400 to 1,000 ft south of the Creek. A Turnpike maintenance facility is located approximately 1,000 ft south of the Marsh Run Creek Dam. The highway maintenance facility surface runoff discharges into Marsh Run Creek via storm drainage ditches.

Incipient surface water runoff from Marsh Run Field is channeled into Marsh Run Creek via a drainage swale along the southwest and south property boundaries. The northern portion of the site is drained via a north swale which channels water into the marsh east of the site.

3.1.5.1 Stream Drainage

Marsh Run Creek is classified as a warmwater fishery by the State of Pennsylvania. During the February sampling event, streamflow measurements were estimated at 65 and 74 ft^3/min at sampling stations SWS-2 and SWS-3, respectively (Figure 2-1).

Previous hydrological studies (Taylor and Werkheiser 1984) have estimated that ground-water base flow constitutes approximately 65 percent of total streamflow in the area, although measured base flow contributions vary between 49 and 80 percent depending on land topography and geology. An estimation of average aquifer transmissivity of the area between SWS-2 and SWS-3 was made from the volume of ground-water discharge to the stream, the slope of the water table, and the length of streams receiving discharge in the area. The stream discharge volumes were estimated during the surface water sampling event. The cross-sectional geometry of the stream was measured at each station and flow measurements taken at six evenly spaced points across the stream at 0.65 ft, the depth of the stream, at each measurement point. The slope of the water table was determined from the onsite monitoring wells and the stream discharge point elevations along the predicted flow-path lengths. The length of the streams receiving discharge were measured from a U.S. Geological Survey (USGS) topographic map. The streamflow measured at SWS-2 was assumed to be representative of stream base flow from Marsh Run Creek, from Marsh Run Pond east, and the north-flowing stream segments. Streamflow measured to station SWS-3, which was higher than SWS-2, was assumed to represent the supplementation of ground-water base flow from the Marsh Run Creek stream segment adjacent to Marsh Run Field (i.e., between SWS-2 and SWS-3). Since no precipitation had occurred within the previous 72 hours, bank storage or surface runoff were considered negligible. However, some incipient runoff to the stream may have resulted due to melting of ice.

In comparing the total estimated surface water flow at SWS-2 of 65 ft^3/min to 74 ft^3/min at SWS-3, it is evident that a 14 percent increase in streamflow is attributable to the 850-ft segment of Marsh Run Creek adjacent to the site. However, this addition to Marsh Run Creek base flow is from both sides of the stream (i.e., site and depot sides of stream).

Assuming that base flow to a stream is calculated by the following equation:

$$Q = T\ 2L\ I$$

where
- Q = streamflow (ft^3/day)
- I = water table average gradient (ft/mi)
- L = stream segment length (mi)
- T = transmissivity (gpd/ft)

The average transmissivity of the aquifer discharge to Marsh Run Creek between any given point, and in this case from SWS-2 to SWS-3, is determined:

$$Q = T \times 2(L)I$$

where
- Q = 9 ft^3/min (12,960 ft^3/day)
- L = 850 ft (0.16 mi)
- I = 70 ft/mi
- T = 578 ft^3/day (4,327 gpd/ft)

The estimate of aquifer transmissivity of 4,327 gpd/ft is highly dependent on the true water-table slope which steepens to the south with topography. However, comparisons of this estimate with the average transmissivity determined from slug tests are useful in evaluating potential deeper ground-water underflow of Marsh Run Creek in the bedrock aquifer and to assist in ground-water flow model calibration. This comparison is discussed further in Chapter 4.

The surface water sample taken at station SWS-2, based on analysis of shallow ground-water flow patterns at the site, is apparently upstream with respect to the site and is primarily representative of stream water quality of the depot. However, due to the predicted radial flow patterns of shallow ground water, some ground-water discharge from the site may periodically reach this portion of the stream. The chemical quality of the surface water at this location, although possibly influenced by shallow ground-water discharge to the stream from the site, is at the extreme uppermost probable zone of influence from site ground water. Consequently, the chemical quality is near background or upstream quality. Surface water sample SWS-3 is situated downstream of the site where shallow ground-water discharge to the stream is taking place both at and upstream of this sample.

Surface water sample SWS-1 is representative of stream water quality unaffected by the depot or Marsh Run Field. The SWS-1 sampling location is considered a true background stream surface water quality sample, based on its relative location to developed areas and its higher elevation. Surface water sample SWS-5, although upgradient of the site, is adjacent to and downstream of filled marsh areas previously documented as contributing low-level organic and inorganic contaminants to the stream. The water quality of this sample when compared to the water quality of SWS-2 and SWS-3 was used as an evaluation tool on the effect that shallow ground-water discharge from the site has on the water quality of Marsh Run Creek. However, since SWS-5 was collected on a different date than the other surface water samples (i.e., 6 months later), a direct comparison of chemical quality between SWS-5 and the other samples was not appropriate in that temporal variations are inevitable. Sample SWS-4 was taken in the marsh area east of the site. The water quality of this sample would be impacted from site-derived surface water runoff from the north-northeast fill. Ground-water base flow is not considered a contributory factor at this location. Chapter 4 discusses the distribution of contaminants in the surface water of Marsh Run Creek.

3.1.5.2 Site Drainage

Incipient surface water runoff onsite is controlled by surface topography. Figure 3-16 illustrates drainage patterns onsite. Ultimately, surface water runoff from the northeast portion of the site is channeled toward an east-west trending shallow swale into the marsh area east of the site. Surface water runoff from the south and southwestern portion of the site is directed toward a northwest-southeast trending ditch that empties into a low-lying depression at the southern edge of the site, immediately adjacent to Marsh Run Creek.

Approximately 40 percent of the area identified as being underlain by waste fill is drained by the northern boundary's east-west trending ditch. The remaining 60 percent is drained into the southern swale which empties into Marsh Run Creek. Surface water drainage is somewhat impeded by the relatively low topographic gradients and the presence of ground cover. Undoubtedly, much of the incipient rainfall percolates into the fill rather than flowing overland as surface runoff. Thus, erosion of the cover fill is minimal. Surface water runoff in general occurs primarily in the immediate vicinity of the site drainage swales and was observed to pond in flatter areas in the central portions of the site. Site surface water runoff is effectively captured by the drainage swales. No runoff crosses either the NCAD access road or Marsh Run Road. However, once surface water runoff flows into these drainage swales it flows unchecked into the marsh area to the east or into Marsh Run Creek. Surface water runoff from the site will encounter the surficial cover soils and will not directly contact any waste fill materials, since no waste material was observed on the landfill surface. In light of the healthy ground cover over the site, erosion of the cover fill and subsequent transport of the sediments to Marsh Run Creek is not considered a primary contaminant migration pathway.

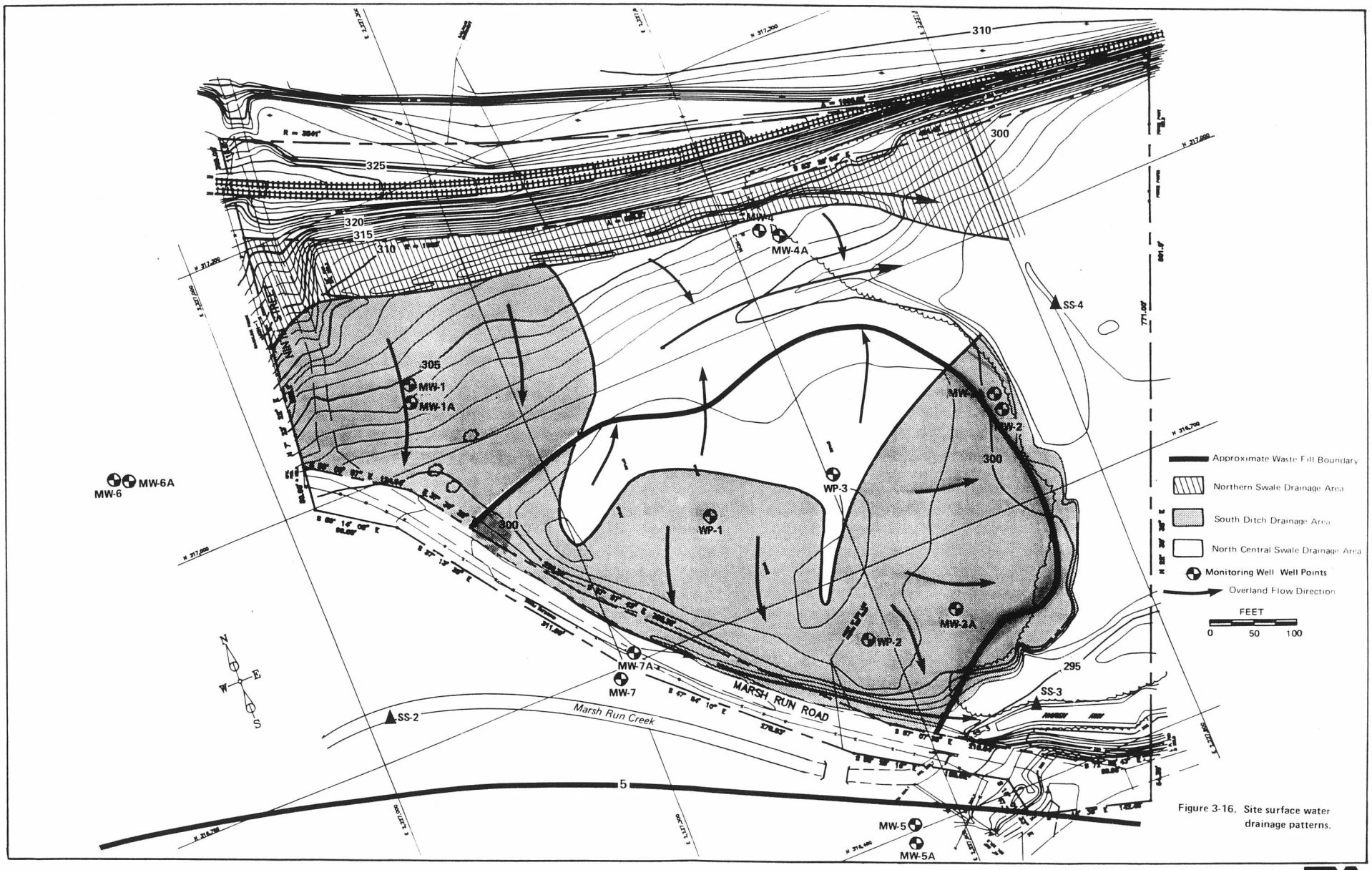


Figure 3-16. Site surface water drainage patterns.

In summary, surface runoff from the site is not considered a major pathway of contaminant transport based on the physical conditions at the site. All waste material is covered with topsoil. Surface water runoff drainage is hampered by the gentle topography and relatively continuous and dense ground cover. Erosion of cover fill material is not occurring because of topography and ground cover. Much of the rainfall percolates into the fill. Surface water runoff that does occur is either channeled by topography or the two shallow drainage swales at the north and south boundaries of the site. Runoff channeled through these swales is ultimately channeled into the marsh east of the site or into Marsh Run Creek.

3.1.6 Sediment Sampling

The chemical character of stream sediments at the stream surface water sampling points and sediments of the marsh area east of the site were evaluated as part of this RI. Figure 2-3 shows surface water and sediment sample locations. Sediment samples collected from streams at locations SS-1, SS-2, SS-3, and SS-5 were representative of sediment in direct contact with flowing stream waters. Sediment transport due to erosion and redeposition between points SS-5 and the confluence of Marsh Run Creek and the north flowing segment is considered low due to low flow velocities between these points. Downstream of the confluence, surface water flow velocities increase, and as a result sediment is eroded and transported downstream. Sediment samples collected at points SS-2 and SS-3 are allochthonous in nature (i.e., mobilized from somewhere else along the stream). The sediment sample SS-4 collected in the marsh area is representative of relatively static sediment (i.e., no sediment erosion or deposition). No overland surface water flow was observed in the vicinity of SS-4 even though ponding is prevalent in the area most of the year. The marsh area is covered with tall grasses and decayed organic matter and is not readily accessible to erosion.

In summary, based on streamflow velocities, sediment transport in Marsh Run Creek is most active below the confluence of Marsh Run Creek and an unnamed north-flowing stream segment. Due to the good ground cover onsite, erosional sediment transport of cover soils to Marsh Run Creek facilitated by surface runoff is not considered significant. Stream sediment transport in the lower reaches of Marsh Run Creek adjacent to the site does occur, although no evidence suggests that major stream sediment loading occurs. Stream sediment transport in Marsh Run Creek is not considered a significant transport mechanism of contamination offsite. The quality and distribution of chemical compounds of sediment samples collected in Marsh Run Creek and the marsh area are discussed in more detail in Chapter 4.

3.1.7 Ground Water

The Marsh Run Field site is situated at the base of hills which rise abruptly several hundred feet south of the site. Specifically, the site lies on an infilled floodplain adjacent to the Susquehanna River. A tributary of the Susquehanna, Marsh Run Creek, flows west to east through the site parallel to the floodplain depositions. The primary regional aquifer is the Gettysburg Formation. Ground-water flow through this

aquifer occurs through narrow, secondary openings, such as bedding planes, joints, and faults. These openings provide an interconnected system of conduits through which ground water can migrate.

The regional trend of ground-water movement in the area is from the higher elevation hills towards the lower ground-water discharge point, the Susquehanna River. Typical of this area, ground-water flow occurs in an intermediate-to-local flow regime. Specifically, under water-table conditions, ground-water recharge occurs at high elevations and discharge occurs in the immediately adjacent low-lying areas such as tributaries (local) or major streams or rivers (regional). In general, shallow-zone ground-water flow, usually less than 100 ft, occurs in a local pattern, and deeper flow, i.e., >100 ft, occurs in a more regional pattern. In many instances, fracture size and/or interconnectivity decrease within increased depth, thereby retarding deeper (regional) flow (Wood 1980).

The primary fluid flow properties of fractured rock are generally controlled by a system of interconnected and discontinuous fractures. Ideally, detailed knowledge of the hydraulic and geometric properties of such discontinuous fracture systems is required to understand the patterns of fluid and solute movement in fractured rock. The hydraulic properties of fractures are usually expressed as an equivalent hydraulic aperture. The geometric properties of fractures include spacing, size, and orientation.

Deterministic characterization of the hydraulic properties of the fracture system was not within the scope of work. The geometry of the fracture system was investigated using methods such as logging of boreholes and rock cores and using available geologic maps.

With respect to the fracture geometry of the rock aquifer underlying the site, several initial assumptions have been made: (1) It is assumed that the area of investigation is consistent with representative elementary volume (REV) (i.e., the area of investigation constitutes an area large enough and encompasses enough fractured media so that the aquifer responds as a typically anisotropic porous media). This concept of the REV has been described by Neuman and others (Neuman 1987). (2) The density of fractures is sufficient such that enough intersections exist for a general flow between. The degree of connectivity is a function of both fracture density and fracture length. When the point is reached where the potential for connectivity is high, the fracture network can be assumed infinite in extent, allowing for flow throughout the entire medium. This concept is generally referred to as the "percolation threshold." The percolation threshold concept is viable as long as several families (i.e., separate fracture sets of differing orientation) are distributed throughout the rock matrix. (3) The hydraulic conductivity of the rock matrix is negligible. A double porosity (i.e., fracture porosity and matrix porosity) scenario was not inferred for purposes of this study.

The number and width of fracture openings in part dictate the permeability of a rock at different depth intervals or locations. Using the concept of REV, average values are given to a particular lithology (i.e., bedrock, clay, fill, etc.).

Not only do variations in lithology account for variable hydraulic properties of a medium, distinct textural variations within a specific medium can account for heterogeneity in hydraulic characteristics. The degree to which fractures have developed depends on the composition of texture or texture of the rock. Shale tends to deform with stress without extensive fracture while hard beds of sandstone develop more extensive water-transmitting fractures (Wood 1980).

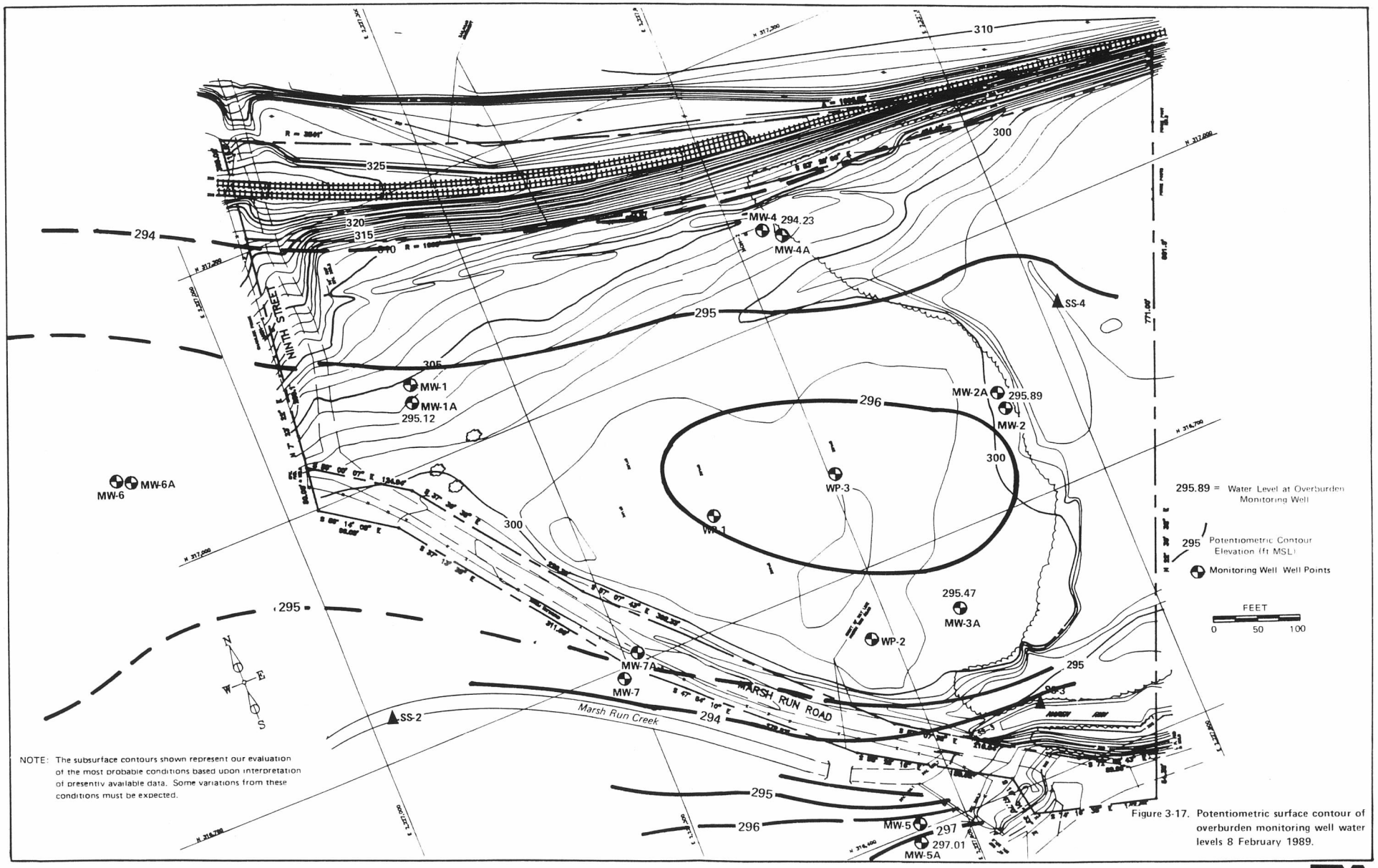
In addition to the regional aquifer ground-water flow patterns, shallow, unconsolidated Quaternary sand, clay, and silt facilitate a localized shallow ground-water flow regime that has been further facilitated by the placement of fill at the site and the development of Made Land on the NCAD property.

The saturated unconsolidated deposits are associated with and primarily restricted to the floodplain deposits adjacent to the Susquehanna River. The hydrogeologic conditions at the site with respect to the unconsolidated zone and bedrock aquifer and the singular and cumulative interaction of these differing hydrogeologic units with the surface water stream were the focus of the ground-water investigation. Pursuant to the understanding of the site hydrogeologic model, the ground-water transport mechanisms can then be evaluated.

3.1.7.1 Shallow (Unconsolidated) Saturated Zone Characterization

As previously discussed, the site fill material is placed on top of unconsolidated floodplain sediments. This area existed originally as a low-lying swamp; thus, most of the area not covered by fill and north of Marsh Run Road is saturated or is at an elevation near the water table. The placement of fill on top of the marsh has resulted in an elevated water table (above the marsh). The apparently continuous clay and sand above the bedrock, the waste fill, and other (inert) fill comprises the unconsolidated saturated zone. The assemblage of unconsolidated fill and sediments has been termed "saturated zone" rather than "aquifer" because they are not utilized as a domestic water source, and, in the case of "waste fill" material, are not areally extensive. Furthermore, it is the fill material and discontinuous sand lenses and not the extensive silt clay deposits that comprise the most permeable of these unconsolidated materials.

Figures 3-17 and 3-18 illustrate the contoured water-level data from site monitoring wells installed in the unconsolidated material on 8 February and 16 August 1989, respectively. Both sets of data indicate a radial flow pattern as a result of ground-water mounding beneath the fill. This radial-flow pattern was also observed during the 1987 site Confirmation Study. The 16 August data are more refined as more monitoring wells were installed prior to the latter sampling event. Depth to the saturated



NOTE: The subsurface contours shown represent our evaluation of the most probable conditions based upon interpretation of presently available data. Some variations from these conditions must be expected.

Figure 3-17. Potentiometric surface contour of overburden monitoring well water levels 8 February 1989.

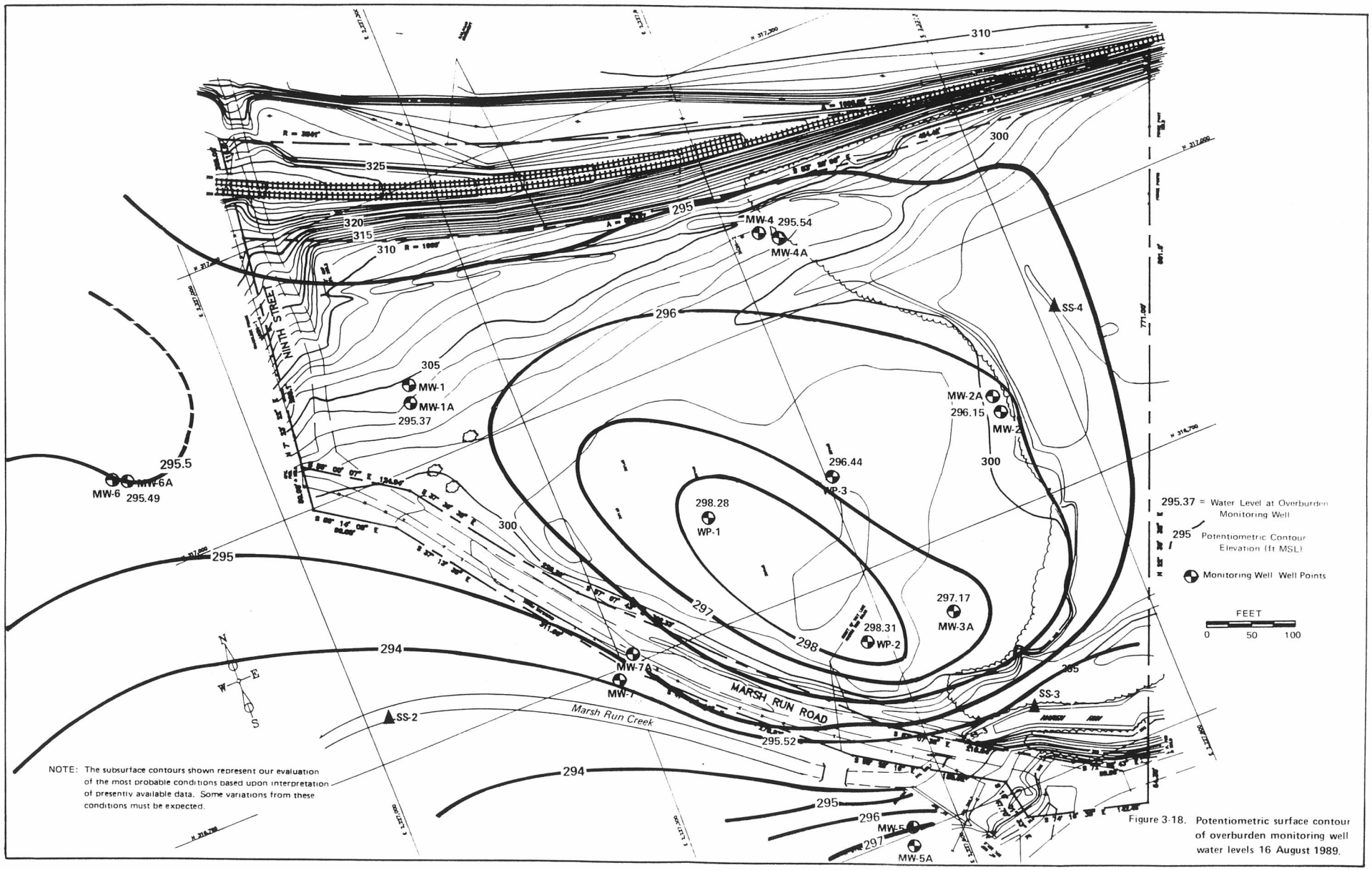


Figure 3-18. Potentiometric surface contour of overburden monitoring well water levels 16 August 1989.

overburden water table ranged from 4 to 7 ft across the fill area. The saturated fill is under water-table conditions (unconfined). Examination of Figures 3-17 and 3-18 shows shallow ground water radiating from the south-central portion of the site primarily toward Marsh Run Creek and toward the Susquehanna River to the south and north, respectively.

Based on the two sets of water-level data, the shallow water table was observed to fluctuate 1.5 to 2 ft in a 6-month period (i.e., February to August). Maximum shallow ground-water fluctuations are not anticipated to vary more than 3-4 ft due to the close proximity to Marsh Run Creek and the Susquehanna River. These two perennial discharge areas limit the maximum low water-table elevation at the site. Recharge to the fill area occurs primarily as rain water infiltration. The cover fill, although continuous across the site, is a silty loam of moderate permeability, which when coupled with the low site topographic gradient facilitates surface water infiltration. The "waste fill" and heavily reworked soils onsite are clearly more permeable than the surrounding in situ residual material or the less reworked soils. Monitoring wells MW-1A, MW-2A, and MW-3A, and well point WP-1, which are situated in or at the edge of the "waste fill," exhibited higher hydraulic conductivities than the surrounding wells MW-4A, MW-5A, MW-6A, and MW-7A, which are installed in natural residual soils or the less reworked soils.

The average hydraulic conductivities, based on slug-test data of the fill and in situ overburden surrounding the fill to the north, west, and south, are 8.8×10^{-3} cm/sec and 7×10^{-5} cm/sec, respectively. This relationship indicates an increase greater than 2 orders of magnitude in hydraulic conductivity of the fill over the surrounding soils. This condition is evident (as shown in Figure 3-18) along the south portion of the site, just north of Marsh Run Creek, by the steepened hydraulic gradient near the creek. The relatively steep, shallow ground-water gradient is also apparent south of Marsh Run Creek in the vicinity of MW-5A, also indicative of lower-permeability residual soils outside the landfill boundaries.

Water-table contours depicted in Figure 3-18 imply ground-water discharge to Marsh Run Creek, specifically from 650 ft upstream of where the NCAD access road crosses Marsh Run Creek to several hundred feet downstream of the access road crossing. Shallow ground-water discharge is also occurring east of the site into the marsh area and ultimately into Marsh Run Creek. Remaining shallow ground-water discharge is to the north and northeast toward the Susquehanna River.

Comparison of both the February and August water-table data (Figures 3-17 and 3-18) shows similar shallow ground-water patterns; however, lower water-table elevations in the center of the fill during February resulted in a lower overall hydraulic gradient. Consequently, total shallow ground-water discharge rates are reduced. A shallow ground-water flow divide separating the predominantly north and south flow components trends northwest-southeast across the south and southwest portions of the fill. Comparison of Figures 3-17 and 3-18 indicates that as the shallow water table is lowered and the fill becomes less saturated, the ground-water flow divide migrates to the north-northeast. As a result of this

flow-divide movement, more of the ground water in the saturated fill area periodically discharges to Marsh Run Creek.

Although water-table fluctuations in the fill were observed to vary approximately 2 ft during the course of the investigation, fluctuation to the south of Marsh Run Creek (MW-5A) was observed to be less than 1 ft during the same period. This observation may be due to the high propensity for surface water infiltration in the fill with respect to less disturbed soils outside the fill boundaries.

From examination of both sets of water-table data (Figures 3-17 and 3-18) it is evident that south and west of Marsh Run Creek the water table becomes elevated above the stream, and in the vicinity of MW-5A and MW-6A ground-water mounding results from high topography. The significance of the higher water-table elevation across Marsh Run Creek is that the stream acts as a ground-water discharge zone that precludes water-table underflow beneath Marsh Run Creek. Therefore, any lateral ground-water flow within the saturated zone of the site toward Marsh Run Creek will ultimately discharge to Marsh Run Creek and not flow beneath the stream to areas on the other side. The other water-table mechanism of ground-water flow is the vertical component to deeper portions of the bedrock aquifer. Section 3.1.7.3, Ground-Water Movement, discusses the ground-water flow pattern in the saturated overburden in more detail.

Because of the inferred presence of the natural silt and clay deposits beneath the fill (based on monitoring well boring data), ground-water flow in the vertical direction is retarded more than if there were no underlying clay. The thickest confirmed portion of the clay (>5 ft) was encountered in the central portion of the site in MW-4A. However, further south, relatively permeable sand lenses were encountered below 2 to 3 ft of clayey silt. Along the northern portion of the site the clay grades laterally into a clayey sand which, based on grain-size distribution, is estimated to be approximately one magnitude higher in hydraulic conductivity. These high permeability units will facilitate vertical ground-water migration if hydraulic head gradients are downward.

The uncertainty of the continuity of the clay beneath the entire site presents a potential for enhanced vertical ground-water migration in excess of what would be predicted if the clay is continuous. However, using practical geologic sense it can be inferred that the clay is present and that only the thickness of the clay is the uncertain factor.

Boring data indicate that the clayey silt material and the sand unit are present at the depth of the Marsh Run Creek stream bottom. Therefore, shallow ground-water base flow to the stream is through the clay and sand. It is the material in the stream bottom and banks and immediately adjacent soils and their respective permeability that regulate ground-water base flow to Marsh Run Creek.

As previously mentioned, Marsh Run Creek is positioned with respect to the site so as to predictably prevent lateral migrating of shallow, site-derived ground water to the south, west, or east beyond Marsh Run Creek.

3.1.7.2 Bedrock Aquifer Characterization

The regional aquifer of concern in the project area is the Gettysburg Formation. This aquifer is used by residences south, east, and southeast of the site, all of which are at a higher elevation and hydraulically upgradient of Marsh Run Field. The ground-water flow patterns in this aquifer are more intimately associated with the regional flow (i.e., south to north), although the saturated overburden zone flow patterns influence the overall configuration of the bedrock aquifer beneath the site.

Ground-water movement through this aquifer occurs primarily along interconnected fractures. Although ground-water flow is driven by hydraulic head differentials (i.e., from higher to lower head), fracture orientation may alter flow patterns from those normally expected in an isotropic system. Thus, ground-water flow transverse to hydraulic head differentials can occur in the bedrock aquifer. However, ground-water flow is always from a higher hydraulic head to a lower one. Figures 3-19 and 3-20 illustrate the contoured potentiometric surface levels taken on 8 February and 16 August, respectively. These sets of data represent the potentiometric head distribution at a nominal depth of 50 ft below surface. Both sets of data show similar potentiometric surface configurations to respective overburden zones during each date (i.e., mounding beneath the site). In general, a potentiometric surface mounding was observed during both dates. The ground-water mounding occurs beneath the southern portion of the site, slightly south of the respective shallow zone ground-water mounding apex. As a result, a ground-water flow divide is also apparent at a 50-ft nominal depth in the bedrock aquifer, which indicates ground-water flow to the south (Marsh Run Creek) and to the north (Susquehanna River).

Examination of Figures 3-19 and 3-20 reveals that a larger portion of the site ground water at this elevation is moving in a northward, more regional direction to the major discharge point (Susquehanna River). At this depth the influence of the shallower ground-water system is evident, but its effect has apparently dissipated with depth. A comparison of the February and August shallow and bedrock potentiometric configurations illustrates the lessening effect of the shallow zone on the bedrock aquifer as the shallow water-table level declines. The ground-water mounding in the bedrock aquifer was more subdued and regional flow to the north was more pronounced in February when the overburden water table was lower. This comparison illustrates that the shallow zone flow system recharges the bedrock aquifer by vertical migration and thus influences ground-water flow paths at depth.

The bedrock aquifer appears to be semiconfined locally below the floodplain silt/clay deposits. Elsewhere, where the clay layer is absent, it is anticipated to be under near water-table (unconfined) conditions. Ground-water fluctuations in the bedrock aquifer were observed to be a maximum of 3 ft in MW-4 at the northern part of the site. Elsewhere, fluctuation was on the order of 1.5 ft. As previously discussed for the shallow saturated zone, maximum ground-water fluctuations in the bedrock

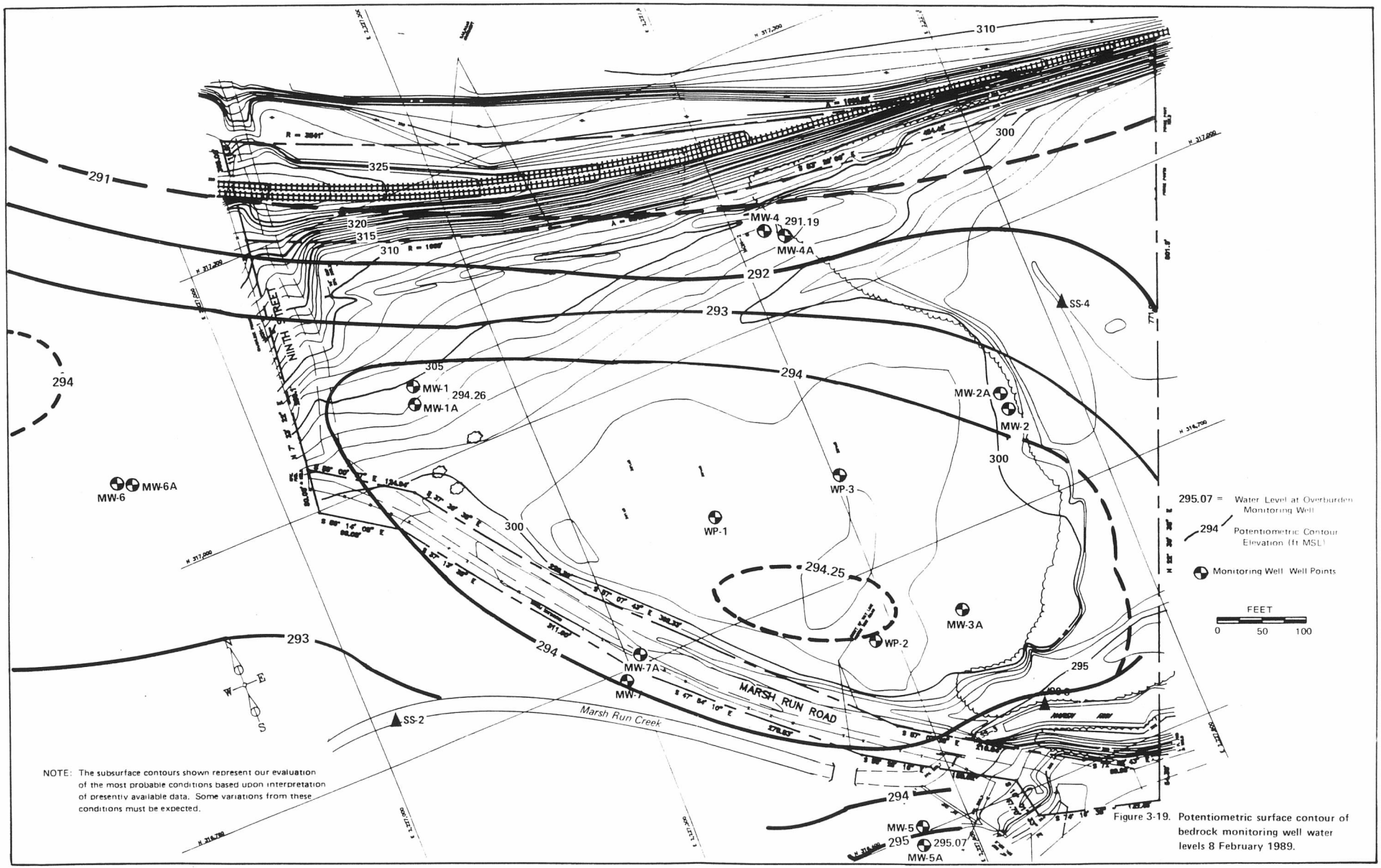


Figure 3-19. Potentiometric surface contour of bedrock monitoring well water levels 8 February 1989.

NOTE: The subsurface contours shown represent our evaluation of the most probable conditions based upon interpretation of presently available data. Some variations from these conditions must be expected.

Figure 3-20.
Potentiometric surface contour of bedrock monitoring well water levels, 16 August 1989.

aquifer are somewhat moderated by the Susquehanna River. Slug tests were conducted on bedrock monitoring wells MW-1, MW-2, MW-4, MW-5, MW-6, and MW-7. Hydraulic conductivity values ranged from 1.79×10^{-5} cm/sec to 1.3×10^{-3} cm/sec for monitoring wells MW-5 and MW-2, respectively. These values reflect a variation of two magnitudes in hydraulic conductivity of two wells at the same depth. The average of the hydraulic conductivities of all bedrock wells tested is 7.3×10^{-4} cm/sec.

In general, the potentiometric levels of the bedrock wells were lower than those of the unconsolidated overburden wells at each cluster location by a range of 0.8 to 3 ft. No incidence of the reverse condition was observed. The net downward vertical hydraulic gradient implies downward movement from the shallow zone to the bedrock aquifer through the clay silt layer.

Potentiometric surface contours of the bedrock well data imply discharge into Marsh Run Creek and to the Susquehanna River. Bedrock aquifer recharge occurs onsite by vertical migration of ground water, and recharge occurs offsite to the south from the higher elevations.

As discussed for the shallow saturated overburden zone the bedrock aquifer potentiometric surface elevations, being a high or higher across Marsh Run Creek (i.e., to the south and west), imply that no underflow is occurring from the site across Marsh Run Creek.

3.1.7.3 Ground-Water Movement

From the examination and comparison of monitoring well water-level data and slug-test data, a ground-water flow model can be developed. The site can be characterized as being part of a singular ground-water flow system with two distinct zones. The upper zone consists of saturated, unconsolidated fill, residual soil, and floodplain deposits. Specifically, the fill materials are the local focus of the unconsolidated saturated zone. The second zone is comprised of the fractured shale and sandstone bedrock of the Gettysburg Formation. An intervening silt/clay layer with lensoidal sand separates the saturated fill from the underlying bedrock, and although it exhibits relatively low permeability, allows for vertical downward migration from the upper zone to the lower zone. Both sets of water-table surface data indicate radial, lateral ground-water flow from the fill south to Marsh Run Creek and to the north toward the Susquehanna. Higher elevation topography and correspondingly higher hydraulic head to the south, east, and west preclude migration of ground water across Marsh Run Creek. The radial flow component evident at the site is resultant from mounding of ground water in the loose, permeable fill. The dominant driving force in the shallow zone is rain water infiltration into the fill.

A second component of saturated-zone flow (vertical flow) is illustrated by the net downward vertical gradients across the site. The magnitude of the ground-water flux in the vertical direction is controlled by the clay/silt layer and the total potentiometric head distribution across the clay layer.

Linear ground-water velocities in the shallow zone were calculated in the north and south directions using the average of the hydraulic gradients measured in February and August, respectively, and an average effective porosity of 35 percent. Because of the heterogeneity of the fill, an average hydraulic conductivity of 7.6×10^{-5} cm/sec representative of the residual or reworked soils was used, because it was assumed that these lower permeability soils around the perimeter of the fill regulated lateral flow toward discharge points. Using the above hydraulic conductivity, a porosity of 35 percent, and an average hydraulic gradient in the south portion of the site of 0.013, linear ground-water velocity was calculated as 0.008 ft/day (2.9 ft/yr). Using the same hydraulic conductivity and porosity average, shallow ground-water linear velocity toward the north was calculated as 0.0043 ft/day (1.5 ft/yr). These linear velocities are low, suggesting high residence time due to slow lateral movement of ground water in the shallow saturated zone.

Assuming an average ground-water linear velocity of 0.0043 ft/day, total ground-water discharge as base flow to the 900-ft segment of Marsh Run Creek (i.e., 650 ft upstream of the NCAD access road crossing of Marsh Run Creek) would be on the order of 70 gal/day. This discharge value, which appears low, is based on the lower estimate of hydraulic conductivity of shallow soils 7.6×10^{-5} cm/sec. The presence of lensoidal sands in the vicinity of Marsh Run Creek may increase base flow volumes. Based on the relatively low shallow ground-water contribution to streamflow, it is evident that the increase in streamflow between SWS-2 and SWS-3 is primarily attributable to deeper ground-water discharge from the bedrock aquifer from both sides of the stream.

Conversely, the ground-water linear velocity in the bedrock aquifer to the north at a nominal depth of 50 ft was calculated at 0.34 ft/day (124 ft/yr) using an average hydraulic conductivity of 7.3×10^{-4} cm/sec, effective porosity of 5 percent, and an average hydraulic gradient of 0.008. Although the variability of bedrock ground-water linear flow rates compared to that of the overburden zone is an order of 2 magnitudes greater, total ground-water flux volumes (i.e., volume of flow per unit area of aquifer per unit head) is approximately the same for both zones.

Since lateral linear ground-water velocities in the unconsolidated overburden are slow, vertical migration of shallow ground water to deeper zones through the clay layer is facilitated.

In light of the slow lateral, linear, ground-water velocity in the saturated overburden, vertical migration of ground water from the saturated overburden through the intervening clay layer into the bedrock aquifer occurs.

To put this condition into perspective, a migration rate through a clay 2 ft thick with a hydraulic conductivity of 2.5×10^{-6} cm/sec (0.007 ft/day), a 30 percent effective porosity, and a 1-ft hydraulic head differential dissipated over the thickness of the clay was calculated at 0.01 ft/day (4.2 ft/year). Assuming the same hydraulic conditions with the exception of using a 5-ft-thick clay, migration rates were calculated at 0.005 ft/day (1.7 ft/year).

It is evident from the above analysis that ground water could conceivably migrate vertically through the underlying clay into the bedrock in less than 1 year to several years (ultimately dependent on clay thickness and hydraulic head differentials), whereas it would take many years for ground water to migrate horizontally from a point in the landfill to a surface water discharge point even if the total distance was several tens of feet.

From the comparison of vertical migration rates, ranging from 1.7 to 4.2 ft/year, to the average horizontal migration rate in the saturated overburden, ranging from 1.5 to 2.9 ft/year, and allowing for the larger areal expanse of the underlying clay as compared to the relative thinness of the saturated overburden, it is clear that more ground water in the saturated overburden will revert to vertical migration to the bedrock aquifer rather than ultimately reach surface water discharge areas.

To further illustrate the specific ground-water flow characteristics at the site, the USGS three-dimensional MOD-FLOW ground-water model was utilized. The corresponding hydraulic conductivities and thicknesses were assigned to the various hydrostratigraphic units as follows:

Hydrostratigraphic Unit	Hydraulic Conductivity (cm/sec)	Thickness (ft)
Waste Fill (horizontal)	1×10^{-3}	6
Fill/Borrow (horizontal)	5×10^{-5}	6
Bedrock (horizontal)	8×10^{-4}	100
Clay Layer (vertical)	2.5×10^{-6}	variable
Clayey Sand (vertical)	1×10^{-5}	variable

The flow boundaries were established so that both the Susquehanna River and Marsh Run Creek were assigned constant head boundaries relative to the stream water elevation on 17 July 1989. With only these two areas set at a constant head boundary and the hydraulic parameters and thickness mentioned above, net infiltration values were varied to approximate the observed heads on 17 July 1989. The best head match was obtained by the application of 9 in. net infiltration (total precipitation - evapotranspiration and surface runoff) over the "waste fill" where the topography was flat and 6 in. net infiltration over the steeper topography surrounding the fill.

The thickness assigned the upper saturated zone was predicated on approximate fill thickness encountered during monitoring well installation. The bedrock aquifer was assigned 100 ft thickness as it is reported in the technical literature that unconfined water-table flow in the Gettysburg Formation may occur to a depth of 100 ft (Wood 1980). The clay and sandy clay lithology thickness was scaled off of the isopachous map (Figure 3-14).

Typically, average annual net infiltration for the area is reported at 6 in. of recharge to the Triassic sandstone aquifers per year or about 200 gpm per square mile (Wood 1980). Higher values of 12 in. per year

are reported for the general area of the lower Susquehanna River basin. The good agreement between the model-generated potentiometric heads and observed heads and a reasonable net recharge suggest that the hydraulic conductivity and thickness values are relatively accurate. Appendix D provides the model input parameters, head variances, and water balance calculations.

Once good agreement was achieved, the system was modeled for 1 day stress periods for purposes of evaluating net ground-water recharge and discharge volumes. Figure 3-21 illustrates the calculated flow conditions and net discharge volumes to the Susquehanna and Marsh Run Creek, and vertical leakages from the saturated overburden to the bedrock aquifer.

A summary of the model flow analysis, based on the aforementioned parameters are as follows:

Net Recharge
- Waste Fill: 9 in./yr (0.002 ft/day)
- Elsewhere: 6 in./yr (0.0014 ft/day)
- Total ground-water recharge volume per day (over site area) 16,050 gal

Net Discharge from Saturated Overburden
- To Susquehanna River: 34 gpd
- To Marsh Run Creek: 218 gpd

Leakage from Saturated Overburden to Bedrock Aquifer
- (over site area): 15,798 gpd

Net Discharge from Bedrock Aquifer
- To Marsh Run Creek: 2,602 gpd
- To Susquehanna River: 13,196 gpd

It is apparent from this analysis that of the net ground-water recharge available to the site about 2 percent is discharged to the Susquehanna or Marsh Run Creek via lateral ground-water flow in the saturated overburden/fill. The remaining 98 percent migrates vertically through the clay layer into the bedrock where it reverts to flow towards the Susquehanna River or to a lesser degree towards Marsh Run Creek. Approximately 83 percent of the total water leaked through the clay is discharged to the Susquehanna and the remaining 17 percent to Marsh Run Creek.

Examination of the potentiometric contours of bedrock wells suggests that recharge to Marsh Run Creek is occurring at a 50-ft depth in the aquifer. At greater depth it is anticipated that underflow to the east and north beneath Marsh Run Creek is occurring. The depth at which the radial flow dissipates to the point where regional flow (i.e., from south to north) prevails is uncertain. Based on estimated base flow to Marsh Run Creek, the transmissivity of the average aquifer system discharging to Marsh Run Creek in the vicinity of the site is 4,327 gal/day/ft^2. Comparison of the above transmissivity to the average bedrock hydraulic conductivity 7.3×10^4 cm/sec (15.5 gal/ft^2) suggests that to a depth of at least 230 ft ground water is discharged to Marsh Run Creek. This assumes aquifer homogeneity, where in fact isolated zones of higher

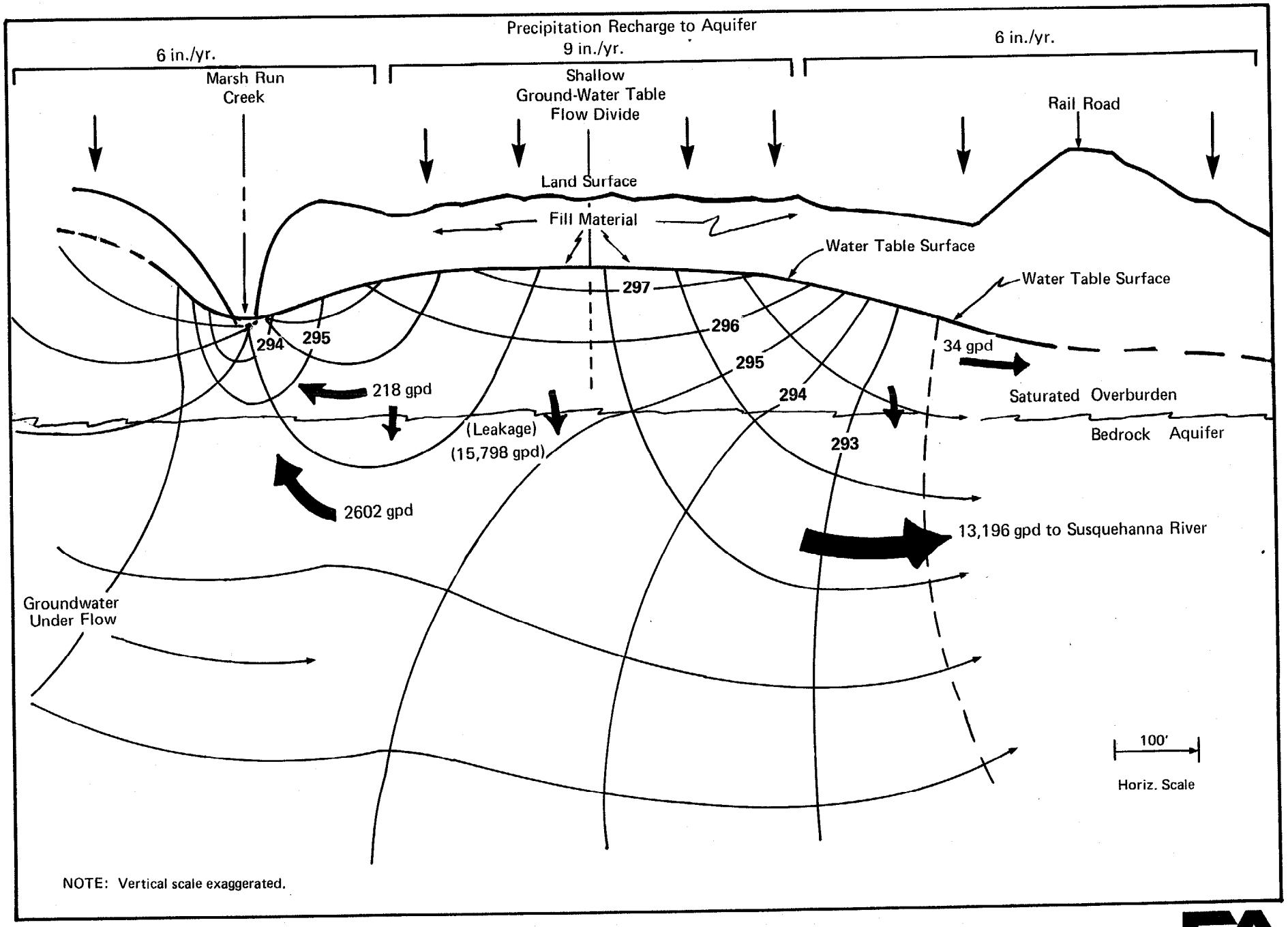


Figure 3-21. Idealized vertical cross section of ground water balance model.

hydraulic conductivity (greater fracture interconnectivity) may disproportionately influence discharge volumes to the stream. Nonetheless, it is reasonable to assume that to a depth of 50 ft all ground water south of the ground-water flow divide beneath the site is discharged to Marsh Run Creek.

The movement of ground water within and between the two distinct hydrogeologic zones comprises the mechanism whereby site-derived contaminants will migrate. Based on the data generated from the field investigation and a ground-water flow model utilizing the USGS three-dimensional MOD-Flow numerical ground-water flow model, the following assumption of ground-water flow mechanisms at the site are summarized as follows:

- Nearly all of the water that infiltrates Marsh Run Field (i.e., 98 percent) will ultimately migrate vertically into the bedrock aquifer. A small portion (i.e., near the edge of the fill adjacent to Marsh Run Creek) will migrate laterally and discharge to Marsh Run Creek. In effect, the fill material serves as a source and ground-water storage/recharge area for the bedrock aquifer. Consequently, only ground water in the saturated overburden very near the surface water discharge points will ever reach these discharge areas via horizontal migration. Saturated overburden ground water further from these discharge points (i.e., in central portion of the landfill) will most likely migrate vertically into the bedrock aquifer.

- The dominant flow pattern of ground water in the bedrock aquifer beneath the site is to the north towards the Susquehanna River.

- The position of the ground-water mound within the fill and the resulting flow divide position (i.e., apex of mound) dictates the respective direction of ground-water flow either to Marsh Run Creek or the Susquehanna River in the saturated overburden. Specifically, the mounding of ground water within the fill alters the regional south-to-north ground-water flow patterns.

- Marsh Run Creek serves as a hydraulic barrier which prevents ground water beneath Marsh Run Field from underflowing Marsh Run Creek to the east or to the south.

- The presence of the natural hydraulic barrier (Marsh Run Creek) and the topographically higher elevations to the southeast and east of the site further prevent potential migration of ground water from beneath the site to existing residences along Marsh Run Road. In order to induce ground-water flow towards the residences located southeast and east of the site, the potentiometric levels at the residences and extending toward Marsh Run Creek would have to be lowered in excess of the leakage capacity of Marsh Run Creek to the bedrock aquifer. Based on present or plausible future use, such a scenario is highly unlikely.

4. NATURE AND EXTENT OF CONTAMINATION

The following sections discuss the findings of the chemical analysis of the Marsh Run Field ground and surface water, subsurface and surficial soils, and sediments. The environmental and health impacts and significance of these concentrations are discussed in Chapter 6.

In keeping with EPA guidance, a sample concentration associated with the sampling events in question had to be greater than 5 times the associated trip or rinsate blank concentration, or greater than 10 times common laboratory contaminants or 5 times the contaminants in the associated method blank, in order to be considered a valid value. Concentrations of compounds not meeting this criteria are flagged in the accompanying tables with an "S" when compared to trip and rinsate blanks or with an "M" when compared to method blanks. Also in keeping with EPA guidance, the criterion that laboratory method blanks contain less than 5 times the contract required detection limits (CRDLs) for common laboratory contaminants (methylene chloride, acetone, and toluene) and less than the CRDL for all other list compounds was applied.

4.1 NATURE AND EXTENT OF CONTAMINATION IN THE SOIL

4.1.1 Volatile Organic Compounds (VOCs) in Soil Samples

Volatile organic compounds (VOCs) detected in the soil samples collected during the installation of monitoring wells are listed in Tables 4-1 and 4-2 for Phase I and Phase II monitoring well installation, respectively. As previously discussed, volatile organic concentrations were "flagged" if the respective contaminant was also detected in the field, trip (field sampling quality control), or internal laboratory quality control method blanks associated with the sample. The only positively identified volatile organic compounds detected in the Phase I soil samples were acetone and methylene chloride. Methylene chloride was detected as 120 µg/kg in MW-5A, S-5 (Dup), which was collected at 8-10 ft depth (below water table) and in MW-4, S-4 (4-6 ft depth), at 41 µg/kg. Acetone was detected in soil samples MW-4A, S-1 (0-2 ft depth) and MW-4, S-1, and S-2 (0-4 ft depth) at 15, 27, and 30 µg/kg, respectively. Although methylene chloride and acetone were not detected in either field, rinsate, or laboratory method blanks, they are very common laboratory contaminants. These two volatile compounds are common compounds used in sample extraction and labware cleaning. During soil sample preparation, airborne concentrations of the compounds typically show up in soil matrix analysis. Consequently, these two volatile compounds should be flagged as questionable and regarded with skepticism.

During the Phase II monitoring well installation, methylene chloride and acetone were again detected. In particular, methylene chloride was detected in every soil sample collected, ranging in concentration from 5 to 23 µg/kg. Based on normalization criteria, these sample concentrations should be regarded with scrutiny due to similar levels found in the associated laboratory method blank or trip blank analyzed along with the samples. Acetone was detected in all samples collected from MW-2, with

TABLE 4-1 SUMMARY OF VOLATILE ORGANIC COMPOUND ANALYSIS OF SOIL SAMPLES COLLECTED DURING PHASE I MONITORING WELL INSTALLATION (μg/kg)

Compounds	CQL[b] (μg/kg)	MW-5					MW-5A				Rinsate Blank #1	Trip Blank #1	MW-1					MW-4A		
		S-1	S-2	S-3	S-4	S-5	S-1	S-3	S-5	S-5 Dup			S-1	S-2	S-3	S-4	S-6	S-1	S-3	S-6
Methylene Chloride	5	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	15	U	U	U
Acetone	10	U	U	U	U	U	U	U	U	120	U	U	U	U	U	U	U	U	U	U
Tentatively Identified Compounds or Unknowns[(a)]					[1]	[1]		[1]				[1]								

(a) Total number of unknown compounds detected in peak library search.
(b) Compound Certified Quantification Limit (CQL).
U = Compound analyzed for but not detected. Sample quantification limit corrected for dilution and percent moisture (for soil samples only).

TABLE 4-1 EXTENDED

Compounds	MW-4 S-1	MW-4 S-2	MW-4 S-3	MW-4 S-4	MW-4 S-6	MW-4 S-3 Dup	Trip Blank #2	Rinsate Blank #2
Methylene Chloride	27	30	U	U	U	U	U	U
Acetone	U	U	U	41	U	U	U	U
Tentatively Identified Compounds or Unknowns[(a)]								

TABLE 4-2 SUMMARY OF VOLATILE ORGANIC COMPOUND ANALYSIS OF SOIL SAMPLES COLLECTED DURING PHASE II MONITORING WELL INSTALLATION (μg/kg)

Compounds	CQL[b] (μg/kg)	MW-2 S-1	MW-2 S-1 Dup	MW-2 S-2	MW-2 S-3	MW-2 S-4	MW-2 S-5	Trip Blank #7	MW-6A S-1	MW-6A S-3	MW-6A S-4	MW-6 S-1	MW-6 S-2	MW-6 S-3	MW-6 S-4	MW-7A S-1	MW-7A S-3	MW-7A S-4	Trip Blank #8	MW-7 S-1	MW-7 S-2	MW-7 S-2 Dup	MW-7 S-3	MW-7 S-4	MW-7 S-5	Trip Blank #9
Methylene Chloride	6	11	8	9	10	5J	11	U	17BS	24BS	23BS	6S	5JS	7JS	6S	15BS	19BS	17BS	5J	6JS	6JS	5JS	6JS	10S	10S	7J
Acetone	12	U	U	56	69	66	25	U	U	U	U	U	U	U	U	U	U	U	U	37	U	U	U	U	U	U
Carbon Disulfide	6	U	U	4J	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
1,2-Dichloroethene (total)	6	U	U	1J	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Tentatively Identified Compounds or Unknowns[(a)]																										

(a) Total number of unknown compounds detected in peak library search.
(b) Compound Certified Quantification Limit (CQL).
B = Compound detected in method blank.
J = Estimated value (below Certified Quantification Limit).
S = Compound detected in sample at <5 times the concentration detected in associated trip or rinsate blank.
U = Compound analyzed for but not detected. Sample quantification limit corrected for dilution and percent moisture (for soil samples only).

the exception of S-1 (0-2 ft), at concentration levels ranging from 25 to 69 µg/kg. Due to nondetectable concentrations of acetone in any blanks associated with MW-2 samples, the detected acetone concentration values are reported in Table 4-2 and were not flagged as questionable. Nonetheless, acetone at levels detected in the soil samples is suspect and should be regarded with scrutiny. Very low levels of carbon disulfide and 1,2-dichloroethene were detected in MW-2, S-2 (2-4 ft) at concentrations of 4 and 1 µg/kg, respectively.

In summary, volatile organic contaminant patterns in the soil were not evident at the site. MW-2, which is at the edge of the "waste fill," exhibited very low levels (near the instrument detection limit) of the volatile compounds carbon disulfide and 2-dichloroethene. Acetone, being a typical laboratory artifact, was detected at MW-5, MW-5A (offsite), and MW-4 (onsite) at similar concentration levels. Volatile organic compound contamination of the soils within the site boundaries but outside of the "waste fill" and outside of the site boundaries does not appear to be a problem.

4.1.2 Semivolatile Compounds in Soil Samples

Tables 4-3 and 4-4 summarize the semivolatile compounds detected in soil samples collected during the Phase I and Phase II monitoring well installations, respectively. Low-level semivolatile compounds were detected in Phase I primarily in offsite soil samples collected from monitoring well borings MW-5 and MW-5A. The highest variety of semivolatile compounds was detected in MW-5 and MW-5A (>20 compounds). Most of the samples collected from these borings were from fill made up largely of asphalt. Specifically, many of those compounds detected comprise a group of semivolatiles known as polynuclear aromatic hydrocarbons (PAHs). PAHs are ubiquitous in the environment and are many times the results of oil spillage and are also common coal tar pitch constituents. Low concentration levels of semivolatiles were also detected, but in much less variety (mostly PAHs) in onsite wells MW-1, MW-4, and MW-4A, all of which were near or below contract reporting limits (CRL). Semivolatile compounds detected above the CRL but at relatively low levels were 2-methyl napthalene, phenanthrene, fluorene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, and benzo(a)pyrene, at maximum concentrations of 3.0, 1.9, 2.5, 3.4, 1.7, 2.2, 2.2, and 1.8 mg/kg, respectively (i.e., total PAH concentration of 16.9 mg/kg). All of the aforementioned compounds, except benzo(b)fluoranthene, were detected in soil samples collected from MW-5. The aforementioned compounds are reported as µg/kg in Tables 4-3 and 4-4 (i.e., parts per billion rather than parts per million).

Phase II soil samples collected from MW-2, which is near the "waste fill" boundary at the eastern edge of the fill, were found to contain a variety of semivolatile compounds above contract reporting limits. The semivolatile compounds phenanthrene and fluoranthene were detected in MW-2, S-1 (0-2 ft) at concentration levels in excess of 1,000 mg/kg. The uppermost sample collected from MW-2, Sample 1 (0-2 ft), exhibited the highest concentration of semivolatile compounds detected onsite. In addition to the previously mentioned semivolatiles, napthalene, dibenzofuran,

TABLE 4-3 SUMMARY OF SEMIVOLATILE COMPOUND ANALYSIS OF SOIL SAMPLES COLLECTED DURING PHASE I MONITORING WELL INSTALLATION (μg/kg)

	CQL[b] (μg/kg)	MW-5					MW-5A				Rinsate Blank #1	MW-1				
		S-1	S-2	S-3	S-4	S-5	S-1	S-3	S-5	S-5 Dup		S-1	S-2	S-3	S-4	S-6
SEMIVOLATILES																
Phenol	1,200	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Dibenzo(a,h)Anthracene	1,200	U	U	U	590J	U	420J	U	U	U	U	U	U	U	U	U
Ideno(1,2,3-cd)Pyrene	1,200	U	U	U	1,100J	U	980J	200J	U	U	U	U	U	U	U	U
Benzoic Acid	1,200	220J	340J	300J	260J	440J	280J	390J	390J	460J	U	120	250J	310J	380J	230J
bis(2-ethylhexyl)phthalate	1,200	U	U	200J	140J	U	140J	U	U	360J	U	U	U	U	U	U
Napthalene	1,200	U	U	U	260J	U	210J	U	U	U	U	U	U	U	U	U
2-Methylnapthalene	1,200	U	U	U	3,000	U	2,600	450J	U	U	U	520	U	260J	5,400	U
Acenaphthylene	1,200	U	U	U	150J	U	140J	U	U	U	U	U	U	U	U	U
Fluorene	1,200	U	U	U	140J	U	120J	U	U	U	U	U	U	U	U	U
Phenanthrene	1,200	U	U	U	1,900	U	1,600	460J	U	U	U	U	U	U	U	U
Anthracene	1,200	U	U	U	270J	U	250J	U	U	U	U	U	U	U	U	U
Di-n-butyl phthalate	1,200	U	U	U	130J	U	U	U	U	U	U	U	U	U	U	U
Fluoranthene	1,200	U	U	U	2,500	U	2,300	570J	U	U	U	U	U	U	U	U
Pyrene	1,200	U	U	U	3,400	U	2,900	960J	U	U	U	U	U	U	U	U
Benzo(a)Anthracene	1,200	U	U	U	1,700	U	1,600	U	U	U	U	U	U	U	U	U
Chryzene	1,200	U	U	U	2,200	U	2,100	510J	U	U	U	U	U	U	U	U
Benzo(b)Fluoranthene	1,200	U	U	U	1,600	U	2,200	560J	U	U	U	U	U	U	U	U
Benzo(k)Fluoranthene	1,200	U	U	U	1,200J	U	U	U	U	U	U	U	U	U	U	U
Benzo(a)Pyrene	1,200	U	U	U	1,800	360J	1,700	420J	250J	U	U	U	U	U	U	U
Benzo(g,h,i)Perylene	1,200	U	U	U	190J	U	1,200	280J	U	U	U	U	U	U	U	U
Tentatively Identified Compounds or Unknowns[(a)]		[8]	[4]	[5]	[7]	[13]	[10]	[7]	[5]	[6]	[3]	[3]	[1]	[5]	[7]	[2]
Hexanedoic acid, dioctyl ester					650J											
Elemene						620J										
Hexatriacantane						1,600J										
1-Hexadecene						2,800J										
11 H-benzo[a]Fluorene						850J										
1,2-Benzene dicarbo oxylic acid, dibutyl ester								1,700J								
Phosphoric acid, dioctadecyl ester								6,500J								7,300J
2-Hexen-1-01(2)										910J			860J			710J
Hexadecanol												750J				
1-Tetracosanol													3,800J			
2,2,4-Trimethyl 1,3-Dioxolene														490J		
4-Methyl-decane														600J		
Decane														1,300J		
2,10-Dimethyl-undecane															620J	
1,1-bis(dodecyloxy)-hexadecane																460J

(a) Total number of unknown compounds detected in peak library search.
(b) Compound Certified Quantification Limit (CQL).
B = Compound found in method blank.
J = Estimated value.
U = Compound analyzed for but not detected. Sample quantification limit corrected for dilution and percent moisture (for soil samples only.

TABLE 4-3 EXTENDED

	MW-4A			MW-4						Rinsate Blank #2
	S-1	S-3	S-6	S-1	S-2	S-3	S-4	S-6	S-3 Dup	
SEMIVOLATILES										
Phenol	U	U	U	U	U	U	U	U	U	U
Dibenzo(a,h)Anthracene	U	U	U	U	U	U	U	U	U	U
Ideno(1,2,3-cd)Pyrene	U	U	U	U	U	U	U	U	U	U
Benzoic Acid	420J	220J	240J	280J	230J	U	U	U	U	U
bis(2-ethylhexyl)phthalate	U	U	U	U	U	U	U	U	130J	U
Napthalene	U	U	U	U	U	U	U	U	U	U
2-Methylnapthalene	1,400	U	U	1,100J	U	U	U	U	U	U
Acenaphthylene	U	U	U	U	U	U	U	U	U	U
Fluorene	U	U	U	U	U	U	U	U	U	U
Phenanthrene	160J	U	U	200J	U	U	U	U	U	U
Anthracene	U	U	U	U	U	U	U	U	U	U
Di-n-butyl phthalate	U	U	U	U	U	U	U	U	U	U
Fluoranthene	240J	U	U	270J	U	U	U	U	U	U
Pyrene	200J	U	U	210J	U	U	U	U	U	U
Benzo(a)Anthracene	U	U	U	U	U	U	U	U	U	U
Chryzene	U	U	U	U	U	U	U	U	U	U
Benzo(b)Fluoranthene	190J	U	U	U	U	U	U	U	U	U
Benzo(k)Fluoranthene	U	U	U	U	U	U	U	U	U	U
Benzo(a)Pyrene	U	U	U	U	U	U	U	U	U	U
Benzo(g,h,i)Perylene	U	U	U	U	U	U	U	U	U	U
Tentatively Identified Compounds or Unknowns[(a)]	[7]	[2]	[2]	[7]	[4]	[1]	[3]	[2]	[2]	[3]
Octadecanol	1,300J									
2-Hexan-1-01		640J								
Tetradecanol			480J							
Phosphoric acid dioctadecyl ester				9,300J				3,100J		
Hexanoic acid, 6-amino									870J	

TABLE 4-4 SUMMARY OF SEMIVOLATILE COMPOUND ANALYSIS OF SOIL SAMPLES COLLECTED DURING PHASE II MONITORING WELL INSTALLATION (μg/kg)

	CQL MW-2 (S-1, S-1 Dup, and S-2 only) (μg/kg)	MW-2						CQL[b] (μg/kg)	MW-6A		
		S-1	S-1 Dup	S-2	S-3	S-4	S-5		S-1	S-3	S-4
Napthalene	50,000	120,000	47,000	13,000	U	990J	820J	1,200	U	U	U
2-Methylnaphthalene	50,000	77,000	17,000J	17,000	U	460J	400J	1,200	U	U	U
Dibenzofuran	50,000	170,000	31,000J	7,600J	U	1,000J	900J	1,200	U	U	U
Acenaphthene	50,000	200,000	34,000J	5,900J	U	1,400	1,300	1,200	U	U	U
Fluorene	50,000	280,000	51,000	6,300J	U	1,500	1,300	1,200	U	U	U
Phenanthrene	50,000	1,200,000	250,000	63,000	U	8,600	8,000	1,200	U	U	U
Anthracene	50,000	410,000	70,000	14,000	U	2,300	2,200	1,200	U	U	U
Fluoranthene	50,000	1,100,000	280,000	79,000	U	8,100	7,000	1,200	U	U	U
Pyrene	50,000	790,000	210,000	58,000	U	5,600	5,000	1,200	U	U	U
Benzo(a)Anthracene	50,000	500,000	120,000	40,000	U	3,500	3,000	1,200	U	U	U
bis(2-ethylhexyl)phthalate	50,000	3,400J	U	U	U	170J	210J	1,200	U	U	U
Chrysene	50,000	450,000	110,000	42,000	U	3,800	3,000	1,200	U	U	U
Benzo(b)Fluoranthene	50,000	350,000	86,000	35,000	U	2,500	2,000	1,200	U	U	U
Benzo(k)Fluoranthene	50,000	230,000	77,000	36,000	U	2,700	2,100	1,200	U	U	U
Benzo(a)Pyrene	50,000	350,000	91,000	37,000	U	3,000	2,400	1,200	U	U	U
Indeno(1,2,3-cd)Pyrene	50,000	160,000	49,000	22,000	U	1,600	1,200J	1,200	U	U	U
Dibenzo(a,h)Anthracene	50,000	55,000	28,000J	U	U	U	U	1,200	U	U	U
Benzo(g,h,i)Pyrene	50,000	150,000	48,000	23,000	U	1,600	1,200J	1,200	U	U	U
4-Methylphenol	50,000	U	2,200J	1,500J	U	U	U	1,200	U	U	U
Benzoic Acid	250,000	U	U	U	410JBM	590JBM	560JBM	6,000	U	U	U
Di-n-butyl phthalate	50,000	U	U	U	190J	430J	160J	1,200	U	U	U
Diethylphthalate	50,000	U	U	U	U	170J	U	1,200	U	U	U
Tentatively Identified Compounds or Unknowns[(a)]		[10]	[7]	[19]	[8]	[14]	[16]		[3]	[5]	[4]
4-Methyldibenzofuran		39,000J									
4 H-Cyclopenta(def)phenanthrene		35,000J									
Benzo(e)Dyrene		130,000J									
1,2-Dimethyl Benzene				7,600J							
Hexadecanoic acid					670J		1,800J		440J		
1,2-Propanediol					3,700J	4,500J	3,700J				
2-(2-bitoxyethoxy)-,acetate					890J	2,600J					470J
Ethanol(2-methoxyethoxy)						640J					
Formamide N,N-dimethyl									540J		580J
Phosphoric acid											3,700J

(a) Total number of unknown compounds detected in peak library search.
(b) Compound Certified Quantification Limit (CQL).
B = Compound found in method blank.
J = Estimated value.
M = Compound detected in sample at <10 times concentration of common laboratory contaminant or at <5 times concentration of other laboratory compounds detected in associated method blank.
U = Compound analyzed for but not detected. Sample quantification limit corrected for dilution and percent moisture (for soil samples only).

TABLE 4-4 EXTENDED

	MW-6				MW-7A			MW-7					
	S-1	S-2	S-3	S-4	S-1	S-3	S-2 S-4	S-1	S-2	Dup	S-3	S-4	S-5
Napthalene	U	U	U	U	U	U	U	U	U	U	U	U	U
2-Methylnaphthalene	U	U	U	U	U	U	U	U	U	U	U	U	U
Dibenzofuran	U	U	U	U	U	U	U	U	U	U	U	U	U
Acenaphthene	U	U	U	U	U	U	U	U	U	U	U	U	U
Fluorene	U	U	U	U	U	U	U	U	U	U	U	U	U
Phenanthrene	330J	U	U	U	U	U	U	U	U	U	U	U	U
Anthracene	U	U	U	U	U	U	U	U	U	U	U	U	U
Fluoranthene	560J	U	U	U	U	U	U	U	U	U	U	U	U
Pyrene	370J	U	U	U	130J	U	U	U	U	U	U	U	U
Benzo(a)Anthracene	250J	U	U	U	U	U	U	U	U	U	U	U	U
bis(2-ethylhexyl)phthalate	U	U	U	U	U	U	U	U	U	120J	U	U	U
Chrysene	270J	U	U	U	U	U	U	U	U	U	U	U	U
Benzo(b)Fluoranthene	220J	U	U	U	U	U	U	U	U	U	U	U	U
Benzo(k)Fluoranthene	200J	U	U	U	U	U	U	U	U	U	U	U	U
Benzo(a)Pyrene	240J	U	U	U	U	U	U	U	U	U	U	U	U
Indeno(1,2,3-cd)Pyrene	130J	U	U	U	U	U	U	U	U	U	U	U	U
Dibenzo(a,h)Anthracene	U	U	U	U	U	U	U	U	U	U	U	U	U
Benzo(g,h,i)Pyrene	140J	U	U	U	U	U	U	U	U	U	U	U	U
4-Methylphenol	U	U	U	U	U	U	U	U	U	U	U	U	U
Dibenzofuran	1,700J	U	U	5,500J	U	U	U	U	U	U	U	U	U
Benzoic Acid	U	U	U	U	U	U	U	U	U	180J	190J	U	U
Di-n-butyl phthalate	U	U	U	U	U	U	U	U	230J	140J	U	130J	U
Diethylphthalate	U	U	U	U	U	U	U	U	U	U	U	U	U
Tentatively Identified Compounds or Unknowns[(a)]	[5]	[5]	[3]	[4]	[4]	[3]	[3]	[2]	[3]	[6]	[10]	[5]	[7]
Hexadecanoic acid				440J	710J					1,600J	1,200J	620J	470J
1,2-Propanediol	1,400J									2,000J			32,000J
2-(2-bitoxyethoxy)-,acetate		620J							560J			670J	
Formamide N,N-dimethyl	570J	570J		440J	740J	690J							
Tetrateracontane	610J												
1-Octadecene	2,100J												
Propanoic acid 2-methyl	740J												
3-Eicosene							5,500J						
Phosphoric acid								8,700J					
1-Datriacontanol										5,400J			

acenapthene, fluorene, anthracene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno (1,2,3-cd)pyrene, and benzo(g,h,i)pyrene were all detected at levels in excess of 100 mg/kg. Samples collected from MW-2 from depths near the surface to a depth of 10 ft were found to have concentration levels of semivolatile compounds several to over 100 times higher in concentration than those found elsewhere onsite or offsite. In general, detectable concentrations of semivolatile compounds decreased with increased sample depth in MW-2. Concentrations of semivolatiles decreased one to two orders of magnitude between 0-2 ft and 8-10 ft. At the 10-ft depth in MW-2, S-5 concentration levels of semivolatiles were similar (within one magnitude) to those detected at other locations both onsite and offsite.

No criteria for semivolatile contamination in soils exist. Most semivolatiles in the PAH group are not particularly water soluble and therefore typically not mobile in ground water.

In summary, with exception of MW-2, low-level concentrations (usually below contract reporting limits) were detected both onsite at the periphery of the "waste fill" and offsite where other fill has been placed. The highest levels of semivolatile concentrations were obviously distributed in the upper 5-6 ft of MW-2 which was the closest boring to the "waste fill" sampled. The family of semivolatiles known as PAH was common onsite in boring MW-2 and offsite in MW-5, MW-5A. A discernible pattern of semivolatile distribution is that it is primarily restricted to the upper fill onsite and concentration levels dissipate rapidly away from the waste fill. The presence of low concentration levels offsite in MW-5 and MW-5A have been attributed to the nature of the fill material (asphalt) placed at this location for subsequent perimeter road construction. The presence of the higher concentration and more diverse compounds located onsite in the vicinity of MW-2 reflect the chemical nature of the material proximal to the boring. The rapid decrease in concentration levels with increased depth indicates that the relatively immobile semivolatile constituents are primarily restricted to the fill. The presence of low concentration levels of semivolatile compounds offsite indicates that allocthonous fill material placed as a result of depot development facilitates a random distribution of these low-level semivolatile constituents in the area outside the site boundaries.

4.1.3 Trace Metal Concentrations in the Soil

Due to the relative absence of *in situ* soil that has been neither reworked nor filled upon, a true background concentration of trace metals in the soil was difficult to establish. Natural soils in the immediate area have been reworked or mixed with other fill materials.

The area in the vicinity of monitoring well borings MW-7, MW-5, MW-5A, MW-6, and MW-6A has been filled with material ranging in thickness from 2.5 to 6 ft. Subsequently, natural soils underlying the fill may have potentially been impacted by leaching of trace metals, as well as other constituents, from the fill to deeper soils. Consequently, the comparison of onsite trace metal to offsite trace metal concentrations in the soil was the only method available for evaluating distribution patterns

of trace metal contamination. Metal concentrations in soil samples were identified as elevated relative to (1) the metal concentrations in onsite soils when compared to offsite soils, (2) anomalous concentration of metals in soil samples when compared to a range of consistent metal concentration in soil samples throughout the project area, and (3) anomalous metal concentration occurrences within a particular boring (i.e., high concentration in soil sample sandwiched between two lower concentrations).

Tables 4-5 and 4-6 list the concentrations of trace metals detected from the Phase I and Phase II soils collected during monitoring well installation.

Arsenic showed no discernible distribution pattern either onsite or offsite. Concentration ranges were detected from 1.7 to 30.7 mg/kg in soil samples MW-7, S-3, and MW-6, S-1, respectively.

Barium was detected at elevated levels in soil samples collected from MW-2. In particular, MW-2, S1 and MW-2, S1 (Dup) were found to contain levels of 1,400 and 719 mg/kg, respectively.

Cadmium was not detected in significant concentrations, with a maximum soil concentration detected in offsite soil sample MW-7, S-5 at 4.5 mg/kg. In general, cadmium concentrations in soil samples collected from MW-7 were higher than those from other borings. Cadmium concentrations in the soil ranged from below the detection limit to 4.5 mg/kg.

No pattern of chromium distribution was evident. Chromium was detected across the project area from 12.0 to 70.2 mg/kg in sample MW-4A, S-1, and MW-2, S1, respectively.

Copper was detected in elevated concentration levels of as high as 1,970 mg/kg in MW-2, S-1; 1,360 mg/kg in MW-2, S-1 (Dup); and 639 mg/kg in MW-2, S-3, indicating a significant concentration above the concentration range encountered elsewhere of below detection limit to 30.7 mg/kg (MW-1, S-1).

Lead was also detected at elevated levels of 1,140, 671, 279, and 236 mg/kg in MW-2 samples S-1, S-1 (Dup), S-2, and S-4, respectively. Elsewhere lead concentration ranged from 1.3 to 43.5 mg/kg (MW-5A, S-5 and MW-1, S-1).

Mercury, although below detection limits in most instances, was detected at concentration levels of between 0.14 to 0.74 mg/kg in soil samples collected from monitoring well boring MW-2.

Silver was also detected only in MW-2 soil samples at concentrations between 19.3 and 33.8 mg/kg.

Zinc was also detected at elevated concentration levels in MW-2, between 55.6 and 2,110 mg/kg compared to the concentration range detected elsewhere of between 31.5 and 101 mg/kg.

TABLE 4-5 SUMMARY OF METALS ANALYSIS OF SOIL SAMPLES COLLECTED DURING PHASE I MONITORING WELL INSTALLATION (mg/kg)

	MW-5					MW-5A				Rinsate Blank	MW-1				
Parameter	S-1	S-2	S-3	S-4	S-5	S-1	S-3	S-5	S-3 Dup	#1	S-1	S-2	S-3	S-4	S-6
Aluminum	9,750	10,600	8,510	13,300	14,600	14,200	8,800	12,300	16,900	U	11,900	16,100	19,000	10,900	14,900
Antimony	U	U	U	8.1	U	7.0	U	U	U	U	U	U	U	U	U
Arsenic	2.9S	14.3	8.0S	7.9S	13.7	17.8	11.7	10.3S	20.0	2.2	8.9	16.4	22.6	12.0	5.1
Barium	73.9	69.1	39.3	82.7	100	46.9	43.2	72.7	123	U	154	120	46.4	47.9	124
Beryllium	U	0.64	0.37	1.6	0.66	0.47	0.56	0.57	0.80	U	0.45	0.82	0.78	0.67	0.95
Cadmium	1.1	U	0.68	0.96	0.69	0.80	U	0.64	U	U	0.91	U	U	0.83	0.51
Calcium	12,900	1,930	542	989	769	24,100	973	1,010	1,010	58.6	1,440	890	1,450	1,250	3,110
Chromium	13.4	17.4	14.1	23.8	18.0	16.0	14.0	17.3	17.9	U	19.2	14.7	23.9	18.5	32.5
Cobalt	9.1	11.1	13.7	19.3	8.7	9.7	13.7	9.6	13.6	U	13.0	11.1	19.9	17.3	19.2
Copper	14.2	8.9	2.8	6.4	5.1	15.6	5.6	7.4	8.0	U	30.7	4.5	17.7	14.3	4.2
Iron	15,300	15,800	11,800	21,700	13,100	23,500	12,600	13,800	14,700	62.6	24,700	18,300	35,300	24,900	28,200
Lead	43.5	32.7	7.3S	12.5	7.0S	20.1	2.7S	1.3S	2.1S	1.8	25.5	11.7	18.1	13.3	23.3
Magnesium	5,070	3,140	2,200	2,710	2,620	2,940	3,070	2,490	4,130	U	2,700	2,580	4,270	3,020	6,730
Manganese	542	424	118	469	176	447	233	186	271	U	1,090	1,090	423	828	785
Mercury	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Nickel	15.8	18.9	12.0	19.2	15.1	18.1	19.2	16.9	25.1	U	22.0	20.6	25.4	23.3	35.5
Potassium	749	574	534	651	787	839	617	730	673	U	787	911	1,140	816	2,870
Selenium	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Silver	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Sodium	80.1S	47.6S	90.6S	106S	134S	43.5S	87.8S	105S	137S	344	57.0	56.5	56.8	48	132
Thallium	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Vanadium	18.4	21	18.0	30.2	23.1	20.8	15.0	19.5	U	U	20.0	18.9	43.9	33.9	19.9
Zinc	101S	76S	35.8S	59.9S	49.9S	85.5S	47.2S	45.1S	51.9S	30.1	69.4	62.7	66.8	72.9	72.8
Boron	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Molybdenum	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Silicon	619S	871	413S	626S	695	463S	837	582S	990	130	895	883	1,220	510	411

S = Indicates compound detected in sample at <5 times the concentration detected in associated trip or rirnsate blank
U = Below detection limit

TABLE 4-5 EXTENDED

Parameter	MW-4A S-1	MW-4A S-3	MW-4A S-6	MW-4 S-1	MW-4 S-2	MW-4 S-3	MW-4 S-4	MW-4 S-6	MW-4 S-3 Dup	Rinsate Blank #2
Aluminum	14,000	10,100	7,830	13,400	14,800	11,900	8,870	10,800	10,100	110
Antimony	U	U	U	U	U	U	U	12.4	9.2	U
Arsenic	14.8	7.5	8.3	15.4	15.6	14.2	14.1	10.7	6.8	U
Barium	184	73.5	56.6	130	141	71.7	57.1	147	79.4	U
Beryllium	0.86	0.49	0.49	0.72	0.88	0.62	U	0.70	0.33	U
Cadmium	0.76	U	U	U	U	0.72	U	U	U	U
Calcium	819	1,340	1,440	647	1,030	862	1,050	1,950	950	U
Chromium	12.0	17.0	15.4	12.7	15.6	16.9	17.1	19.2	14.4	U
Cobalt	10.0	14.2	13.9	10.2	9.1	18.7	2.7	14.6	12.4	U
Copper	4.4	13.5	11.9	4.0	9.5	14.3	13.8	U	14.8	U
Iron	16,700	22,500	22,100	18,100	18,100	26,500	20,800	20,500	22,100	U
Lead	13.7	13.2	11.4	14.6	17.1	13.6	11.1	15.0	12.0	1.8
Magnesium	1,850	4,450	3,240	1,840	2,070	3,370	3,800	5,980	2,740	U
Manganese	962	591	764	1,440	1,650	819	450	861	671	6.8
Mercury	0.13	U	U	U	U	U	U	U	U	0.39
Nickel	19.0S	20.7S	20.5S	19.0S	21.5S	23.6S	20.6S	35.6S	21.5S	24.4
Potassium	589	651	800	698	749	1,170	1,030	2,440	914	U
Selenium	U	U	U	U	U	U	U	U	U	U
Silver	U	U	U	U	U	U	U	U	U	U
Sodium	43.2S	61.2S	60.9S	54.3S	42.9S	59.1S	71.4S	298S	253S	307
Thallium	U	U	U	U	U	U	U	U	U	U
Vanadium	15.1	31.4	31.2	17.3	19.2	27.9	30.0	15.6	27.3	U
Zinc	54.6S	55.4S	43.8S	55.8S	75.4S	52.5S	54.9S	63.4S	57.4S	18.7
Boron	U	U	U	U	U	U	U	U	U	U
Molybdenum	U	U	U	U	U	U	U	U	U	U
Silicon	592	541S	745	758	538S	719	572S	494S	425S	117

TABLE 4-6 SUMMARY OF METALS ANALYSIS OF SOIL SAMPLES COLLECTED DURING PHASE II MONITORING WELL INSTALLATION (mg/kg)

	MW-2						MW-6A			MW-6			
Parameter	S-1	S-1 Dup	S-2	S-3	S-4	S-5	S-1	S-3	S-4	S-1	S-2	S-3	S-4
Aluminum	11,900	11,200	19,500	17,700	16,800	16,300	13,400	16,700	11,200	17,600	17,400	17,300	7,060
Antimony	U	U	U	U	U	7.6	U	9.1	U	U	U	U	U
Arsenic	14.4	8.4	10.9	11.6	11	4.8	11.1	4.4	5.6	30.7	19.4	15.9	12.9
Barium	1,400	719	351	143	283	336	43.5	108	61.3	188	97.6	81.1	34.0
Beryllium	0.96	0.59B	1.2	1.1	0.76	2.3	0.27B	0.89	0.49B	1.1	0.99	0.78	1.1
Boron	14.4	U	U	U	U	U	U	U	U	U	U	U	U
Cadmium	2.0	0.79	U	U	U	U	U	U	U	U	U	U	0.51
Calcium	29,000	9,290	25,700	3,460	5,420	3,520	1,350	922	920	18,500	1,780	1,760	822
Chromium	70.2	47.4	30.8	21.5	28.3	23.8	13.4	19.6	13.5	13.0	32.7	19.0	13.2
Cobalt	9.6	7.9	10.2	8.0	9.0	22.6	11.3	10.7	6.6	9.1	8.1	6.4	4.6B
Copper	1,970	1,360	639	10.0	431	27.1	11.9	15.1	9.3	17.2	14.7	13.2	10.2
Cyanide	0.3	0.1	U	0.1	U	U	U	U	U	0.1	U	U	U
Iron	38,500	41,700	25,500	44,300	32,900	42,000	25,000	26,900	12,900	24,000	34,500	27,000	22,500
Lead	1,140	671	279	22.2	236	22.2	15.5	15.9	9.8	26.1	15.7	1.4	9.4
Magnesium	12,100	3,250	10,000	1,650	1,840	4,140	2,310	3,330	2,440	3,940	2,850	2,880	1,340
Manganese	590	540	624	282	261	2,480	253	96.8	43.5	962	106	58.8	41.7
Mercury	0.74	0.34	0.21	0.14	U	0.20	U	U	U	0.17	U	U	U
Molybdenum	7.2	2.4	4.3	U	U	U	U	U	U	U	U	U	U
Nickel	28.6	21.4	17.0	9.1	2.8B	37.5	14	18.3	14.2	13.4	18.1	13.1	8.9
Potassium	1,170	990	801	1,510	902	1,360	1,430	938	910	887	1,340	1,110	884
Selenium	0.21B	U	0.78	0.54	0.22B	U	U	U	U	0.14B	U	U	U
Silicon	U	19.7	U	U	13.8	U	21.7	732	1,190	690	649	443	67.1
Silver	33.8	19.3	20.5	U	U	U	U	U	U	U	U	U	U
Sodium	139B	386B	167B	119B	175B	104B	271B	102B	149B	88.7B	76.1B	83.8B	95.4B
Thallium	U	U	U	U	U	U	U	U	U	U	U	U	U
Vanadium	24.7	18.3	24.8	40.5	U	45.4	17.2	21.1	15.4	15.6	21.2	19.7	22.5
Zinc	2,110	1,320	575	55.6	910	117	46.9	56.6	45.6	64.7	60.5	48.5	31.5

B = Compound found in method blank
U = Below detection limit

TABLE 4-6 EXTENDED

Parameter	MW-7A S-1	MW-7A S-3	MW-7A S-4	MW-7 S-1	MW-7 S-2	MW-7 S-2 Dup	MW-7 S-3	MW-7 S-4	MW-7 S-5
Aluminum	14,100	16,300	20,600	21,600	18,300	15,100	20,500	16,400	7,600
Antimony	U	U	U	U	18.4	U	11.3	U	8.5
Arsenic	6.2	18.8	15.9	1.8	5.8	5.3	1.7	4.0	6.1
Barium	106	144	144	53.7	61.7	58.9	141	114	117
Beryllium	0.84	1.2	1.4	0.75	0.83	0.53	1.3	0.77	0.47
Boron	U	U	U	U	U	U	U	U	8.2
Cadmium	U	U	U	3.3	3.0	2.8	2.8	3.1	4.5
Calcium	2,170	2,350	2,880	835	1,600	964	2,100	2,470	2,130
Chromium	16.9	29.4	28.1	21.0	19.5	16.0	20.9	27.0	13.9
Cobalt	U	12.1	13.1	9.5	11.5	7.6	14.4	4.9B	8.2
Copper	U	20.9	25.1	18.3	13.1	9.0	19.8	15.5	13.2
Cyanide	0.1	U	U	U	U	U	U	U	U
Iron	22,200	36,000	50,900	32,200	31,200	26,800	34,800	26,600	22,400
Lead	26.7	14.5	23.1	14.9	20.8	15.5	16.6	11.4	6.1
Magnesium	2,370	4,680	4,460	2,170	3,760	2,850	4,560	3,660	2,610
Manganese	1,130	428	228	277	293	200	767	105	1,000
Mercury	U	U	U	0.12	U	U	U	U	U
Molybdenum	U	U	U	U	U	U	U	U	U
Nickel	13.2	18.5	20.6	14.6	15.2	10.2	19.9	15.2	20.7
Potassium	655	942	1,060	819	745	770	806	789	601
Selenium	0.21B	U	U	0.12B	0.22B	0.23B	U	U	U
Silicon	674	131	159	143	953	1,120	1,410	673	135
Silver	U	U	U	U	U	U	U	U	U
Sodium	285B	160	158B	60.3B	89.1B	77.8B	133B	152B	99.3B
Thallium	U	U	U	U	U	U	U	U	U
Vanadium	28.4	32.7	30.7	35.8	49.3	40.8	41.7	27.6	26.2
Zinc	72.8	75.3	81.8	52.2	65.8	56.5	90.2	75.7	47.8

The remaining trace metals occurred at concentrations relatively consistent across the project area.

In summary, elevated concentration levels of the trace metals barium, copper, lead, silver, and zinc were found primarily restricted to site boring MW-2, which is located near the "waste fill."

MW-2 soil samples were also found to have the highest chromium concentration levels and the only mercury levels above detection limits when compared to other soil samples collected. The general pattern of elevated trace metal concentrations indicates that the fill near MW-2 is characteristically higher in content of the trace metals barium, chromium, copper, lead, silver, and zinc. In comparison, soil samples in the upper 4 ft of fill exhibit the highest concentration of the above identified trace metals, suggesting fill-derived contamination. In particular, lead and silver are considerably excessive in soil samples collected from MW-2 when compared to other soil sample concentrations across the project area. However, lead is prevalent throughout the project site, but typically at 20 to 50 times less than the concentrations encountered in MW-2. A significant point to trace metal contamination in MW-2 is that the highest concentration levels are detected in the upper 2 ft of soil, most of which is cover fill. In light of the elevated trace metal concentrations in the soil samples collected from MW-2, which is located at the extreme edge of "waste fill," the potential exists that levels of trace metals within the "waste fill" itself may be higher still. No criteria exist for maximum trace metal contaminant levels in soil; however, human exposure risk can be evaluated based on the trace metal contaminant levels encountered, exposure pathways (dust, dermal), and toxicity of the trace metal. Table 4-7 lists significant levels of trace metals in soil which appear to be related to the fill material onsite and which are not typical of the surrounding offsite soils.

4.1.4 Pesticide/PCB Concentration in the Soil

Tables 4-8 and 4-9 summarize pesticide/PCB compounds detected in the soil during Phase I and Phase II monitoring well installation, respectively.

Pesticides and pesticide metabolites were detected in soil samples at MW-5A, S-1 (0-2 ft) and S-3 (4-6 ft); MW-1, S-1 (0.2 ft) and S-2 (2-4 ft); and MW-4, S-1 (0-2 ft) during Phase I monitoring well installation. Compounds 4,4'-DDE, 4,4'-DDD, and 4,4'-DDT are all chemically related. Compounds 4,4'-DDE and 4,4'-DDD are decomposition by-products of the pesticide 4,4'-DDT. Concentration levels of pesticides and metabolites were highest in MW-5A, ranging from 260 to 500, 190 to 320, and 1,440 to 3,200 µg/kg for 4,4'-DDE, 4,4'-DDD, and 4,4'-DDT, respectively. Low levels of 4,4'-DDE and 4,4'-DDT (i.e., less than 61 µg/kg) were also detected in near-surface soil samples in MW-1 and MW-4.

4,4'-DDD, 4,4'-DDE, and 4,4'-DDT were detected at very low levels (280 to 340 µg/kg) in soil samples analyzed from 0 to 10 ft depth from Phase II monitoring well boring installation MW-2. No pesticides were detected in any other soils collected from the Phase II monitoring well installation.

TABLE 4-7 SIGNIFICANT CONCENTRATION OF TRACE METALS IN SOILS COLLECTED AT MARSH RUN FIELD

Parameter	Samples Number With Significant Detection	Range of Detectable Concentrations (mg/kg)	Sample With Highest Concentration
Arsenic	MW6, S1	1.7-30.7	MW6, S1
Barium	MW2-S1, MW2-S1 (Dup)	34-1,400	MW2, S1
Chromium	MW2, S1	12.0-70.2	MW2, S1
Copper	MW2-S1, MW2-S1 (Dup), MW2-S2, MW2-S4	ND-1,970	MW2, S1
Lead	MW2-S1, MW2-S1 (Dup), MW2-S2, MW2-S4	1.3-1,140	MW2-S1
Silver	MW2-S1, MW2-S1 (Dup), MW2-S2	ND-33.8	MW2-S1
Zinc	MW2-S1, MW2-S1 (Dup)	31.5-2,110	MW2-S1

TABLE 4-8 SUMMARY OF PESTICIDE/PCB ANALYSIS OF SOIL SAMPLES COLLECTED DURING PHASE I MONITORING WELL INSTALLATION (μg/kg)

	CQL[a]	MW-5					MW-5A				MW-1					MW-4A			MW-4						Rinsate Blank	Rinsate Blank
	μg/kg	S-1	S-2	S-3	S-4	S-5	S-1	S-3	S-5	S-5 Dup	S-1	S-2	S-3	S-4	S-6	S-1	S-3	S-6	S-1	S-2	S-3	S-4	S-6	S-3 Dup	#1	#2
Pesticide																										
4,4'-DDE	20	U	U	U	U	U	260	500	U	U	60	61	U	U	U	U	U	U	37	U	U	U	U	U	U	U
4,4'-DDD	20	U	U	U	U	U	190	320	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
4,4'-DDT	20	U	U	U	U	U	1,400	3,200	U	U	U	43	U	U	U	U	U	U	U	U	U	U	U	U	U	U
PCB																										
[none detected]																										

(a) Certified Quantification Limit
U = Compound not detected

TABLE 4-9 SUMMARY OF PESTICIDE/PCB ANALYSIS OF SOIL SAMPLES COLLECTED DURING PHASE II MONITORING WELL INSTALLATION (μg/kg)

	CQL[a][b]	MW-2						MW-6A			MW-6				MW-7A			MW-7					
	(μg/kg)	S-1	S-1 Dup	S-2	S-3	S-4	S-5	S-1	S-3	S-4	S-1	S-2	S-3	S-4	S-1	S-3	S-4	S-1	S-2	S-2 Dup	S-3	S-4	S-5
Pesticide																							
4,4'-DDE	20	280	U	340	4.8J	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
4,4'-DDD	20	170J	120J	150J	15J	3.8	2.6	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
4,4'-DDT	20	U	U	U	3.1J	4.3	3.1	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
PCB																							
[none detected]																							

(a) Certified Quantification Limit.
(b) For samples MW-2 (S-1, S-2, S-1 dup) the CQL for DDE, DDD, and DDT was 220 μg/kg due to dilution factor.
J = Estimated value.
U = Compound not detected.

No PCB compounds were detected in any soil samples collected from the site.

In summary, low levels of 4,4'-DDT and its degradation by-products 4,4'-DDE and 4,4,'-DDD were detected onsite and offsite at or near the surface or distributed in the fill to a depth of 6 ft below the surface. Spraying of pesticide in a marsh environment is common. The use of 4,4'-DDT was illegal after 1967.

4.1.5 Total Petroleum Hydrocarbons and Cyanide Concentrations in Soil

Total cyanide concentration levels in the soil ranged from below the detection limit to a maximum of 0.5 mg/kg. Total petroleum hydrocarbon (TPH) concentrations were highest in MW-2, ranging from 60 to 780 mg/kg. Elsewhere, TPH was detected both onsite and offsite at values ranging from 5.29 to 693 mg/kg. Tables 4-10 and 4-11 summarize the analytical data for these parameters during Phase I and Phase II monitoring well installation, respectively.

4.2 NATURE AND EXTENT OF CONTAMINATION IN GROUND WATER

4.2.1 Volatile Organics in Ground Water

Ground-water samples were collected from site monitoring wells sampled twice during the site investigation. The first round was on 8 February 1989 the second round was 16, 17 August 1989. The second round included those monitoring wells sampled during the first round along with the newly installed Phase II monitoring wells. Table 4-12 summarizes the volatile organic compounds detected during the Phase I and Phase II ground-water sampling events.

Trichloroethene (TCE) was detected during both sampling events in the bedrock aquifer and during the second sampling event in the shallow saturated overburden zone. TCE was detected in bedrock well MW-1 at 160 and 170 µg/L during the first and second sampling events, respectively. Ground-water samples collected from MW-4, also a bedrock well, were found to contain TCE at concentrations of 380 and 400 µg/L during the first and second sampling events, respectively. A duplicate sample taken of MW-4 during the first sampling event confirmed the presence of TCE by showing similar concentration levels (370 µg/L). TCE was detected in only the bedrock wells during the first event. During the second event, TCE was also detected in shallow overburden saturated zone wells MW-1A and MW-4A at lower concentrations of 24 and 6 µg/L, respectively.

TCE concentrations detected in the bedrock aquifer during both sampling events exceeded the maximum contaminant level (MCL) established by the EPA at (5 µg/L) by 30 to 80 times. The levels of TCE detected during the second sampling event in the saturated overburden monitoring wells (i.e., MW-1A and MW-4A) slightly exceeded the MCL.

Other volatile organic compounds that were detected in the site monitoring wells were 1,1-dichloroethene (MCL of 7 µg/L), 1,2-dichloroethene

TABLE 4-10 SUMMARY OF CYANIDE AND TOTAL PETROLEUM HYDROCARBONS (TPH) ANALYSIS OF SOIL SAMPLES COLLECTED DURING PHASE I MONITORING WELL INSTALLATION (mg/kg)

Parameter	CQL[a] (mg/kg)	MW-5					MW-5A				Rinsate Blank #1	MW-1					MW-4A			MW-4					
		S-1	S-2	S-3	S-4	S-5	S-1	S-3	S-5	S-5 Dup		S-1	S-2	S-3	S-4	S-6	S-1	S-3	S-6	S-1	S-2	S-3	S-4	S-6	S-3 Dup
Cyanide	0.1	0.50	0.25	U	U	U	0.25	U	U	0.16	--	0.24	0.12	U	U	U	0.53	U	U	0.25	0.39	U	U	U	U
TPH	0.1	5.29	146	U	26.3	116	76.9	24.5	U	298	U	U	U	U	693	U	U	U	U	U	U	U	U	U	U

(a) Certified Quantification Limit
U = Below detection limit

TABLE 4-11 SUMMARY OF CYANIDE AND TOTAL PETROLEUM HYDROCARBONS (TPH) ANALYSIS OF SOIL SAMPLES COLLECTED DURING PHASE II MONITORING WELL INSTALLATION (mg/kg)

		MW-2						MW-6A			MW-6				MW-7A			MW-7					
Parameter	CQL[a] (mg/kg)	S-1	S-1 Dup	S-2	S-3	S-4	S-5	S-1	S-3	S-4	S-1	S-2	S-3	S-4	S-1	S-3	S-4	S-1	S-2	S-2 Dup	S-3	S-4	S-5
Cyanide	0.1	0.3	0.1	U	0.1	U	U	U	U	U	0.1	U	U	U	0.1	U	U	U	U	U	U	U	U
TPH	0.1	780	460	300	70.0	70.0	60.0	60.0	60.0	80.0	70.0	U	40	U	70.0	40.0	50.0	70.0	U	U	U	U	U

(a) Certified Quantification Limit
U = Below detection limit

TABLE 4-12 SUMMARY OF ORGANIC COMPOUND ANALYSIS OF GROUND-WATER SAMPLES COLLECTED FROM MONITORING WELLS ON 8 FEBRUARY (PHASE I) AND 16, 17 AUGUST (PHASE II) 1989 (μg/L)

	CQL[b] (μg/kg)	MW-1		MW-1A		MW-2		MW-2A			MW-3A	
		8 Feb	16 Aug	8 Feb	16 Aug	16 Aug	16 Aug Dup	8 Feb	8 Feb Dup	16 Aug	8 Feb	17 Aug
VOLATILES												
Ethylbenzene	5	7BM	U	U	U	U	U	18B	24	U	U	U
1,1-Dichloroethene	5	12	U	U	U	U	U	U	U	U	U	U
1,1,2,2-Tetrachloroethane	5	46	33	U	7	U	U	U	U	U	U	U
Trichloroethene	5	160	170	U	24	U	U	U	U	U	U	U
Toluene	5	U	U	U	U	U	U	U	U	U	U	U
Acetone	10	U	U	U	U	U	U	U	U	U	U	U
Methylene Chloride	5	U	U	U	U	U	U	U	U	11	U	U
1,2-Dichloroethene (total)	5	U	45	U	82	U	U	U	22	13	U	U
Vinyl Chloride	10	U	U	U	U	U	U	U	U	U	U	U
1,1,2-Trichloroethane	5	U	5J	U	U	U	U	U	U	U	U	U
Tetrachloroethene	5	U	U	U	U	U	U	U	U	U	U	U
SEMIVOLATILES												
bis(2-ethylhexyl)phthalate	10	U	U	U	26	U	U	U	U	U	U	U
Benzoic Acid	50	U	U	U	U	U	U	U	U	U	U	U
Fluoranthene	10	U	U	U	U	U	U	U	U	U	U	U
Pyrene	10	U	U	U	U	U	U	U	U	U	U	U
Tentatively Identified Compounds or Unknowns[(a)]		[2]	[4]		[3]	[1]	[1]			[2]		
Propanoic acid												9J
Cyclopentasiloxane												16J
Hexamethylcyclotrisiloxane					25JB							
Octamethylcyclotetrasiloxane					28J							
Ben<amide,N,N-diethyl-3methyl										12J		
PESTICIDE/PCB												
[none detected]												

(a) Total number of unknown compounds detected in peak library search.
(b) Compound Certified Quantification Limit (CQL).
B = Compound found in method blank.
J = Estimated value.
M = Compound detected in sample at <10 times concentration of common laboratory contaminant or at <5 times concentration of other compounds detected in associated method blank.
S = Compound detected in sample at <5 times the concentration detected in associated trip or rinsate blank.
U = Compound analyzed for but not detected.

TABLE 4-12 EXTENDED

	MW-4			MW-4A		MW-5		MW-5A		MW-6	
	8 Feb	8 Feb Dup	16 Aug	8 Feb	16 Aug	8 Feb	16 Aug	8 Feb	16 Aug	16 Aug	16 Aug Dup
VOLATILES											
Ethylbenzene	U	U	U	U	U	U	U	U	U	U	U
1,1-DichloroetheneU	U	U	U	U	U	U	U	U	U	U	U
1,1,2,2-Tetrachloroethane	U	U	3J	U	1J	U	U	U	U	U	U
Trichloroethene	380	370	400	U	6	U	U	U	U	U	U
Toluene	U	U	U	U	U	U	U	U	U	U	U
Acetone	U	U	32S	U	U	U	U	34	24S	U	U
Methylene ChlorideU	U	U	U	U	U	U	U	U	U	U	U
1,2-Dichloroethene (total)	35	36	99	U	5J	U	U	U	U	U	U
Vinyl ChlorideU	U	U	U	U	U	U	U	U	U	U	U
1,1,2-Trichloroethane	U	U	10	U	U	U	U	U	U	U	U
Tetrachloroethene	U	U	1J	U	U	U	U	U	U	U	U
SEMIVOLATILES											
bis(2-ethylhexyl)phthalate	U	U	U	4JB	U	U	U	U	U	U	U
Benzoic Acid	U	U	U	U	U	U	U	U	3J	U	U
FluoranthenеU	U	U	U	U	U	U	U	U	U	U	U
Pyrene	U	U	U	U	U	U	U	U	U	U	U
Tentatively Identified Compounds or Unknowns[(a)]	[4]	[4]	[3]	[3]	[1]	[2]		[3]	[1]		
Pentadecane,2,6,10,14-tetramethyl				33J							
Dodecane,2,7,10,trimethyl				40J							
Hexamethylcyclotrisiloxane			54JB			14J					
Decamethylcyclopentasiloxane			22JB			10J					
Benzimide									20J		
Dodecamethylcyclohexasiloxane			12JB								
1,2 propanedol					9J						
PESTICIDE/PCB											
[none detected]											

TABLE 4-12 EXTENDED (Cont.)

	MW-6A	MW-7	MW-7A	WP-1	WP-3	Rinsate Blank		Trip Blank	
	16 Aug	16 Aug	16 Aug	17 Aug	16 Aug	8 Feb	16 Aug	8 Feb	16 Aug
VOLATILES									
Ethylbenzene	U	U	U	U	U	U	U	U	U
1,1-Dichloroethene	U	U	U	U	U	8B	U	8B	U
1,1,2,2-Tetrachloroethane	U	U	U	U	U	U	U	U	U
Trichloroethene	U	U	U	4J	U	U	U	U	U
Toluene	U	U	U	U	U	U	U	U	U
Acetone	U	U	U	U	U	U	U	U	77
Methylene Chloride	U	U	U	U	U	U	U	U	U
1,2-Dichloroethene (total)	U	U	U	110	3J	U	U	U	U
Vinyl Chloride	U	U	U	96	11	U	U	U	U
1,1,2-Trichloroethane	U	U	U	U	U	U	U	U	U
Tetrachloroethene	U	U	U	U	U	U	U	U	U
SEMIVOLATILES									
bis(2-ethylhexyl)phthalate									
Benzoic Acid									
Fluoranthene									
Pyrene									
Tentatively Identified Compounds or Unknowns[(a)]		[1]	[2]			[1]			
Hexamethyclylotrisiloxane		74JB							
Cyclopentasilacane		52JB							
Dodecamethylcyclohexasiloxane		23JB							
Crotonic acid			12J						
1,2-Propanodiol					29J				
PESTICIDE/PCB									
[none detected]									

(total) (cis and trans), vinyl chloride (MCL of 2 µg/L and proposed of 1 µg/L), and 1,1,2,2-tetrachloroethane. In actuality, 1,2-dichloroethene (total) was quantified against a standard of trans-1,2-dichloroethene. Trans-1,2-dichloroethene has a proposed maximum contaminant level goal (MCLG) of 100 µg/L. MCLGs, unlike MCLs, are not enforceable.

The volatile organic compound 1,2-dichloroethene (total) is a degradation product of TCE. In actuality, the compound reported as 1,2-dichloroethene (total) is both trans and cis combined as per Contract Laboratory Protocol (CLP) reporting requirements. EPA does not recognize the differentiation of the reporting of 1,2-dichloroethene as cis or trans and as such is reported as total. During the first sampling round, 1,2-dichloroethene (total) was detected in bedrock well MW-4 at 35 µg/L. The compound was not detected in bedrock well MW-1 during the first sampling round. Also during the first sampling round, 1,2-dichloroethene was detected in overburden well MW-2A duplicate sample at 22 µg/L. Volatile compound 1,2-dichloroethane was detected in MW-1 and MW-4 (bedrock aquifer) at 45 and 99 µg/L, respectively, and in the shallow overburden well MW-1A at 82 µg/L during the second sampling event. It was also detected in shallow overburden wells MW-2A and MW-4A at 13 and 5 µg/L, respectively. Volatile organic compounds were also present in onsite shallow overburden monitoring wells in close proximity to the fill. Vinyl chloride, which can also be a degradation by-product of TCE and is persistent in the environment, was detected only in the saturated overburden during the second sampling event at concentrations of 96 and 11 µg/L in WP-1 and WP-3, respectively. Table 4-13 lists the significant detections of volatile organic compounds found on the site and compares the highest detected level with established or proposed MCLs for the respective compound. Figure 4-1 illustrates the volatile organic compound distribution at the site.

In summary, volatile organic compounds characteristic of industrial solvents are present in the bedrock aquifer, several of which exceeded current or proposed MCLs.

With the exception of acetone, which may be an artifact of laboratory contamination, no volatile compounds were detected in either the upgradient offsite bedrock or offsite overburden wells. The presence of volatile organic contamination in the ground water beneath the site indicates the fill placed on site as a potential source of these volatile constituents and that volatile contamination has migrated vertically in the bedrock aquifer from the fill material.

The occurrence of detectable volatile organic compounds in the saturated overburden and the overall greater variety of compounds during the second sampling round may be attributed to seasonal flushing of the contaminants when water levels are highest and ground-water flux volumes are greatest. Water levels were generally higher during the second sampling round in the overburden wells, ranging from 0.3 to 1.5 ft in MW-2A and MW-3A, respectively. Consequently, bedrock aquifer potentiometric levels were higher, ranging from 0.1 to 2.8 ft in MW-2 and MW-4, respectively.

TABLE 4-13 SUMMARY OF SIGNIFICANT ORGANIC DETECTION IN THE GROUND WATER (FIRST AND SECOND SAMPLING ROUNDS)

Organic Compound	Sample Numbers With Significant Detection	Range of Detected Concentration (µg/L)	Sample Number With Highest Concentration	Applicable Criteria (µg/L)
Ethylbenzene	MW-2A	3-24	MW-2A	700[1]
1,1-Dichloroethene	MW-1	12	MW-1	
1,1,2,2-Tetrachloroethane	MW-1, MW-1A, MW-4, MW-4A	1-46	MW-1	
Trichloroethene	MW-1, MW-1A, MW-4, MW-4A, WP-1	4-400	MW-4	5[2]
1,2-Dichloroethene (total)[a]	WP-1, MW-1, MW-1A, MW-2A, MW-4, MW-4A	5-110	WP-1	70/100[3]
Vinyl Chloride	WP-1, WP-3	11-96	WP-1	2[2]
1,1,2-Trichloroethane	MW-1, MW-4	5-10	MW-4	
Tetrachloroethene	MW-4	1	MW-4	5[1]

(a) 1,2-dichloroethene (total) (cis and trans). MCLG for cis = 70 µg/L; MCLG for trans = 100 µg/L.
(1) Proposed MCL
(2) Current MCL
(3) MCLG

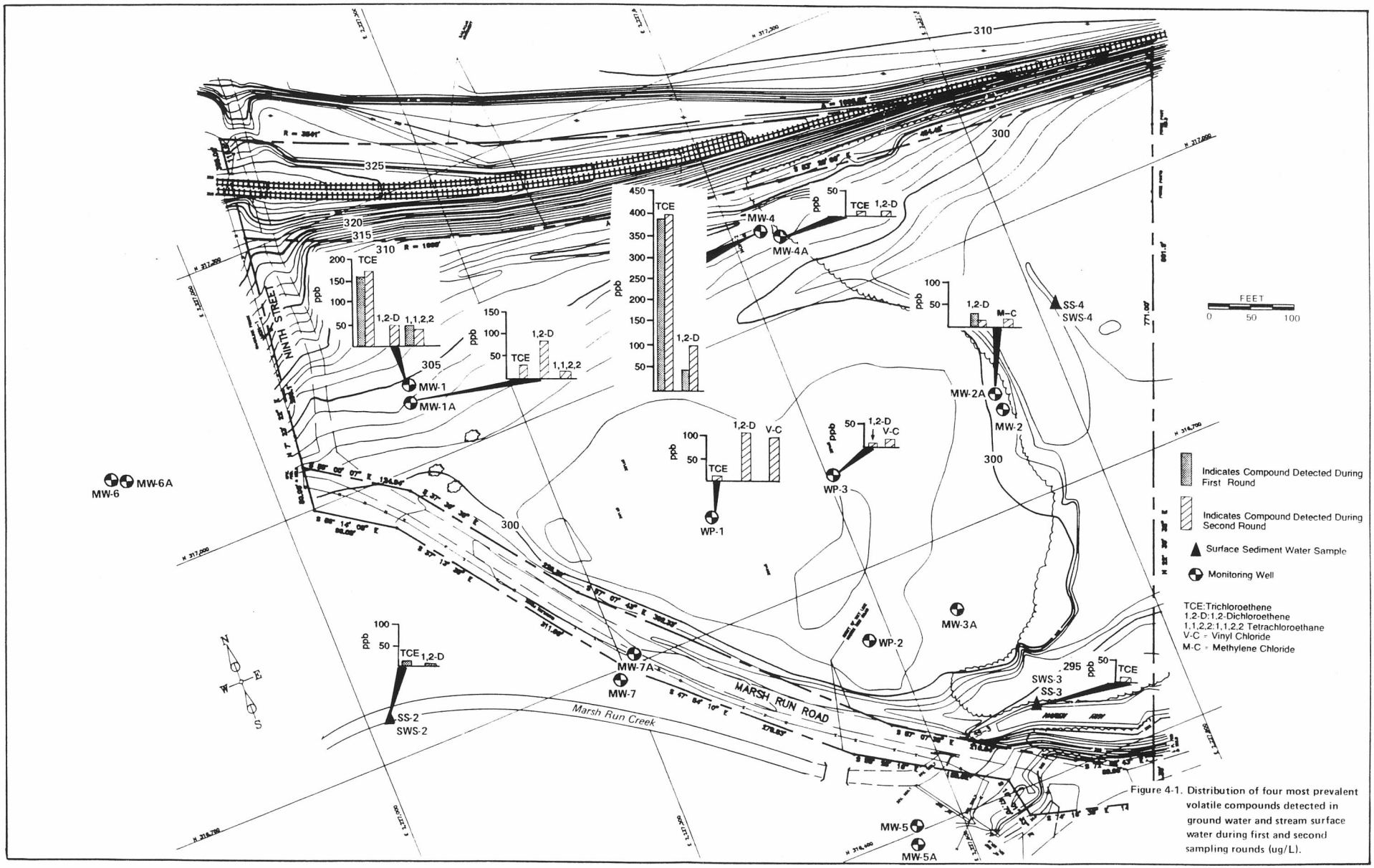


Figure 4-1. Distribution of four most prevalent volatile compounds detected in ground water and stream surface water during first and second sampling rounds (ug/L).

4.2.2 Trace Metal Concentrations in Ground Water

Ground-water samples were collected from the site monitoring wells on two occasions. The first round (8 February) sampled for total metals analysis only. In the second sampling event (16, 17 August), aliquots for both total (unfiltered) and dissolved (filtered) trace metals were collected. Table 4-14 lists the total metals analysis for samples collected from each well on both sampling events. Table 4-15 lists a comparison of total and dissolved metals analysis of monitoring well samples collected during the second sampling event.

Examination of the total metal analysis shows that aluminum was elevated in shallow overburden well MW-1A during both sampling events at concentrations of 79,200/51,300 µg/L (79.2/51.3 mg/L), and in MW-4A during the first sampling event at 264,000 µg/L (264 mg/L). Aluminum was detected at 267,000 µg/L (267 mg/L) in MW-5A during the second sampling event. Concentration levels of aluminum in other monitoring wells both in the overburden and bedrock aquifer elsewhere ranged from below detection limit (i.e., <225 µg/L) to 36,700 µg/L (36.7 mg/L). No drinking water criterion is applicable to aluminum; however, a secondary MCL of 50 µg/L is proposed. Comparison of the total and dissolved levels of aluminum for each well indicates that aluminum is present as an undissolved species as would be expected for aluminum.

Arsenic was detected in the total metals analysis of MW-1A and MW-4A at concentrations of 73.7 and 127 µg/L, respectively, during the first sampling round, exceeding the current MCL of 50 µg/L. During the second round, the sample collected from MW-5A was found to contain arsenic at a level of 71.6 µg/L. Comparison of total vs. dissolved concentrations for arsenic indicated arsenic to be present primarily in an undissolved state.

Total barium was detected at 2,360 and 1,980 µg/L in MW-4A and MW-5A, respectively; these levels are elevated with respect to other wells onsite and offsite. Concentration of total barium elsewhere ranged from 47 to 838 µg/L. A comparison of total vs. dissolved barium shows barium to be slightly lower in the dissolved phase in the ground water. Dissolved barium ranged in concentration from 37 to 476 µg/L in WP-3 and MW-4A, respectively.

Total cadmium was detected in MW-4A during both sampling events at 22.4 and 33.6 µg/L, respectively, exceeding the current MCL of 10 µg/L on both occasions. The current MCL for cadmium is 10 µg/L. An MCL for cadmium of 5 µg/L is proposed. During the second sampling event, MW-5A was found to contain total cadmium at a concentration level of 31.9 µg/L, whereas during the first round cadmium was below the detection limit. Total cadmium levels of 10.1 µg/L slightly above the current MCL were detected in MW-3A during the second sampling round. Dissolved cadmium levels in all ground-water samples were below the detection limit.

Total chromium was detected at concentrations exceeding the MCL of 50 µg/L in MW-1A at 65 µg/L (second sampling event), MW-3A at 57.9 µg/L (second sampling event), MW-4A at 64.3 and 149 µg/L (first and second

TABLE 4-14 SUMMARY OF TOTAL (UNFILTERED) METALS ANALYSIS OF GROUND-WATER SAMPLES COLLECTED FROM MONITORING WELLS ON 8 FEBRUARY (PHASE I) AND 16, 17 AUGUST (PHASE II) 1989 (μg/L)

	MW-1		MW-1A		MW-2		MW-2A			MW-3A		MW-4		
Parameter	8 Feb	16 Aug	8 Feb	16 Aug	16 Aug	16 Aug Dup	8 Feb	8 Feb Dup	17 Aug	8 Feb	16 Aug	8 Feb	8 Feb Dup	16 Aug
Aluminum	1,280	376	79,200	51,300	2,580	2,560	4,070	8,440	9,190	5,440	36,700	12,300	9,000	877
Antimony	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Arsenic	5.0	U	73.7	15.1	U	U	9.2	11.8	9.5	8.4	7.6	14.9	13.3	U
Barium	542	433	619	401	257	247	195	157	188	114	342	561	604	229
Beryllium	0.99	U	3.4	2.5	U	U	U	U	U	U	2.1	0.97	0.95	U
Cadmium	U	U	4.8	U	U	U	U	U	U	U	10.1	U	U	U
Calcium	85,700	72,200	101,000	48,500	64,800	63,500	148,000	139,000	124,000	245,000	200,000	115,000	115,000	76,000
Chromium	U	U	19.4	65.3	U	U	U	U	16.8	U	57.9	17.9	U	U
Cobalt	U	U	15.1	47.3	U	U	U	22.8	43.5	U	U	13.4	16.3	U
Copper	U	U	16.9	59.8	U	U	U	U	U	U	48.5	26.3	32.3	U
Iron	1,090	183	123,000	71,200	2,050	1,850	15,800	19,100	24,100	9,180	52,400	18,000	12,600	145
Lead	2.4	U	13.6	25.8	0.60	U	5.6	9.7	6.0	11.9	37.0	15.0	14.6	U
Magnesium	14,300	12,800	28,000	17,800	16,500	16,400	56,500	54,600	47,200	48,000	42,200	29,500	28,000	18,800
Manganese	99	27.4	4,750	3,500	45.1	42.0	4,440	4,410	5,460	434	1,310	1,310	1,220	19.3
Mercury	0.47	U	0.53	U	U	U	0.47	0.47	U	0.53	U	0.47	0.60	U
Nickel	U	U	120	71.0	U	U	21.3	34.2	31.9	U	57.5	U	U	U
Potassium	2,540	1,720	10,300	9,700	1,550	1,500	2,830	3,640	4,510	8,570	12,400	5,040	4,180	1,530
Selenium	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Silver	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Sodium	8,860	8,150	6,930	11,800	8,410	8,070	18,900	17,500	20,400	16,300	11,900	11,600	12,200	10,400
Thallium	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Vanadium	U	U	124	83.2	U	U	U	U	21.9	U	72.5	U	U	U
Zinc	173	10.1	377	221	20.7	15.6	16.3	148	54.2	170	269	187	171	15.7
Boron	57.2	37.1	U	94.0	U	U	72.2	64.6	108	609	390	45.9	68	U
Molybdenum	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Silicon	13,900	13,000	10,900	76,000	16,400	15,600	23,600	32,000	30,400	20,700	80,300	37,000	30,000	13,200

S = Compound detected in sample at <5 times the concentration detected in associated trip or rinsate blank.
U = Below detection limit.

TABLE 4-14 EXTENDED

Parameter	MW-4A		MW-5		MW-5A		MW-6		MW-6A	MW-7	MW-7A	WP-1	WP-3	Rinsate Blank	
	8 Feb	16 Aug	8 Feb	16 Aug	8 Aug	16 Aug	16 Aug	16 Aug Dup	16 Aug	16 Aug	16 Aug	17 Aug	16 Aug	8 Feb	16 Aug
Aluminum	264,000	114,000	29,300	2,200	7,500	267,000	364	U	5,950	2,250	5,220	U	U	U	U
Antimony	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Arsenic	127	28.2	28.3	U	5.2	71.6	9.4	8.4	U	U	U	U	U	U	U
Barium	2,360	838	486	299	285	1,980	219	242	187	293	779	47.0	40.0	U	U
Beryllium	11.9	U	1.9	U	0.98	17.4	U	U	U	U	U	U	U	U	U
Cadmium	22.4	33.6	U	U	U	31.9	U	U	U	U	U	U	U	U	U
Calcium	79,000	34,800	211,000	12,300	74,600	93,900	50,500	48,100	144,000	119,000	173,000	262,000	305,000	62.0	118
Chromium	64.3	149	48.2	17.1	U	372	U	U	U	U	14.9	U	U	U	U
Cobalt	51.5	112	25.4	U	U	177	U	U	U	U	U	U	U	U	U
Copper	68.8S	125S	17.1S	U	U	199	U	U	U	U	19.1S	U	U	U	25.4
Iron	564,000	185,000	46,500	1,990	57,300	286,000	256	91	8,820	1,350	10,900	22,800	3,780	3.3	U
Lead	39.4	74.0	20.2	2.2	4.9	168	U	U	11.1	U	5.2	2.1	15.7	U	U
Magnesium	84,300	31,300	39,300	20,900	15,100	54,700	17,100	16,500	57,900	30,300	50,900	45,200	34,200	U	U
Manganese	16,000	5,600	1,820	104	8,560	11,700	17.8	16.5	1,760	148	2,120	341	684	0.40	U
Mercury	0.53	U	0.53	0.7	1.0	0.39	U	0.79	U	U	U	U	U	U	U
Nickel	41.5	163	61.7	U	U	270	U	U	U	U	23.5	U	U	U	U
Potassium	18,800	12,000	12,700	2,090	2,840	10,400	1,980	1,650	2,210	3,350	3,020	11,200	11,400	U	U
Selenium	U	U	U	1.3	U	U	U	1.9	1.5	U	U	U	U	U	U
Silver	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Sodium	8,810	7,780	62,200	65,500	65,400	71,900	10,400	10,100	234,000	16,900	48,200	16,400	15,500	89.0	U
Thallium	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Vanadium	482	233	54.4	U	U	523	U	U	14.5	U	U	U	U	U	U
Zinc	1,160	507	225	39.2	145	1,170	16.3	U	40.5	18.2	51.0	2,840	4,050	128	23.4
Boron	33	U	U	U	U	U	179	139	55.0	U	60.5	343	709	U	U
Molybdenum	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Silicon	113,000	126,000	61,000	14,100	23,500	167,000	11,200	11,300	15,700	16,800	28,500	15,900	16,800	132	212

TABLE 4-15 SUMMARY OF TOTAL AND DISSOLVED METALS ANALYSIS OF GROUND-WATER SAMPLES COLLECTED FROM MONITORING WELLS ON 16, 17 AUGUST (PHASE II) 1989 (μg/L)

	MW-1		MW-1A		MW-2		MW-2 Dup		MW-2A		MW-3A		MW-4	
Parameter	Total	Dis-solved	Total	Dis-solved	Total	Dis-solved	Total	Dis-solved	Total	Dis-solved	Total	Dis-solved	Total	Dis-solved
Aluminum	376	U	51,300	U	2,580	U	2,560	U	9,190	U	36,700	503	877	U
Antimony	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Arsenic	U	U	15.1	U	U	U	U	U	9.5	U	7.6	U	U	U
Barium	433	476	401	306	257	233	247	253	188	109	342	80.0	229	228
Beryllium	U	U	2.5	U	U	U	U	U	U	U	2.1	U	U	U
Cadmium	U	U	U	U	U	U	U	U	U	U	10.1	U	U	U
Calcium	72,200	54,400	48,500	50,800	64,800	45,000	63,500	40,700	124,000	129,000	200,000	186,000	76,000	70,200
Chromium	U	U	65.3	U	U	U	U	U	16.8	U	57.9	U	U	U
Cobalt	U	U	47.3	U	U	U	U	U	43.5	U	U	U	U	U
Copper	U	U	59.8S	U	14.8U	15.2S	U	U	U	U	48.5S	U	U	U
Iron	183	U	71,200	48.0	2,050	376	1,850	21.0	24,100	2,220	52,400	1,020	145	U
Lead	0.5U	1.0S	25.8	33.4	0.60	1.6S	U	1.0S	6.0	1.2S	37.0	1.8S	0.5U	1.0S
Magnesium	12,800	12,300	17,800	7,660	16,500	15,600	16,400	16,000	47,200	45,000	42,200	36,700	18,800	16,600
Manganese	27.4	U	3,500	U	45.1	10.7	42.0	U	5,460	5,350	1,310	58.5	19.3	U
Mercury	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Nickel	U	U	71.0	20.5	U	20.5	U	U	31.9	22.4	57.5	U	18.4U	25.4
Potassium	1,720	1,380	9,700	2,760	1,550	1,170	1,500	897	4,510	2,230	12,400	8,320	1,530	1,170
Selenium	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Silver	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Sodium	8,150	7,820	11,800	10,400	8,410	9,020	8,070	7,840	20,400	18,900	11,900	10,600	10,400	8,860
Thallium	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Vanadium	U	U	83.2	U	U	U	U	U	21.9	U	72.5	U	U	U
Zinc	10.1	12.6	221	122	20.7	18.0	15.6	15.0	54.2	15.0	269	34.3	15.7	20.6
Boron	37.1	89.7	94.0	232	U	50.4	29.9U	63.2	108	231	390	U	U	108
Molybdenum	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Silicon	13,000	12,100	76,000	6,810	16,400	11,500	15,600	11,600	30,400	15,400	80,300	19,100	13,200	11,200

S = Compound detected in sample at <5 times the concentration detected in associated trip or rinsate blank.
U = Below detection limit.
Note: In some instances it is apparent that several dissolved metal concentrations are reported as being higher than the total phase. The discrepancy of the reported data can be due to the following conditions:
(1) Dissolved value reported is only slightly elevated with repsect to the Certified Quantification Limit (CQL) of the total metal. In this case the CQL is reported next to the U in the total metals column.
(2) Variability of the total vs. dissolved less than 5 times the CQL (i.e., within normal analytical variances).
(3) Slight difference in the sample split (total and dissolved) even under the most careful sampling conditions.
(4) Potential filter break through, however aluminum is a good indicator. Dissolved aluminum is not a common occurrence.

TABLE 4-15 EXTENDED

Parameter	MW-4A Total	MW-4A Dis-solved	MW-5 Total	MW-5 Dis-solved	MW-5A Total	MW-5A Dis-solved	MW-6 Total	MW-6 Dis-solved	MW-6 Dup Total	MW-6 Dup Dis-solved	MW-6A Total	MW-6A Dis-solved	MW-7 Total	MW-7 Dis-solved
Aluminum	114,000	U	2,200	U	267,000	U	364	U	U	U	5,950	U	2,250	U
Antimony	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Arsenic	28.2	U	U	U	71.6	U	9.4	6.1	8.4	7.3	U	U	U	U
Barium	838	45.0	299	310	1,980	171	219	257	242	252	187	148	293	281
Beryllium	U	U	U	U	17.4	U	U	U	U	U	U	U	U	U
Cadmium	33.6	U	U	U	31.9	U	U	U	U	U	U	U	U	U
Calcium	34,800	19,000	12,300	117,000	93,900	48,300	50,500	45,900	48,100	47,400	144,000	141,000	119,000	111,000
Chromium	149	U	17.1	U	372	U	U	U	U	U	U	U	U	U
Cobalt	112	U	U	U	177	U	U	U	U	U	U	U	U	U
Copper	125S	U	14.8U	17.3S	199	16.4	U	U	U	U	U	U	U	U
Iron	185,000	46.0	1,990	17.0	286,000	19,600	256	25.0	91.0	42.0	8,820	U	1,350	U
Lead	74.0	2.3S	2.2	2.2S	168	1.2S	U	1.3S	0.5U	16.6	11.1	1.6S	U	1.1S
Magnesium	31,300	10,200	20,900	19,900	54,700	8,860	17,100	14,800	16,500	15,300	57,900	53,500	30,300	28,300
Manganese	5,600	21.1	104	83.6	11,700	6,230	17.8	20.3	16.5	18.7	1,760	1,900	148	U
Mercury	U	U	0.7	U	0.39	U	U	U	0.79	U	U	U	0	U
Nickel	163	31.2	U	U	270	U	U	27.3	U	U	U	23.4	0	U
Potassium	12,000	828	2,090	2,850	10,400	2,460	1,980	1,760	1,650	U	2,210	8,390	3,350	2,310
Selenium	U	U	1.3	U	U	U	U	U	1.9	U	1.5	U	U	U
Silver	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Sodium	7,800	6,660	65,500	67,600	71,900	62,900	10,400	9,700	10,100	9,290	234,000	231,000	16,900	16,600
Thallium	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Vanadium	233	U	U	U	523	U	U	U	13.2U	14.3	14.5	U	U	U
Zinc	507	24.9	39.2	40.5	1,170	25.8	16.3	31.6	7.5U	20.8	40.5	28.5	18.2	17.3
Boron	29.9U	99.0	29.9U	57.4	29.9U	86.3	179	191	139	231	55.0	122	29.9U	66.6
Molybdenum	U	U	U	U	U	U	U	19.6	U	20.9	U	U	19.4U	19.6
Silicon	126,000	12,700	14,100	11,200	167,000	9,590	11,200	11,100	11,300	10,400	15,700	7,570	16,800	14,200

TABLE 4-15 EXTENDED (Cont.)

Parameter	MW-7A Total	MW-7A Dis-solved	WP-1 Total	WP-1 Dis-solved	WP-3 Total	WP-3 Dis-solved	Rinsate Blank Total	Rinsate Blank Dis-solved
Aluminum	5,220	U	U	U	U	U	U	U
Antimony	U	U	U	U	U	U	U	U
Arsenic	U	U	U	U	U	U	U	U
Barium	779	668	47.0	50.0	40.0	37.0	U	U
Beryllium	U	U	U	U	U	U	U	U
Cadmium	U	U	U	U	U	U	U	U
Calcium	173,000	177,000	262,000	257,000	305,000	244,000	118	719
Chromium	14.9	U	U	U	U	U	U	U
Cobalt	U	U	U	U	U	U	U	U
Copper	19.1S	U	U	U	U	U	25.4	U
Iron	10,900	60.0	22,800	20,800	3,780	3,540	U	U
Lead	5.2	1.1S	2.1	0.60S	15.7	2.4S	U	1.1
Magnesium	50,900	47,000	45,200	46,700	34,200	34,600	U	112
Manganese	2,120	1,840	341	367	684	684	U	U
Mercury	U	U	U	U	U	U	U	U
Nickel	23.5	20.5	U	U	18.4U	24.4	U	U
Potassium	3,020	1,510	11,200	11,100	11,400	10,600	U	U
Selenium	U	U	U	U	U	U	U	U
Silver	U	U	U	U	U	U	U	U
Sodium	48,200	46,200	16,400	15,300	15,500	15,000	U	256
Thallium	U	U	U	U	U	U	U	U
Vanadium	U	U	U	U	U	U	U	U
Zinc	51.0	27.8	2,840	2,540	4,050	2,960	23.4	19.3
Boron	60.5	135	343	998	709	748	U	U
Molybdenum	U	U	U	28.9	U	U	U	U
Silicon	28,500	14,400	15,900	1,520	16,800	16,100	212	U

sampling events), and MW-5A at 372 µg/L (second sampling event). Dissolved chromium was below the detectable limit in all cases. An increase of the MCL for chromium from 50 to 100 µg/L is proposed.

Although MCL criteria does not apply to iron, MW-1A, MW-4A, and MW-5A samples were found to contain elevated levels of total iron with respect to surrounding wells, with the highest concentrations during any sampling event of 123,000 (123), 564,000 (564), and 286,000 (286) µg/L (mg/L), respectively. Comparison of total and dissolved iron clearly illustrates that iron is primarily in the undissolved species except in MW-5A, which was found to have a concentration of dissolved iron at 19,000 µg/L (19 mg/L). Dissolved iron was also elevated in WP-1 with a concentration of 20,800 µg/L (20.8 mg/L). Pennsylvania Department of Environmental Resources (PaDER) drinking water standards specify that water supplies not exceed 1,500 µg/L total iron and 300 µg/L dissolved.

Total lead was detected in MW-1A, MW-3A, MW-4, and MW-4A during both sampling events at 13.6/25.8, 11.9/37.0, and 15.0/14.6 µg/L, respectively. Total lead was also detected in MW-5, MW-5A, MW-6A, and WP-3 at 20.2, 16.8, 11.1, and 15.7 µg/L, respectively, during the first sampling event for MW-5 and the second event for the other wells. All of the above-reported lead levels, although not above the current lead MCL of 50 µg/L, are above the proposed lead MCL of 5 µg/L. Dissolved lead was below the proposed MCL of 5 µg/L in all monitoring well samples except MW-1A (33.4 µg/L).

Total mercury, although not detected above the MCL of 2 µg/L, was detected in monitoring wells in concentrations ranging from below the detection limit to 1 µg/L.

Total manganese was detected in both onsite and offsite wells at elevated concentrations. MW-1A ground-water samples collected during the first and second sampling rounds were found to contain 4,750 and 3,500 µg/L, respectively. In MW-2A levels exceeded 4,000 µg/L during both sampling events, and levels in MW-4A during the first and second sampling events were measured at 16,000 and 5,600 µg/L, respectively. Other samples collected from both onsite and offsite shallow wells were found to contain total manganese concentrations between 341 and 11,700 µg/L. Dissolved manganese was detected at elevated levels in MW-2A (5,350 µg/L), MW-5A (6,230 µg/L), and MW-6A (1,900 µg/L). PaDER drinking water quality standards specify that drinking water supplies not exceed manganese concentrations of 1,000 µg/L.

In summary, the trace metal distribution patterns of constituents indicate two distinct patterns. The first is the occurrence of trace metals at elevated levels which are primarily restricted to the shallow saturated overburden zone. These trace metals are arsenic, cadmium, and chromium. These trace metals are found both within the site confines and west of the site in monitoring wells that are hydraulically separated from the site by Marsh Run Creek or that are hydraulically upgradient of the site. These constituents were found to be primarily in an undissolved state in the ground water.

A second pattern consists of total lead and manganese which were detected at elevated levels in samples collected from shallow and bedrock wells both onsite and offsite. This is indicative of vertical movement of lead and manganese into the bedrock aquifer. Other metals such as iron and barium, which do not have MCLs but are regulated by state water quality criteria or have proposed MCLs, appear to be elevated when compared to mean values reported for the bedrock aquifer in the area (see Table 1-2). In general, total metal concentrations are higher in the shallow overburden zone; however, dissolved metal concentrations are similar in both the bedrock aquifer and the shallow zone.

Elevated trace metal concentrations in the saturated overburden with respect to the bedrock may be partly due to a higher percentage of particulate matter in the shallow ground water. Contamination of the ground water by the trace metals arsenic, barium, cadmium, lead, iron, and chromium appears to be associated with the fill onsite; however, during the second sampling round offsite and upgradient, well MW-5A was found to have relatively high levels of arsenic, cadmium, chromium, lead, nickel, and manganese, which is indicative of an offsite source of contamination. Although total metals analysis has been discussed with respect to MCLs (MCLs do not apply specifically to dissolved only), it should be emphasized that with respect to trace metal mobility in ground water the dissolved species data are more appropriate. Much of the total metal analyte results are related to suspended solids in the sample. The contributing offsite source of trace metals is not known. Possible candidates are the filled-in areas west of the site where previous contamination has been documented by other environmental investigations or the fill placed on the depot property for road construction. MW-5A has also been previously identified during this RI as an area of soil PAH contamination, but no discernible anomalous trace metal concentrations in the soil samples collected from MW-5A were evident.

Table 4-16 summarizes significant concentrations of trace metals in the ground water. Figure 4-2 illustrates the occurrence and distribution of trace metals across the site.

4.2.3 Pesticide and PCB Concentration in the Ground Water

No pesticides or PCBs were detected in the bedrock aquifer or saturated overburden onsite or offsite.

4.2.4 Other Ground-Water Quality Parameter Concentration in the Ground Water

Table 4-17 summarizes the ground-water quality parameters of ground-water samples collected during the first and second sampling rounds.

Chloride was elevated in monitoring wells near the NCAD perimeter road, including MW-5A, MW-5, MW-6A, and MW-7, and in MW-7A, adjacent to the NCAD access road. The chloride level is probably due to the deicing salts used on these roadways. Chloride concentrations in MW-7A and MW-6A were detected above the EPA ambient drinking water quality criteria of 250 mg/L at 400 and 610 mg/L, respectively.

TABLE 4-16 SIGNIFICANT CONCENTRATION OF TRACE METALS IN GROUND-WATER SAMPLES

Parameter	Sample Number With[a] Significant Concentration Levels	Range of Detected Concentrations (µg/L)	Sample Number With Highest Concentration	Pennsylvania Drinking Water Criterion or MCL Criteria (µg/L)
Arsenic	MW-1A, MW-4A, MW-5A	ND-127	MW-4A	30[2]
Barium	MW-4A, MW-5A	40-2,360	MW-4A	4,700[2]
Cadmium	MW-3A, MW-4A, MW-5A	ND-33.6	MW-4A	5[2]
Chromium	MW-1A, MW-3A, MW-4A, MW-5A	ND-372	MW-5A	100[2]
Iron	MW-1A, MW-2, MW-2(a), MW-2A, MW-2A(a), MW-3A, MW-3A(a), MW-4, MW-4A, MW-5, MW-5A, MW-5A(a), MW-6A, MW-7A, WP-1, WP-1(a), WP-3, WP-3(a)	91-564,000 ND-20,800	 MW-4A, WP-1[a]	1,500[3] 300[4]
Lead	MW-1A, MW-1A(a), MW-3A, MW-4, MW-4A, MW-5 MW-5A, MW-5A, MW-6 (Dup)(a), MW-7A	ND-168 ND-16.6[a]	MW-5A MW-6 (Dup)[a]	50[1] 5[2]
Manganese	MW-1A, MW-2A, MW-3A, MW-4, MW-4A, MW-5, MW-5A, MW-6A, MW-7A	27.4-16,000	MW-4A	1,000[5]
Nickel	MW-1A, MW-2A, MW-3A, MW-4A, MW-5, MW-5A, MW-6	ND-270	MW-5A	
Zinc	WP-1, WP-3	ND-4,050	WP-3	

(a) Denotes dissolved trace metal analysis
ND Below detection limit
(1) Current MCL
(2) Proposed MCL
(3) Pennsylvania drinking water standard for total iron
(4) Pennsylvania drinking water standard for dissolved iron
(5) Pennsylvania drinking water standard

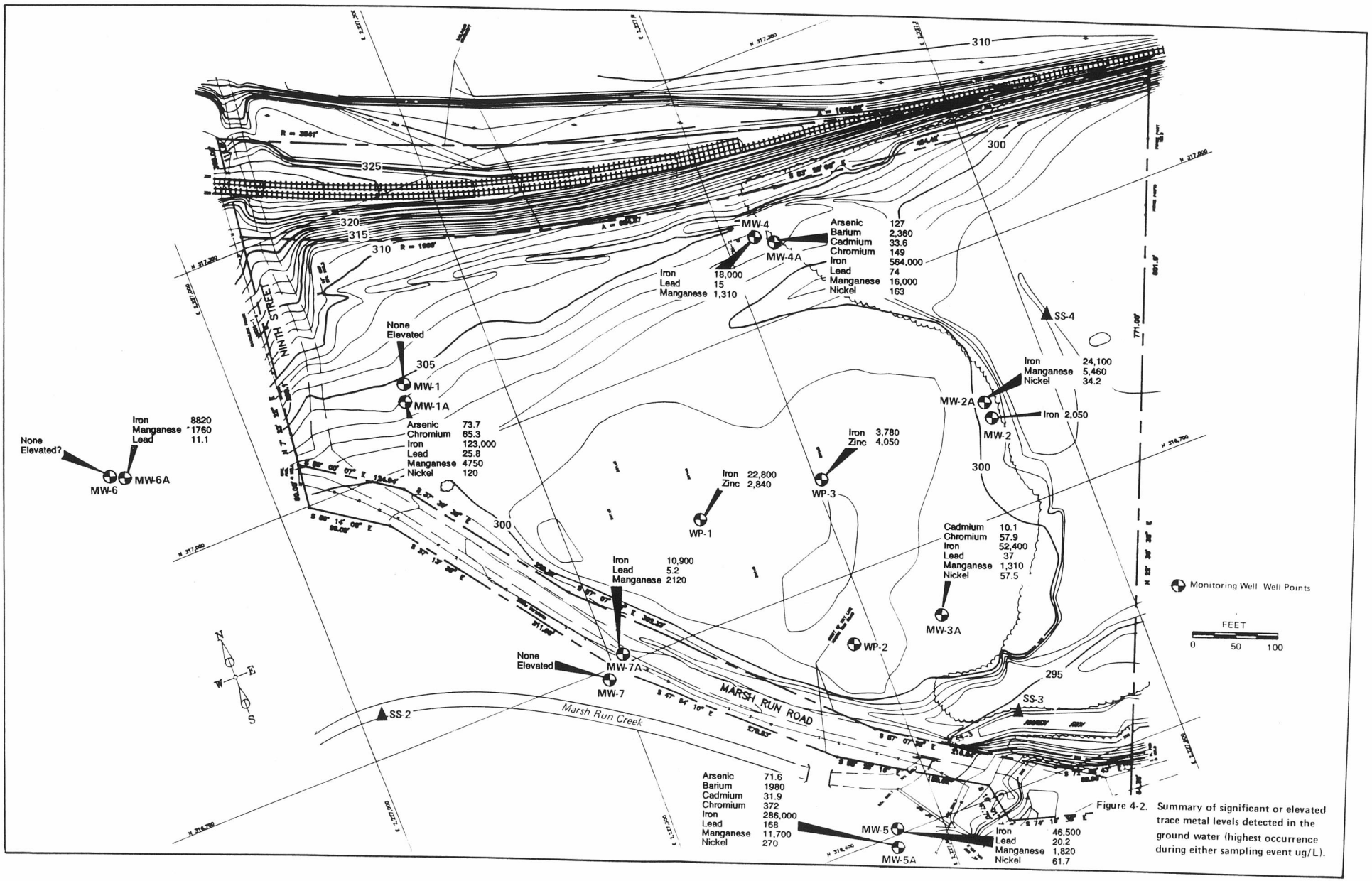


Figure 4-2. Summary of significant or elevated trace metal levels detected in the ground water (highest occurrence during either sampling event ug/L).

TABLE 4-17 SUMMARY OF WET CHEMISTRY ANALYSIS OF GROUND-WATER SAMPLES COLLECTED FROM MONITORING WELLS ON 8 FEBRUARY (PHASE I) AND 16, 17 AUGUST (PHASE II) 1989 (mg/L)

Parameter	CQL[a] (mg/L)	MW-1		MW-1A		MW-2		MW-2A			MW-3A		MW-4			MW-4A	
		8 Feb	16 Aug	8 Feb	16 Aug	16 Aug	16 Aug Dup	8 Feb	8 Feb Dup	16 Aug	8 Feb	17 Aug	8 Feb	8 Feb Dup	16 Aug	8 Feb	16 Aug
Alkalinity		140	210	110	204	157	147	380	390	171	420	46.9	230	210	222	60	167
Chloride	0.5	39	41	4.3	11.9	22.2	22.2	18.5	15.7	13.7	19.5	7.8	44.4	42.4	27.8	6.3	6.4
Cyanide, Total	0.01	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Fluoride	0.1	0.1	U	U	U	U	U	0.4	0.4	0.3	0.2	0.2	U	U	U	U	U
TPH	0.1	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Nitrogen	0.01	0.44	0.38	6.6	0.76	1.6	1.4	0.10	0.12	0.16	1.6	0.03	1.1	1.1	1.2	0.84	0.91
Phosphorous	0.01	0.04	0.1	0.73	1.1	0.2	0.1	0.35	0.65	0.8	0.22	0.5	0.28	0.26	0.2	0.52	0.7
Residue, Total	5	320	291	290	1,400	324	315	58	630	664	22	803	450	370	390	350	108
Sulfate	1	34.1	25.9	82.6	76.3	45.0	42.8	136	126	145	214	157	49.5	49.3	39.9	54.9	52.2

(a) Certified Quantification Limit
U = Compound not detected

TABLE 4-17 EXTENDED

Parameter	MW-5		MW-5A		MW-6		MW-6A	MW-7	MW-7A	WP-1	WP-3	Rinsate Blank	
	8 Feb	16 Aug	8 Feb	16 Aug	16 Aug	16 Aug Dup	16 Aug	16 Aug	16 Aug	16 Aug	16 Aug	8 Feb	16 Aug
Alkalinity	180	186	200	169	159	159	204	171	231	180	210	U	U
Chloride	164	240	128	128	28.5	28.5	610	185	400	19.4	16.1	U	182
Cyanide, Total	U	U	U	U	U	U	U	U	U	U	U	U	U
Fluoride	0.1	U	0.1	U	U	U	U	U	0.2	0.3	U	U	U
TPH	U	U	U	1.2	U	U	U	U	U	U	U	U	U
Nitrogen	2.2	2.7	U	0.01	2.6	2.8	2.0	1.3	0.19	U	0.04	U	0.01
Phosphorous	0.70	0.1	0.15	0.2	0.1	0.2	0.1	0.1	0.2	0.1	0.1	U	U
Residue, Total	700	850	400	440	260	560	1,430	710	1,020	1,100	1,200	U	U
Sulfate	43.4	38.5	4.9	7.5	13.0	13.1	106	37.8	25.2	340	460	U	U

Sulfide was detected in well points WP-1 and WP-3 at 340 and 360 mg/L, respectively, both of which exceed the Pennsylvania ambient drinking water standard of 250 mg/L.

4.3 NATURE AND EXTENT OF CONTAMINATION IN THE MARSH RUN SURFACE WATER AND SEDIMENT SAMPLES

4.3.1 Volatile Organic Compounds in Stream Surface Water and Sediment Samples

Table 4-18 summarizes the organic analysis data in the Marsh Run surface water and sediments.

All volatile organics were below the detection limit in the stream sediment samples collected in Marsh Run Creek and in the adjacent swamp east of the site. TCE was detected in surface water samples SWS-2 and SWS-3 at low concentration levels (near instrument detection limit) of 7 and 6 µg/L, respectively. A duplicate sample of SWS-2 was also found to contain 7 µg/L of trichloroethene. Federal ambient water quality criteria for carcinogenicity protection is 2.7 µg/L and 80 µg/L for ingesting water and organisms and for ingesting organisms only. Volatile compound 1,2-dichloroethene (total) (cis and trans) was detected in the SWS-2 duplicate at 2 µg/L. There is no ambient water quality criteria for protection of human health for this compound.

Further upstream, surface water sample SWS-5 was collected for purposes of assessing whether or not upstream sites were contributing to the low levels of TCE detected in the stream. A low level (4 µg/L) of TCE was detected in the upstream surface water sample. Low concentrations of the volatile compounds 1,2-dichloroethene (1 µg/L) and 1,1,2,2-tetrachloroethane (2 µg/L) were also detected in SWS-5. The ambient water quality criteria for carcinogenicity protection in humans for 1,1,2,2-tetrachloroethene is 0.17 µg/L for ingesting of water and organisms and 10.7 µg/L for ingesting organisms only. However, VOCs detected in SWS-5 are not attributable to Marsh Run Field. Background surface water sample SWS-1 was found to contain no detectable organic compounds. Acetone was detected at 83 and 67 µg/L in SWS-5 and SWS-5 duplicate, respectively; however, the associated trip blank was found to contain acetone at a concentration of 77 µg/L. Based on the normalization criteria, acetone was discounted as laboratory/field sampling artifact contamination.

Based on the distribution of low-level concentrations of volatile organic compounds in the surface water, an upgradient source with respect to the site is suspected to be contributing low levels of volatiles to the stream water. Marsh Run Field may also be contributing to the low-level volatiles in the surface water via ground-water base flow to the stream. Due to the low concentration levels encountered, it is difficult to determine the proportion of onsite to offsite contribution of volatiles to the surface water. The persistence of low levels in moving surface water, which would promote relatively rapid volatilization of the compounds away from the immediate source, suggests that a source(s) is both

TABLE 4-18 SUMMARY OF ORGANIC COMPOUND ANALYSIS OF STREAM SURFACE WATER (μg/L) AND SEDIMENT (μg/kg) SAMPLES

	Stream Sediments								CQL[b]	Trip Blank		Rinsate Blank		Stream Water Sample		
	SS-1	SS-1 Dup	SS-2	SS-3	SS-4	SS-4 Dup	SS-5	SS-5 Dup	(μg/L)	18 Jan #3	18 Jan #4	18 Jan #3	18 Jan #4	SWS-1	SWS-1 Dup	SWS-2
VOLATILES																
Trichloroethene									5							7
Acetone			[none detected]						10							
1,2-Dichloroethene, total									5							
1,1,2,2-Tetrachloroethane									5							
SEMIVOLATILES																
Benzo(g,h,i)Perylene							280J	450J	10							
Benzo(a)Pyrene							480J	900J	10							
Benzo(k)Fluoranthene							370J	850J	10							
Benzo(b)Fluoranthene							310J	790J	10							
Fluorene								290J	10							
Anthracene								490J	10							
Benzoic Acid									50							
2-Methylnaphthalene							150J		10							
Diethylphthalate							150J		10							
Phenanthrene							570J	2,100	10							
Di-n-Butyl phthalate							270J	200J	10							
Fluoranthene							780J	2,600	10							
Pyrene							860J	2,000	10							
Benzo(a)Anthracene							430J	1,100J	10							
bis(2-ethylhexyl)phthalate							160J	180J	10							
Chrysene							590J	1,300J	10							
Indeno(1,2,3-cd)Pyrene							230J	480J	10							
Tentatively Identified Compounds or Unknowns[(a)]	[1]	[1]	[1]	[3]	[7]	[3]	[7]	[8]				[4]	[5]	[3]	[4]	[5]
4-bromo-2-penene				513J												
Acetic acid														17J		
3 Penten-2-one														7J	8J	7JB
Hexadecanoic acid							3,500JB	2,500JB							20J	
1-2 Propanediol							1,900JB	3,500JB								
Ethanol,2-(2-methoxyethoxy)							740J									
1-Hexadecanol,2-methyl							1,000J									
Hexanedioic acid, dioctyl ester							670J									
2-ethylhexanoic acid								1,100JB								
PESTICIDES																
4,4'-DDE					620	540										
4,4'-DDD					120	100										
4,4'-DDT					300	190										
PCB																
[none detected]																

(a) Total number of unkown compounds detected in the peak library search.
(b) Certified Quantification Limit (for aqueous samples), specified for aqueous samples only. Soil CQL may vary with percent moisture and dilution factor.
B = Compound detected in method blank.
J = Estimated value.
S = Compound detected in sample at <5 times the concentration detected in associated trip or rinsate blank.

TABLE 4-18 EXTENDED

	Stream Water Sample				Trip Blank		Rinsate Blank	
	SWS-2 Dup	SWS-3	SWS-4	SWS-5	SWS-5 Dup	19 Jan #5	16 Aug	19 Jan #5
VOLATILES								
Trichloroethene	7	6		4J	4J			
Acetone				83S	67S		77	
1,2-Dichloroethene, total	2				1J			
1,1,2,2,-Tetrachloroethane				2J	2J			
SEMIVOLATILES								
Benzo(g,h,i)Perylene								
Benzo(a)Pyrene								
Benzo(k)Fluoranthene								
Benzo(b)Fluoranthene								
Fluorene								
Anthracene					2J			
Benzoic Acid								
2-Methylnaphthalene								
Diethylphthalate								
Phenanthrene								
Di-n-Butyl phthalate								
Fluoranthene					3J			
Pyrene					2J			
Benzo(a)Anthracene								
bis(2-ethylhexyl)phthalate								
Chrysene								
Indeno(1,2,3-cd)Pyrene								
Tentatively Identified Compounds or Unknowns[(a)]	[6]	[3]	[4]		[2]	[7]		[7]
Acetic acid	22J	23J						
3 Penten-2-one	8J	300JB	7J					
Hexadecanoic acid	20J							
Cyclotrisiloxane					22JB			
2-Furancuboxaldehyde					10J			
Clyclopetasiloxane					9JB			
15-tetracosenoic acid					58J			
Hexadecanoic					40J			
PESTICIDES								
4,4'-DDE					0.16			
4,4'-DDD				0.24	0.51			
4,4'-DDT								
PCB								
[none detected]								

near surface water sampling points SWS-5 (offsite) and SWS-2 and SWS-3 (onsite).

4.3.2 Semivolatile Compounds in the Stream Surface Water and Sediments

Table 4-18 summarizes the semivolatile compounds detected in the stream sediments. Low-level semivolatiles were detected in stream sediment samples SS-5 and SS-5 (Dup). The majority of semivolatile compounds were PAH compounds, all of which were detected at concentrations below the contract reporting limit but above the instrument detection limit, with the exception of fluoranthene, phenanthrene, and pyrene which were detected at 2,600, 2,100, and 2,000 µg/kg, respectively.

Low levels of anthracene, fluoranthene, and pyrene were detected in surface water sample SWS-5 (Dup) at 2 µg/L each. Stations SS-5 and SWS-5 are located upstream of Marsh Run Field. Consequently, low-level contamination encountered in sediment and surface water is not attributable to Marsh Run Field.

In summary, low-level concentrations of semivolatile compounds were detected in the sediment and surface water at stream sampling points SWS-5 (surface water) and SS-5 (sediment). This sampling station is upstream of Marsh Run Field. Surface water concentrations are diluted further downstream. The sediments at stream sediment location SS-5 suggest sediment loading or seepage from adjacent landfilled marsh area Site 4 on NCAD (see Section 1.2.2). Sampling stations SS-5 and SWS-5 are also located adjacent to a heavy equipment storage area which may account for oil/asphalt-related compounds. The semivolatile compounds detected are not readily soluble in water.

4.3.3 Pesticides and PCBs in Stream Surface Water and Sediments

Table 4-18 summarizes the pesticide/PCB analysis data.

The pesticide 4,4'-DDT and its metabolites 4,4'-DDE and 4,4'-DDD were detected in stream sediment sample SS-5 at 620, 120, and 300 µg/kg, respectively. A duplicate analysis of SS-5 revealed the same compounds at 540, 100, and 190 µg/kg, respectively.

Low-level pesticides are present at the SWS-5 surface water and SS-4 sediment locations. These pesticides are not related to fill placed at Marsh Run Field, but rather, in the case of SS-4, an artifact of pesticide spraying in the area, and in the case of SWS-5, most likely from pesticides in leachate seeps from offsite sources which have been previously documented during other environmental investigations.

4.3.4 Trace Metal Concentrations in Stream Sediment and Surface Water

Stream sediment and surface water samples collected in Marsh Run Creek were compared to background sample SS-1 (sediment) and SWS-2 (surface water). Table 4-19 summarizes the trace metals analysis data.

TABLE 4-19 SUMMARY OF METALS ANALYSIS OF STREAM SURFACE WATER (TOTAL) AND SEDIMENT SAMPLES

	Stream Sediments (mg/kg)									
									Rinsate Blank	
Parameter	SS-1	SS-1 Dup	SS-2	SS-3	SS-4	SS-4 Dup	SS-5	SS-5 Dup	18 Jan #3	18 Jan #4
Aluminum	6,170	5,300	22,130	12,200	7,200	16,200	13,600	13,300	U	U
Antimony	U	U	U	U	U	U	4	U	U	U
Arsenic	11.8	9.2	36.4	13.1	32.4	23.3	7.6	9.8	U	U
Barium	51.9	51.6	175	69.9	108	94.6	64.3	59.2	U	U
Beryllium	0.32	0.22	1.1	0.49	0.66	0.49	0.59	0.44	U	U
Cadmium	U	U	U	0.62	1.5	1.8	0.63	0.44	U	U
Calcium	2,170	1,950	2,750	1,910	3,810	4,240	5,180	3,280	45.0	59.0
Chromium	9.9	8.9	24.9	12.6	18.2	19.1	20.9	15.9	U	U
Cobalt	8.5	8.9	11.1	11.7	7.6	7.5	10.3	10.0	U	U
Copper	8.9S	17.0S	14.0S	13.4S	27.2S	32.7S	16.3	15.0	16.1	U
Iron	17,500	11,900	19,800	16,100	29,800	26,900	26,700	22,000	U	U
Lead	13.2S	20.7S	19.4S	12.7S	75.8	73.2	21.5	25.8	8.9	2.4
Magnesium	1,450	1,240	2,810	3,430	2,090	2,190	2,840	2,450	U	U
Manganese	372	249	175	175	300	345	898	555	29.5	26.8
Mercury	U	U	0.16S	U	0.24S	0.16S	U	U	U	0.20
Nickel	8.2	10.6	18.6	17.2	15.9	16.4	14.5	13.1	U	U
Potassium	408	368	746	622	922	994	991	735	U	U
Selenium	U	U	0.37	U	0.84	0.53	U	0.10	U	U
Silver	U	U	U	U	U	U	U	U	U	U
Sodium	135S	148S	119S	107S	115S	151S	248	1,400	245	176
Thallium	U	U	U	U	U	U	U	U	U	U
Vanadium	26.3	17.8	42.8	22.6	33.0	34.1	25.9	20.4	U	U
Zinc	75.2S	70.5S	81.8S	60.9S	136S	157	59.4	58.8	25.2	31.9
Boron	U	U	U	U	U	U	U	U	U	U
Molybdenum	U	U	U	U	U	U	U	U	U	U
Silicon	999	824	1,430	962	1,170	1,570	32.7	128	107	96

S = Compound detected in sample at <5 times the concentration detected in associated trip or rinsate blank.
U = Below detection limit.

TABLE 4-19 EXTENDED

Parameter	Stream Water Samples (μg/L)								
	SWS-1	SWS-1 Dup	SWS-2	SWS-2 Dup	SWS-3	SWS-4	SWS-5	SWS-5 Dup	Rinsate Blank #5
Aluminum	354	134	U	U	162	1,410	12,000	4,990	U
Antimony	U	U	U	U	U	U	U	U	U
Arsenic	U	2.3	U	U	3.7	U	U	U	U
Barium	43.8	36.0	57.6	62.0	61.3	10.2	215	139	U
Beryllium	U	U	U	U	U	U	U	U	U
Cadmium	U	U	U	U	U	U	U	U	U
Calcium	43,900	41,800	75,400	73,700	75,600	51,000	67,300	59,700	90.0
Chromium	U	U	U	U	U	U	23.2	U	U
Cobalt	U	U	U	U	U	U	U	U	U
Copper	14.7S	14.5	15.5S	14.2S	13.9S	10.9S	23.7	U	15.2
Iron	345	143	655	640	900	1,610	22,800	9,470	U
Lead	5.2S	2.6S	U	U	4.4S	5.6S	53.5	23.4	1.8
Magnesium	8,510	8,520	10,900	10,700	11,100	7,600	12,100	10,600	U
Manganese	67.0S	43.6S	204	211	225	180	1,040	680	23.1
Mercury	U	1.1	2.1	U	U	0.51	U	U	U
Nickel	U	U	U	U	U	U	U	U	U
Potassium	4,710	4,720	2,390	2,430	2,480	3,120	2,680	2,230	U
Selenium	U	U	U	U	U	U	U	U	U
Silver	U	U	U	U	U	U	U	U	U
Sodium	14,600	14,200	54,700	54,400	54,500	34,400	35,400	34,400	279
Thallium	U	U	U	U	U	U	U	U	U
Vanadium	U	U	U	U	U	U	27.2	U	U
Zinc	33.7S	33.3S	31.8	36.2S	42.1S	51.0S	170	77.2	34.1
Boron	U	U	71.0	82.0	U	U	161	184	U
Molybdenum	U	U	U	U	U	U	U	U	U
Silicon	9,670	9,510	4,940	5,070	5,570	4,730	17,700	10,100	520

Arsenic was detected in sediment samples SS-2 (adjacent to the site) and SS-4 (in swamp area) at 36.4 and 32.4 mg/kg. These concentrations were approximately 3 times the background (9.2-11.8 mg/kg) concentration detected in SS-1. Remaining sediment arsenic concentrations were consistent with background levels.

Barium was detected at elevated levels in sediment samples SS-2 and SS-4 at 175 and 108 mg/kg, respectively, which is approximately 2 to 3 times background levels of 51.9 mg/kg.

Chromium was detected in SS-2 and SS-4 at elevated levels of 24.9 and 18.2 mg/kg, respectively, compared to background levels of 8.9-9.9 mg/kg.

Lead was detected at slightly elevated levels in SS-4 and SS-4 (Dup) at 75.8 to 73.2 mg/kg, respectively. All other trace metals analyses indicate trace metal concentrations to be consistent with background levels.

Low-level mercury was detected in samples SS-2, SS-4, and SS-4 (Dup). Background sample SS-1 showed no detectable level of mercury.

The occurrence of slightly elevated levels of arsenic, barium, chromium, and lead in Marsh Run Creek at SS-2 and in the swamp at SS-4 appears to suggest some localization of elevated trace metals in the stream sediments in the vicinity of Marsh Run Field. The nature of the elevated levels, whether due to sediment load transport in the stream or surface water runoff suspended load deposited in the stream, is unclear. Due to the coverage of the site with vegetation, the latter scenario would most likely have occurred prior to final cover placement and planting of grass (circa. 1976).

Trace metal concentrations in the stream surface water and ponded swamp water showed no apparent deviation from background levels except in the following instances. Mercury was detected in upgradient surface water sample SWS-1 and in downgradient samples SWS-2 and SWS-4 at 1.1, 2.1, and 0.51 µg/L, respectively. Chromium was detected at 23.2 µg/L in SWS-5. Lead, although detected in upgradient sample SWS-1 at 5.2 µg/L, was also detected in samples SWS-5 and SWS-5 (Dup) at 53.5 and 23.4 µg/L, respectively. If should be noted that the upgradient concentration of lead and the similar concentration levels in SWS-3 and SWS-4 should be regarded with caution, as they are flagged because of low levels detected in the associated rinsate blank.

Trace metal contamination in the surface water due to Marsh Run Creek does not appear to be occurring. Concentration levels of lead and chromium are slightly elevated at SWS-5, suggesting sediment bed load transport from a nearby or upgradient source on the depot property.

4.3.5 Total Petroleum Hydrocarbons and Cyanide Concentration in Surface Water and Sediment

Table 4-20 summarizes cyanide and total petroleum hydrocarbons analysis results.

TABLE 4-20 SUMMARY OF CYANIDE AND TPH RESULTS OF SURFACE WATER AND STREAM SEDIMENT SAMPLES

Parameter	CQL[a] (mg/kg)	Sediments (mg/L)										Surface Water (mg/L)								
		SS-1				SS-4			SS-5	Rinsate		SWS-1		SWS-2				SWS-5		
		SS-1	Dup	SS-2	SS-3	SS-4	Dup	SS-5	Dup	#3	#4	SWS-1	Dup	SWS-2	Dup	SWS-3	SWS-4	SWS-5	Dup	Rinsate
Cyanide	0.1	U	U	0.14	U	0.34	0.33	0.2	0.1	U	U	U	U	U	U	U	U	U	U	U
TPH	0.1	U	U	116	U	U	U	150	100	U	U	U	U	U	U	U	U	U	U	10.0

(a) Certified Quantification Limit
U = Below detection limit

Total petroleum hydrocarbons were detected in sediment samples SS-2, SS-5, and SS-5 (Dup) at 116, 150, and 100 mg/kg. These sample locations are near roadways or, in the case of SS-5, near heavy equipment storage areas. Surface runoff from parking lots and access roads are the most likely sources of these contaminants. Elsewhere, total petroleum hydrocarbons were below detectable levels. Low levels of cyanide were detected above background in SS-2, SS-4, SS-4 (Dup), SS-5, and SS-5 (Dup) at 0.14, 0.34, 0.33, 0.2, and 0.2 mg/kg, respectively.

Total petroleum hydrocarbons and cyanide were not detected in any surface water samples collected onsite or offsite.

4.4 NATURE AND EXTENT OF CONTAMINATION IN RESIDENTIAL WELLS LOCATED OFF OF MARSH RUN ROAD

4.4.1 Volatile Organic Compounds in Private Wells

Table 4-21 summarizes the organic compound analysis of ground-water samples collected from private residence supply wells. No volatile organic compounds were detected in any private wells tested.

4.4.2 Semivolatile Compounds in Private Wells

No semivolatile compounds were detected in any wells except benzoic acid, which was detected in the supply well located at 354 Marsh Run Road at a concentration of 3 µg/L. Benzoic acid is a common, rather ubiquitous organic acid often used in food preparation as well as other domestic uses. Benzoic acid at this location is not anticipated to be related to Marsh Run Field.

4.4.3 Pesticides and PCBs in Private Wells

All pesticide and PCB compounds were below detection limits in all residences' supply wells.

4.4.4 Trace Metals in Residential Supply Wells

Table 4-22 summarizes trace metal concentrations in the residences' supply wells. All trace metal concentrations were detected at levels below state and federal drinking water criteria. No apparent site-related trace metal contamination is present in the ground-water supply wells of the residences sampled as part of this investigation.

4.4.5 Other Ground-Water Quality Parameters in Residential Supply Wells

Table 4-23 summarizes the results of general water quality parameters analysis of the residences' supply wells. No apparent ground-water quality degradation has occurred in those wells sampled as a result of Marsh Run Field or past activities at the site.

TABLE 4-21 SUMMARY OF ORGANIC COMPOUND ANALYSIS OF GROUND-WATER SAMPLES COLLECTED FROM RESIDENTIAL SUPPLY WELLS ON 31 AUGUST 1989 (µg/L)

	CQL[b] (µg/L)	354 Marsh Run Rd.	358 Marsh Run Rd.	306 Marsh Run Rd.	284 Marsh Run Rd.
VOLATILES					
[none detected]					
SEMIVOLATILES					
Benzoic Acid	10	3J			
Tentatively Identified Compounds or Unknowns[(a)]		[3]		[1]	
PESTICIDES					
[none detected]					
PCB					
[none detected]					

(a) Total number of unknown compounds detected in peak library search
(b) Certified Quantification Limit
J = Estimated value

TABLE 4-22 SUMMARY OF METALS ANALYSIS OF GROUND-WATER SAMPLES COLLECTED FROM RESIDENTIAL SUPPLY WELLS ON 31 AUGUST 1989 (µg/L)

Parameter	CQL[a] (µg/L)	354 Marsh Run Rd.	358 Marsh Run Rd.	306 Marsh Run Rd.	284 Marsh Run Rd.
Aluminum	144	218	U	U	U
Antimony	39	U	U	U	U
Arsenic	2.0	2.7	U	U	U
Barium	94.0	141	94.0	65.0	63.0
Beryllium	1.0	U	U	U	U
Boron	29.9	U	U	U	U
Cadmium	4.0	U	U	U	U
Calcium	40.0	63,400	47,200	66,600	22,300
Chromium	6.0	U	U	U	U
Cobalt	27.0	U	U	U	U
Copper	14.8	50.8	64.3	90.0	89.9
Iron	16.0	324	89.0	27.0	71.0
Lead	0.5	1.3	2.7	4.7	2.0
Magnesium		15,200	12,100	10,200	10,100
Manganese	2.0	2.5	U	U	U
Mercury	0.2	U	U	U	U
Molybdenum	19.0	U	24.7	28.4	U
Nickel	18.4	4.1	11.0	5.0	0.40
Potassium	296.0	1,540	1,310	1,550	1,340
Selenium	1.0	U	U	U	1.3
Silicon	31.8	8,960	8,940	8,990	7,000
Silver	4.0	U	U	U	U
Sodium	184.0	48,600	50,500	10,700	64,100
Thallium	126	U	U	U	U
Vanadium	30.9	U	U	U	U
Zinc	16.0	16.0	31.6	66.9	23.9

(a) Certified Quantification Limit
U = Below detection limit

TABLE 4-23 SUMMARY OF WET CHEMISTRY ANALYSIS OF GROUND-WATER SAMPLES COLLECTED FROM RESIDENTIAL SUPPLY WELLS ON 31 AUGUST 1989 (mg/L)

Parameter	CQL[a] (mg/L)	354 Marsh Run Rd.	358 Marsh Run Rd.	306 Marsh Run Rd.	284 Marsh Run Rd.
Alkalinity	1.0	81.3	68.5	161	10.7
Chloride	1.0	155	134	10.7	122
Cyanide, total	0.01	U	U	U	U
Fluoride	0.2	U	U	U	U
TPH	1.0	U	U	U	U
Nitrogen	0.01	1.9	1.8	4.5	2.2
Phosphorous	0.1	U	0.05	U	U
Residue, total	5.0	530	430	310	325
Sulfate	5.0	37.5	36.3	45.8	34.2

(a) Certified Quantification Limit
U = Below detection limit

4.5 CONCLUSIONS

In light of the analytical results presented in this section, the conclusions as to the nature and extent of contamination at the Marsh Run Field site are as follows:

1. Although not directly sampled, the "waste fill" onsite can be characterized indirectly, based on peripheral analytical data, as exhibiting elevated concentrations of semivolatile compounds, specifically PAHs. These compounds are ubiquitous and are common constituents of asphalt, coal tar, and creosote. They are fairly immobile in ground water. Analytical data for soils collected from MW-2 (eastern edge of fill) showed relatively high concentrations of several PAH compounds, particularly phenanthrene and fluoranthene, at levels exceeding 1,000,000 µg/kg (1,000 mg/kg). Although the highest concentrations were obviously detected onsite, much lower levels (i.e., approximately two to three orders of magnitude lower) were found dispersed offsite in other fill material, which indicates that these semivolatile compounds are not unique to the site.

2. Elevated concentrations of the trace metals barium, lead, copper, and silver, which were detected in soil samples collected onsite, are apparently related to the "waste fill." Soil samples collected from MW-2 characteristically exhibited the highest concentrations of trace metals. Coincidentally, MW-2 is located closest to the "waste fill."

3. Based on ground-water data from shallow overburden wells and the respective water level and saturated thickness of fill during each of the two sampling events, the fill is identified as a potential source of VOCs. The detection of the VOCs vinyl chloride and 1,2-dichloroethene (total) in shallow overburden wells during the second sampling event when water levels were higher and a greater portion of the "waste fill" was saturated indicates the fill as a potential temporal VOC source. Based on inferred ground-water flow patterns at the site, the presence of VOCs in the shallow ground water implicates the fill as a potential source of VOCs. It is unlikely that an offsite source would result in VOC contamination in the shallow overburden onsite based on inferred ground-water flow paths. Furthermore, with the exception of acetone detected in MW-5A no VOC contamination was detected in the ground water anywhere offsite in either the overburden, bedrock, or residential wells.

4. Volatile organic contamination appears to be present in a localized area in the bedrock aquifer beneath the site. The persistence of detected TCE and other chlorinated aliphatics at very similar concentrations during both sampling events suggests that a contaminant source exists that has impacted the bedrock aquifer beneath the site. The VOC contamination

is not present in monitoring wells to the west, to the southwest, or in residential wells to the east. Based on inferred ground-water flow patterns of the bedrock aquifer, the predominant contaminant migration direction would be to the north towards the Susquehanna River. Monitoring wells located further north of the site would be needed to better define or assess potential migration pathways.

5. The source of volatile organic compound contamination in both the bedrock and overburden ground water appears to be the fill material placed at Marsh Run Field. The varying ratios of TCE versus its probable biodegradation by-products in the saturated overburden and bedrock aquifer respectively may be related to the unique effects of each of the saturated matrix materials (fill clay and peat or bedrock) on the biotransformation capability of the microorganisms. The aforementioned relative variance of TCE vs. probable transformation products may also be an indication that vertical migration of contaminants to the bedrock aquifer is rapid enough to compensate for rapid biodegradation in the overburden. Consequently, TCE invades the bedrock in a less transformed state. Interactions between environmental conditions such as dissolved oxygen, re-dox potential, temperature, pH, and salinity, and the presence of particulate matter as well as the critical concentration range of the compound of interest, and the presence of adapted or adaptable organisms often control the occurrence, rate, and product of biodegradation (Parsons et al. 1982). The environmental fate and transport of the volatile organic compounds detected onsite will be discussed in more detail in Chapter 5, Fate and Transport of Contamination.

6. Low-level volatile organic compounds are discharging to Marsh Run Creek upstream and adjacent to Marsh Run Field. There are documented sources of low-level volatiles and semivolatiles upstream of Marsh Run Field. However, based on ground-water flow paths there is a potential that ground-water base flow to Marsh Run Creek from beneath Marsh Run Field may be or may have been contributing to the low-level volatile organics in the surface water. This speculation has not been confirmed by recent sampling. MW-7, which is situated between the "waste fill" and Marsh Run Creek (i.e., downgradient of Marsh Run Field), has not exhibited VOC contamination.

7. Total trace metal contamination in the ground water appears to be partially site derived, but the presence of elevated trace metals in upgradient wells suggests that an offsite source of trace metals (possibly fill or the sewage sludge land treatment area) is also contributing to the elevated trace metals in the ground water. In evaluating the mobility of the metals in ground water, dissolved metals analysis is more applicable.

8. The site has not adversely affected the ground-water quality of those residences' wells that were sampled and analyzed. These residences are hydraulically upgradient of the site and are not expected to be affected in the future.

9. Stream sediment transport and fugitive dust emissions were not identified as exposure pathways.

5. FATE AND TRANSPORT OF CONTAMINATION

The results of the physical and chemical characterization of the study site implicate the former NCAD landfill, Marsh Run Field, as a source for low-level volatile organics and trace metal contamination of the ground water and low-level volatile contamination of the surface water in the vicinity of the site. This chapter discusses the potential transport mechanisms of site-derived contaminants based on the conceptualized site model developed from the site's historical background, physical conditions, and nature and extent of contamination. In light of the site's physical condition (Chapter 3) and nature and extent of contamination (Chapter 4), the following migration pathways will be evaluated in this section:

- Ground-water migration of contaminants within the overburden fill and in the bedrock aquifer. Specifically, the movement of contaminants from the saturated "waste fill" (presumed source) to the deeper bedrock aquifer will be discussed. A second component of ground-water transport of contaminants is the interaction with the surface waterbodies (i.e., Marsh Run Creek and the Susquehanna River) which surround the site.

- Surface water and sediment transport via site surface water runoff.

- Surficial soil transport via fugitive dust emissions or erosion or leaching of contaminants into the ground water.

Of the aforementioned potential contaminant transport mechanisms, ground-water transport is considered the most significant vehicle for offsite migration of site-derived contaminants.

Because of the site's topographic position and location with respect to surface waterbodies, which serve as hydraulic barriers, it can be postulated that the Marsh Run Field "waste fill" represents the source of volatile contaminants detected in the ground water collected from site monitoring wells. The natural hydraulic barriers--in particular Marsh Run Creek--prevent site-derived contamination from migrating further to the south or east beneath Marsh Run Creek.

With the exception of methylene chloride and acetone, none of the volatile organic chemicals detected in the ground water, both within the fill and in the underlying bedrock aquifer, were detected in any soil sample. However, only peripheral testing (i.e., soil samples collected near or outside the "waste fill") were analyzed as per the scope of work, and it is therefore conceivable that volatile organic source areas were not encountered in the monitoring well borings. The monitoring wells exhibiting the highest volatile organic compound (VOC) concentration in the saturated fill/overburden were well points WP-1 and WP-3, which were installed within the "waste fill" proper. However, these well points were pushed into the fill and consequently no soil sampling and analysis accompanied their installation. In light of the hydrogeologic conditions at the site, the presence of detectable VOCs in onsite overburden wells

is a direct implication that the source(s) of VOCs are present within the site confines.

The occurrence of VOCs in the bedrock aquifer beneath the site was consistently confirmed with similar concentrations of the same compounds detected during both sampling events. As previously stated, in light of the inferred ground-water flow paths, the relative topographic position of the site to the surrounding area, and the absence of detectable volatile ground-water contamination offsite, it appears that Marsh Run Field is a primary source of volatile compounds. Chapter 4, Nature and Extent of Contamination, discusses specific VOCs and respective concentrations in the ground water.

Elevated trace metal concentrations were detected in the ground water within the saturated fill and overburden and in the bedrock aquifer. Although the occurrence of elevated trace metals was most prevalent in the peripheral fill in the Marsh Run Field confines or in the bedrock aquifer beneath the site, elevated levels were also detected in monitoring wells upgradient. The occurrence of elevated trace metal concentrations upgradient of the site suggests a potential allochthonous (offsite) source of trace metals. As previously stated in Chapter 4, past waste management practices suggest that waste high in leachable trace metals (sewage sludge) further upstream along Marsh Run Creek may be a likely source of trace metals. The location and description of the potential offsite trace metal source(s) are described in Chapter 1.

The occurrence and distribution of contaminant compounds in each environmental matrix (i.e., ground water, soil, and surface water/sediments) have been previously discussed in Chapter 4 (Nature and Extent of Contamination). The following sections address, to the extent possible, each environmental matrix and the fate and transport mechanisms for the specific chemicals of concern.

5.1 GROUND-WATER TRANSPORT

In summary, ground-water movement in the vicinity of Marsh Run Field can be characterized as follows. The regional ground-water flow in the bedrock aquifer consists of a primarily south-to-north trend from the higher elevation Triassic uplands toward the low ground-water discharge point at the Susquehanna River. This general south-to-north regional trend is complicated by the roughly west-east trending perennial Marsh Run Creek. Marsh Run Creek serves locally as an intermediate ground-water discharge point for ground water in the immediately adjacent saturated overburden and shallow bedrock aquifer. At some depth, presumably greater than 100 ft, intermediate ground-water discharge to Marsh Run Creek ceases to occur and ground-water underflow beneath Marsh Run Creek results in a more regional flow pattern (i.e., south to north) to the Susquehanna River. The exact nature and velocity of flow at these greater depths was not investigated as part of this project.

Further complicating regional flow patterns is the presence of saturated fill placed over Marsh Run Field. As a result of the placement of relatively higher permeability and porosity fill material with respect to the

surrounding natural soils, a shallow ground-water mounding occurs. This mounding was observed to fluctuate several feet over the period of investigation. Consequently, the effect of shallow ground-water mounding within the fill on the bedrock aquifer ground-water flow pattern is proportional to the height of the mound. For example, when net precipitation infiltration is high, the ground-water mound beneath the site increases and the result is a radial ground-water flow pattern from the mound apex out in several directions towards the lower discharge area (stream, river, and marsh). The higher the elevation of the ground-water mound, the greater the influence exerted on the bedrock ground-water flow patterns via downward leakage to the bedrock aquifer. Comparison of Figures 3-17 and 3-19 with Figures 3-18 and 3-20 illustrates the increased influence on bedrock aquifer flow patterns from higher shallow ground-water mounding.

Ultimately, the cumulative ground-water flow field influence from the mounding in the saturated fill and intermediate discharge point to Marsh Run Creek has resulted in a quasi-radial flow from Marsh Run Field towards Marsh Run Creek and the Susquehanna River. Consequently, the Susquehanna River and Marsh Run Creek serve as hydraulic boundaries that prohibit ground-water flow across these boundaries to at least the depth investigated (i.e., 50 ft). It is postulated that in deeper bedrock zones ground-water flows under Marsh Run Creek from south to north on a more regional basis. Due to the physical size of the Susquehanna as compared to Marsh Run Creek, the Susquehanna can be considered a regional and ultimate ground-water discharge point. Discharged ground water to Marsh Run Creek is carried as surface water flow into the Susquehanna River.

In addition to the aforementioned ground-water flow considerations, it is important to reemphasize the other significant (i.e., vertical) component of ground-water flow. Based on observed field conditions and the results of the ground-water flow model (Chapter 3), the vertical migration of contaminants from the saturated fill to the underlying bedrock is the primary source loading mechanism. More specifically, the transference of site ("waste fill") derived contamination can either migrate laterally in the saturated overburden/fill towards adjacent discharge points or migrate vertically (or a resultant flow vector of vertical flow) downward into the bedrock. The convening and apparently continuous silt and clay layer between the saturated "waste fill" and bedrock is the controlling factor in vertical migration rates. Conversely the primary controlling factor affecting horizontal flow is the surrounding natural and reworked soils peripheral to the waste fill. Simply stated, the magnitude of horizontal flow and discharge to surface waterbodies per unit thickness of saturated overburden versus the magnitude of vertical leakage from the saturated fill via the clay layer to the bedrock aquifer over the areal extent of the site constitutes the total site-related ground-water flux into the environment. Ground-water modeling (Chapter 3) indicates a 1 to 49 (i.e., 2% to 98%) ratio of saturated overburden ground-water flux into the surface waterbodies versus the leakage to the bedrock aquifer. Comparison of the vertical to horizontal linear ground-water velocity in the overburden (Chapter 3) indicates that only the ground water in the saturated overburden close to the discharge points (i.e., Marsh Run Creek and

the Susquehanna River) will reach these discharge areas via horizontal flow. Conversely, in areas in the central portion of the landfill on the order of hundreds of feet from the nearest ground-water discharge point, the saturated overburden ground water will tend to migrate vertically into the bedrock aquifers. It should be noted, however, that even though the majority of saturated overburden ground water initially migrates vertically to the bedrock aquifer, the bedrock ground-water flow paths ultimately migrate to the same surface water discharge points.

As the source of volatile contamination migrates vertically in the bedrock, the ground-water flow pattern strongly reverts to a northward flow toward the Susquehanna River. The contaminant flux to the ground water can be expressed by contamination concentration of ground water times the ground-water discharge volume. Complicating factors to this generic approach are dispersion, retardation, decay, and dilution. Some of these parameters can be estimated or inferred, such as retardation and decay; others are not significant or are not able to be quantified within the context of this investigation (i.e., dispersion). Figure 3-21 shows an idealized concept of ground-water flow patterns at the site.

5.1.1 Volatile Organic Transport in Ground Water

Of all the chemical compounds of concern, VOCs are of particular concern. The volatile compounds trichloroethene, 1,2-dichloroethene (total), 1,1-dichloroethene, 1,1,2,2-tetrachloroethene, and vinyl chloride were all detected in site monitoring wells. The occurrence of these organic compounds follows several discernible patterns of distribution with respect to onsite/offsite and bedrock aquifer/saturated overburden occurrence. In general, VOCs (except acetone) were detected in monitoring wells directly beneath or downgradient of the site. The speciation and temporal occurrence of VOCs, however, were unique to the overburden and bedrock wells, respectively. Specifically, the relative concentration of trichloroethene compared to other volatile compounds 1,2-dichlorothene (total) (cis and trans), 1,1,2,2-tetrachloroethane and vinyl chloride exhibit a unique pattern of occurrence.

In general, in bedrock wells MW-1 and MW-4, concentration ratios of trichloroethene compared to 1,2-dichloroethene (total) were 4.2:1 and 4.0:1, respectively. This comparison was made from analytical results from the second sampling round. During the first sampling round, the ratio of trichloroethene to 1,2-dichloroethene (total) in MW-4 was 10.5:1. The comparison for the first round was not performed for MW-1, because 1,2-dichloroethene (total) was not detected.

For the same comparison of the VOCs detected in overburden wells MW-1A, MW-4A, and WP-1, the relative ratios of trichloroethene to 1,2-dichloroethene (total) were 0.2:1, 1.2:1, and 0.04:1, respectively. In overburden well MW-2A, although 1,2-dichloroethene (total) was detected in both the first and second sampling rounds, trichloroethene was not. The higher percentage of other VOC speciation compounds relative to trichloroethene in the overburden suggests that a mechanism of transformation is degrading trichloroethene at a more rapid rate relative to that which is occurring is the bedrock aquifer. The relatively higher percentage of

1,2-dichloroethene (total), which is a chemical with limited industrial use, implies that trichloroethene transformation is occurring.

Work by others (Gibson 1978) has investigated the biotransformation of the industrial solvents tetrachloroethene, trichloroethene, 1,1,1-trichloroethane, and tetrachloromethane by microbial organisms in the environment. Specifically, transformation by-products of trichloroethene (cis- and trans-1,2-dichloroethene, and vinyl chloride) were detected in bench scale studies of microbial transformation in muck sediments from the Florida Everglades (Parsons et al. 1984). They reported that reductive dehalogenation (i.e., dechlorination) of trichloroethene resulted in the formation of the chlorinated aliphatics cis and trans 1,2-dichloroethene. Neither of these compounds are heavily produced for industrial use.

In order to facilitate microbial transformation of chlorinated aliphatics, the essential elements are: available electrons, a mediator between electron donor and acceptor, and an electron acceptor (Parsons 1983). In the saturated overburden environment encountered at Marsh Run Field, electron donors could exist in the decay products of the organic waste accumulations, mediators for transferring electrons such as microbial populations, and the electron acceptor being the halogenated organic solvents.

Abiotic transformation (i.e., for example Fe+3 mediation) of halogenated aliphatics can also account for speciation of daughter compounds, but this transformation mechanism is generally slow when compared to biotransformation mechanisms. However, In light of the monitoring well chemical data (presented in Chapter 4), the primary elements of specific interest are the distinct speciation of VOCs in the saturated overburden and bedrock aquifer, respectively. It can be postulated that trichloroethene, a common industrial metal degreaser, was initially the primary source compound. Tetrachloroethene, also a common industrial solvent, may also have been an original source but degraded rather quickly to trichloroethene. Vinyl chloride is another common chemical produced in large quantities; however, it has been observed that vinyl chloride can also be a transformation by-product of trichloroethene and tetrachloroethene. Conversely, cis- and trans-1,2-dichloroethene (total) are not heavily used industrial compounds and are not produced in large quantities. Table 5-1 lists the annual production rates in 1985 of several of the common halogenated aliphatic compounds.

Examination of the ground-water chemical data for overburden monitoring wells clearly indicates transformation (biotic or abiotic) occurring in the overburden zone by the relative abundance of 1,2-dichloroethene (total) in comparison to trichloroethene in WP-1 and MW-2A. The transformation of trichloroethene has occurred and is probably occurring in the saturated overburden at a sufficient rate to have depleted most of the trichloroethene species after initial release. In overburden well MW-4A, both 1,2-dichloroethene (total) and trichloroethene were detected at similar concentrations, near the detection limit. However, based on inferred vertical ground-water flow rates compared to lateral ground-water flow in the saturated overburden, it is postulated that upon the

TABLE 5-1 PRODUCTION RATE OF INDUSTRIAL SOLVENT IN THE U.S. (1985)

Compound	Production (million lb/year)
Vinyl Chloride	7,000
1,1-Dichloroethene	200
Trans-1,2-Dichloroethene	<0.001
Trichloroethene	200
Tetrachloroethene	550
1,1-Dichloroethane	<0.001
1,2-Dichloroethane	12,000
1,1,1-Trichloroethane	600
Methylene Chloride	600

initial release of potential parent compounds such as TCE, that vertical migration would occur quickly enough to allow for some TCE to enter the bedrock before extensive transformation could occur.

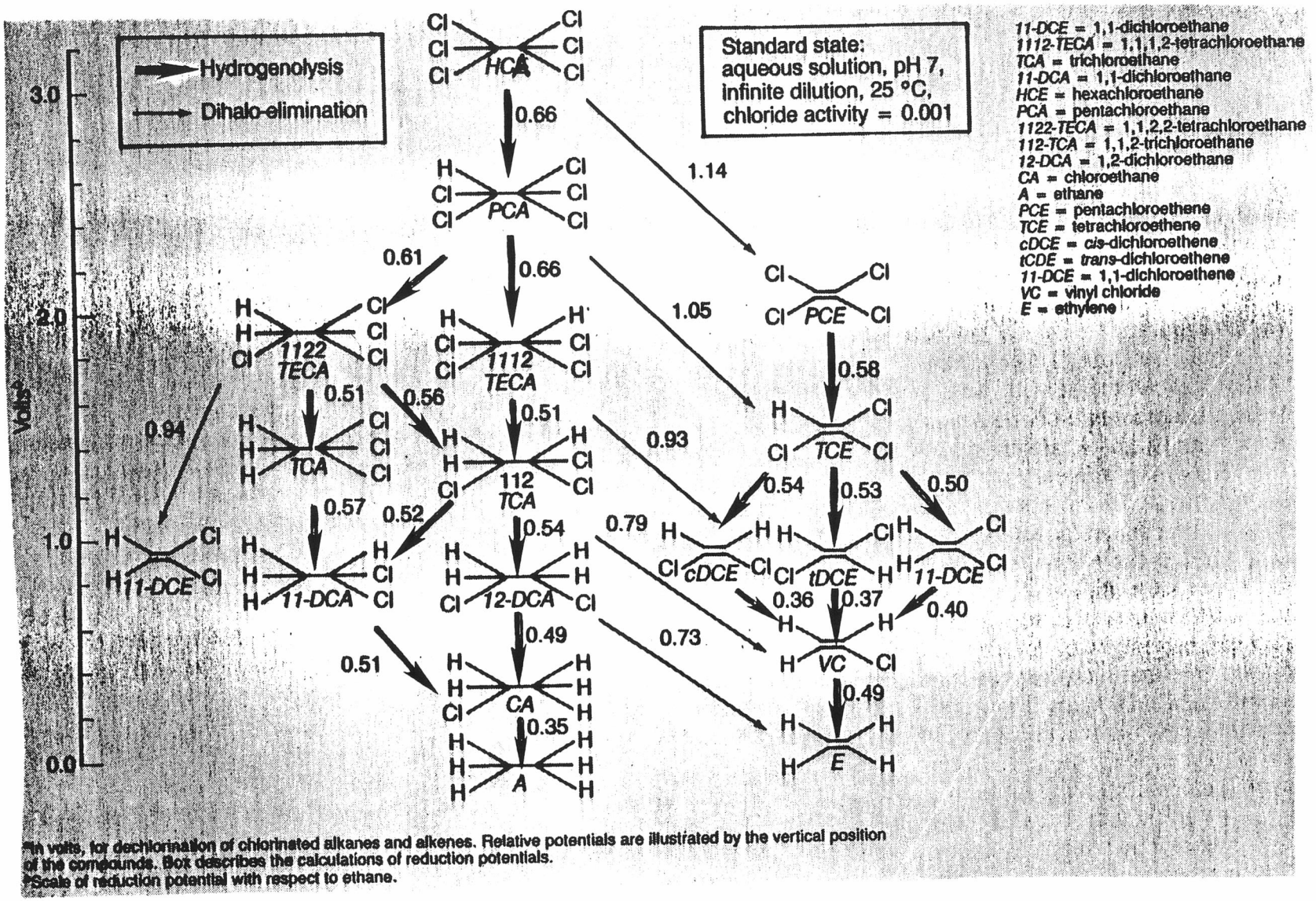
Given the vertical hydraulic conductivity of 2.5×10^{-6} cm/sec (0.007 ft/day) of the clay which underlies the site, the variable thickness of clay encountered beneath the site from 2 to 5 ft, an estimated effective porosity of 30 percent, and average hydraulic head differential between the saturated overburden and bedrock aquifer of 1 ft dissipated over the thickness of the clay, vertical migration rates through the clay would range from 0.5 to 2.7 years. This assumes no discontinuities of fissuring of the clay.

In overburden well points WP-1 and WP-3, vinyl chloride and 1,2-dichloroethene (total) were detected at similar concentrations. In WP-1, vinyl chloride and 1,2-dichlorothene (total) were detected at 96 and 110 µg/L, respectively. In WP-3, vinyl chloride and 1,2-dichloroethene (total) were detected at 3 and 11 µg/L, respectively. Although vinyl chloride could potentially be a parent source compound, its presence with probable trichloroethene daughter compound 1,2-dichlorothene (total) at a similar concentration suggests that it may also be a biotransformation by-product of trichloroethene. A study of the occurrence of vinyl chloride with other chlorinated aliphatics (Brass 1985) reported that the co-occurrence of vinyl chloride with cis- and trans-1,2-dichloroethene was most common in a survey of ground-water supply wells. Figure 5-1 illustrates an idealized reaction profile for various volatile compounds.

In general, the biotransformation by-products 1,2-dichloroethene (total) and vinyl chloride (either parent product or by-product) are persistent, with long half lifes in the environment in both abiotic and microbial environments. Conversely, trichloroethene has been reported to have a half life of as little as 43 days in a muck (organic rich) biotic environment (Parsons et al. 1984). In the absence of transformation mechanisms, trichloroethene may persist for much longer periods. The half life of trichloroethene in an abiotic environment in pH 7 water is reported at between 0.9 and 2.5 years (Vogel and McCarty 1987). The aforementioned half life of trichloroethene is for 10 C water with a 3.5-fold decrease in half life for each 10 C increase in temperature (Vogel and McCarty 1987). The abiotic mechanism for the slower reaction rates is reported as dehydrohalogenation (i.e., removal of halogen and concomitant removal of hydrogen from adjacent carbon).

The very low concentrations of the VOC 1,1,2,2-tetrachloroethene detected in overburden wells MW-1A and MW-4A may be representative of typical impurities found in trichloroethene and tetrachloroethene supplies. The reaction profile of 1,1,2,2-tetrachloroethene is shown in Figure 5-1.

In contrast with the saturated overburden, the bedrock aquifer exhibits a discernible speciation of volatile organics with trichloroethene detected at higher relative concentration with respect to other potential daughter volatile compounds.



*In volts, for dechlorination of chlorinated alkanes and alkenes. Relative potentials are illustrated by the vertical position of the compounds. Box describes the calculations of reduction potentials.
*Scale of reduction potential with respect to ethane.

Figure 5-1. Transformation profile of chlorinated alkane and alkenes.
(Source: Environ. Sci. Technol., Vol. 21, No. 8, 1987).

Specifically, trichloroethene is the most prevalent volatile compound in the bedrock aquifer and was detected during both ground-water sampling events with good repeatability in bedrock wells MW-1 and MW-4. Volatile compounds 1,2-dichloroethene (total) and 1,1-dichloroethene, both of which are potential by-products of trichloroethene abiotic or biotic transformation (Figure 5-1), were also prevalent in MW-1. The relative high ratio of trichloroethene to other potential by-products suggests that the transformation mechanisms occurring in the bedrock aquifer are slower than those occurring in the saturated overburden or that migration occurred to a slower reacting environment before transformation could progress.

In general, from a qualitative perspective, the following initial assumptions concerning the fate of the source volatile compounds are:

1. Trichloroethene is a primary source compound. It is present both in the saturated overburden (i.e., from not detected to 24 µg/L) and in the bedrock aquifer (i.e., from not detected to 400 µg/L).

2. Trichloroethene and possibly tetrachloroethene have undergone and are currently undergoing transformation to the more environmentally persistent daughter compounds 1,2-dichloroethene (total), 1,1-dichloroethene, and possibly vinyl chloride.

3. Based on the relative percentages of parent vs. daughter volatile compounds, it appears that the mechanism of transformation occurring in the saturated overburden is microbial reductive dehalogenation. This process has been investigated by others in an anaerobic environment. Results of these analyses on samples in muck (organic decay rich environment) indicate that transformation half lifes of trichloroethene in the aforementioned environment are on the order of 1 to 2 months.

   Slower transformation by abiotic mechanisms which utilize inorganic electron transfer mediators or by dehydrohalogenation may be the primary process occurring in the bedrock aquifer. Consequently, the relative parent to daughter ratios observed in the bedrock aquifer are higher (indicating transformation is slower) than those encountered in the saturated overburden. Vinyl chloride, which is a potential second step transformation intermediary, was not detected in the bedrock aquifer. However, due to its high volatility, very low concentrations (i.e., near detection limit) may have off-gased during sampling.

4. Secondary volatile sources such as 1,1,2,2-tetrachloroethane are also present and are typically found as impurities in industrial grade trichloroethene. These compounds also degrade or transform by similar abiotic and microbial mechanisms.

5. Other source-specific volatile compounds such as methylene chloride and acetone spuriously detected in site monitoring wells have been regarded with scrutiny, because they are potential artifact laboratory contaminants.

The source area, presumably the fill, has been observed to generate volatile contamination in a temporal loading scenario. Volatile compounds were detected during the second sampling round but not the first, an indication of the cyclic source generation, although source loading to the bedrock may be relatively continuous. It is unknown how old the sources are. Realistically, periodic source generation by flushing of solvent-laden areas or breaching of potential containers of solvents constitute the major sources within the fill.

Organic compounds differ widely in their solubility, from infinitely miscible polar compounds to extremely low-solubility compounds such as polynuclear aromatic hydrocarbons (PAHs). Common halogenated aliphatics tend to have moderately low solubilities (<1 percent). All of the chlorinated aliphatic compounds are denser than water. This physical characteristic has implications regarding the behavior of nonaqueous phase product and its ability to sink relatively uncoupled to the hydraulic gradient that drives advective transport. However, at the dissolved concentrations encountered in the ground water, density variations are negligible and no nonaqueous phases are thought to exist. Table 5-2 lists physical and chemical characteristics of common VOCs encountered at Marsh Run Field.

The water solubility of a substance is a critical property affecting environmental fate; highly soluble chemicals can be leached from wastes and soils and are mobile in surface water and ground water.

Volatilization of a compound from environmental media will depend on its vapor pressure, water solubility, and diffusion coefficient. For estimating releases from water to air, the Henry's Law constant, the partition coefficient which expresses the ratio of the chemical concentration between air and water at equilibrium, is more appropriate than vapor pressure alone and is frequently measured for volatile chemicals. The Henry's Law constant can be estimated for chemicals of low aqueous solubility (less than a few percent) by the ratio of vapor pressure and solubility at similar temperatures (Mackay and Shiu 1981). Compounds with Henry's Law constants in the range of 10^{-3} atm m^3/mole and larger can be expected to volatilize readily from water; those with values ranging from 10^{-3} to 10^{-5} atm m^3/mole are associated with significant, but lesser volatilization, while compounds with values less than 10^{-5} atm m^3/mole volatilize from water only to a limited extent (Lyman et al. 1982).

The octanol-water partition coefficient (K_{OW}) is often used to estimate the extent to which a chemical will partition from water into lipophilic parts of organisms, for example into animal fat. The higher the K_{OW} value, the greater is a chemical's tendency to partition into fat. Similarly, the organic carbon partition coefficient (K_{OC}) reflects the propensity of a compound to adsorb to the organic carbon found in soil.

TABLE 5-2 PHYSICAL-CHEMICAL PROPERTIES OF ORGANIC CHEMICALS OF POTENTIAL CONCERN AT NCAD

Chemical Name	Molecular Weight (g/mol)	Solubility in Water 20-25 C (mg/L)	Vapor Pressure 20-25 C (mm Hg)	Henry's Law Constant 20-25 C (atm-m3/mol)	Koc (ml/g)
Alkylbenzenes					
Ethylbenzene	106.17	1.53E+02	7.00E+00	7.90E-03	2.20E+02
Chlorinated Aliphatics					
1,1-Dichloroethene	96.94	2.25E+03	6.00E+02	1.54E-01	6.50E+01
Trans-1,2-Dichloroethene	96.94	6.30E+03	3.24E+02	6.60E-03	5.90E+01
Methylene Chloride	84.93	1.80E+04	3.62E+02	2.60E-03	8.80E+00
Tetrachloroethene	165.85	4.84E+02	1.78E+01	2.30E-02	3.64E+02
1,1,2-Trichloroethane	133.41	4.50E+03	3.00E+01	1.20E-03	5.60E+01
Trichloroethene	62.50	2.67E+03	2.66E+03	6.90E-01	8.20E+00

The higher the K_{OC} value, the greater is a chemical's tendency to adsorb to soil organic carbon. In addition to organic carbon, sorption to soil is also a funtion of the surface area of the soil particle as well as the size, shape, structure, and surface area of the adsorbing molecule.

With respect to volatile organic source generation at the site, it is unclear how the source is generated (i.e., as a continuous or pulsed source). For practical consideration, because the landfill has been closed since 1959 it must be assumed that the source loading to the bedrock is presently continuous, but variable with respect to source strength. The most conservative approach would be to assume the simultaneous onset of leachate generation with the initiation of site activities. However, due to the age of the landfill, this is presumably not the case. It was not until the early 1940s when the rapid expansion in the manufacture and use of organic chemicals prevailed. The use of the landfill reportedly ceased in the mid to late 1950s.

For transport modeling purposes, the initial ground-water flow parameters established from the U.S. Geological Survey (USGS) three-dimensional MODFLOW model (Chapter 3) indicate that of the total precipitation infiltrating into the area, 98 percent continues to migrate vertically into the bedrock aquifer. The remaining 2 percent migrates laterally in the shallow overburden and fill, primarily towards Marsh Run Creek and to a lesser degree towards the Susquehanna River. Therefore, from this flow analysis, the saturated fill/overburden can be considered a source and not a major transport mechanism. The relative absence of VOCs in ground water collected from overburden and monitoring wells MW-7A and MW-3A and the very low levels detected in MW-4A further suggest that lateral ground-water transport in the fill/overburden is minimal. Based on observed and measured hydraulic parameters at the site, the average lateral linear ground-water velocity in the saturated overburden is 1.5 and 2.9 ft/year to the north and south, respectively. In light of the low linear ground-water velocities it can be postulated that since the closure of the landfill (i.e., approximately 30 years) maximum lateral migration distances of contaminants within the saturated overburden from a specific source in the "waste fill" would be on the order of 75 ft. This simplistic model further alludes to the fill's and the surrounding overburden's primary function as a source with respect to contaminant transport.

As previously discussed, it is suspected based on the VOC speciation in the overburden/fill that microbial transformation is primarily responsible for the transformation of trichloroethene residing in the overburden. Trichloroethene migrating vertically, conversely, may not be as rapidly transformed, resulting in a higher percentage of trichloroethene in the bedrock aquifer. In light of this scenario, the model was initially set up to mimic the flow fields previously established with the USGS three-dimensional model.

5.1.1.1 Ground-Water Modeling

Marsh Run Field was modeled using two USGS models for flow and solute transport analysis. The flow field was first calculated using the three-dimensional ground-water flow model MODFLOW (Chapter 3). Head elevations and leakage rates between layers from MODFLOW were then used to establish boundary conditions for the two-dimensional solute transport model SUTRA. The SUTRA model was executed for three orientations: two-dimensional horizontal in the upper (overburden) and lower (bedrock) layers and two-dimensional vertical between the upper and lower layers. The vertical cross section was taken through the main portion of the landfill.

A 100 x 100 ft cell size was used for both MODFLOW and the two-dimensional horizontal orientation for SUTRA (Figure 5-2). In MODFLOW, cell-by-cell parameters were used for the upper and lower layers with the confining layer input as a vertical resistance between the two. The vertical resistance between the two layers was calculated as the vertical hydraulic conductivity divided by confining layer thickness for each cell in the grid. Values ranged from 0.014 to 0.082 day^{-1}.

A site area of 1,300 ft (13 row cells) by 1,600 ft (16 column cells) was modeled. For MODFLOW, in the upper layer a constant head boundary of 93.0 ft was set along row 1 for the Susquehanna River. Marsh Run Creek started in row 13 and curved around to the Susquehanna River along column 16. Constant head boundaries along the stream varied from 94.3 ft to 93.0 ft at the confluence with the Susquehanna River. In the lower layer, a constant head boundary of 93.0 ft was used only along the Susquehanna. For the lower layer to discharge to Marsh Run Creek, MODFLOW must develop a head gradient which would force the flow back up through the confining area. Hydraulic conductivities used in the upper layer were 0.14 ft/day outside of the landfill site and 2.8 ft/day inside the landfill. A hydraulic conductivity (both vertical and horizontal) of 2.2 ft/day was used in the lower aquifer which was set at a 100-ft thickness.

With the established constant head boundary conditions, MODFLOW was executed for a series of recharge rates over the entire site in order to match the observed head distribution. The selected recharge rate was 6 in./year over the entire site, with 9 in./year in the central portion of the landfill. The resulting head distribution was 1-2 ft low near the center of the landfill and typically within ±0.5 ft over the rest of the site. Similarly, heads in the lower layer were approximately 0.5 ft underestimated below the landfill and 0.5 ft high over the rest of the site. MODFLOW predicted that leakage from the upper to lower layer occurs throughout the entire site except under Marsh Run Creek where the lower layer discharges back up through the confining layer. This is considered good agreement with observed conditions.

In order to model the solute transport, SUTRA was set up using the flow field information from MODFLOW. A source strength of 1,000 ppb was arbitrarily used over the landfill. Modeled concentrations at any point in the plume may then be related back to the source as a conservative dilution ratio.

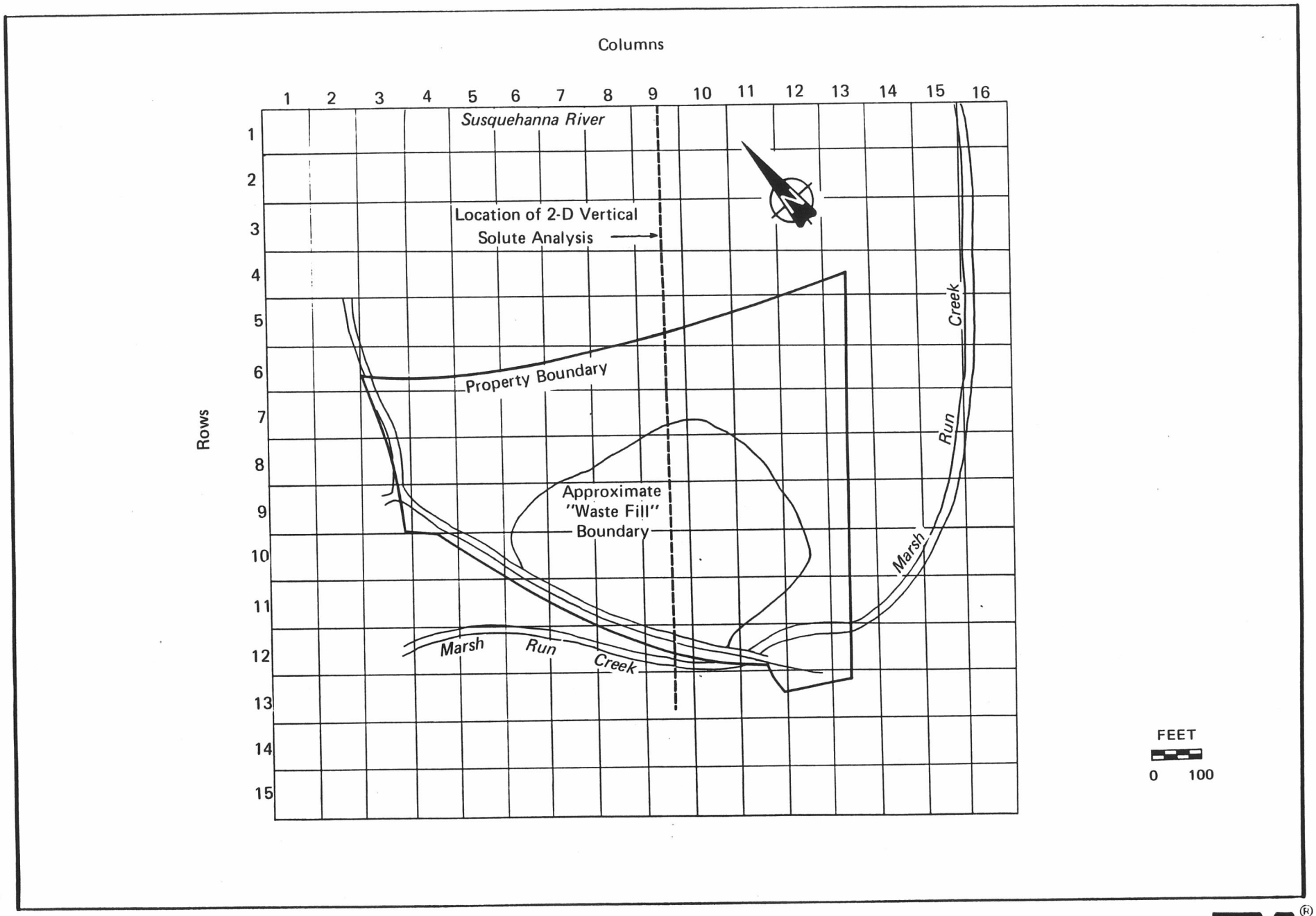


Figure 5-2. Ground-water model grid.

For the two-dimensional model in the upper layer, two flows are associated with each cell: a 6-9 in./year recharge rate into the top and a leakage rate out of the bottom. The cell-by-cell leakage rates from MODFLOW were input to SUTRA as the flow boundary condition recharge flows were input by setting all the model nodes to the steady-state constant head boundary conditions calculated by MODFLOW. It is assumed that by using the same leakage rates and steady-state boundary heads that the resultant inflow created at each constant head cell will be equivalent to the original recharge rates. The 1,000 ppb source over the landfill was included as a constant solute mass flux boundary condition calculated as 1,000 ppb multiplied by the flow associated with the 6-9 in./year recharge rate.

For the two-dimensional horizontal lower layer model, the same head boundary was used along the Susquehanna as was used in MODFLOW. The cell-by-cell vertical leakage rates were input as a flow boundary with a 0 concentration outside the landfill and a 1,000 ppb concentration inside the landfill area.

For the two-dimensional vertical model, the vertical cross section was taken along row 9 (Figure 5-2), which was centered on the landfill. A cell length of 50 ft was used resulting in 23 cells from Marsh Run Creek to the Susquehanna River. The lower layer was modeled as ten 10-ft high cells (each cell 10 x 50 ft) and the confining layer was modeled as four 1.25-ft high cells (each cell 1.25 x 50 ft). The upper layer was modeled as two cells, with the lower cell 2.5 ft high and the upper cell of variable height to accommodate the ground-water elevation. Hydraulic conductivity in the clay/silt layer was 0.01-0.03 ft/day. The 6-9 in./year recharge rate was applied along the top row as a flow boundary with a 1,000 ppb concentration associated with the cells within the landfill.

SUTRA was executed for 40 years for each of the three observations with print out every 10 years. Contoured plume maps of the model results after 10, 20, 30, and 40 years are presented in Figures 5-3 through 5-6 for the overburden layer horizontal, Figures 5-7 through 5-10 for the bedrock aquifer horizontal, and Figures 5-11 through 5-14 for the vertical orientation. In general, the plume growth between the 30 and 40 year time step has decreased compared to initial expansion as the plume approaches a steady state condition.

In the upper layer (Figures 5-3 through 5-6), after 10 years the plume is still confined primarily to the area directly associated with the landfill. The changes in the plume between 10 and 30 years are very slight and the 30 and 40 year plumes are virtually the same. These results indicate that the plume in the upper layer quickly reaches a steady state distribution on a time scale of less than 20 years. The vertical leakage of the majority of the water being recharged to the upper layer into the bedrock aquifer inhibits the longitudinal movement of the upper layer plume to the Susquehanna River. After 40 years, concentrations of up to 60 ppb (17:1 dilution) are reaching Marsh Run Creek.

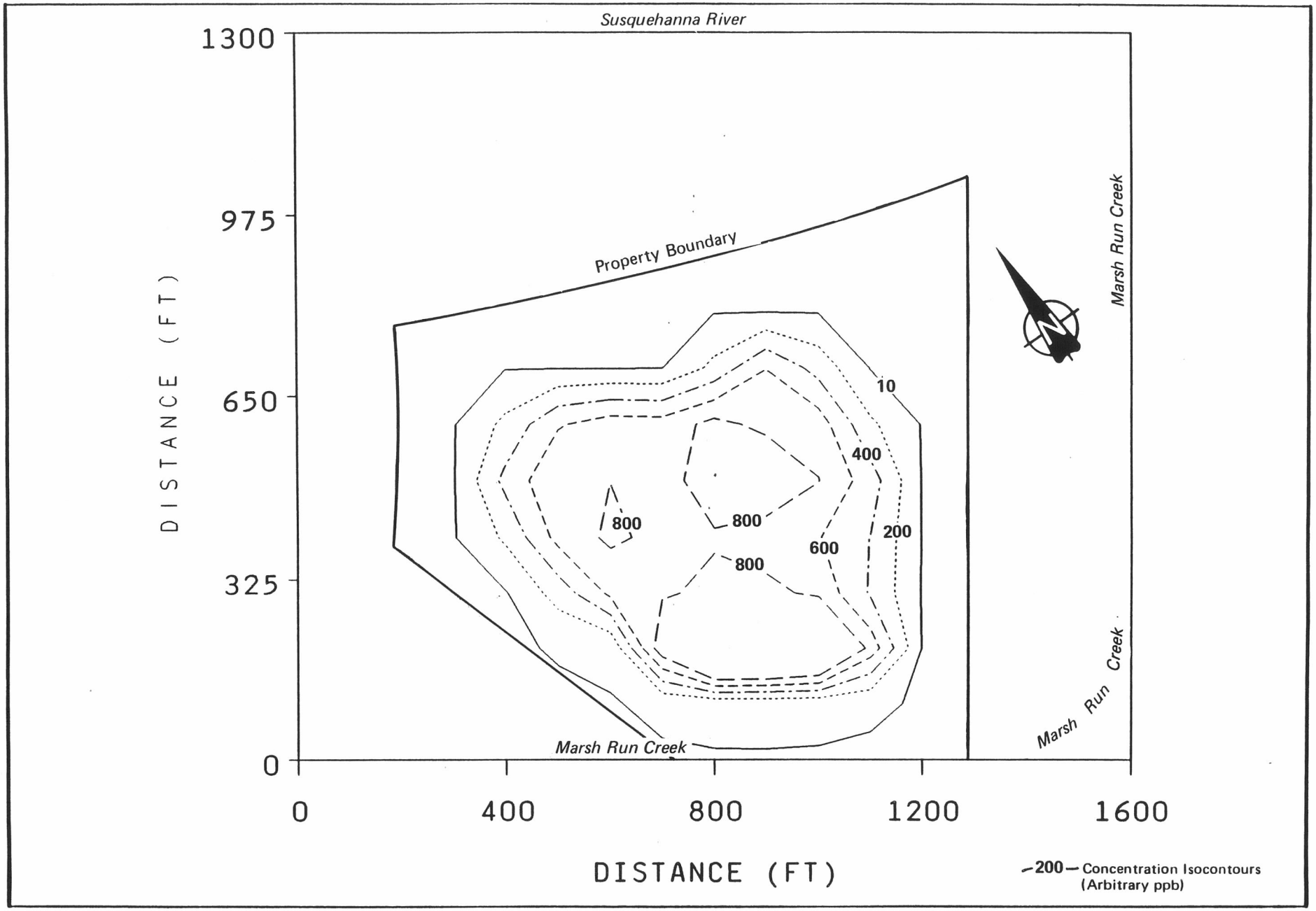


Figure 5-3. Overburden layer at 10 years.

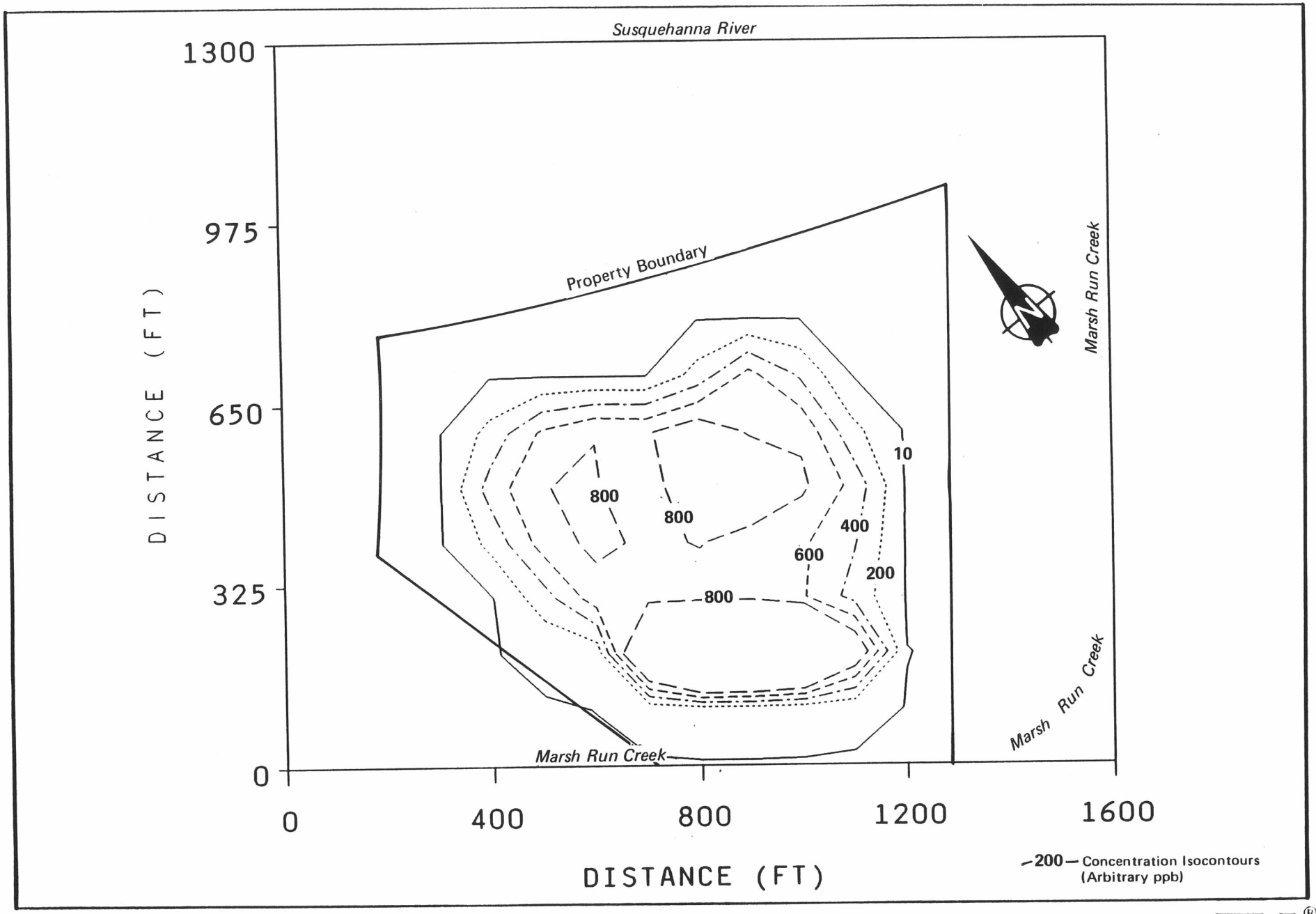


Figure 5-4. Overburden layer at 20 years.

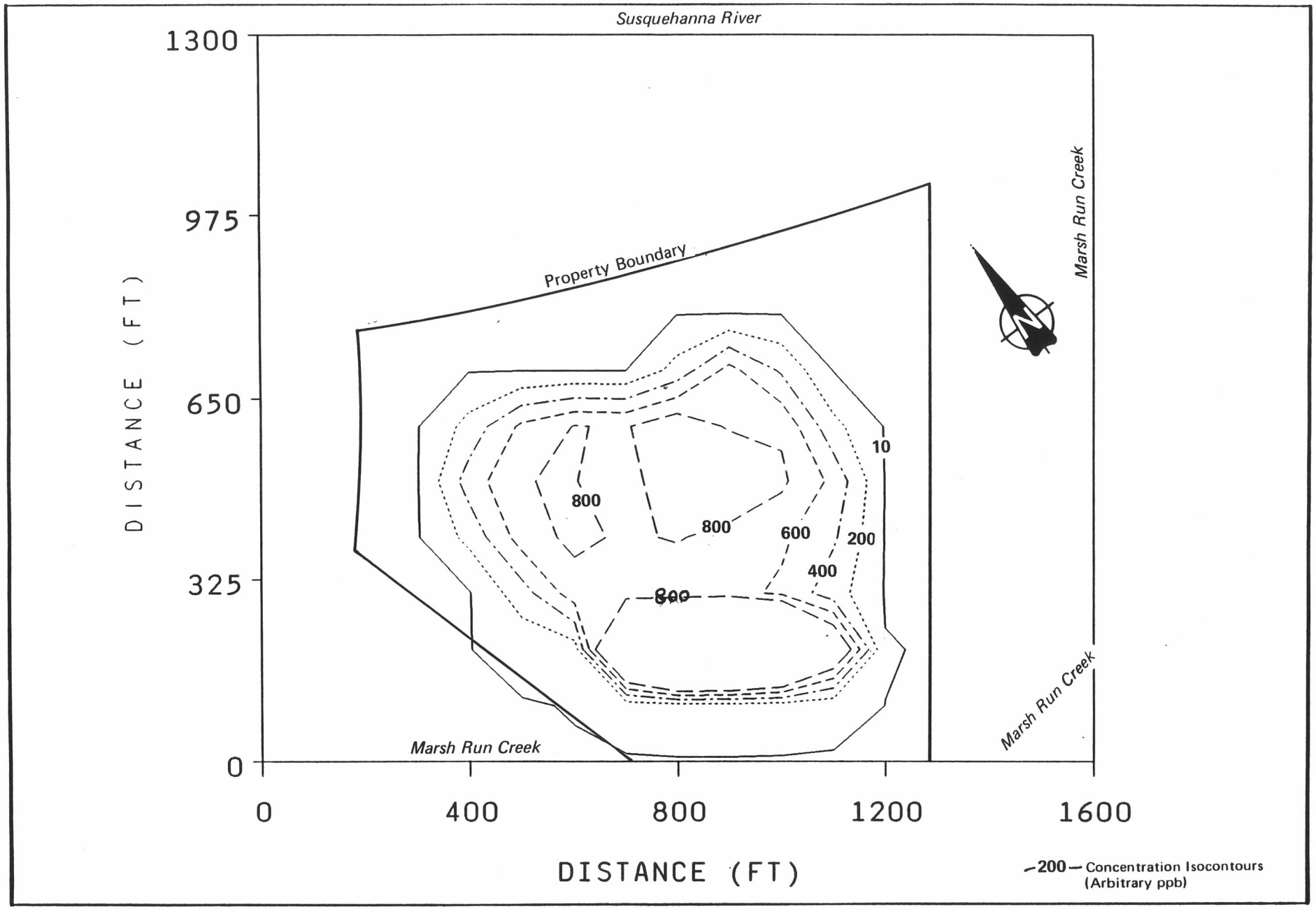


Figure 5-5. Overburden layer at 30 years.

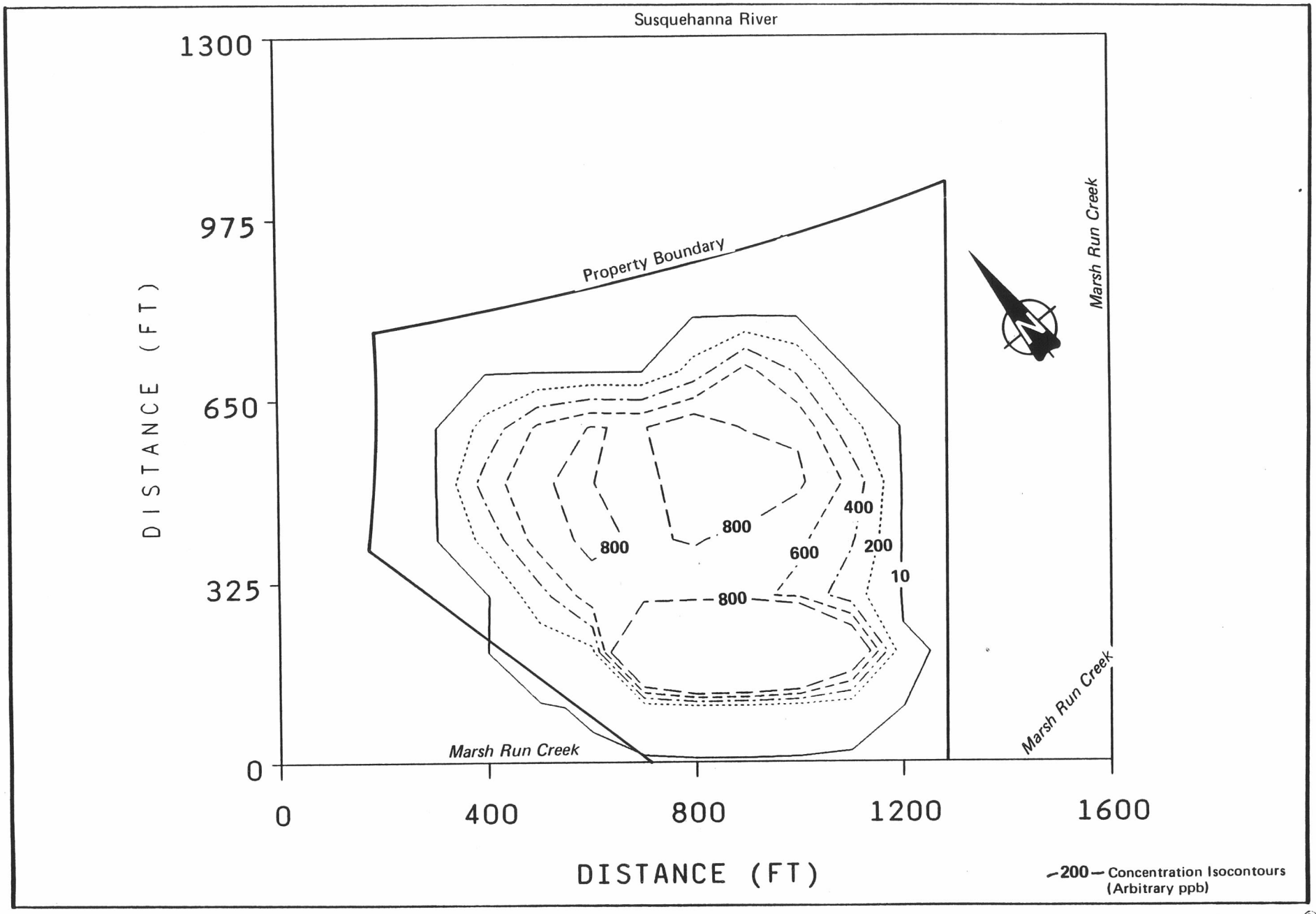


Figure 5-6. Overburden layer at 40 years.

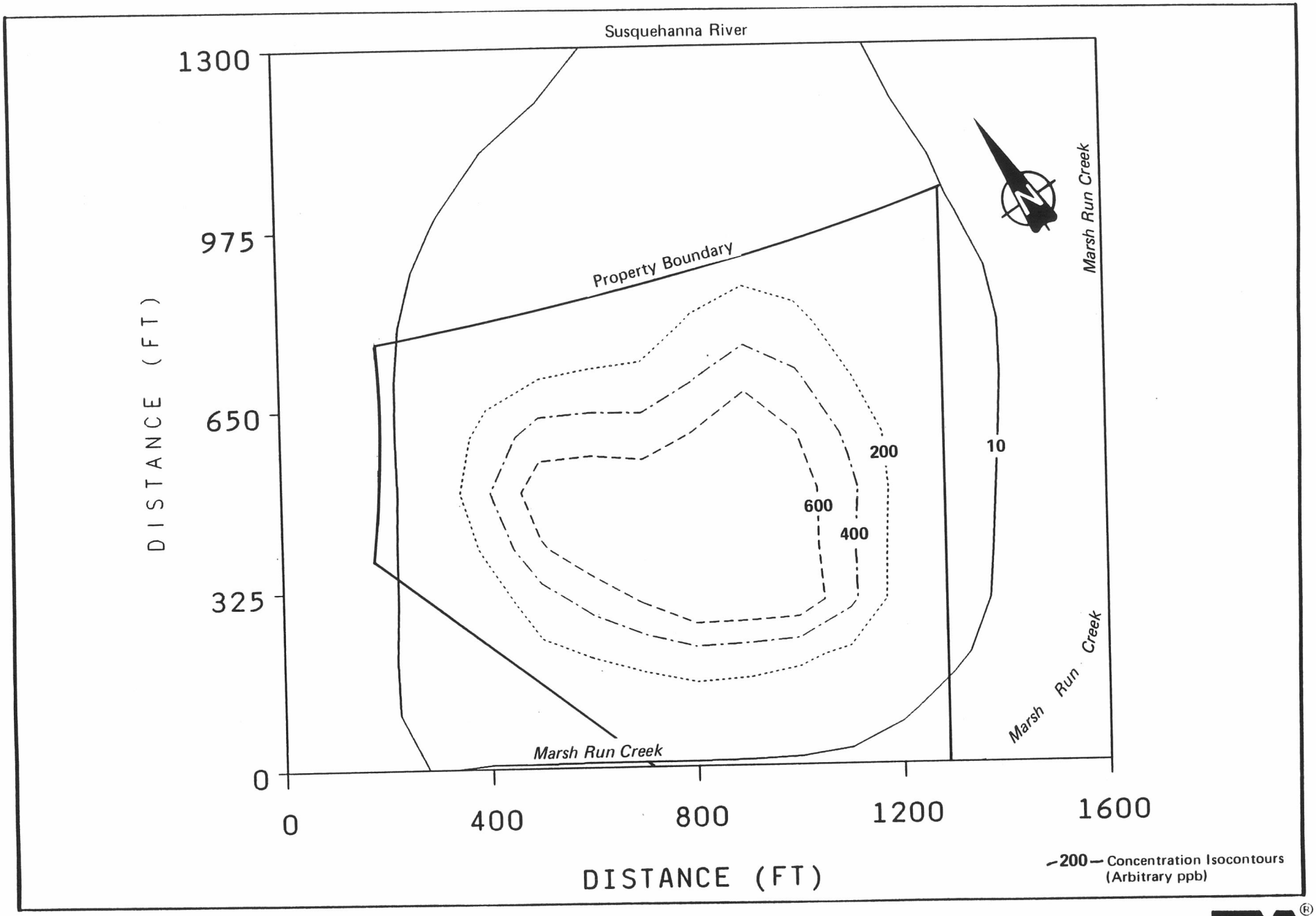


Figure 5-7. Bedrock layer at 10 years.

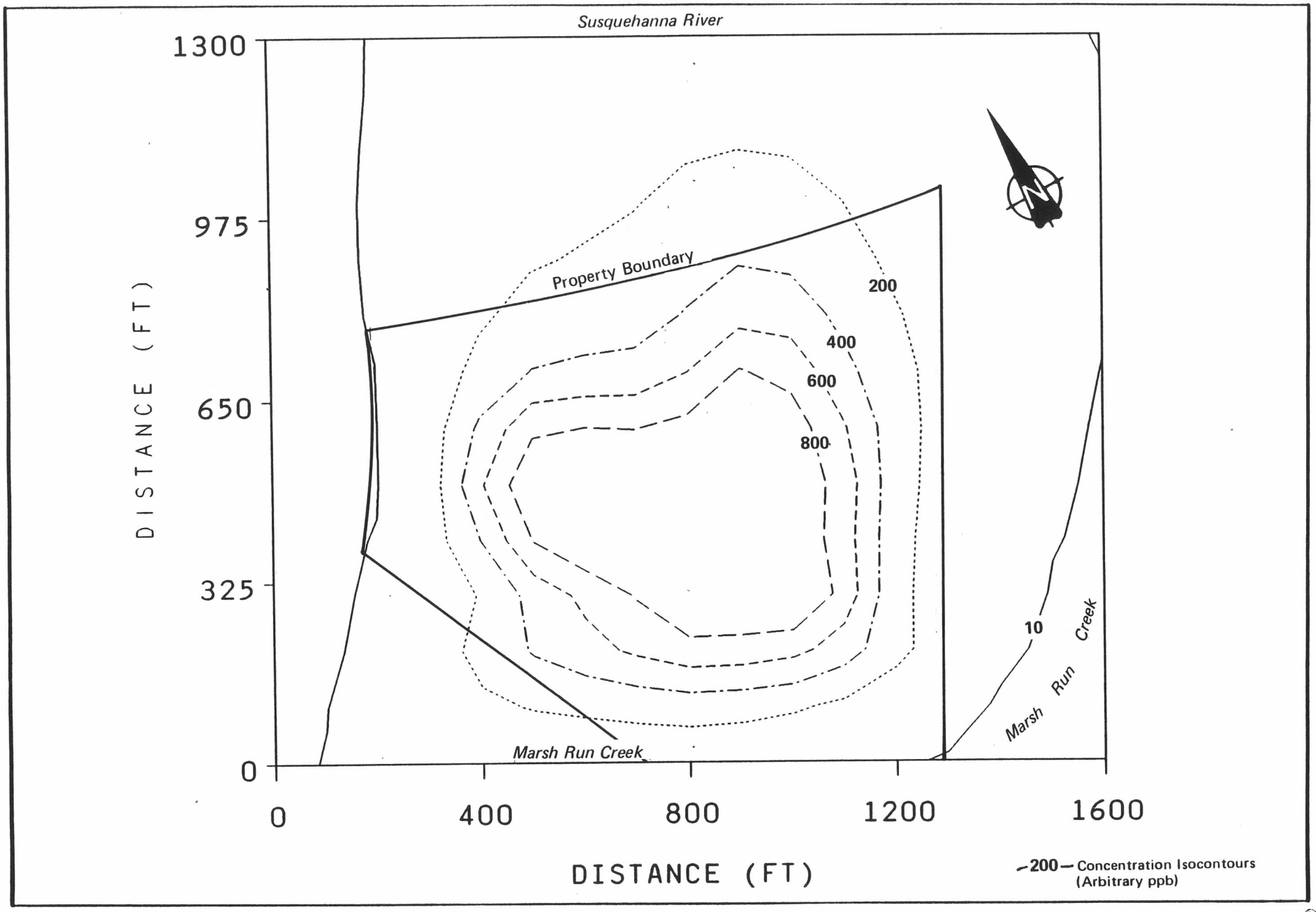


Figure 5-8. Bedrock layer at 20 years.

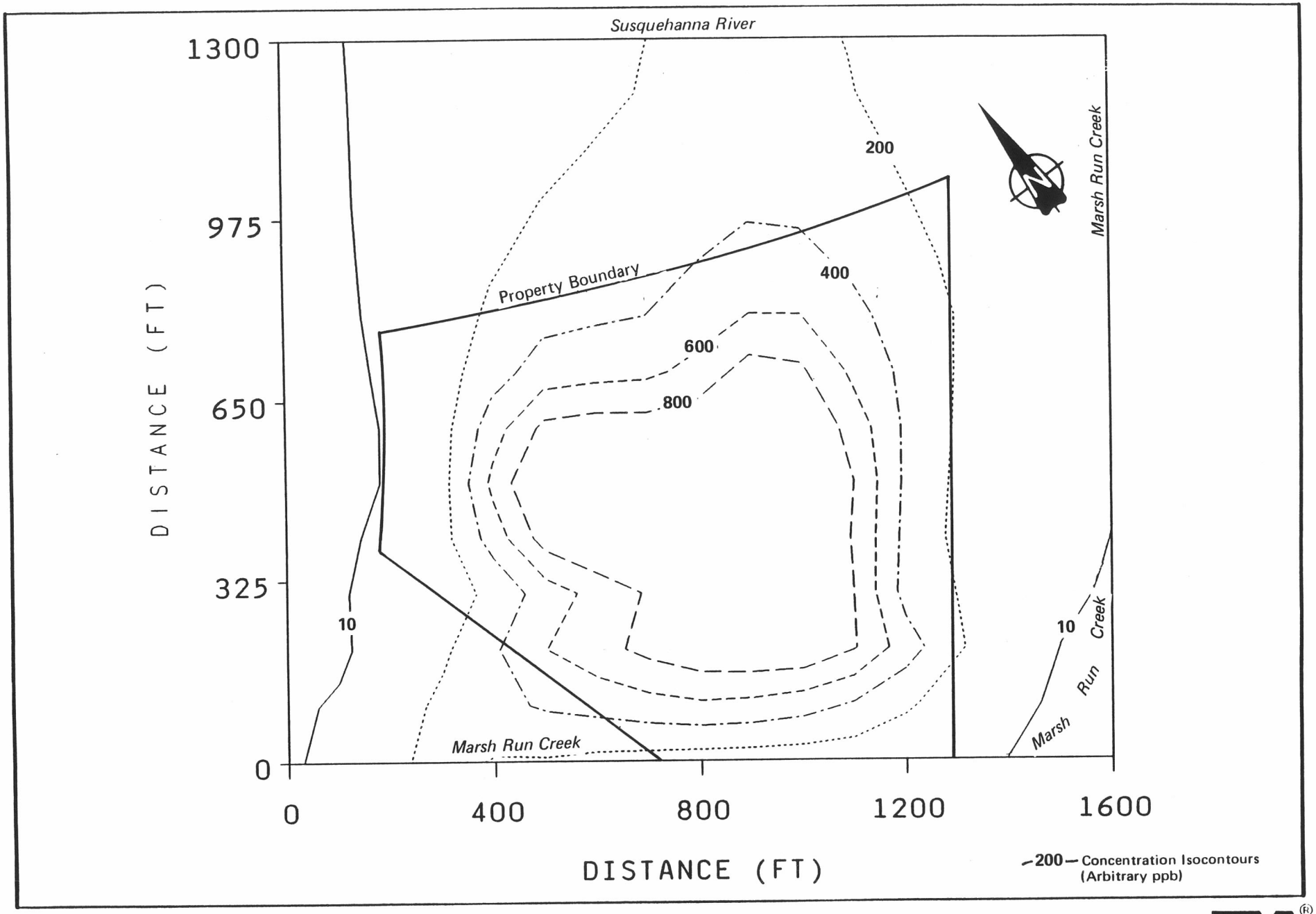


Figure 5-9. Bedrock layer at 30 years.

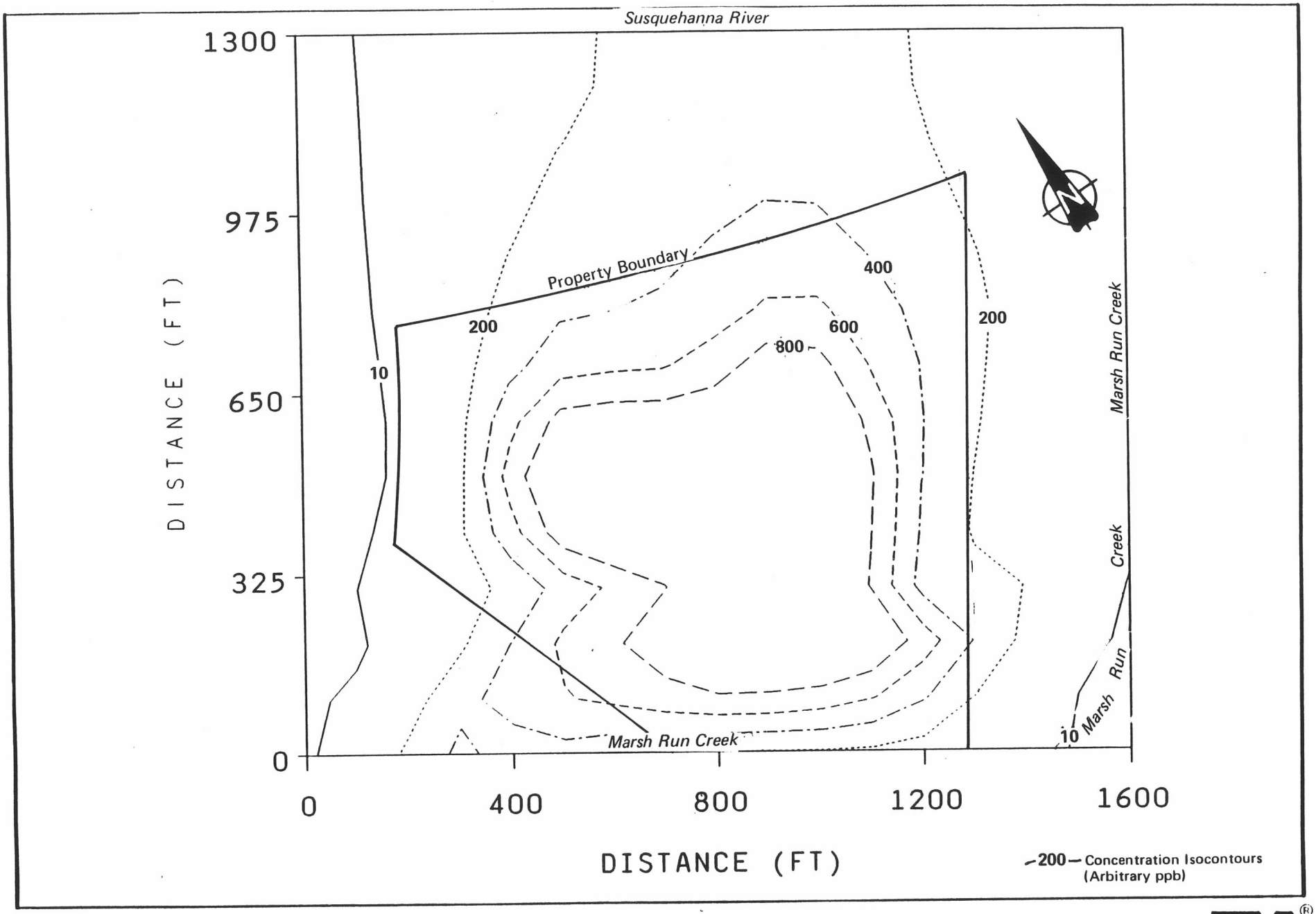


Figure 5-10. Bedrock layer at 40 years.

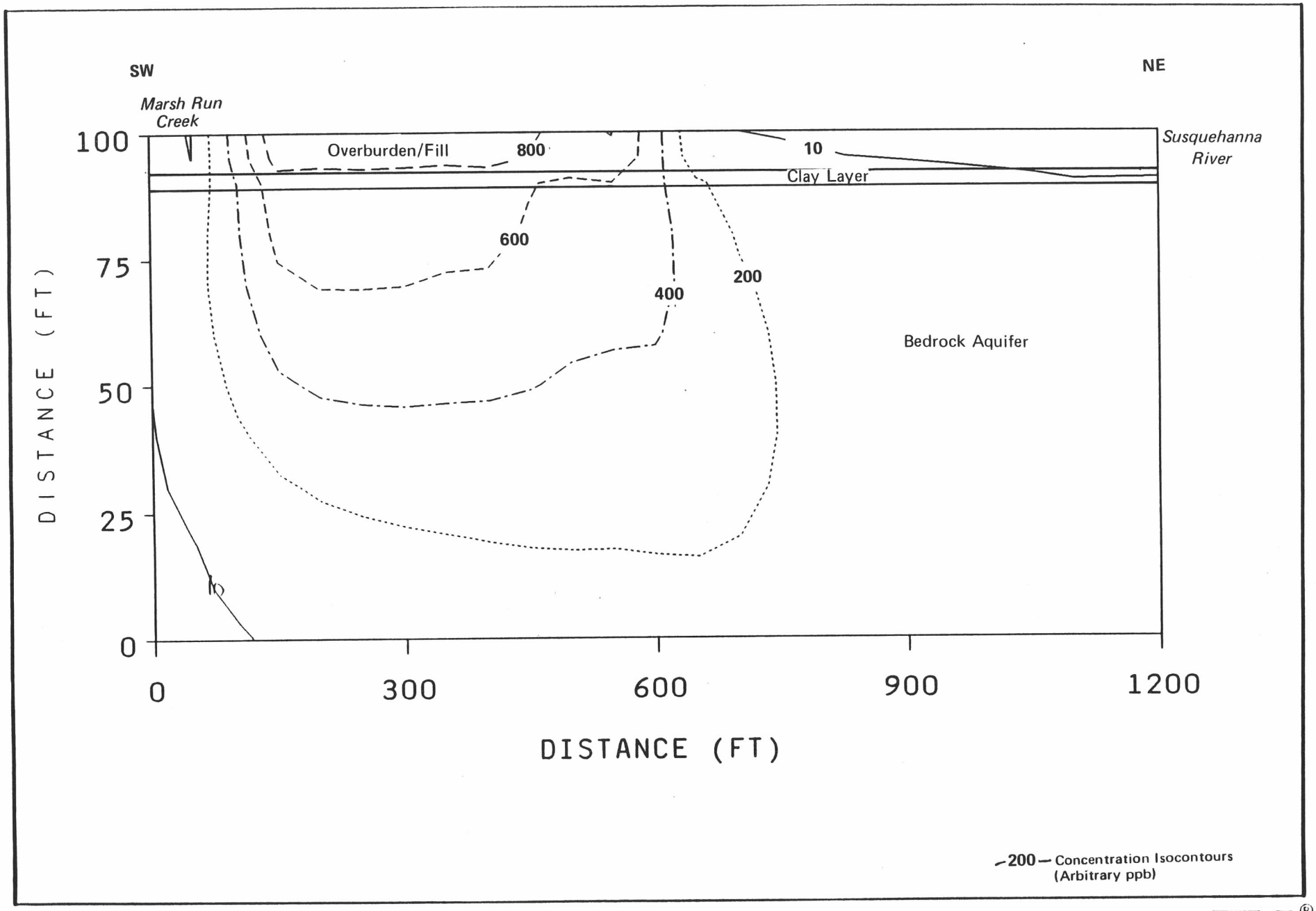


Figure 5-11. Vertical cross-section of contaminant transport in overburden and bedrock at 10 years. (1,000 ppb arbitrary source to overburden)

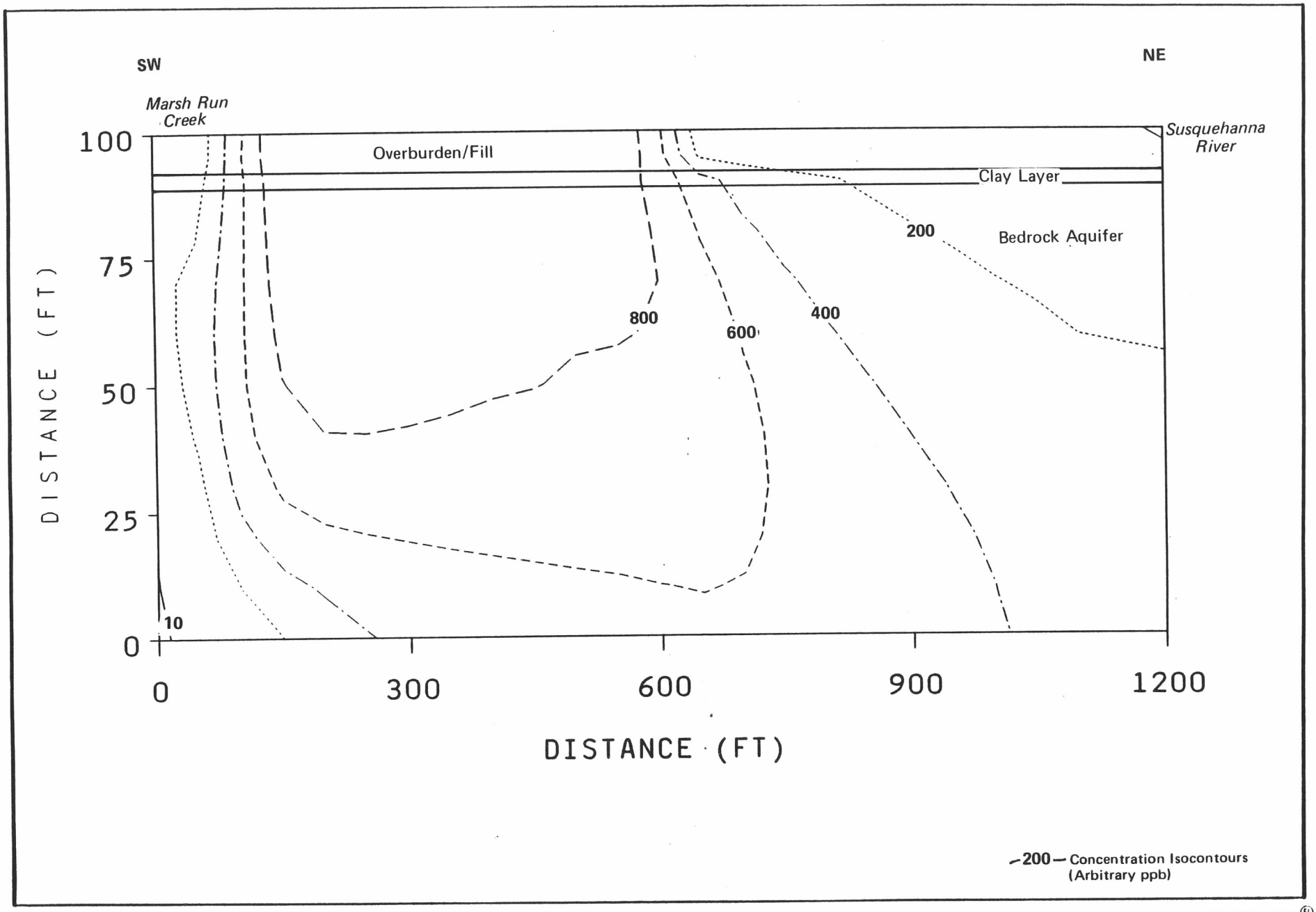


Figure 5-12. Vertical cross-section of contaminant transport in overburden and bedrock at 20 years. (1,000 ppb arbitrary source to overburden)

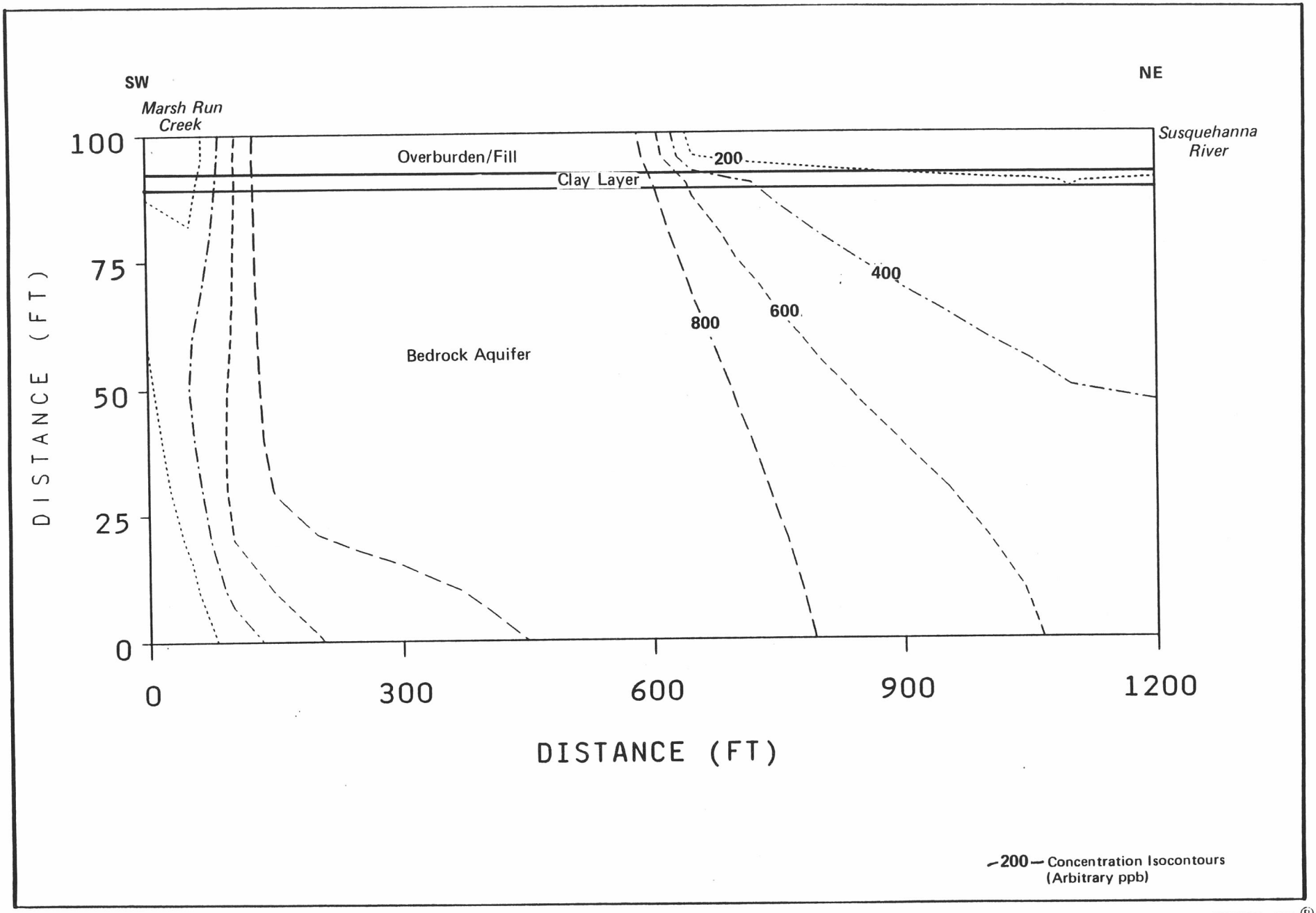


Figure 5-13. Vertical cross-section of contaminant transport in overburden and bedrock at 30 years. (1,000 ppb arbitrary source to overburden)

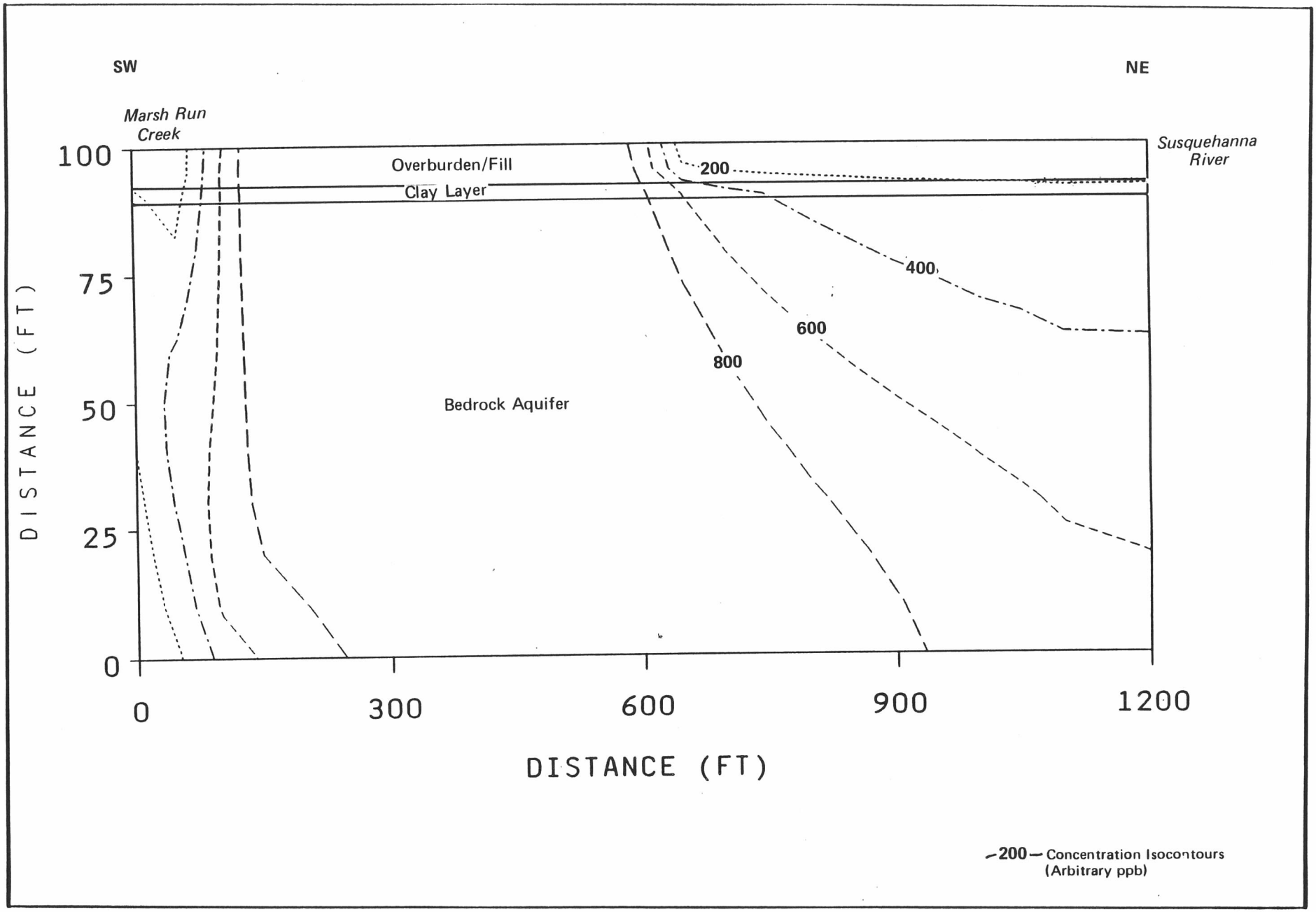


Figure 5-14. Vertical cross-section of contaminant transport in overburden and bedrock at 40 years. (1,000 ppb arbitrary source to overburden)

Comparison of Figures 5-3 through 5-6, which show the movement of the contaminant plume from 10, 20, 30, and 40 years in the overburden, illustrates the relative slow expansion of the plume with time. This scenario further supports the inferred slow lateral migration rates in the overburden and the propensity for vertical migration of contaminants to the bedrock aquifer. As previously stated, a constant source with an arbitrary concentration of 1,000 ppb was continuously applied to the model for the entire 40-year modeling scenario.

In the lower layer (Figures 5-7 through 5-10), the solute plume increases in concentration in the direction towards the Susquehanna River over time. After 10 years the 10 ppb (100:1 dilution) contour had reached the Susquehanna River, while after 30 years the 200 ppb (15:1 dilution) concentration had reached the river. In the lower layer model cells lying under Marsh Run Creek, concentrations had reached a 3.5:1 dilution after 20 years and a 2:1 dilution after 30 years. Both the observed heads and the model indicate that lower layer (bedrock aquifer) flow enters Marsh Run Creek by passing back up through the clay/silt layer. Since the primary hydraulic gradients are from the landfill vicinity towards the stream and Susquehanna River (i.e., north and south), plume movements in the lateral directions (i.e., east and west) are small. In this lateral direction, a 10 ppb (100:1 dilution) concentration took 30 years to reach the model cells directly under Marsh Run Creek where it curves around towards the north.

Since the source is closest to Marsh Run Creek, concentration isocontours are higher nearest Marsh Run Creek than at the Susquehanna River boundary. However, since bedrock ground-water discharge volumes to Marsh Run Creek are lower than to the Susquehanna River, the contaminant flux is not directly proportional to the isocontour at each ground-water discharge boundary.

The concentration mass flux to the environment at each time step is simply the flow rate per unit discharge area times the concentration over the aforementioned area. The mass flux can be characterized as follows, assuming the arbitrary source concentration to be 1,000 µg/L (ppb).

Time Step (Years)	Flux to Marsh Run (grams/day)	Flux to Susquehanna (grams/day)
10	0.000018	0.0006
20	0.00065	0.0059
30	0.0021	0.011
40	0.002	0.014

Since the source age and strength is uncertain and undoubtedly variable with time, no attempt to relate actual observed concentration to the above modeled concentrations was made. Nonetheless, an arbitrary source of 1,000 µg/L has resulted in a lateral distribution of relative concentrations between MW-1 and MW-4 at ratios comparable to observed concentration. For example, the observed ratio of trichloroethene concentration in MW-4 to MW-1 is 1:0.43 (i.e., 400 to 170 µg/L). The model

predictions of the trichloroethene ratio in MW-4 to MW-1 at each time interval are as follows.

Time Interval (Years)	Model Prediction (ratio of contaminants in MW-4:MW-1)
10	1:0.52
20	1:0.62
30	1:0.70
40	1:0.75

The preceding lower layer results are for average concentrations over an assumed 100-ft vertical thickness. In order to develop a better description of the actual plume distribution throughout the multi-layered system, the model was executed in a two-dimensional vertical mode as previously discussed.

Figures 5-11 through 5-14 illustrate a vertical cross section of an arbitrary concentration of 1,000 loaded to the upper overburden layer only. The lower layer bedrock is consequently subject to a time-dependent variable contaminant flux resulting from vertical leakage of upper layer contaminated ground water. This approach in modeling of the cross-sectional area of the upper and lower layer approximates the dissemination effects and relative migration and concentration ratios that could be expected in the respective layers with time.

Comparison of time increments 10, 20, 30, and 40 years clearly depicts the preferential contaminant migration in the bedrock aquifer. Vertical mixing in the bedrock occurs to the full modeled depth of 100 ft. Deeper vertical mixing most likely would occur unless restricted by impermeable lithology at depth. However, any potential deeper flow would ultimately trend towards a regional south to north flow pattern. There are currently no deep wells in the vicinity withdrawing ground water at depths in excess of 100 ft.

Even though the same recharge rate per unit surface area was used in the two-dimensional vertical model as was used in MODFLOW, the hydraulic heads in the lower layer under the landfill were approximately 1.5 ft higher. This resulted in a more pronounced movement of the solute plume towards the Susquehanna River. In the upper layer where the two-dimensional horizontal model showed no concentration buildup between the landfill and the Susquehanna River, the two-dimensional vertical model resulted in approximately 10 concentration units after 10 years and 50 units after 30 years between the landfill and the Susquehanna. The vertical leakage of lesser concentration solute outside of the landfill results in a concentration gradient increasing from below the silt/clay layer to the 100 ft depth. In the lower layer two-dimensional horizontal model, the vertically averaged 200 unit concentration had reached the Susquehanna River boundary after 20 years. In the two-dimensional vertical model at 20 years, the lower layer concentration increased from 130 units directly beneath the clay/silt layer to approximately 300 units at a 100-ft depth.

In summary, the slight discrepancy between the two-dimensional horizontal and two-dimensional vertical model scenarios is a result of the two-dimensional vertical "slice" along row 9 (model grid) inability to allow flow perpendicular to the two-dimensional flow field. Consequently, all flow is forced to travel within the two-dimensional plane of the model, thereby increasing linear flow rates to constant head boundaries.

The uncertainty of the age of contaminants (upon release) and the exact transformation rates occurrences in either the bedrock aquifer or saturated overburden make it difficult to apply a specific source concentration term to either the upper or lower layers. For example, the majority of source loading may have occurred 10, 20, 30 or more years ago. Conversely, the source strength could have increased with time and may be approaching its highest concentration strength. As a more realistic approach, due to the age of the landfill, the source strength is declining and subsequently the speciation of trichloroethene to daughter product is undoubtedly altering the chemistry of the VOC plume. Furthermore, the uncertainty of the northward extent of the VOC plume limits the ability of the model to simulate plume boundaries which would in turn allow for a qualitative dating of the plume (based on migration rates).

In light of the aforementioned uncertainties, the solute transport model's primary functions were:

- To demonstrate the direction and rate of plume movement given the flow conditions and hydrogeologic conditions of the site.

- To illustrate the dilution rates and effect of advective flow on an arbitrary source concentration (1,000) with time.

- To establish when near-equilibrium conditions may be expected from initial onset of plume generation.

It has been reported MacKay and Roberts (1985) that trichloroethene has a retardation factor (i.e., hindrance of migration due to its propensity to chemically interact with aquifer matrix) of 2 to 2.5. For example, a compound with a retardation factor of 2 would be expected to migrate at approximately one-half the linear ground-water velocity at the site. Retardation was purposely omitted from this simulated model to allow for a worst-case migration rate comparable with the linear ground-water velocities at the site.

The model predictions discussed in this section have been based on input parameters that have either been measured at the site or inferred, based on practical application of standard hydrogeologic theories and fundamentals. It is important to recognize that the constraints imposed on any simulation model are those imposed by the limit of knowledge of the governing physical and chemical factors at a particular site. However, confidence in a model can be gained when the observed site conditions compare favorably with the modeled results. An observed condition at Marsh Run Field of critical importance is that no site-derived contamination has been detected in nearby residential wells. Due to the position of Marsh Run Creek, which serves as a hydraulic barrier to underflow of

site ground water further towards the south or east, site-related contamination is not expected to ever reach residences.

It is a highly unlikely scenario that high volume ground-water withdrawal south or east of the site would occur that would alter ground-water flow paths, towards nearby residences. In order to alter ground-water flow paths sufficiently to induce migration of contaminants from the site to the south and east beneath Marsh Run Creek, ground-water withdrawal rates would essentially have to lower potentiometric levels near the residences below the elevation of Marsh Run Creek (i.e., Marsh Run Creek would then become a positive ground-water recharge boundary). Further lowering of the potentiometric surface would have to exceed the ultimate leakage capacity of Marsh Run Creek to the bedrock aquifer. This scenario is unlikely.

5.1.2 Trace Metal Transport in Ground Water

The potential for migration of trace metals is greatly dependent upon external factors seldom measured as part of a site investigation. These factors include several site-specific factors, such as (1) the identity of other ions which enhance or limit mobility through competitive complex formation; (2) cation exchange capacity of the soil; (3) presence of humic materials, hydrous oxides, silicates, and carbonate minerals; (4) oxidizing or reducing conditions; and (5) presence of microbes. The only specific factor measured which influences trace metal mobility was pH of the water. Moreover, important physicochemical properties such as the solubility of inorganics depend upon the identity of the metal complex, which is rarely known. For these reasons, to the extent possible, the migration potential of metals will be evaluated and discussed by a comparison of unfiltered (total) and filtered (dissolved) ground-water sample results.

Elevated levels of the trace metals arsenic, barium, cadmium, chromium, lead, manganese, nickel, and iron were detected both onsite and offsite. The offsite occurrence of elevated levels of trace metals was primarily at the MW-5A and MW-5 locations.

Comparison of filtered (dissolved) and unfiltered (total) samples (Table 4-15) appears to indicate that the majority of elevated trace metals detected in site monitoring wells are in the total phase (i.e., undissolved and a function of suspended solids and turbidity). The only significant elevated concentrations of trace metals in the dissolved phase were for iron in wells MW-2A, MW-3A, MW-5A, WP-1, and WP-2 and lead in wells MW-1A and MW-6 (Dup). The spuriously high dissolved lead in MW-6 (Dup) is questionable due to the relative absence of total lead in MW-6 (Dup).

Comparison of total and dissolved trace metal data in both the bedrock and overburden clearly indicates the propensity for elevated trace metals to be restricted to the saturated overburden. In general, with the exception of MW-5, the elevated trace metals are also restricted to wells hydraulically downgradient of the site. A ground-water sample collected

from offsite and upgradient bedrock well MW-5 exhibited elevated iron, lead, manganese, and nickel in the total phase.

The prevalence of the elevated trace elements of concern only in the suspended or total phase infers that the mobility of these metals will be low. The presence of the underlying clay/silt layer beneath the fill further impedes the migration of these constituents into the bedrock aquifer. In general, clay soils tend to retard metal mobility in comparison to sand soils. Metal immobilizing capacity increases with pH, clay content, cation exchange capacity, and hydrous oxides in the soil or aquifer matrix. The pH values measured at the site ranged from slightly acidic to near neutral (i.e., ph of 5.7 to 7.6).

Trace metal transport and mobility in ground water, and specifically in the bedrock aquifer, does not appear to be a significant contaminant transport mechanism. Furthermore, residential wells, which are located hydraulically upgradient of the site, cannot receive any site-related trace metal contamination.

Any potential transport of trace metals derived from the site, however unlikely, would follow the ground-water flow paths inferred by the ground-water model used to predict organic compound transport. Consequently, flow paths would be towards the north to the Susquehanna and to Marsh Run Creek.

5.2 CONTAMINANT TRANSPORT IN THE SURFACE WATER AND STREAM SEDIMENTS

5.2.1 Organic Contaminant Transport

Interactions between the site ground water and the surface water system (Marsh Run Creek and the Susquehanna River) comprise the mechanism whereby site-derived contamination could potentially migrate. Surface water runoff from the site does not appear to be a contributing factor to volatile organic contamination to Marsh Run Creek, in light of the absence of VOC contamination of the cover soils at Marsh Run Field. With respect to stream surface water contamination, the only significant contaminant detections were low-level concentrations of trichloroethene and 1,2-dichloroethene (total). The low concentrations of trichloroethene were detected at surface water sampling points SWS-2 and SWS-3 at 7 and 6 µg/L, respectively.

As evidenced by the ground-water flow model (Chapter 3), approximately 2,820 gpd of site-derived ground water are discharged to Marsh Run Creek (based on the flow conditions used for modeling) via the bedrock aquifer (to a depth of 100 ft) and saturated overburden. The measured stream flow at SWS-2 was 702,000 gpd. The simple comparison of ground-water discharge from the site into Marsh Run Creek to the cumulative upstream flow at SWS-2 indicates a dilution factor of greater than 240:1. Additional base flow from the south and east sides of Marsh Run Creek and from deeper bedrock zones further increases dilution.

The detection of the low-level volatile compounds trichloroethene, 1,2-dichloroethene, and 1,1,2,2-tetrachloroethene at upstream station

SWS-5 indicates another source of volatile compounds upstream of the site. The detection of trichloroethene at surface water sampling stations SWS-2 and SWS-3 of 6 and 7 µg/L respectively (sampled at a different time than SWS-5) may be the result of an upstream source(s) as well as a potential cumulative effect from Marsh Run Field. SUTRA groundwater modeling predicts an interaction with the surface water and the bedrock aquifer. However, MW-7, located apparently downgradient of the landfill but upgradient of Marsh Run Creek, exhibited no detectable volatile contamination. It is conceivable that concentration levels are very low at this point or that no contamination of ground water in this area has resulted from the landfill facility. It is also conceivable that the primary source of VOC contamination is located far enough to the north of the apparent radial ground-water divide in the bedrock aquifer that no VOC contamination is migrating to the south. The flux predicted by SUTRA was based on a constant arbitrary source which was loaded over the entire landfill area. The absence of the more volatile compound vinyl chloride (which was detected in the well points during the second round) in the surface water is due to the high vapor pressure and propensity for this compound to volatilize easily.

The reported mean flow rate of the Susquehanna River 2 mi upstream of where Marsh Run Creek empties into the river is approximately 30,000 ft^3/second (13,500,000 gpm) and an annual low daily flow rate of approximately 3,000 ft^3/second (1,350,000 gpm). As a conservative assumption using the reported low flow rate of the Susquehanna compared to the estimated flow rate of Marsh Run on 16 August (555 gpm) yields a dilution factor of over 2,400:1. It is clear that surface water transport is not a significant contaminant transport mechanism. Assuming a constant trichloroethene concentration of 7 µg/L in Marsh Run Creek surface water (constant assuming an upstream contributing source) where it empties into the Susquehanna River, the total influx of trichloroethene into the Susquehanna River on a daily basis (at Marsh Run Creek, discharge of 800,000 gpd) would be 0.02 grams of trichloroethene per day. This analysis shows a rather large discrepancy with the modeled flux to Marsh Run Creek using SUTRA (Section 5.1.1.1) of 0.002 after 40 years. This may be in part due to the presence of upgradient sources of trichloroethene in surface water sample SWS-5.

The limitation of the above analysis is simply the uncertainty of the vertical extent in the bedrock aquifer from which flow discharges into Marsh Run Creek.

The other key surface water interaction is the total flux of contamination, specifically trichloroethene from the bedrock aquifer into the Susquehanna River. For worst-case predictions, the highest trichloroethene concentration values detected in site monitoring wells (400 µg/L) times the daily bedrock aquifer discharge (modeled) into the Susquehanna of approximately 13,200 gpd would equate to approximately 0.02 gm/day net flux to the Susquehanna. This value is relatively consistent with the SUTRA flux for 40 years of 0.014 gms/day.

Sediment transport is not considered a transport mechanism of organic contaminants. No volatiles were detected in stream sediments. Semivolatile compounds--specifically PAHs--were detected at low levels in sediment sample SS-5, which is located upstream of the site. These semivolatiles are not considered mobile due to the low stream velocity at this location. The close proximity of SS-5 to a heavy equipment storage area suggests that the source of these semivolatile compounds may be local.

5.2.2 Inorganic Contaminant Transport

Examination of trace metal concentrations in surface water samples (Table 4-19) indicates elevated chromium and lead at SWS-5. Further downstream at SWS-2, both chromium and lead were below detection limits. It appears as if SWS-5 is near a local source of both of these constituents. Elevated concentrations of both chromium and lead are most likely reflective of a suspended load as evidenced by the high values for aluminum, which is not soluble in water of these pH values. Since SWS-5 is upstream of the site, neither lead nor chromium in the surface water is specifically due to Marsh Run Field.

Sediment samples collected at location SS-4 showed slightly elevated lead levels with respect to other sediment samples. These sediments are located in the marsh area east of the site. The area is flat with ponded water or a near-surface water table much of the year. Transport of sediments in this area is not considered significant.

5.3 SOIL TRANSPORT

The transport of contamination from the site soils is not considered to be a significant transport mechanism. The "waste fill" is covered with an approximately 2-ft-thick layer of cover fill of which approximately 6 in. is topsoil reportedly imported from offsite. All of the site cover soils are covered with ground cover and the site is flat. Consequently, erosion and transport due to surface water runoff to Marsh Run Creek is negligible. Fugitive dust emissions are also restrained by the relatively extensive and thick ground cover.

The cover soil placed over Marsh Run Field, although slightly elevated in PAH compounds, does not pose a potential source of these compounds to the ground water. PAHs are relatively immobile in ground water and have a preference for soil with a high organic carbon content. The full extent of contamination of soils and "waste fill" at Marsh Run Field was not completely investigated with test borings; however, ground-water quality data indicate that only leaching of volatile compounds from subsurface fill or reworked soil has affected the ground water. This condition is a direct result of percolation of meteoric waters through the fill.

5.4 CONCLUSIONS

In summary, the fate and transport of contamination derived from Marsh Run Field can be characterized as follows:

- The potential source of volatile organic contamination detected in site monitoring wells is the fill placed at Marsh Run Field. Leaching of the buried waste materials (i.e., "waste fill") by percolating meteoric waters has carried these volatile compounds vertically to the bedrock aquifer. There is also a potential that a remote offsite source of volatile contamination is present, but as of yet, undetected during this investigation. In light of the monitoring well placement, such an undetected source is unlikely. To the degree addressed during this investigation the ground-water flow patterns indicate that the ground-water flow conditions have been adequately assessed.

- The primary transport mechanism of VOCs is most likely by the migration of these constituents under regional and intermediate ground-water flow conditions within the bedrock aquifer to ground-water discharge points at the Susquehanna River and Marsh Run Creek.

- Abiotic and microbial transformation of presumed parent volatile compounds trichloroethene, and possibly tetrachloroethene and 1,1,2,2-tetrachloroethane has resulted in the formation of daughter volatile compounds, specifically 1,2-dichloroethene (total) and possibly vinyl chloride. Vinyl chloride may itself also be a parent compound since it is a commonly used industrial solvent. These daughter compounds are more persistent (resistant to further degradation) than the parent compounds in the environment.

  Vinyl chloride is a highly volatile substance with a maximum contaminant level (MCL) of 2 µg/L (ppb). Concentrations of this compound exceeded the MCL in the saturated overburden. The MCLs are established by the EPA and are enforceable standards for public water supply systems.

- Ground-water modeling of the Marsh Run Field hydrogeologic conditions indicate that the primary migration path of the VOC contamination appears to be in the bedrock towards the north to the Susquehanna River. A southward bedrock aquifer component of flow is quasi-radial towards the intermediate ground-water discharge point, Marsh Run Creek.

- Marsh Run Creek's location with respect to the site, serves as a hydraulic barrier which intercepts all intermediate ground-water discharge from the site. Marsh Run Creek does not allow for ground-water in the bedrock aquifer or saturated overburden to migrate beyond its boundaries to residences to the south, southeast, and east. These residences are also topographically higher in elevation than Marsh Run Field. In order to induce ground-water flow from the site towards the nearby residences, potentiometric levels at the residences would have to be lowered below the water level of

Marsh Run Creek. Marsh Run Creek would then become a positive recharge boundary to the household wells. Presently, the residences are uphill and upgradient of the site and exhibit no apparent site-derived contamination. Under current or realistic future ground- water pumping scenarios, site-derived contamination will not impact the nearby residences.

- Elevated trace metals detected in site monitoring wells appear to be both related to site-derived contamination and from an offsite source. An offsite source is indicated by the elevated trace metals in upgradient monitoring wells MW-5 and MW-5A. The offsite source is presumably west of Marsh Run Field where treated sewage sludge was disposed adjacent to Marsh Run Creek. Based on inferred ground-water paths to the depth investigated (i.e., 50 ft) interaction between an offsite source(s) and onsite source is unlikely due to Marsh Run Creek's role as a hydraulic barrier. However, deeper (i.e., greater than 50 ft) interaction for both organic and inorganic offsite and onsite source(s) was not fully investigated during this RI.

- Trace metal mobility in ground water is low based on the comparison of dissolved (filtered) and total (nonfiltered) in the ground water. Ground-water data show elevated metals to be primarily restricted to the suspended solids (undissolved phase).

- The surface water of Marsh Run Creek has exhibited low levels of volatile organic concentrations adjacent to Marsh Run Field. However, surface water samples collected upstream have also shown similar compounds and concentrations. Although an upstream source of VOC contamination of Marsh Run Creek is evident, ground-water modeling indicates that ground-water base flow to Marsh Run Creek from the overburden and bedrock aquifer may also contribute to low-level surface water VOC contamination. This condition was not evident in MW-7, which is situated between Marsh Run Field and Marsh Run Creek.

- Both VOC solute mass flux via ground water to the Susquehanna and the resultant solute mass flux of Marsh Run Creek surface water discharge to the Susquehanna are greatly diluted by the Susquehanna River.

  Figure 5-15 illustrates an ideal diagram of solute mass flux to the environment based on observed conditions and ground-water modeling.

- Migration of contaminants via soil erosion or dust emissions is not a significant transport mechanism.

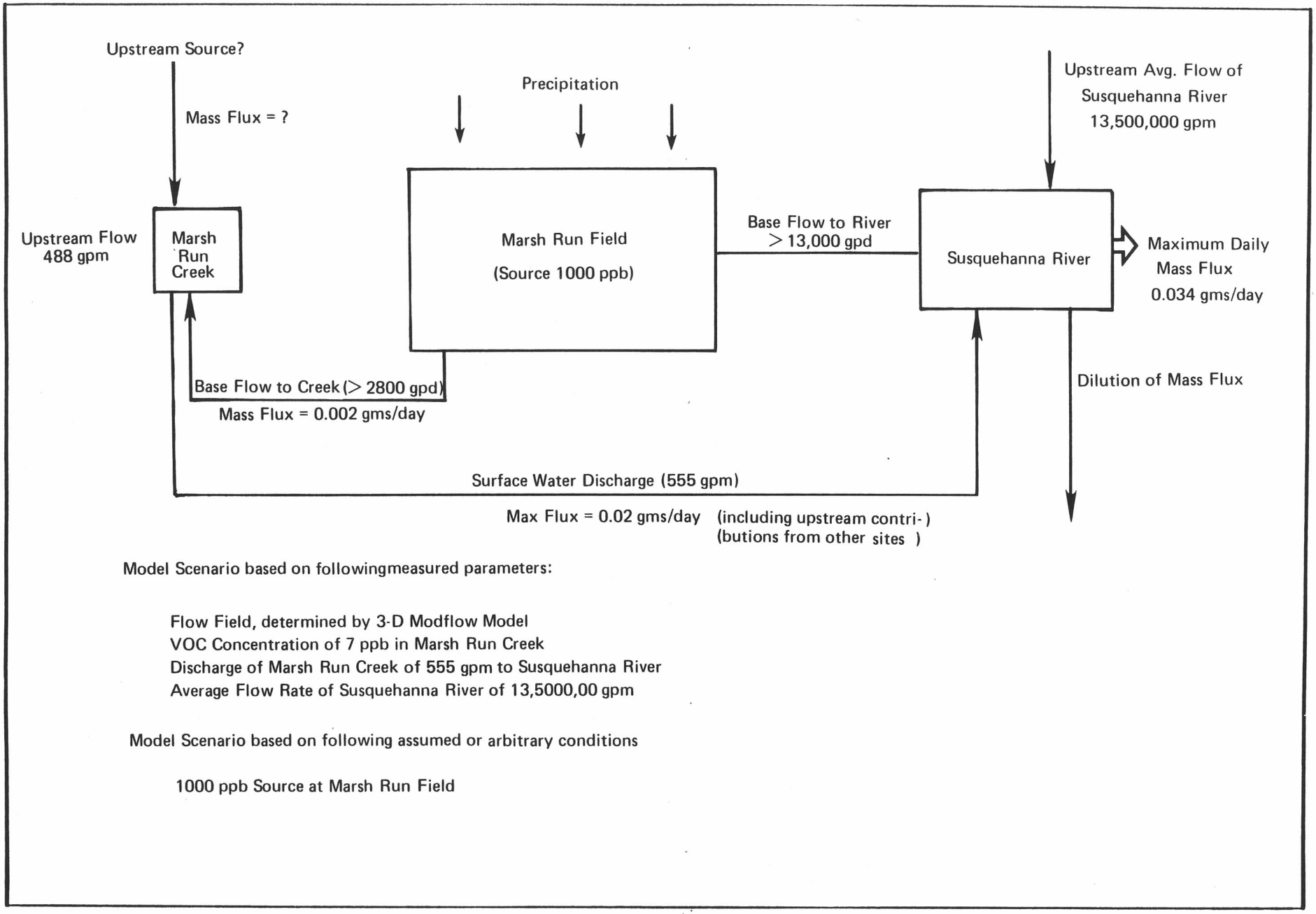


Figure 5-15. Schematic of idealized solute daily mass transport flux (assumed arbitrary source of 1000 ppb) - 40 yr. model scenario.

6. BASELINE RISK ASSESSMENT

This risk assessment evaluates Marsh Run Field, which is adjacent to the New Cumberland Army Depot (NCAD) in Fairview Township, York County, Pennsylvania. The site is of concern because it was formerly owned by NCAD and used by the depot as a landfill. Beginning in the early 1900s, waste material of various kinds was deposited on the marshy ground of the original site. In 1976, the site was sold to Fairview Township, which used it as a soccer field until 1987. The site is currently covered with low, thick vegetation. Site background is given in detail in Chapter 1 of this report. The sampling carried out for the remedial investigation is described in Chapter 2 and results of field investigations are given in Chapter 3.

This risk assessment consists of two parts, the human health evaluation and the environmental evaluation. The overall objective of the assessment is to evaluate effects on humans and on the environment from releases from the site. The assessment considered releases from the former landfill site to ground water, to surface water and sediment, to soil, and to air.

6.1 HUMAN HEALTH EVALUATION

The human health risk assessment considered the following topics: (1) contaminants detected during the remedial investigation at the site; (2) potential environmental pathways by which populations might be exposed to compounds released from the site; (3) estimated exposure point concentrations of the compounds of concern; (4) estimated intake levels of the compounds of concern; (5) toxicity values of the compounds of concern; (6) past, current, and future land-use conditions; and (7) uncertainties in the exposure and toxicity assessments. The level of risk that the site posed to human health was then quantified and discussed.

6.2 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

The nature and extent of contamination in various media on or surrounding the site have been discussed in detail in Chapter 4 and will not be repeated here. In this section, chemicals of potential concern in different media are identified and data management conventions used in the risk assessment are discussed.

Chemicals of potential concern are defined as chemicals detected during sample analysis and considered likely to have originated from site-related activities. Since the number of compounds detected at the site in any one media was reasonable, all compounds could be considered in the human health evaluation, i.e., selection of a subset of indicator chemicals was not necessary.

The identification of chemicals of potential concern does eliminate those chemicals associated with sampling or laboratory contamination and those chemicals that were detected at naturally occurring levels.

The following guidelines were used in identifying chemicals of potential concern:

- Chemicals present in site samples at levels similar to those in trip, rinsate, or method blanks were not considered to be site-related. These values were indicated in the data tables by the qualifiers S or M and were handled in the risk assessment in the same manner as nondetected values, i.e., one-half the qualified value was used.

- Levels of inorganic chemicals detected in various media were compared with naturally occurring levels to determine if sample concentrations were elevated significantly above background levels. Maximum inorganic levels which were within the range of elemental concentrations available in the literature or which were within two times the concentrations of background measurements taken during sampling, were considered to be naturally occurring and were not further evaluated in the risk assessment.

The following guidelines were used in managing the analytic data for the chemicals identified as being of potential concern:

- Analytic chemical data were summarized by calculating arithmetic means as a measure of average concentrations and by determining the maximum concentrations of each chemical in each medium sampled at or about the site.

- In calculating arithmetic means, one-half the sample quantitation limit (or one-half the contract required quantitation limit in the case of ground water) was used as the value for those samples in which a compound was not detected.

- In the case of duplicate samples, the duplicates were first averaged, and this result was then averaged with other sample values.

- In evaluating data for polycyclic aromatic hydrocarbons (PAHs), noncarcinogenic PAHs (ncPAHs) were evaluated separately from carcinogenic PAHs (cPAHs).

In addition to these general guidelines, sampling and data management issues specific to soil, surface water/sediment, and ground water are discussed in the following sections.

6.2.1 Soils

In May and June, 1988, 8 and 15 surface soil samples from Marsh Run Field were collected by the Army Corps of Engineers (COE) and EPA's Technical Assistance Team (TAT), respectively, and analyzed for volatile organic chemicals (VOCs), semivolatile organic chemicals, and inorganic chemicals. These data are presented in detail in Tables 1-6 and 1-7. Based on these analyses, chemicals of potential concern in surface soils are listed in Table 6-1 and include ncPAHs, cPAHs, three phthalate esters,

TABLE 6-1 CHEMICALS OF POTENTIAL CONCERN IN SURFACE SOILS AT THE MARSH RUN FIELD SITE, NEW CUMBERLAND, PA[a]

Chemical	Average (mg/kg)	Reasonable Worst Case (mg/kg)	Frequency of Detection
ncPAHs (c)	3.63	21.7	7/17
cPAHs (d)	2.94	20.2	4/17
Diethylphthalate	0.15	0.19	6/17
Di-n-butylphthalate	0.8	1.12	7/17
bis(2-Ethylhexyl) phthalate	0.8	1.60	5/17
Cadmium	2.55	5.7	10/17
Copper	61.5	797	17/17
Lead	111	1,080	17/17
Mercury	0.19	0.36	11/17
Selenium	1.01	3.8	15/17
Silver	0.64	5.6	2/17
Thallium	4.5	16	3/17
Zinc	138	1,510	17/17
Cyanide (total)	0.25	1.75	1/17

(a) Values are based on results of sampling conducted by the COE and EPA TAT in June 1988.
(b) NR = not reported. Due to detection limit values, average values were calculated to be higher than the maximum detected value; therefore averages were not reported.
(c) Noncarcinogenic PAHs include acenaphthene, anthracene, bezo(g,h,i) perylene, fluoranthene, fluorene, naphthalene, phenanthrene, pyrene, and 2-methylnaphthalene.
(d) Carcinogenic PAHs include benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h) anthracene, and indeno(1,2,3-c-d)pyrene.

eight metals, and total cyanide. One of these samples, sample SS-7 collected by the ACE, was considered to be representative of background concentrations; however, this location was fairly close to the site sample locations; therefore, USGS (1984) was used to compare site inorganic concentrations with elemental naturally occurring levels. In ACE data in Table 1-6, samples SS2D and SS8D were duplicate samples and were averaged with SS2 and SS8, respectively. SS7 was background and was omitted from averaging. This left seven samples collected by ACE. From the EPA TAT data in Table 1-7, the 10 samples S1 to S10 were included. Sample S11 was background and the last four samples in the table were subsurface samples. As a result of this evaluation, arsenic, nickel, and chromium sample concentrations were determined to be within background levels and these elements were not further evaluated.

6.2.2 Surface Water/Sediments

During the RI, four surface water/sediment samples were collected from Marsh Run Creek, one upstream of both the site and the depot, one on NCAD property upstream of Marsh Run Field and two downstream of the site. In addition, one surface water/sediment sample was collected from the marshy area directly east of the site. Both water and sediment samples were analyzed for VOCs, semivolatile organic compounds, pesticides, PCBs, metals, and total cyanide. Surface water and sediment data from the RI samples are presented in Tables 4-18, 4-19, and 4-20.

Organic chemicals of potential concern for surface water samples are trans-1,2-dichloroethene (reported as 1,2-dichloroethene, total), trichloroethene, tetrachloroethane, ncPAHs, 4,4'-DDE, and 4,4'-DDD. Downstream surface water concentrations of arsenic, calcium, magnesium, potassium, and silicon were within twice the respective concentrations detected in the upstream sample; therefore, these chemicals were not evaluated further in this risk assessment. Concentrations of the nine inorganic chemicals which were significantly elevated above background in the downstream samples, along with organic levels, are presented in Table 6-2.

Organic chemicals of potential concern for sediment samples are ncPAHs, cPAHs, diethylphthalate, di-n-butyl phthalate, bis(2-ethylhexyl)phthalate, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT. Concentrations of aluminum, barium, beryllium, chromium, cobalt, copper, iron, magnesium, mercury, nickel, potassium, selenium, sodium, and vanadium were within ranges of background values measured by USGS (1984) in this region; therefore, these elements were not further considered in this risk assessment. Concentrations of the remaining six inorganic chemicals detected above naturally occurring levels, as well as concentrations of the organic chemicals and cyanide, are presented in Table 6-2.

6.2.3 Ground Water

Ground water was sampled in two phases during the RI. Phase I sampling was carried out in February 1989 and included sampling five shallow and three deep wells as described in Chapter 2. Phase II was done in August

TABLE 6-2 CHEMICALS OF POTENTIAL CONCERN IN SURFACE WATER/SEDIMENTS AT THE MARSH RUN FIELD SITE, NEW CUMBERLAND, PA[a]

Chemical	Average	Reasonable Worst Case	Frequency of Detection
Surface Water (mg/liter):			
Trichloroethene	0.005	0.007	3/4
1,2-Dichloroethene (total)	NR(b)	0.001	1/4
Tetrachloroethane	NR(b)	0.002	1/4
ncPAHs (a)	0.0067	0.007	1/4
4,4'-DDE	0.000075	0.0001	1/4
4,4'-DDD	0.00013	0.00038	1/4
Aluminum	2.52	8.50	3/4
Barium	0.077	0.177	4/4
Chromium	0.0038	0.012	1/4
Copper	0.0082	0.013	1/4
Iron	4.82	16.4	4/4
Lead	0.011	0.038	1/4
Manganese	0.368	0.860	4/4
Vanadium	0.0078	0.016	1/4
Zinc	0.085	0.168	2/4
Sediments (mg/kg):			
ncPAHs (b)	1.51	5.53	1/4
cPAHs (c)	1.10	3.92	1/4
Diethylphthalate	NR(b)	0.15	1/4
Di-n-butylphthalate	0.182	0.24	1/4
bis(2-Ethylhexyl) phthalate	0.166	0.17	1/4
4,4'-DDE	0.151	0.580	1/4
4,4'-DDD	0.034	0.11	1/4
4,4'-DDT	0.068	0.245	1/4
Antimony	NR(b)	5	1/4
Arsenic	21.5	36.4	4/4
Cadmium	0.82	1.6	3/4
Lead	27.3	74.5	2/4
Manganese	350	726	4/4
Zinc	60.6	112	2/4
Cyanide (total)	0.28	0.34	3/4

(a) Values in table are based on sampling conducted during the RI.
(b) NR = not reported. Due to detection limit values, average values were calculated to be higher than the maximum detected value; therefore averages were not reported.

1989 and consisted of sampling seven shallow and six deep wells. Monitoring wells 1, 1A, 2, 2A, 3A, 4, 4A, 7, and 7A are considered to be influenced by the site (see Figure 2-1). Monitoring wells 5 and 5A are across Marsh Run Creek from the site and are not influenced by the site since the creek acts as a hydraulic barrier. Monitoring wells 6 and 6A are upgradient of the site and not subject to radial flow from the site.

Ground-water data are presented in Tables 4-12, 4-14, and 4-17. In these tables the only volatile and semivolatile compounds listed are those which were detected in at least one of the Phase I or Phase II samples. No pesticides nor PCBs are listed because none were detected in any of the samples. The metals initially included for consideration include the 23 metals on the target compound list plus boron, molybdenum, and silicon. For ground water, when a compound was not detected, one-half the contract required quantification limit (CRQL) was used as the value of the concentration. Since all samples were analyzed in EA Laboratories under the Contract Laboratory Program, the instrument detection limits were less than or equal to the CRQLs. The CRQLs which were used are shown in Table 6-3.

Table 6-4 summarizes the ground-water data and gives the average concentration for each well for each compound detected. Table 6-4 includes eight VOCs which were carried through the risk assessment. Three VOCs included in Table 4-12 were omitted from further consideration. Toluene and vinyl chloride were not detected in any of the ground water monitoring wells. (Vinyl chloride was detected in the waste itself at well points 1 and 3.) Tetrachloroethene was detected in well MW-4 at less than one-half the CRQL.

Table 6-4 lists only one semivolatile compound. Other semivolatiles listed in Table 4-12 were omitted from further consideration because, in the case of fluoranthene and pyrene, the compounds were not detected in any monitoring well and, in the case of benzoic acid, the compound was detected at less than the CRQL in an offsite well (MW-5A).

Several metals were deleted from further consideration because they were not detected in any ground-water monitoring wells. These metals were antimony, silver, thallium, and molybdenum. Other metals were included in Table 6-4 but were not further considered in the risk assessment because they were considered to be within the range of natural occurrence. Specifically, the maximum average concentration in onsite wells was less than twice the maximum average concentration found in the background wells (wells 5, 5A, 6, and 6A). Metals excluded because they fall within naturally occurring background ranges include aluminum, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, lead, magnesium, manganese, mercury, nickel, selenium, sodium, vanadium, zinc, and silicon.

Of the compounds listed in Table 4-17, cyanide was dropped from further quantification because it was not detected in any wells. Fluoride was included in the risk assessment.

TABLE 6-3 CONTRACT REQUIRED QUANTIFICAL LIMITS (CRQLs) FOR COMPOUNDS DETECTED IN GROUND WATER AT MARSH RUN FIELD, 1989

Volatiles	CRQL (µg/L)
Ethylbenzene	5
1,1-Dichloroethene	5
1,1,2,2-Tetrachloroethane	5
Trichloroethene	5
Toluene	5
Acetone	10
Methylene Chloride	5
1,2-Dichloroethene (total)	5
Vinyl Chloride	10
1,1,2-Trichloroethane	5
Tetrachloroethene	5

Semivolatiles	CRQL (µg/L)
bis(2-ethylhexyl)phthalate	10
Benzoic Acid	50
Fluoranthene	10
Pyrene	10

Other Inorganics	CRQL (µg/L)
Cyanide	---(c)
Fluoride	200(a)

Metals	CRQL (µg/L)
Aluminum	200
Antimony	60
Arsenic	10
Barium	200
Beryllium	5
Cadmium	5
Calcium	5,000
Chromium	10
Cobalt	50
Copper	25
Iron	100
Lead	5
Magnesium	5,000
Manganese	15
Mercury	0.2
Nickel	40
Potassium	5,000
Selenium	5
Silver	10
Sodium	5,000
Thallium	10
Vanadium	50
Zinc	20
Boron	30(a)
Molybdenum	20(a)
Silicon	--(b)

(a) Not on target compound list. Maximum instrument detection limit used.
(b) Compound always detected.
(c) Compound never detected, and therefore omitted from risk assessment.

TABLE 6-4 AVERAGE GROUND-WATER CONCENTRATIONS (μg/L) IN MONITORING WELLS AT MARSH RUN FIELD FOR COMPOUNDS INCLUDED IN THE HUMAN HEALTH RISK ASSESSMENT

	MW-1	MW-1A	MW-2	MW-2A	MW-3A	MW-4	MW-4A
Volatiles							
Ethylbenzene	3.0	2.5	2.5	11.8 (b)	2.5	2.5	2.5
1,1-Dichloroethene	7.3 (b)	2.5	2.5	2.5	2.5	2.5	2.5
1,1,2,2-Tetrachloroethane	39.5 (b)	4.8	2.5	2.5	2.5	2.8	1.8
Trichloroethene	165.0	13.3	2.5	2.5	2.5	387.5 (b)	4.3
Acetone	5.0	5.0	5.0	5.0	5.0	10.5 (b)	5.0
Methylene Chloride	2.5	2.5	2.5	6.8 (b)	2.5	2.5	2.5
1,2-Dichloroethene (total)	23.8	42.3	2.5	12.6	2.5	67.3 (b)	3.8
1,1,2-Trichloroethane	3.8	2.5	2.5	2.5	2.5	6.3 (b)	2.5
Semivolatiles							
bis(2-ethylhexyl)phthalate	5.0	15.5 (b)	5.0	5.0	5.0	5.0	4.5
Metals							
Aluminum (c)	828	65,250	2,570	7,723	21,070	5,764	189,000 (b)
Arsenic (c)	5.0	44.4	5.0	10.0	8.0	9.6	77.6 (b)
Barium (c)	488	510	252	182	228	406	1,599 (b)
Beryllium (c)	1.7	3.0	2.5	2.5	2.3	1.7	7.2 (b)
Cadmium (c)	2.5	3.7	2.5	2.5	6.3	2.5	28.0 (b)
Calcium (c)	78,950	74,750	64,150	133,750	222,500 (b)	95,500	56,900
Chromium (c)	5.0	42.4	5.0	10.9	31.5	8.2	106.7 (b)
Cobalt (c)	25.0	31.2	25.0	33.7	25.0	19.9	81.8 (b)
Copper (c)	12.5	38.4	12.5	12.5	30.5	20.9	96.9 (b)
Iron (c)	637	97,100	1,950	20,775	30,790	7,723	374,500 (b)
Lead (c)	2.5	19.7	1.6	6.8	24.5	8.7	56.7 (b)
Magnesium (c)	13,550	22,900	16,450	51,375	45,100	23,775	57,800 (b)
Manganese (c)	63	4,125	44	4,943	872	642	10,800 (b)
Mercury (c)	0.29	0.32	0.10	0.29	0.31	0.32 (b)	0.32
Nickel (c)	20.0	95.5	20.0	29.8	38.8	20.0	102.3 (b)
Potassium (c)	2,130	10,000	1,525	3,873	10,485	3,070	15,400 (b)
Selenium (c)	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Sodium (c)	8,505	9,365	8,240	19,300	14,100	11,150	8,295
Vanadium (c)	25.0	103.6	25.0	23.5	48.8	25.0	357.5 (b)
Zinc (c)	92	299	18	68	220	97	834 (b)
Boron	47.2	54.5	15.0	88.2	499.5 (b)	36.0	24.0
Silicon (c)	13,450	43,450	16,000	29,100	50,500	23,350	119,500 (b)
Other Inorganics							
Fluoride	100	100	100	350 (b)	200	100	100

(a) Onsite wells are 1, 1A, 2, 2A, 3A, 4, 4A, 7, and 7A
(b) Maximum average of onsite wells
(c) Omitted from further consideration since maximum average concentration is within range of natural occurrence.

TABLE 6-4 EXTENDED

	MW-5	MW-5A	MW-6	MW-6A	MW-7	MW-7A	Average of Onsite Wells[a]
Volatiles							
Ethylbenzene	2.5	2.5	2.5	2.5	2.5	2.5	3.6
1,1-Dichloroethene	2.5	2.5	2.5	2.5	2.5	2.5	3.0
1,1,2,2-Tetrachloroethane	2.5	2.5	2.5	2.5	2.5	2.5	6.8
Trichloroethene	2.5	2.5	2.5	2.5	2.5	2.5	64.7
Acetone	5.0	23.0	5.0	5.0	5.0	5.0	5.6
Methylene Chloride	2.5	2.5	2.5	2.5	2.5	2.5	3.0
1,2-Dichloroethene (total)	2.5	2.5	2.5	2.5	2.5	2.5	17.7
1,1,2-Trichloroethane	2.5	2.5	2.5	2.5	2.5	2.5	3.1
Semivolatiles							
bis(2-ethylhexyl)phthalate	5.0	5.0	5.0	5.0	5.0	5.0	6.1
Metals							
Aluminum	15,750	137,250	232	5,950	2,250	5,220	33,297
Arsenic	16.7	38.4	8.9	5.0	5.0	5.0	18.8
Barium	393	1,133	231	187	293	779	526
Beryllium	2.2	9.2	2.5	2.5	2.5	2.5	2.9
Cadmium	2.5	17.2	2.5	2.5	2.5	2.5	5.9
Calcium	111,650	84,250	49,300	144,000	119,000	173,000	113,167
Chromium	32.7	188.5	5.0	5.0	5.0	14.9	25.5
Cobalt	25.2	101.0	25.0	25.0	25.0	25.0	32.4
Copper	14.8	105.8	12.5	12.5	12.5	19.1	28.4
Iron	24,245	171,650	174	8,820	1,350	10,900	60,636
Lead	11.2	86.5	2.5	11.1	2.5	5.2	14.2
Magnesium	30,100	34,900	16,800	57,900	30,300	50,900	34,683
Manganese	962	10,130	17	1,760	148	2,120	2,640
Mercury	0.62	0.70	0.45	0.10	0.10	0.10	0.24
Nickel	40.9	145.0	20.0	20.0	20.0	23.5	41.1
Potassium	7,395	6,620	1,815	2,210	3,350	3,020	5,873
Selenium	1.9	2.5	2.2	1.5	2.5	2.5	2.5
Sodium	63,850	68,650	10,250	234,000	16,900	48,200[b]	16,006
Vanadium	39.7	274.0	25.0	14.5	25.0	25.0	73.1
Zinc	132	658	13	41	18	51	188
Boron	15.0	15.0	159.0	55.0	15.0	60.5	93.3
Silicon	37,550	95,250	11,250	15,700	16,800	28,500	37,850
Other							
Fluoride	100	100	100	100	100	200	150

6.2.4 Summary of Chemicals of Potential Concern

Tables 6-1, 6-2, and 6-4 list chemicals of potential concern for soil, surface water/sediments, and ground water, respectively. These are the compounds which were carried through the analysis to quantify the risk posed to humans by releases from the site.

The approximately 14-acre site was handled in the risk assessment as one operable unit, because at this point there was no reason to consider separate segments of the site.

6.3 EXPOSURE ASSESSMENT

This section addresses the potential pathways by which human populations, under past, current, and future land use conditions, were or may be exposed to chemicals of potential concern in various media onsite or associated with the site.

As discussed in U.S. EPA (1989c), an exposure pathway generally consists of the following four elements:

- a source and mechanism of chemical release,
- a retention or transport medium (or media in cases involving media transfer of chemicals),
- a point of potential human contact with the contaminated medium (i.e., the exposure point),
- an exposure route at the contact point.

An exposure pathway is considered complete only if each of these elements is present. The first two components have been discussed in detail in previous sections of this RI. In this section, the third and fourth components are discussed. Potential exposures of humans to site contamination on and adjacent to the site under both current and future land use conditions are evaluated, and the routes through which these individuals may be exposed are discussed.

6.3.1 Exposures under Past Land Use Conditions

The Marsh Run Field site is a 14-acre inactive landfill previously used by the New Cumberland Army Depot for the landfilling of wastes originating from the base. Disposal was conducted in a wetlands area, and the landfill currently rises several feet above the surrounding wetlands. The site has been covered by 1 to 2 ft of soils excavated from a borrow area directly adjacent to and north of the fill area. The site was purchased from the Army by Fairview Township and was used by the Township as a soccer field until 1987.

Risk assessments traditionally consider exposures under current and future land use conditions. However, in the case of Marsh Run Field, one route of exposure associated with past use of the site will be considered. Because the site was used as a soccer field, children playing on the site were exposed to surface soils. Children are considered a sensitive population, and therefore their exposure to surface soil under

a past use scenario will be quantified. Three means of exposure to surface soil were quantified, dermal contact, incidental ingestion, and dust inhalation.

Past exposures to surface water, sediment, and ground water were not evaluated. These exposure media are considered in detail under current and future land use scenarios.

6.3.2 Exposures under Current Land Use Conditions

Currently, the Marsh Run Field site is covered with thick, undisturbed vegetation (primarily fescue grass) and is not used for any recreational or residential activities. There are scattered residences in the area surrounding the site, including one residence which borders the site to the southeast and a few which are situated across Marsh Run Creek from the landfill. The following paragraphs discuss potential pathways under current land uses. These pathways are summarized in Table 6-5.

6.3.2.1 Ground Water

Local residents use ground water as their drinking water supply. During the RI, residential wells at four residences along Marsh Run Road were sampled. The results of the chemical analysis of these residential samples are given in Tables 4-21, 4-22, and 4-23. These tables show that no volatile compounds, pesticides, or PCBs were detected in any residential well. Metals detected in the residential wells are all within the range of natural occurrence in ground water in the area.

One semivolatile compound, benzoic acid, was detected in one residential well. The concentration of benzoic acid in this sample was estimated at 3 µg/L, well below the contract required quantification limit of 50 µg/L. This means that benzoic acid was positively identified in the sample but at a concentration too low to accurately quantify. According to U.S. EPA guidance on the chemical analysis of this compound, an EPA Contract Laboratory must be able to quantify this compound at concentrations over 50 µg/L, i.e., 3 µg/L would formerly have been identified as a trace.

Benzoic acid was not detected in any onsite wells. Therefore, the compound is not site-derived. It was detected at trace level in well MW-5A which is across Marsh Run Creek from the site. This monitoring well is the well nearest the residence in which the compound was also detected.

There is very little toxicity data on benzoic acid (U.S. EPA 1989b). The oral RfD for this compound is 4E+0 mg/kg·day. (See the discussion on toxicity values in Section 6.4.) The weight of evidence of carcinogenicity is D, indicating that there is insufficient data to classify the compound. This is as close as U.S. EPA comes to stating that a compound does not cause cancer. There are no health advisories available and no drinking water standards have been established, indicating that this compound is not a concern via drinking water.

TABLE 6-5 SUMMARY OF POTENTIAL EXPOSURE PATHWAYS UNDER CURRENT LAND USE MARSH RUN FIELD SITE, NEW CUMBERLAND, PA

Potentially Exposed Population	Exposure Pathway	Selected for Evaluation?	Reason for Selection or Exclusion
Residents	Ingestion of GW downgradient of site	No	Residents use GW from local off-site wells but wells are upgradient of site
Local Children	Direct contact with chemicals of potential concern in SW/sediment in vicinity of site	Yes	SW/sediment have low levels of contamination & are in area potentially used by children playing
Residents	Ingestion of chemicals that have bioaccumulated in fish caught from stream	Yes	Potential for significant exposure is considered low since none of the chemicals detected accumulate to great extent in fish and fish are too small to eat
Residents	Inhalation of contaminated dust generated from windblown soils	No	Site is very well-vegetated with no bare areas. Dust will not be significantly generated
Local Children	Direct contact with and inhalation of surface soil	No	Site is not currently used for any purposes, & is covered by thick vegetation with no bare spots. This exposure has been quantified as a past exposure.

As discussed in Section 6.4, the measure of risk of adverse health effects for noncarcinogenic effects is the ratio of daily intake to the RfD. A concentration of 3 µg/L of benzoic acid translates into a daily intake of 8.6×10^{-5} mg/kg·day. The ratio of this intake to the RfD is 2.1×10^{-5}. There is no concern about adverse effects unless this ratio is greater than 1. In this case, the ratio is four-and-one-half orders of magnitude below a level which would cause concern.

In summary, the trace of benzoic acid found in one sample in one residential well will not result in any adverse health consequences.

Because no compounds were detected in residential ground water at concentrations anywhere near those causing concern, it was determined that under current use there is no exposure pathway of concern for residents consuming ground water. This is consistent with the discussion in Section 3.1.7 of Marsh Run Creek as a hydraulic barrier between the residences and the site.

Under current use conditions, ground water from the site is not used for drinking, and therefore this is not a pathway of concern under the current situation.

6.3.2.2 Soils

As discussed above, the site is currently well-vegetated with no exposed surface soil. In addition, since its use as a soccer field ended in 1987, the site has not been used for any purposes. Although a few individuals may cross the site to gain access to the Susquehanna River (a boat launch point is located across the railroad tracks to the north of the site), these individuals are not expected to directly contact soils onsite. Due to the thick vegetation and lack of activities onsite, significant quantities of airborne dust are not expected to be generated; therefore, inhalation of contaminated dust by onsite visitors or nearby residents is not a pathway of concern under current land-use conditions.

Some contaminants were found in subsurface soils, but there is no complete pathway from these soils to human receptors. As long as there is no disturbance to the area, e.g., excavation for a building, there is no potential for contact with contaminants below the surface. As long as the cap remains in place, volatilization of any organics in the subsurface is greatly retarded so that this also is not a potential pathway.

6.3.2.3 Surface Water/Sediments

As stated above, residential homes are located adjacent to Marsh Run Creek, across the stream from the landfill. A large wetlands area also separates the landfill from these homes. Although concrete evidence is not available, it is conceivable that children play in and around this shallow stream and marsh, particularly during the summer months. Although not expected to swim in the stream, these children may wade or otherwise directly contact the surface water and sediments. Therefore, dermal contact with surface water and sediments in both the stream and in the wetlands area is considered a complete pathway. We also included

incidental ingestion of surface water when evaluating this exposure media. It should be noted that in general, only very low levels (i.e., close to the detection limit) of a few volatile organic chemicals were detected in the surface water, and given the steady, quick flow of the stream, these chemicals are expected to volatilize rapidly from the surface water. Other chemicals of potential concern such as the phthalate esters, pesticides, and metals, may be of concern for this pathway.

Marsh Run Creek is classified by the Pennsylvania Department of Environmental Resources as a warmwater fishery. Available site information and observations during visits to the site indicate that fish present in the stream are too small to be eaten. In addition, the type and levels of chemicals detected in the surface water are not expected to yield significant bioaccumulation in fish. However, exposure of individuals via ingestion of chemicals that have accumulated in fish caught from the stream was considered as a potential, although unlikely, pathway.

6.3.3 Exposures under Future Land Use Conditions

Future uses of the Marsh Run Field site are not expected to differ significantly from current uses. The landfill site is located in a rural area with a low population density, low growth potential, and is adjacent to a railroad. Marsh Run Field was formerly a landfill site. If not for the waste disposed here and the cap over the waste, the entire site would be a wetlands/marsh area. The site is located within a floodplain and, for this reason, zoning precludes development of the site. For all of these reasons, future residential development of the site is considered highly unlikely. However, there may be some future activity on the site. For example, the site may again be used for organized recreational activity such as soccer. If not used for organized sports and in the absence of strict access limitations, the site may be used informally as a recreational area. Based on the assumption that future development of the site is not likely to be extensive but that some future access is possible, several exposure pathways were considered. These are summarized in Table 6-6.

6.3.3.1 Ground Water

Although the potential for future residents to install drinking water wells onsite or directly adjacent to the site is highly unlikely, the ingestion of ground water onsite by future residents was evaluated. Ingestion of contaminated ground water is potentially the most significant route of exposure, and risk in the absence of any remediation will be quantified.

6.3.3.2 Soils

Based on site history, it is conceivable that in the future children may directly contact chemicals of potential concern in surface soils onsite if the site is again used for recreational activities. This pathway was evaluated under past usage. Future use of the area for recreation is not expected to differ from past use, so this pathway was not re-evaluated.

TABLE 6-6 SUMMARY OF POTENTIAL EXPOSURE PATHWAYS UNDER POTENTIAL FUTURE LAND USE, MARSH RUN FIELD SITE, NEW CUMBERLAND, PA

Potentially Exposed Population	Exposure Pathway	Selected for Evaluation?	Reason for Selection or Exclusion
Residents	Ingestion of GW from onsite wells	Yes	Pathway is unlikely, but will be evaluated since it may have significant impact
Local Children	Direct contact with chemicals of potential concern in SW/sediment in vicinity of site	No	Future pathway not expected to differ from current use which has been quantified
Residents	Ingestion of chemicals that have bioaccumulated in fish caught from stream	No	Future pathway not expected to differ from current use
Residents	Inhalation of contaminated dust generated from windblown soils	No	Even if site is used recreationally, significant quantities of dust are not expected to be generated
Local Children	Direct contact with surface soil	No	Area could be used again for soccer or other sports. Exposure has been quantified as a past exposure.
Residents	Direct contact with onsite soils	No	Site in rural area with low growth potential. Future residential development of landfill unlikely

The air exposure pathway is of concern when contaminants from soil migrate to the atmosphere resulting in exposure to humans via inhalation. U.S. EPA suggests two mechanisms by which fugitive dust from contaminated soil can be generated--wind erosion and vehicles traveling over bare earth (1988a). No vehicular traffic is expected on the site so this method of generating dust was not considered. Two factors must exist for wind erosion to be significant. Large areas of soil must be exposed and the soil must be loose so that it can be entrained by the wind. Even under extensive recreational use, large areas of exposed soil are not generated. If by the end of a recreational season some areas of bare soil are uncovered, grass will grow back during the off season, again providing ground cover. When soil is exposed, it is not expected to be loose soil as would be found after plowing an area. The exposed area on a playing field is level (i.e., not rutted) and is weathered. Both of these factors inhibit wind erosion. In addition, the entire issue of wind erosion of contaminants can be eliminated by the addition of a cap of clean cover.

Since generation of significant quantities of dust is not considered likely, the air exposure pathway through wind erosion and inhalation of contaminants via this pathway is not considered to be of significance and was not quantified.

Because construction on the landfill site is highly unlikely, there is little potential for any exposure to subsurface soils. As for the current use conditions, this is not a complete pathway and will not be evaluated.

6.3.3.3 Surface Water/Sediments

Pathways related to exposure of future onsite residents to site-related contaminants in soils or surface water/sediments will not be reevaluated. The exposure of residents and children to surface water/sediments remains the same under anticipated future use as under current use conditions.

6.3.4 Exposure Pathways to be Quantitatively Evaluated

Based on the discussion of potential pathways, the following human exposure pathways will be quantitatively evaluated:

- Past exposure of local children to surface soils onsite via direct contact (i.e., incidental ingestion and dermal contact) and via inhalation of dust during activities involving use of the site as a playing field.

- Current exposure of local children to surface water/sediment contamination via direct contact (i.e., dermal contact) and incidental ingestion during wading and other recreational activities;

- Current exposure of residents to contaminants in surface water which have bioaccumulated in fish eaten by the residents.

- Future exposure of hypothetical onsite residents to ground-water contaminants via ingestion of ground water from onsite wells;

6.3.5 Determination of Exposure Point Concentrations

In this section, exposure point concentrations for the four complete exposure pathways listed in Section 6.3.4 are developed. Average exposure point concentrations were calculated to represent the concentrations to which individuals would most likely be exposed under the conditions discussed in this risk assessment. Reasonable worst case concentrations were also determined to represent the levels to which, although unlikely, an individual could be exposed under certain circumstances.

6.3.5.1 Past Direct Contact with Surface Soils Onsite

Both the COE data and the EPA TAT data were used to determine average and reasonable worst case concentrations of chemicals of potential concern in surface soils on the Marsh Run Field site. These data are summarized in Table 6-1.

6.3.5.2 Current Direct Contact with Surface Water/Sediments

Since children may play in either the creek or in the wetlands area near the landfill, data for this pathway were summarized by calculating the average and maximum concentrations of chemicals of potential concern detected in both the creek downstream of the site and in the wetlands area. Surface water/sediment concentrations presented in Table 6-2 will be used to evaluate this exposure pathway. Surface water data in Table 6-2 were also the basis for quantifying exposure to residents consuming fish from Marsh Run Creek.

6.3.5.3 Future Ingestion of Onsite Ground Water

For this exposure pathway, data from monitoring well sampling on the site were used to calculate exposure point concentrations. Most of these wells were sampled in both Phases I and II. Therefore, average concentrations within individual wells were calculated first. Then, the arithmetic mean of these average well values was calculated to obtain the average exposure point concentrations for the site. Reasonable worst case exposure point concentrations were the highest average well concentrations detected in any of the onsite wells. These calculations are summarized in Table 6-4.

Consideration was given to using results of ground-water modeling in Chapter 5 in place of RI sampling data to assess risk from future ingestion of ground water. We decided to use the RI sampling data for the following reasons. Modeling is based on the assumption of a steady source concentration of 1,000 µg/L. The RI sampling gives a current concentration but does not describe likely temporal changes in the source nor pinpoint where we are in time in the dispersion of the plume (e.g., 10 years?, 20 years?). Because of this it would be difficult to derive a

concentration for each compound of concern on which to base exposure. Using the current RI sampling data adds a measure of conservatism to the assessment since future concentrations in ground water are not likely to be any greater than at the time of current sampling.

6.3.6 Estimation of Chemical Intakes

To quantitatively assess the potential risks to human health associated with the exposure scenarios considered in this assessment, the exposure point concentrations were converted to intakes. Intakes are expressed as the amount of a substance taken into the body per unit body weight per unit time. They are commonly expressed in units of mg/kg·day. An intake is averaged over a lifetime for carcinogens and over the exposure period for noncarcinogens. The information presented previously in Chapter 6 concerning the distribution of chemicals, exposed populations, and exposure conditions were used to develop assumptions concerning exposure parameters needed to estimate intakes.

6.3.6.1 Past Direct Contact with Soils during Recreational Activities Onsite

In this exposure scenario, children 6 to 12 years old are assumed to incidentally ingest and dermally contact surface soils as well as inhale dust entrained from the surface soils during recreational activities such as soccer matches. Assumptions used to estimate intakes for soil ingestion and absorbed dose for dermal contact scenarios are presented in Table 6-7. Under average exposure conditions, children are assumed to play soccer 2 days per week, 16 weeks per year, for 6 years. Under maximum exposure conditions, children are assumed to play soccer onsite for 5 days per week, 16 weeks per year, for 10 years. In both average and maximum cases, children are assumed to weigh an average of 32 kg based on data provided in U.S. EPA (1985).

For the incidental ingestion scenario, children are assumed to ingest 100 mg of soil per day from various activities both indoors and outdoors (U.S. EPA 1989c). Information concerning the fraction of this total ingestion rate which is obtained during soccer matches onsite is not available. Therefore, we conservatively assumed that 100 percent of the fraction of soil ingested would be from the contaminated site for both the average and the maximum exposure cases.

Based on the discussion presented above, estimates of intake during incidental ingestion of surface soil were calculated using the equation below:

$$\text{Intake (mg/kg·day)} = \frac{CS \times IR \times CF \times FI \times EF \times ED}{BW \times AT}$$

where:

CS = Chemical concentration in soil (mg/kg)
IR = Soil Ingestion Rate (mg/day)
CF = Conversion factor (10^{-6} kg/mg)

TABLE 6-7 ASSUMPTIONS USED TO ESTIMATE EXPOSURE OF LOCAL CHILDREN PLAYING ONSITE VIA DIRECT CONTACT WITH SOIL

Parameter	Average Exposure	Reasonable Worst Case Exposure
Age of Children (years) (c)	6-12	6-12
Skin Surface Area Exposed (cm^2) (a)	2800	4440
Soil to Skin Adherence Factor (mg/cm^2) (a)	1.45	2.77
Absorption Factor (c)	1	1
Exposure Time (hr/day)	2	3
Exposure Frequency (days/yr) (c)	32	80
Exposure Duration (years) (c)	6	10
Average Body Weight (kg) (b)	32	32
Soil Ingestion Rate (mg/day) (a)	100	100
Fraction of Soil ingested from on site (c)	0.05	0.1
Breathing Rates for Children under Exertion (m^3/hr)	3.2	4.2

(a) U.S. EPA 1989c
(b) U.S. EPA 1985
(c) Assumed value. Exposure frequency assumes 2 days per week, 16 weeks per year for average case; 5 days/week, 16 weeks per year for reasonable worst case.

FI = Fraction of ingested soil which comes from the site during sporting activities (unitless)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged in days - duration of exposure for noncarcinogens, average lifetime for carcinogens)

Calculated intakes for incidental ingestion are presented in Table 6-13.

For estimates of dermal exposure to soil contaminants, absorbed doses are also calculated instead of intakes. This is due to the use of absorption factors to reflect the desorption of the chemicals from the soil matrix and the absorption of the chemical across the skin and into the blood stream (U.S. EPA 1989c). As a conservative screening measure, absorption factors were assumed to be 1 for each chemical of potential concern in soil. Using the above exposure parameters, the absorbed dose estimates for dermal contact with soils were calculated using the equation below:

$$\text{Absorbed Dose (mg/kg·day)} = \frac{CS \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT}$$

where:
CS = Site-specific soil concentration (mg/kg)
CF = Conversion factor (10^{-6} kg/mg)
SA = Skin surface area exposed to sediment (cm^2)
AF = soil to skin adherence factor (mg/cm^2)
ABS = Absorption factor (unitless)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged in days - duration of exposure for noncarcinogens, average lifetime for carcinogens)

Absorbed dose estimates for exposure of children to soils are presented in Table 6-13.

Since children playing onsite are expected to incidentally ingest and dermally contact surface soils simultaneously, intakes are combined for these two pathways to yield total chemical intakes for this exposure scenario. These values are presented in Table 6-13.

Children playing on the site will also inhale dust kicked up from the surface during a recreational activity such as a soccer game. For this exposure scenario concentrations of contaminants in the soil must be translated to concentrations in the air. This is done by first estimating emission factors, then emission rates, and finally concentrations in air.

The emission factor E_{10} is the annual average emission of respirable particles (those less than 10 μ in diameter) per unit area of contaminated surface and is expressed as g/hr·m². The emission factor is calculated using the following equation and conservative assumptions from Cowherd (1985).

$$E_{10} = 0.036\ (\mu/\mu_t)^3\ F(x)$$

where:

μ = mean annual wind speed (3.4 m/sec at Harrisburg, Pa.)
μ_t = threshold value of wind speed (7.5 m/sec at 7 m)
$F(x)$ = 0.5 for unlimited erosion (from Figure 4.3 in Cowherd)

The emission rate for each chemical of concern is then calculated using the following equation.

$$ER = E_{10} \times A \times CS \times CF_1 \times CF_2$$

where:

ER = emission rate (mg/sec)
E_{10} = emission factor (1.68E-3 g/hr·m²)
A = area of site (56,000 m²)
CS = concentration in soil (mg/kg)
CF_1 = conversion factor 1 (kg/10³ g)
CF_2 = conversion factor 2 (hr/3600 sec)

The concentration in air for each chemical of concern is calculated using the emission rate in the following equation (Turner 1970).

$$CA = \frac{ER}{\pi \sigma_y \sigma_z u}$$

where:

CA = concentration in air (mg/m³)
ER = emission rate (mg/sec)
σ_y = dispersion coefficient in lateral (crosswind) direction (0.5 m)
σ_z = dispersion coefficient in vertical direction (2.5 m)
u = mean annual wind speed (3.4 m/sec)

Emission rates and air concentrations calculated using these formulas are given in the first columns of Table 6-14.

Once air concentrations have been determined, intakes are calculated using the following equation with these assumptions. Ingestion rate is based on the volume of air breathed and is assumed for children 6-12 to be 3.2 m³/hr in the average case and 4.2 m³/hr in the worst case. Exposure time was estimated as 2 hr/day in the average case and 3 hr/day in the worst case. Exposure frequency and duration are as given for all exposures to soil in Table 6-7.

$$\text{Intake (mg/kg·day)} = \frac{CA \times IR \times ET \times EF \times ED}{BW \times AT}$$

where:

CA = contaminant concentration in air (mg/m^3)
IR = inhalation rate (m^3/hour)
ET = exposure time (hours/day)
EF = exposure fequency (days /year)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (period over which exposure is averaged--days)

Intakes of contaminants in surface soil via the inhalation route are given in Table 6-14.

6.3.6.2 Current Direct Contact with Surface Water/Sediments

Assumptions used in determining intakes for children directly contacting surface water/sediments during play activities are presented in Table 6-8. Children 6 to 10 years of age are assumed to dermally contact the surface water and sediments during wading and other activities in the creek and wetlands area and to incidentally ingest some surface water during these activities. Under average exposure conditions, these activities are assumed to take place for 1 hour per day, 6 days per year (2 days per month for 3 months per year), for a total of 5 years. For the reasonable worst case exposure, children are assumed to play in the stream and the wetlands area for 2 hours per day, 12 days per year (3 days per month for 4 months per year) for a total of 5 years. In both the average and maximum cases, children are assumed to weigh 28.5 kg, which is the average body weight of children in this age range (U.S. EPA 1985). In the average case, only the legs are assumed to be exposed, yielding a skin surface area of 2,800 cm^2 (U.S. EPA 1989c). In the maximum case, the hands, arms, and legs are assumed to be exposed, yielding a skin surface area of 4,440 cm^2. The assumption for incidental ingestion of surface water while playing in the water is based on incidental ingestion while swimming of 50 ml per hour for both average and worst case.

For estimates of dermal exposure to surface water contaminants, absorbed doses are calculated, i.e., the amount of a substance penetrating the exposed skin after contact, instead of intakes. This is due to the use of permeability constants, which reflect the movement of chemicals across the skin to the stratum corneum and into the bloodstream (U.S. EPA 1989c). Chemical-specific permeability constants were not available for the chemicals of potential concern in surface water. The three-page list of permeability constants in the Superfund Exposure Assessment Manual (U.S. EPA 1988a) does not include any of the chemicals of concern in surface water or sediment at Marsh Run Field. Therefore, the permeability of water, 8.4×10^{-4} cm/hour, was used as a default value (U.S. EPA 1989c). Using the above exposure parameters, the absorbed dose estimates for dermal contact with surface water were calculated using the equation below:

$$\text{Absorbed Dose (mg/kg·day)} = \frac{CW \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

TABLE 6-8 ASSUMPTIONS USED TO ESTIMATE EXPOSURE OF CURRENT LOCAL CHILDREN TO SURFACE WATER/SEDIMENTS VIA DERMAL CONTACT

Parameter	Average Exposure	Reasonable Worst Case Exposure
Age of Children (years) (a)	6-10	6-10
Skin Surface Area Exposed (cm^2) (b)	2800	4440
Soil to Skin Adherence Factor (mg/cm^2) (b)	1.45	2.77
Absorption Factor (a)	1	1
Permeability Constant (cm/hr) (c)	8.4×10^{-4}	8.4×10^{-4}
Hours of Exposure (hours/day) (a)	1	2
Exposure Frequency (days/yr) (a)	6	12
Exposure Duration (years) (a)	5	5
Average Body Weight (kg) (d)	28.5	28.5
Contact Rate, i.e., amount ingested (ml/hr)	50	50

(a) Assumed values. Exposure frequency based on 2 days/month, 3 months/year for the average case, 3 days/month, 4 months/year for the reasonable worst case.
(b) U.S. EPA 1989c
(c) Permeability of water from EPA 1989. Chemical-specific values not available.
(d) U.S. EPA 1985

where:

CW = Site-specific water concentration (mg/liter)
SA = Skin surface area exposed to water (cm^2)
PC = Dermal permeability constant (cm/hour)
ET = Exposure time (hours/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
CF = Volumetric conversion factor (1 liter/1000 cm^3)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged in days - duration of exposure for noncarcinogens, average lifetime for carcinogens)

Absorbed dose estimates for exposure to surface water are presented in Table 6-15.

For estimates of dermal exposure to sediment contaminants, absorbed doses are calculated using the same equation presented in Section 6.3.6.1 for dermal exposure to soil contaminants. As with the soil exposures, absorption factors were assumed to be 1 for each chemical of potential concern in sediment. Estimates of absorbed doses for exposure of children to sediments are included in Table 6-15.

In addition to dermal contact with surface water and sediments, children playing in the creek and marshy areas may incidentally ingest some of the surface water. Assuming that the contact rate for this exposure is 50 ml per hour of activity, intake is calculated using the following equation (U.S. EPA 1989c). Since this assumption is based on ingestion of water while swimming, the intake is probably overestimated for wading and playing.

$$\text{Intake (mg/kg·day)} = \frac{CW \times CR \times CF \times ET \times EF \times ED}{BW \times AT}$$

where:

CW = Concentration in surface water (mg/liter)
CR = Contact rate (liters/hour)
CF = Conversion factor (10^{-3} L/ml)
ET = Exposure time (hours/event)
EF = Exposure frequency (events/year)
ED = Exposure duration (years)
BW = Body Weight (kg)
AT = Averaging time (period over which exposure is averaged--days)

Estimated intakes via incidental ingestion of surface water are given in Table 6-15.

Since children playing in the stream and in the wetlands will contact sediment and surface water contaminants simultaneously, doses are combined for chemicals detected in both sediments and surface water to obtain total chemical doses for this pathway. These values are combined in Table 6-15.

6.3.6.3 Current Ingestion of Surface Water Contaminants via Ingestion of Fish by Current Residents

Assumptions used in estimating intakes of adult residents consuming fish from Marsh Run Creek are given in Table 6-9. Fish living in Marsh Run Creek will bioconcentrate contaminants in the water at different rates for different types of compounds. For this assessment, we assumed that semivolatile compounds will have a bioconcentration factor (BCF) of 10 mg/kg in fish per mg/L in water, i.e., the concentration in fish will be 10 times that in water. The BCF for metals was assumed to be 100, and the BCF for DDT and its metabolites DDD and DDE is 1,000. The ingestion rate is assumed to be 0.113 kg/meal in the average case and 0.284 kg/meal for the worst case exposure (U.S. EPA 1989c). The exposure frequency is assumed to be 48 meals per year in both cases. As for other exposure pathways, the exposure duration in the average case is 9 years, the national median time (50th percentile) at one residence. The exposure duration in the worst case was assumed to be 30 years, the national upper-bound time (90th percentile) at one residence.

Using these exposure assumptions, intake via fish ingestion was estimated using the following equation (U.S. EPA 1989c).

$$\text{Intake (mg/kg·day)} = \frac{CSW \times BCF \times IR \times FI \times EF \times ED}{BW \times AT}$$

where:

CSW = Concentration in surface water (mg/L)
BCF = Bioconcentration factor (mg/kg in fish per mg/L in water)
IR = Ingestion rate (kg/meal)
FI = Fraction ingested from contaminated source (unitless)
EF = Exposure frequency (meals/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged--days)

Intakes via ingestion of fish are given in Table 6-16.

6.3.6.4 Future Ingestion of Ground Water by Hypothetical Residents

It is highly unlikely that anyone will be drinking water from the Marsh Run Field site in the future. Development of the site is very unlikely and ground-water studies indicate that Marsh Run Creek is a hydraulic barrier to the south. However, contaminants were found in ground water onsite, and if unremediated and although unlikely, ingestion of ground water is a potential pathway for human exposure. For this reason, intakes were estimated for the ingestion of ground water using the assumptions listed in Table 6-10. Intake was estimated for adults weighing an average of 70 kg and consuming 2 L of contaminated water per day. Assumption for average and worst cases were the same except for exposure duration. The average case assumes an exposure duration of 30 years, the

TABLE 6-9 ASSUMPTIONS USED TO ESTIMATE EXPOSURE OF RESIDENTS EATING CONTAMINATED FISH FROM MARSH RUN CREEK

Parameter	Average Exposure	Reasonable Worst Case Exposure
Age of Resident	Adult	Adult
Bioconcentration Factor (mg/kg in fish tissue per mg/L in water)		
Semivolatile Compounds	10	10
Metals	100	100
DDT and metabolites	1000	1000
Ingestion Rate (kg/meal)[a]	0.113	0.284
Fraction Ingested (unitless)	1.0	1.0
Exposure Frequency (meals/yr)[a]	48	48
Exposure Duration (years)[a]	9	30
Body Weight (kg)[a]	70	70
Averaging Time[a]		
Noncarcinogens	9	30
Carcinogens	70	70

(a) U.S. EPA 1989c

TABLE 6-10 ASSUMPTIONS USED TO ESTIMATE EXPOSURE OF FUTURE RESIDENTS TO CONTAMINANTS VIA INGESTION OF GROUND WATER

Parameter	Average Exposure	Reasonable Worst Case Exposure
Age of Receptor (years)	Adult	Adult
Ingestion Rate (L/day) (a)	2	2
Exposure Frequency (days/year)	365	365
Exposure Duration (years) (a)	30	70
Average Body Weight (kg) (a)	70	70

(a) U.S. EPA 1989c

national upper-bound time (90th percentile) at one residence (U.S. EPA 1989c). The worst case assumes an exposure duration of 70 years, by convention a lifetime of exposure.

The parameters in Table 6-10 were used in the following equation to estimate intake of contaminants through the ingestion of onsite ground water:

$$\text{Intake (mg/kg·day)} = \frac{CW \times IR \times EF \times ED}{BW \times AT}$$

where:
- CW = Site-specific concentration in water (mg/liter)
- IR = Ingestion rate of water (liters/day)
- EF = Exposure frequency (days/year)
- ED = Exposure duration (years)
- BW = Body weight (kg)
- AT = Averaging time (period over which exposure is averaged in days - duration of exposure for noncarcinogens, average lifetime for carcinogens)

Estimates of intake for future hypothetical ingestion of ground water are given in Table 6-17.

6.3.7 Uncertainties in the Exposure Assessment

As with any exposure assessment, there are uncertainties associated with the exposure scenarios used in this risk assessment. There are uncertainties associated with estimates of how often, if at all, an individual would come into contact with the chemicals of concern in various site media and the period of time over which such exposures would occur. For example, the period of time children play in surface water near the site is not known and was estimated. Uncertainty can lead to either under- or overestimation of risk. However, in general conservative assumptions were made through the exposure assessment, and it is likely that these conservative assumptions will overestimate the risks calculated for various exposure scenarios.

In addition to uncertainties, there is a level of confidence which can be placed in the data collected and analyzed for the RI. In this exposure assessment we used RI sampling data for estimates of concentrations in all media for which quantitative risks were calculated (i.e., soil, surface water, sediment, and ground water). In other words, we did not model any concentrations used in the exposure assessment and, therefore, did not introduce uncertainties inherent in modeling. This confidence in concentrations in all media leads to confidence in exposure point concentrations and daily intake estimates.

In addition, there is no uncertainty introduced by the selection of chemicals of concern since all compounds detected onsite in a medium were carried through the risk analysis unless the maximum site concentration

was within the range of background concentration. The following paragraphs discuss media-specific uncertainty issues.

6.3.7.1 Soils

The exposure pathway itself is improbable since, as discussed previously, the site is well-covered with vegetation. Even if the site were to be re-developed in the future as a playing field, a vegetative cover would be maintained, limiting the potential of direct contact with surface soils. Therefore, risks from this exposure pathway may be overestimated in this assessment.

Uncertainties are associated with the use of data from two different groups collecting and analyzing the samples (i.e., COE and EPA TAT). The analytical methods appear comparable; however, differences in the types of chemicals and the concentrations of chemicals detected in the two sample sets may indicate that the two sets are not directly comparable. Information is not available to determine whether this uncertainty leads to overestimation or underestimation of risks for this pathway.

Relatively conservative estimates of exposure time and duration have been used for even the average exposure scenario, thereby possibly overestimating risk.

Finally, concerning some of the chemicals detected in the surface soils, it should be noted that phthalates and PAHs are ubiquitous in the environment and concentrations may be more related to background levels than to disposal of hazardous wastes containing these chemicals. In addition, the presence of pesticides such as DDE, DDD, and DDT may be related to pesticide spraying activities in the area in the past and during the RI, rather than to disposal practices in the landfill itself.

6.3.7.2 Surface Water/Sediments

One source of uncertainty associated with the surface water/sediment risk assessment is the sampling, which was conducted only once in a few areas in the stream and in only one location in the wetlands. Therefore, the concentrations used to estimate risk for exposure of children to surface water/sediment contaminants are based on sparse data and may overestimate or underestimate the associated risk.

Another uncertainty concerning this pathway is the fact that there are insufficient data to determine the contribution of other potential sources (e.g., the depot) to the contamination noted in the stream and wetlands. Certain contaminants detected in the surface water/sediments during the RI may have originated from these other sources. As for soils, the presence of DDE and DDD in these media may be attributable to previous use of pesticides in the area, not to landfill deposition of hazardous wastes. The presence of PAHs in the surface water/sediments may be due to the presence of several asphalt piles in the area.

Finally, several of the chemicals of potential concern detected in the surface water and carried through the risk assessment are volatile organic chemicals which are expected to volatilize relatively quickly compared with the exposure period assumed in this scenario. Therefore, concentrations of these chemicals would be reduced in the future, lowering the exposure potential and the risks.

Concerning the exposure pathway analysis itself, as previously noted, there is not documented evidence that children play in the wetlands or in the stream. They may prefer to play near the more attractive Susquehanna River. In addition, exposure may be lower than that estimated in this assessment due to the likelihood that, prior to incidental ingestion or dermal absorption of site-related contaminants, sediment material may be washed off of skin by movement of water during play activities.

6.3.7.3 Ground Water

The greatest uncertainty in the ground water exposure assessment is that the water would ever be consumed. It is highly unlikely that residential development will occur on the site. It is extremely unlikely that wells would be developed on the site without remediation of the ground water. Another uncertainty is the exposure frequency and duration. The exposure assessment assumes that the residents consume all their drinking water from onsite wells for 365 days of the year. Since it is reasonable that some water is consumed some of the time away from home, this assumption overestimates the risk. When considering carcinogens, it is assumed that the exposure duration is a lifetime, i.e., 70 years. This assumption also overestimates the risk since it is unlikely that any one person will reside on the site for an entire lifetime.

6.4 TOXICITY ASSESSMENT

This step in a human health risk assessment involves identifying relevant health-risk values for the contaminants of concern. These health-risk values are used with estimated intake values from the exposure assessment to quantify the risk posed by releases from the site. For noncarcinogens, the relevant risk value is the chronic reference dose (RfD) expressed in mg of compound per kg of body weight per day (mg/kg·day). The RfD is an estimate of the daily intake level (a threshold value) that is expected to have no appreciable risk of toxicity associated with it during a lifetime. RfDs are based upon relevant animal and/or human toxicity studies and have a margin of safety built in given the various levels of uncertainty associated with the data used for estimating such values (e.g., extrapolating from animals to humans). For those exposure routes which are primarily via ingestion or dermal contact, the most appropriate RfD is that based on oral exposure studies. The oral RfDs for the noncarcinogens are listed in Table 6-11.

In contrast to noncarcinogens, which are believed to have toxicity thresholds, carcinogens are believed to have some level of risk associated with any degree of exposure, even though the level of exposure and the level of risk may be trivial. Because of this difference between carcinogens and noncarcinogens, the quantitative risk values

are expressed differently. The risk value for carcinogens is the slope factor expressed in units of $(mg/kg \cdot day)^{-1}$. This value was formerly referred to as the carcinogenic potency factor and represents the estimated upper bound (95 percent confidence limit) excess cancer risk associated with lifetime exposure to 1 mg/kg·day of a compound. For example, the carcinogenic potency for bis(2-ethylhexyl)phthalate is 1.4E-2 $(mg/kg \cdot day)^{-1}$ or 0.014 $(mg/kg \cdot day)^{-1}$. This means that, if 1,000 people were exposed to 1 mg/kg/day of the compound for a 70-year lifetime, up to 14 excess cancer cases (i.e., number of cases over the background level) could be expected. The use of the 95 percent upper-confidence limit means that there is a 95 percent chance that the true risk value is less than or equal to the predicted value, and therefore its use represents a conservative approach. The carcinogenic slope factors for carcinogenic compounds are presented in Table 6-11.

U.S. EPA provides toxicity information, such as that listed in Table 6-11, in an online computer database called the Integrated Risk Information System (IRIS) (1989b). When information was not available on IRIS, data for Table 6-11 were obtained from Health Effects Assessment Summary Tables (HEAST) published quarterly by EPA's Office of Health and Environmental Assessment (1989a). HEAST contains some information not available on IRIS, such as some toxicity values under review by EPA workgroups and therefore subject to change. This hierarchy of sources (IRIS followed by HEAST) is recommended by U.S. EPA. While the HEAST values do not always have the same level of review as IRIS values, they do provide the best estimates for the toxicity values available at the time, and they give a basis for quantifying risk.

In this table, NA indicates that a toxicity value is not available. If the weight of evidence for carcinogenicity is D or None, then we can assume that the chemical is not likely to be a human carcinogen. Likewise, if NA is given for the RfD, the compound is not likely to have major noncarcinogenic effects and can be omitted from the quantification of these risks.

On the other hand, some toxicity values are listed as not determined (ND). In these cases, there is some reason to believe that there are adverse health effects, but the toxicity values are still being developed. These compounds may add to the total risk, but without the toxicity values there is no way to quantify the risks. The most notable example of this is for lead. It is generally accepted that there are adverse effects from ingesting lead. The current thought is that there is no threshold level below which there are expected to be no adverse effects. However, since RfDs are calculated on the basis of thresholds, the current toxicity value and the method for its calculation are not appropriate for lead. Until there is further guidance from U.S. EPA, risk from the ingestion of lead cannot be quantified.

One route of exposure which was quantified in this risk assessment was via inhalation rather than via ingestion. Toxicity numbers for inhalation are presented in Table 6-12. Only two compounds of concern at Marsh Run Field have toxicity values for inhalation. Cadmium has an inhalation slope factor and selenium has an inhalation RfD. Since there are so few

TABLE 6-11 ORAL TOXICITY VALUES USED IN HUMAN HEALTH EVALUATION FOR CHEMICALS OF POTENTIAL CONCERN AT MARSH RUN FIELD, PA

	Oral RfD (mg/kg·day)	Oral Slope Factor $(mg/kg \cdot day)^{-1}$	Weight of Evidence Classification for Oral Route [a]	Reference
Volatiles				
Ethylbenzene	1E-1	NA	D	IRIS
1,1-Dichloroethene	9E-3	6.0E-1	C	IRIS
1,1,2,2-Tetrachloroethane	ND	2.0E-1	C	IRIS
Trichloroethene	ND	1.1E-2	B2	HEA
Toluene	3E-1	NA	D	IRIS
Acetone	1E-1	NA	None	IRIS
Methylene Chloride	6E-2	7.5E-3	B2	HEA
1,2-Dichloroethene (total) [b]	2E-2	NA	C	IRIS
1,1,2-Trichloroethane	4E-3	5.7E-2	None	IRIS
Tetrachloroethene	1E-2(IRIS)	5.1E-2	B2	HEA
Xylenes	2E+0	NA	D	IRIS
Semivolatiles				
bis(2-ethylhexyl)phthalate	2E-2	1.4E-2	B2	IRIS
Diethylphthalate	8E-1	NA	D	IRIS
Di-n-butylphthalate	1E-1	NA	D	IRIS
ncPAH	ND	NA	None	HEA
cPAH	NA	ND	B2	HEA
Pesticides				
4'4-DDD	ND	2.4E-1	B2	IRIS
4'4-DDE	ND	3.4E-1	B2	IRIS
4'4-DDT	5E-4	3.4E-1	B2	IRIS

NA = Not Applicable.
ND = Not Determined.
(a) Weight of Evidence Classifications.
- A Human Carcinogen
- B1 Potential Human Carcinogen
- B2 Probable Human Carcinogen
- C Possible Human Carcinogen
- D Not Classifiable, Insufficient Data
- None Chemical has not been evaluated by EPA for evidence of human carcinogenic potential.

(b) Toxicity values for trans-1,2-dichloroethene.

TABLE 6-11 (Cont.)

	Oral Rfd (mg/kg·day)	Oral Slope Factor $(mg/kg \cdot day)^{-1}$	Weight of Evidence Classification for Oral Route[a]	Reference
Metals				
Aluminum	NA	NA	None	HEA
Antimony	4E-4	NA	None	IRIS
Arsenic	1E-3(HEA)	1.8E+0	A	IRIS
Barium	5E-2	NA	None	IRIS
Boron	9E-2	NA	None	IRIS
Cadmium	5E-4	NA	D	IRIS
Chromium (III)	1E+0	NA	None	IRIS
Copper	NA	NA	D	IRIS
Iron	NA	NA	None	HEA
Lead	ND	ND	B2	IRIS,HEA
Manganese	2E-1(HEA)	NA	D	IRIS
Mercury	3E-4(HEA)	NA	D	IRIS
Potassium	NA	NA	None	--
Selenium	3E-3	NA	None	HEA
Silver	3E-3	NA	D	IRIS
Thallium	7E-5	NA	None	HEA
Vanadium	7E-3	NA	None	HEA
Zinc	2E-1	NA	None	HEA
Other Organics				
Cyanide	2E-2	NA	None	IRIS
Fluoride	6E-2	NA	None	IRIS

TABLE 6-12 INHALATION TOXICITY VALUES USED IN HUMAN HEALTH EVALUATION FOR CHEMICALS OF POTENTIAL CONCERN IN SOIL AT MARSH RUN FIELD, PA

	Inhalation RfD (mg/kg·day)	Inhalation Slope Factor (mg/kg·day)	Weight of Evidence Classification for Inhalation Route	Reference
Semivolatiles				
bis(2-ethylhexyl)phthalate	NA	ND	B2	HEA
Diethylphthalate	NA	NA	D	IRIS
Di-n-butylphthalate	NA	NA	D	IRIS
ncPAH	ND	NA	None	HEA
cPAH	NA	ND	B2	HEA
Metals				
Cadmium	ND	6.1E+0	B1	IRIS
Copper	NA	NA	D	IRIS
Lead	ND	ND	B2	HEA
Mercury	NA	NA	D	IRIS
Selenium	1E-3	NA	--	HEA
Silver	NA	NA	D	IRIS
Thallium	NA	NA	--	HEA
Zinc				
Other Organics				
Cyanide	NA	NA	None	IRIS

NA = Not Applicable.
ND = Not Determined.
(a) Weight of Evidence Classifications.
- A Human Carcinogen
- B1 Potential Human Carcinogen
- B2 Probable Human Carcinogen
- C Possible Human Carcinogen
- D Not Classifiable, Insufficient Data
- None Chemical has not been evaluated by EPA for evidence of human carcinogenic potential.

inhalation values, the oral values for other compounds were used in addition to these two inhalation values. This adds a measure of uncertainty to the quantification of the inhalation route but is preferable to having few estimates of hazard or risk potential.

6.5 RISK CHARACTERIZATION

In this final step of the baseline risk assessment, the estimated daily intakes that were calculated in the exposure assessment (Section 6.3) are used in conjunction with the risk values identified in the toxicity assessment (Section 6.4) to determine the potential risk posed to human health and the environment by releases from the Marsh Run Field former landfill site.

6.5.1 Risk Characterization Methods for Noncarcinogens

To evaluate the potential risk posed by the noncarcinogenic compounds detected at the site, the estimated daily intake of each contaminant in each environmental medium is compared to the RfD for that compound. These data are presented in Tables 6-13 through 6-17. In each case, if the estimated daily intake does not exceed the RfD, there is considered to be little or no risk to the population from the compound for the exposure pathway being evaluated. For example, daily exposure to a drinking water concentration of boron of 93.3 µg/L (average case in Table 6-4) results in an estimated daily intake of 2.7E-3 mg/kg·day, which is more than one order of magnitude below the RfD for boron of 9E-2 mg/kg·day (Table 6-17).

A hazard quotient (HQ) is calculated for each compound. The HQ is the ratio of the estimated daily intake to the RfD. When the estimated daily intake is less than the RfD, the HQ will be less than 1, indicating that daily consumption of the compound for a lifetime at concentrations used in the exposure assessment is likely to be without appreciable risk of deleterious effects.

For purposes of initially screening the noncarcinogenic total risk, the HQs for all compounds are added together regardless of type of associated toxicity. This total of the individual HQs is referred to as the Hazard Index (HI). If the HI is less than 1, then there is considered to be little or no risk posed to the public by the sum of the exposures to all compounds of potential concern. If the HI is greater than one, further evaluation of the types of critical effects associated with the compounds of concern is warranted. In the further evaluation, noncarcinogenic risks are assumed to be additive within type of critical effect, e.g., neurotoxicity or hepatotoxicity. If, within type of effect, the HI exceeds one, a potential exposure problem is indicated.

6.5.2 Risk Characterization Methods for Carcinogens

For carcinogens, the risk posed by each contaminant is calculated by multiplying the estimated daily intake by the slope factor (formerly the carcinogenic potency factor) to yield the excess cancer risk associated with a lifetime of exposure. For example, a continuous lifetime exposure

to the ground water concentration for 1,1-dichloroethene of 3.0 µg/L (average exposure case, Table 6-4), results in an estimated daily intake of 8.6E-5 mg/kg·day. This estimated daily intake times the slope factor for 1,1-dichloroethene of 6.0E-1 $(mg/kg \cdot day)^{-1}$ yields an excess lifetime risk of 5.1E-5 or 5 in 100,000 (Table 6-17).

Carcinogenic risk is assumed to be additive over the compounds of potential concern. Therefore, to determine the total carcinogenic risk posed by the site, the risks of the individual contaminants are added together. U.S. EPA policy at CERCLA (Superfund) sites has been to select remedies which result in total carcinogenic risk falling within the range of 10^{-4} (i.e., one case in 10,000 people) to 10^{-7} (one case in 10,000,000) (U.S. EPA 1989c). The level of risk within this range that is considered to be acceptable is a risk management decision and is decided on a site-by-site basis.

6.5.3 Risk Characterization for Incidental Ingestion and Dermal Contact with Surface Soils Resulting from Recreational Activities

The risk posed by incidental ingestion and dermal contact of surface soils was evaluated for past use of the site as a recreational area. The estimated daily intakes and the risks posed by this exposure pathway are summarized in Table 6-13.

This table shows that all of the HQs for individual noncarcinogenic compounds together with the total HI are all below 1. This indicates that incidental ingestion and dermal contact of soils by children using Marsh Run Field for recreational activities is not a pathway of concern for noncarcinogens.

The excess lifetime cancer risk for the average case is 5E-9 (5 in 1,000,000,000, i.e., 5 in a billion) which is well below the de minimus risk of 1E-06 (i.e., 1×10^{-6} or 1 in a million). The excess lifetime cancer risk for the more conservative worst case scenario is 3E-07 (one in 10 million) which is also below the de minimus level of risk.

Risk to these same children via inhalation of dust entrained from the surface soil is given in Table 6-14. The hazard index, i.e., the measure of total noncarcinogenic risk, for this route of exposure is below 1 for both the average and worst exposure cases. The potential carcinogenic risk for the average case (5E-8 or 5 in 100 million) and for the worst case (8E-7 or 8 in 10 million) are both well below the de minimus level of risk.

Since children will dermally contact, incidentally ingest, and inhale dust from surface soils simultaneously, the risks in Tables 6-13 and 6-14 should be combined to quantify potential risk to children who have used Marsh Run Field. The total hazard indexes for contact with surface soils are 2E-2 (average case) and 2E-1 (worst case). Since both hazard indexes are less than 1, there are no potential noncarcinogenic risks. The total potential cancer risks are 5E-8 (5 in 100 million) for the average case and 1E-6 (1 in a million) for the worst case exposure scenario. Since both these potential cancer risks are at or below the de minimus risk

TABLE 6-13 ESTIMATES OF INTAKES AND RISKS ASSOCIATED WITH INCIDENTAL INGESTION AND DERMAL CONTACT WITH SURFACE SOILS BY CHILDREN DURING PLAY AT MARSH RUN FIELD--PAST EXPOSURE

POTENTIAL NONCARCINOGENIC RISKS

Chemical	Ingestion Intake (mg/kg·d)		Dermal Contact Absorbed Dose (mg/kg·d)		Total Intake (mg/kg·d)		RfD (mg/kg·d)	HQ = Intake/RfD	
	Average	RWC	Average	RWC	Average	RWC		Average	Maximum
ncPAHs	9.95E-07	1.49E-05	4.04E-05	1.83E-03	4.14E-05	1.84E-03	NA	NQ	NQ
Diethylphthalate	4.11E-08	1.30E-07	1.67E-06	1.60E-05	1.71E-06	1.61E-05	8E-01	2E-06 (<1)	2E-05 (<1)
bis(2-Ethylhexyl)-phthalate	1.04E-07	1.10E-06	4.23E-06	1.35E-04	4.33E-06	1.36E-04	2E-02	2E-04 (<1)	7E-03 (<1)
Di-n-butylphthalate	1.04E-07	7.67E-07	4.23E-06	9.43E-05	4.33E-06	9.51E-05	1E-01	4E-05 (<1)	9E-04 (<1)
Cadmium	6.99E-07	3.90E-06	(b)	(b)	6.99E-07	3.90E-06	5E-04	1E-03 (<1)	8E-03 (<1)
Copper	1.68E-05	5.46E-04	(b)	(b)	1.68E-05	5.46E-04	NA	NQ	NQ
Lead	3.04E-05	7.40E-04	(b)	(b)	3.04E-05	7.40E-04	NA	NQ	NQ
Mercury	5.21E-08	2.47E-07	(b)	(b)	5.21E-08	2.47E-07	3E-04	2E-04 (<1)	8E-04 (<1)
Selenium	2.77E-07	2.60E-06	(b)	(b)	2.77E-07	2.60E-06	3E-03	9E-05 (<1)	9E-04 (<1)
Silver	1.75E-07	3.84E-06	(b)	(b)	1.75E-07	3.84E-06	3E-03	6E-05 (<1)	1E-03 (<1)
Thallium	1.23E-06	1.10E-05	(b)	(b)	1.23E-06	1.10E-05	7E-05	2E-02 (<1)	2E-01 (<1)
Zinc	3.78E-05	1.03E-03	(b)	(b)	3.78E-05	1.03E-03	2E-01	2E-04 (<1)	5E-03 (<1)
Cyanide(total)	6.85E-08	1.20E-06	(b)	(b)	6.85E-08	1.20E-06	2E-02	3E-06 (<1)	6E-05 (<1)
						HAZARD INDEX:		2E-02 (<1)	2E-01 (<1)

POTENTIAL CARCINOGENIC RISKS

Chemical	Ingestion Intake (mg/kg·d)		Dermal Contact Absorbed Dose (mg/kg·d)		Total Intake (mg/kg·d)		Slope Factor $(mg/kg \cdot d)^{-1}$	Lifetime Excess Cancer Risk	
	Average	RWC	Average	RWC	Average	RWC		Average	Maximum
cPAHs	6.90E-08	1.98E-06	2.80E-06	2.43E-04	2.87E-06	2.45E-04	NA	NQ	NQ
bis(2-Ethylhexyl)-phthalate	8.92E-09	1.57E-07	3.62E-07	1.93E-05	3.71E-07	1.94E-05	1.4E-02	5E-09	3E-07
							TOTAL	5E-09	3E-07

(a) Average value not calculated since arithmetic mean concentration not available (see Table 6-1).
(b) Dermal absorbed doses not calculated for metals since dermal absorption of metals is negligible.

RWC = Reasonable Worst Case
NA = Not available
NQ = Not quantified due to lack of RfD, slope factor, or average concentration values.

TABLE 6-14 ESTIMATES OF EMISSION RATES, AIR CONCENTRATIONS, INTAKES, AND RISKS ASSOCIATED WITH INHALATION OF DUST FROM SURFACE SOILS BY CHILDREN PLAYING ON MARSH RUN FIELD

POTENTIAL NONCARCINOGENIC RISKS

Chemical	Emission Rate (mg/sec)		Air Concentration (mg/m³)		Estimated Intake (mg/kg·day)		RfD (mg/kg·d)	HQ = Intake/RfD	
	Average	RWC	Average	RWC	Average	RWC		Average	RWC
cPAHs	7.68E-05	5.28E-04	5.75E-06	3.95E-05	1.01E-07	3.41E-06	NA	NQ	NQ
ncPAHs	9.49E-05	5.67E-04	7.10E-06	4.25E-05	1.25E-07	3.67E-06	NA	NQ	NQ
Diethylphthalate	3.92E-06	4.97E-06	2.94E-07	3.72E-07	5.15E-09	3.21E-08	8.0E-01	6E-09	4E-08
Di-n-butlyphthalate	9.93E-06	2.93E-05	7.44E-07	2.19E-06	1.30E-08	1.89E-07	1.0E-01	1E-07	2E-06
bis(2-ethylhexyl)phthalate	9.93E-06	4.18E-05	7.44E-07	3.13E-06	1.30E-08	2.70E-07	2.0E-02	7E-07	1E-05
Cadmium	6.66E-05	1.49E-04	4.99E-06	1.12E-05	8.75E-08	9.63E-07	5.0E-04	2E-04	2E-03
Copper	1.60E-03	2.08E-02	1.20E-04	1.56E-03	2.11E-06	1.35E-04	NA	NQ	NQ
Lead	2.90E-03	2.82E-02	2.17E-04	2.11E-03	3.81E-06	1.82E-04	NA	NQ	NQ
Mercury	4.97E-06	9.41E-06	3.72E-07	7.05E-07	6.52E-09	6.08E-08	3.0E-04	2E-05	2E-04
Selenium	2.64E-05	9.93E-05	1.98E-06	7.44E-06	3.47E-08	6.42E-07	1.0E-03	4E-05	6E-04
Silver	1.67E-05	1.46E-04	1.25E-06	1.10E-05	2.20E-08	9.46E-07	3.0E-03	7E-06	3E-04
Thallium	1.18E-04	4.18E-04	8.81E-06	3.13E-05	1.54E-07	2.70E-06	7.0E-05	2E-03	4E-02
Zinc	3.61E-03	3.95E-02	2.70E-04	2.96E-03	4.74E-06	2.55E-04	2.0E-01	2E-05	1E-03
Cyanide_(total)	6.53E-06	4.57E-05	4.89E-07	3.43E-06	8.58E-09	2.96E-07	2.0E-02	4E-07	2E-05
								=====	=====
								2E-03	4E-02

POTENTIAL CARCINOGENIC RISKS

Chemical	Emission Rate (mg/sec)		Air Concentration (mg/m³)		Estimated Intake (mg/kg·day)		Slope Factor $(mg/kg\cdot d)^{-1}$	Lifetime Excess Cancer Risk	
	Average	RWC	Average	RWC	Average	RWC		Average	RWC
cPAHs	7.68E-05	5.28E-04	5.75E-06	3.95E-05	8.65E-09	4.87E-07	NA	NQ	NQ
ncPAHs	9.49E-05	5.67E-04	7.10E-06	4.25E-05	1.07E-08	5.24E-07	NA	NQ	NQ
Diethylphthalate	3.92E-06	4.97E-06	2.94E-07	3.72E-07	4.41E-10	4.58E-09	NA	NQ	NQ
Di-n-butlyphthalate	9.93E-06	2.93E-05	7.44E-07	2.19E-06	1.12E-09	2.70E-08	NA	NQ	NQ
bis(2-ethylhexyl)phthalate	9.93E-06	4.18E-05	7.44E-07	3.13E-06	1.12E-09	3.86E-08	1.40E-02	1E-11	5E-10
Cadmium	6.66E-05	1.49E-04	4.99E-06	1.12E-05	7.50E-09	1.38E-07	6.10E+00	5E-08	8E-07
Copper	1.60E-03	2.08E-02	1.20E-04	1.56E-03	1.81E-07	1.92E-05	NA	NQ	NQ
Lead	2.90E-03	2.82E-02	2.17E-04	2.11E-03	3.27E-07	2.61E-05	NA	NQ	NQ
Mercury	4.97E-06	9.41E-06	3.72E-07	7.05E-07	5.59E-10	8.69E-09	NA	NQ	NQ
Selenium	2.64E-05	9.93E-05	1.98E-06	7.44E-06	2.97E-09	9.17E-08	NA	NQ	NQ
Silver	1.67E-05	1.46E-04	1.25E-06	1.10E-05	1.88E-09	1.35E-07	NA	NQ	NQ
Thallium	1.18E-04	4.18E-04	8.81E-06	3.13E-05	1.32E-08	3.86E-07	NA	NQ	NQ
Zinc	3.61E-03	3.95E-02	2.70E-04	2.96E-03	4.06E-07	3.64E-05	NA	NQ	NQ
Cyanide_(total)	6.53E-06	4.57E-05	4.89E-07	3.43E-06	7.35E-10	4.22E-08	NA	NQ	NQ
								=====	=====
								5E-08	8E-07

RWC = Reasonable Worst Case
NA = Not Available
NQ = Not quantified due to lack of RfD or slope factor.

level the cancer risk to children playing on Marsh Run Field could not be detected from background.

6.5.4 Risk Characterization for Dermal Contact with Surface Water/Sediments

The risk associated with dermal contact with surface water and sediments and incidental ingestion of surface water by children playing in Marsh Run Creek was evaluated as an exposure pathway under current use of the site. Estimates of the absorbed doses and risks are given in Table 6-15. This table also presents HQs for the individual compounds evaluated as noncarcinogens, the total HI for noncarcinogens, the lifetime excess cancer risk for individual carcinogens and the total excess cancer risk for all carcinogens combined.

For this exposure scenario, all HQs and the HI are less than 1, indicating that there are no expected adverse noncarcinogenic effects from current exposure to children from playing in Marsh Run Creek. This is the case even under the conservative assumptions of the reasonable worst case exposure scenario.

In addition, the lifetime excess cancer risk in both the average and reasonable worst case exposure scenarios is less than 1E-6 (i.e., 1×10^{-6} or 1 in a million), the de minimus level which is generally accepted as indistinguishable from the background level of carcinogenic risk.

6.5.5 Risk Characterization for Consumption of Fish

The risk associated with eating fish from Marsh Run Creek which have bioconcentrated contaminant found in the surface water was evaluated as an exposure under possible current use of the site. Estimates of intake from this exposure pathway and the resulting risk are shown in Table 6-16. All of the HQs and the total hazard index are less than 1, indicating that there are no expected noncarcinogenic risks.

The total carcinogenic risk from consuming fish from Marsh Run Creek is 2E-6 (2 in a million) in the average case and 3E-5 (3 in 100,000) in the worst case exposure scenario. Both risks are within the range of acceptable risks.

For even these low levels of potential noncarcinogenic and carcinogenic risks to occur, all of the exposure assumptions listed in Table 6-9 must apply. For the average case, 12 pounds of edible fish tissue must be consumed each year for 9 years. For the worst case, 30 pounds of fish must be consumed each year for 30 years. All of this fish must come from Marsh Run Creek, and the fish must spend all their time in the area of Marsh Run Creek. In addition, during the ecological investigation no fish were observed which were large enough for eating.

As Marsh Run Creek flows into the Susquehanna River just downstream of Marsh Run Field, any concentrations in Marsh Run Creek become vastly

TABLE 6-15 ESTIMATES OF ABSORBED DOSES AND RISKS ASSOCIATED WITH DERMAL CONTACT WITH SURFACE WATER/SEDIMENTS BY CHILDREN DURING PLAY ACTIVITES IN STREAM AND WETLAND AREA AT THE MARSH RUN FIELD SITE

POTENTIAL NONCARCINOGENIC RISKS

Chemical	Surface Water Absorbed Dose (mg/kg·d)		Sediment Absorbed Dose (mg/kg·d)		Surface Water Ingestion Intake (mg/kg·d)		Total Dose (mg/kg·d)	
	Average	RWC	Average	RWC	Average	RWC	Average	RWC
Trichloroethene	6.78E-09	6.02E-08	(b)	(b)	1.44E-07	8.07E-07	1.57E-09	8.68E-07
1,2-Dichloroethene	(a)	8.60E-09	(b)	(b)	(a)	1.15E-07	NQ	1.24E-07
Tetrachloroethene	(a)	1.72E-08	(b)	(b)	(a)	2.31E-07	NQ	2.48E-07
ncPAHs	9.09E-09	6.02E-08	3.54E-06	7.84E-05	1.93E-07	8.07E-07	3.74E-06	7.93E-05
Diethylphthalate	(b)	(b)	(a)	2.13E-06	(b)	(b)	NQ	2.13E-06
bis(2-Ethylhexyl)-phthalate	(b)	(b)	3.89E-07	2.41E-06	(b)	(b)	3.89E-07	2.41E-06
Di-n-butylphthalate	(b)	(b)	4.26E-07	3.40E-06	(b)	(b)	4.26E-07	3.40E-06
4,4'-DDT	(b)	(b)	1.59E-07	3.48E-06	(b)	(b)	1.59E-07	3.48E-06

POTENTIAL CARCINOGENIC RISKS

Chemical	Surface Water Absorbed Dose (mg/kg·d)		Sediment Absorbed Dose (mg/kg·d)		Surface Water Ingestion Intake (mg/kg·d)		Total Dose (mg/kg·d)	
	Average	RWC	Average	RWC	Average	RWC	Average	RWC
cPAHs	(b)	(b)	1.84E-07	3.97E-06	(b)	(b)	1.84E-07	3.97E-06
bis(2-Ethylhexyl)-phthalate	(b)	(b)	2.78E-08	1.72E-07	(b)	(b)	2.78E-08	1.72E-07
4,4'-DDE	7.27E-12	6.15E-11	2.52E-08	5.88E-07	1.54E-10	8.24E-10	2.54E-08	5.89E-07
4,4'-DDD	1.26E-11	2.34E-10	5.69E-09	1.11E-07	2.68E-10	3.13E-09	5.97E-09	1.15E-07
4,4'-DDT	(b)	(b)	1.14E-08	2.48E-07	(b)	(b)	1.14E-08	2.48E-07
Trichloroethene	4.84E-10	4.30E-09	(b)	(b)	1.03E-08	5.77E-08	1.08E-08	6.20E-08

(a) Average value not calculated since arithmetic mean concentration not available (see Table 6-2).
(b) Chemical not detected in this medium; therefore, no concentrations values available.

Dermal absorbed doses not calculated for metals since dermal absorption of metals is negligible.
RWC = Reasonable Worst Case
NA = Not available
NQ = Not quantified due to lack of RfD, slope factor, or concentration values.

TABLE 6-15 EXTENDED

POTENTIAL NONCARCINOGENIC RISKS

	RfD (mg/kg·d)	HQ = Intake/RfD Average	HQ = Intake/RfD Maximum
Trichloroethene	NA	NQ	NQ
1,2-Dichloroethene	2E-02	NQ	6E-06 (<1)
Tetrachloroethene	1E-02	NQ	2E-05 (<1)
ncPAHs	NA	NQ	NQ
Diethylphthalate	8E-01	NQ	3E-06 (<1)
bis(2-Ethylhexyl)-phthalate	2E-02	2E-05 (<1)	1E-04 (<1)
Di-n-butylphthalate	1E-01	4E-06 (<1)	3E-05 (<1)
4,4'-DDT	5E-04	3E-04 (<1)	7E-03 (<1)
HAZARD INDEX:		5E-04 (<1)	9E-03 (<1)

POTENTIAL CARCINOGENIC RISKS

	Slope Factor $(mg/kg \cdot d)^{-1}$	Lifetime Excess Cancer Risk Average	Lifetime Excess Cancer Risk Maximum
cPAHs	NA	NQ	NQ
bis(2-Ethylhexyl)-phthalate	1.4E-02	4E-10	2E-09
4,4'-DDE	3.4E-01	9E-09	2E-07
4,4'-DDD	2.4E-01	1E-09	3E-08
4,4'-DDT	3.4E-01	4E-09	8E-08
Trichloroethene	1.1E-02	1E-10	7E-10
TOTAL:		1E-08	3E-07

TABLE 6-16 ESTIMATES OF INTAKES AND RISKS ASSOCIATED WITH INGESTION OF FISH WHICH HAVE BIOCONCENTRATED CONTAMINANTS FROM MARSH RUN CREEK SURFACE WATER

POTENTIAL NONCARCINOGENIC RISKS

Chemical	Estimated Intake (mg/kg·day) Average	Estimated Intake (mg/kg·day) RWC	RfD (mg/kg·day)	HQ = Intake RfD Average	HQ = Intake RfD RWC
Trichloroethene	1.06E-05	3.73E-05	NA	NQ	NQ
1,2-Dichloroethene	(a)	5.34E-06	2.0E-02	NQ	3E-04
Tetrachloroethane	(a)	1.07E-05	1.0E-02	NQ	1E-03
ncPAHs	1.42E-05	3.73E-05	NA	NQ	NQ
4,4'-DDE	1.59E-05	5.34E-05	NA	NQ	NQ
4,4'-DDD	2.76E-05	2.03E-04	NA	NQ	NQ
Barium	1.63E-03	6.24E-03	5.0E-02	3E-02	1E-01
Chromium	8.07E-05	6.40E-04	1.0E+00	8E-05	6E-04
Lead	2.34E-04	2.03E-03	NA	NQ	NQ
Manganese	7.81E-03	4.59E-02	2.0E-01	4E-02	2E-01
Vanadium	1.66E-04	8.54E-04	7.0E-03	2E-02	1E-01
Zinc	1.80E-03	8.96E-03	2.0E-01	9E-03	4E-02
				========	========
				1E-01	5E-01

POTENTIAL CARCINOGENIC RISKS

Chemical	Estimated Intake (mg/kg·day) Average	Estimated Intake (mg/kg·day) RWC	Slope Factor $(mg/kg \cdot day)^{-1}$	Lifetime Excess Cancer Risk Average	Lifetime Excess Cancer Risk RWC
Trichloroethene	1.36E-06	1.60E-05	1.1E-02	2E-08	2E-07
1,2-Dichloroethene	(a)	2.29E-06	NA	NQ	NQ
Tetrachloroethane	(a)	4.57E-06	5.1E-02	NQ	2E-07
4,4'-DDE	2.05E-06	2.29E-05	3.4E-01	7E-07	8E-06
4,4'-DDD	3.55E-06	8.69E-05	2.4E-01	9E-07	2E-05
Lead	3.00E-05	8.69E-04	NA	NQ	NQ
				========	========
				2E-06	3E-05

(a) Average value not calculated since arithmetic mean concentration not available (see Table 6-2).
(b) Chemical not detected in this medium; therefore, no concentration values available.

RWC = Reasonable Worst Case
NA = Not available
NQ = Not quantified due to lack of RfD, slope factor, or concentration values.

diluted. The risk from consuming fish from the Susquehanna in the vicinity of Marsh Run Creek is reduced by the same order as the dilution, so that risk from this exposure in the Susquehanna is negligible.

6.5.6 Risk Characterization for Ingestion of Ground Water

Ingestion of ground water by hypothetical residents was evaluated as an exposure scenario under possible future use of the site. The estimated daily intakes and risks associated with this exposure scenario are summarized in Table 6-17.

All individual HQs and the total HI are all less than 1 for the average exposure scenario , indicating that the risk of adverse noncarcinogenic effects is acceptable for this pathway for average exposure. For the worst case scenario, the HQ for arsenic, and consequently the total HI, exceed 1, indicating that under these worst case conditions the risk of noncarcinogenic effects exceeds the acceptable level.

For the assessment of carcinogenic risk, the individual risks for 1,1-dichloroethene, 1,1,2,2-tetrachloroethane, trichloroethene, 1,1,2-trichloroethane, bis(2-ethylhexyl)phthalate, and arsenic all exceed the de minimus risk of 1E-6. The total carcinogenic risk of 1.1E-3 for the average exposure case and the total carcinogenic risk of 4.5E-3 for the reasonable worst case exposure both exceed the acceptable risk range for Superfund sites.

6.5.7 Risk Characterization Summary

Evaluation of risks associated with the past use of Marsh Run Field as a soccer field leads to the conclusions that this use resulted in very little risk to the children using the field. The quantification of noncarcinogenic risks shows that hazard indexes for both average and worst case scenarios are both less than 1, indicating no expectation of noncarcinogenic effects. The lifetime excess cancer risk for the average case (5×10^{-8} or 5 in 100 million) is approximately two orders of magnitude less than the de minimus risk level of 1 in a million, indicating that this risk could not be distinguished from background risk. The lifetime excess cancer risk under the conservative worst case exposure scenario (1×10^{-6}) is at the de minimus risk level.

Evaluation of risk from ingestion of fish from Marsh Run Creek indicates that there is no noncarcinogenic risk and that carcinogenic risk is at the lower end of the range of acceptable risks for remediation alternatives at Superfund sites.

Evaluation of the current use scenario of children playing in Marsh Run Creek indicates that there is little cause for concern from contact with surface water or sediment. Risk from exposure to both noncarcinogenic and carcinogenic compounds is within acceptable ranges even under the conservative assumptions of the reasonable worst case exposure scenarios.

Evaluation of the risk from ingestion of onsite ground water indicates that there would be potential risk associated with this exposure pathway.

TABLE 6-17 ESTIMATES OF INTAKES AND RISKS ASSOCIATED WITH INGESTION OF ONSITE GROUND WATER BY ADULT RESIDENTS AT MARSH RUN FIELD--FUTURE EXPOSURE

POTENTIAL NONCARCINOGENIC RISKS

Chemical	Ingestion Intake (mg/kg·d) Average	Ingestion Intake (mg/kg·d) RWC	RfD (mg/kg·d)	HQ = Intake/RfD Average	HQ = Intake/RfD Maximum
Ethylbenzene	1.03E-04	3.37E-04	1E-01	1.0E-03 (<1)	3.4E-03 (<1)
1,1-Dichloroethene	8.57E-05	2.09E-04	9E-03	9.5E-03 (<1)	2.3E-02 (<1)
1,1,2,2-Tetrachloroethane	1.94E-04	1.13E-03	NA	NQ	NQ
Trichloroethene	1.85E-03	1.11E-02	NA	NQ	NQ
Acetone	1.60E-04	3.00E-04	1E-01	1.6E-03 (<1)	3.0E-03 (<1)
Methylene Chloride	8.57E-05	1.94E-04	6E-02	1.4E-03 (<1)	3.2E-03 (<1)
1,2-Dichloroethene (total)	5.06E-04	1.92E-03	2E-02	2.5E-02 (<1)	9.6E-02 (<1)
1,1,2-Trichloroethane	8.86E-05	1.80E-04	4E-03	2.2E-02 (<1)	4.5E-02 (<1)
bis(2-Ethylhexyl)-phthalate	1.74E-04	4.43E-04	2E-02	8.7E-03 (<1)	2.2E-02 (<1)
Arsenic	5.37E-04	2.22E-03	1E-03	5.4E-01 (<1)	2.2E+00
Iron	1.73E+00	1.07E+01	NA	NQ	NQ
Potassium	1.68E-01	4.40E-01	NA	NQ	NQ
Boron	2.67E-03	1.43E-02	9E-02	3.0E-02 (<1)	1.6E-01 (<1)
Fluoride	4.29E-03	1.00E-02	6E-02	7.1E-02 (<1)	1.7E-01 (<1)
			HAZARD INDEX:	7.1E-01 (<1)	2.7E+00

POTENTIAL CARCINOGENIC RISKS

Chemical	Ingestion Intake (mg/kg·d) Average	Ingestion Intake (mg/kg·d) RWC	Slope Factor $(mg/kg\cdot d)^{-1}$	Lifetime Excess Cancer Risk Average	Lifetime Excess Cancer Risk Maximum
1,1-Dichloroethene	8.57E-05	2.09E-04	6.0E-01	5.1E-05	1.3E-04
1,1,2,2-Tetrachloroethane	1.94E-04	1.13E-03	2.0E-01	3.9E-05	2.3E-04
Trichloroethene	1.85E-03	1.11E-02	1.1E-02	2.0E-05	1.2E-04
Methylene Chloride	8.57E-05	1.94E-04	7.5E-03	6.4E-07	1.5E-06
1,2-Dichloroethene (total)	5.06E-04	1.92E-03	NA	NQ	NQ
1,1,2-Trichloroethane	8.86E-05	1.80E-04	5.7E-02	5.0E-06	1.0E-05
bis(2-Ethylhexyl)-phthalate	1.74E-04	4.43E-04	1.4E-02	2.4E-06	6.2E-06
Arsenic	5.37E-04	2.22E-03	1.8E+00	9.7E-04	4.0E-03
			TOTAL:	1.1E-03	4.5E-03

RWC = Reasonable Worst Case
NA = Not available
NQ = Not quantified due to lack of RfD, slope factor, or average concentration values.

The hazard quotient associated with arsenic indicates that ingestion of this element in drinking water would be at unacceptable levels regarding noncarcinogenic effects. In addition the carcinogenic risks from drinking this ground water would not be acceptable. As stated previously, this is a highly unlikely exposure scenario since residential development is not likely to occur on the site. The site has very low growth potential. Development is unlikely to occur on a former hazardous waste site. The site itself would be a wetlands/marsh area if it were not for the waste deposited on the site and the cap covering the fill. The area is in a floodplain and is bounded by railroad tracks. All of these factors combine to make any development on the site unlikely. In addition, development is not likely to occur in areas north of the site and adjacent to the Susquehanna since this area is also a wetlands and is prone to flooding.

Evaluation of the offsite residential wells in the neighboring area showed that these wells did not contain contaminants and hence posed no risk from the ingestion of water from the residential wells. Groundwater monitoring described in Chapter 4 and modeling in Chapter 5 indicate that current residents are not downgradient of the site and that contaminants from the site are not likely to reach residential wells, indicating that there is no risk to current residents in the vicinity of Marsh Run Field.

6.6 ECOLOGICAL ASSESSMENT

6.6.1 Existing Conditions

As described in other sections of this report, the Marsh Run site consists of a 14-acre grass-covered field adjacent to the New Cumberland Army Depot. To the west and southwest, the site is bounded by the depot, a road, and a 6-ft chain-linked fence topped with barbed wire which separates the site from the depot. To the north, the site is bounded by a high bluff atop which are several sets of Conrail (formerly Penn Central) railroad tracks. The Susquehanna River is further to the north on the other side of the railroad tracks. To the south, the site is bounded by Marsh Run Creek and Marsh Run Road, and to the east the site is bounded by a marsh. Access to the site is limited by road, railroad tracks, and fence.

6.6.1.1 Terrestrial Habitats

Field evaluation of existing vegetative communities and wildlife was conducted on 10 and 21 November 1989. Three terrestrial communities were identified: grassland, wooded upland, and wooded wetland. Vegetation identified at the site is listed in Table 6-18.

The majority of the site was grassland dominated by tall meadow fescue (*Festuca elatior*). In addition, three large silver maples were identified in the southwest corner of the field. This assemblage was typical of open grassy old field maintained by periodic mowing.

TABLE 6-18 VEGETATION IDENTIFIED AT THE MARSH RUN FIELD SITE
10 NOVEMBER 1989

Scientific Name	Common Name	Hydrophytic Status[a]
TREES		
Acer rubrum	Red maple	FAC
Acer saccharinum	Silver maple	FACW
Ailanthus altissima	Tree-of-heaven	UP**
Fraxinus pennsylvania	Red ash	FACW
Platanus occidentalis	American sycamore	FACW
Prunus serotina	Black cherry	FACU*
Quercus bicolor	Swamp white oak	FACW
Quercus palustris	Pin oak	FACW
Robinia pseudoacacia	Black locust	FACU
Ulmus americana	American elm	FACW
SHRUBS		
Cornus amomum	Silky dogwood	FACW
Ligustrum vulgare	European privet	FACU
Rhus typhina	Staghorn sumac	UP**
Rubus occidentalis	Black raspberry	UP**
VINES		
Celastrus scandens	Bittersweet	FACU
Clematis virginiana	Virgin's bower	FAC
Lonicera japonica	Japanese honeysuckle	FAC
Toxicodendron radicans	Poison ivy	FAC
Smilax rotundifolia	Greenbrier	FAC
GRASSES, SEDGES, AND RUSHES		
Andropogon virginicus	Broomsedge	FACU
Carex tribuloides	Sedge	FACW
Cinna arundinacea	Woodreed grass	FACW

(a) Hydrophytic status follows U.S. Fish and Wildlife Service (1988) National List of Plant Species that Occur in Wetlands unless indicated otherwise. Abbreviations:
OBL = Obligate (found in wetlands in more than 99% of all findings)
FACW = Faculative wetland (66-99%)
FAC = Faculative (33-66%)
FACU = Faculative upland (1-33%)
UP = Upland (<1%)

Note: *Hydrophytic status not provided by USFWS (1988), so Dawson and Burke (1985) was used.
**Hydrophytic status not reported; status presented is based on professional judgement and is supported by appropriate literature.

TABLE 6-18 (Cont.)

Scientific Name	Common Name	Hydrophytic Status[a]
GRASSES, SEDGES, AND RUSHES (Cont.)		
Cyperus strigosus	Straw-colored flatsedge	FACW
Dactylis glomerata	Orchard grass	FACU
Dichanthelium clandestinum	Deer tongue witch grass	FAC
Elymus virginicus	Virginia wild-rye	FACW
Eragrostis spectabilis	Showy lovegrass	UP**
Festuca elatior	Meadow fescue	UP**
Glyceria striata	Fowl mannagrass	OBL
Juncus tenuis	Slender rush	FAC
Poa pratensis	Kentucky bluegrass	FACU
Setaria glauca	Bristle grass	FAC
Setaria italica	Fox-tail bristle grass	FACU
Tridens flavus	Purple-top tridens	FACU
HERBS		
Agrimonia parviflora	Small-flowered agrimony	FAC
Allium vineale	Field garlic	FACU
Ambrosia artemesifolia	Common ragweed	FACU
Aster dumosus	Bush aster	FAC
Bidens frondosa	Devils beggarticks	FACW
Boehmeria cylindrica	False nettle	FACW
Chelone glabra	Turtlehead	OBL
Cirsium arvense	Canadian thistle	FACU
Cornillia varia	Crown vetch	UP**
Daucus carota	Queen Anne's lace	UP**
Duchesnea indica	Indian mock-strawberry	FACU
Galium tinctorium	Dye bedstraw	OBL
Geum laciniatum	Rough avens	FAC
Glecoma hederacea	Ground ivy	FACU
Lysimachia nummularia	Moneywort	OBL
Melilotus alba	White sweetclover	FACU
Mentha spicata	Spearmint	FACW
Oenothera biennis	Evening primrose	FACU
Oxalis florida	Wood sorrel	UP**
Phytolacca americana	Pokeweed	FACU
Plantago lanceolata	English plantain	UP**
Plantago rugellii	Broad-leaf plaintain	FACU
Polygonum perfoliatum	Asian tear-thumb	FAC
Polygonum persicaria	Lady's thumb	FACW
Potentilla recta	Cinquefoil	FACU
Rumex crispus	Curly dock	FACU
Scrophularia marilandica	Carpenter's square	FACU
Solanum carolinense	Horse nettle	UP**
Solidago gigantea	Giant goldenrod	FACW
Taraxacum officionale	Dandelion	FACU
Trifolium repens	White clover	FACU
Verbascum thapsis	Wooly mullein	UP**
Xanthium strumarium	Rough cocklebur	FAC

Wooded uplands occurred along the railroad berm which formed the northern boundary of the site, and on both sides of Ninth Street along the western boundary of the site. These areas were dominated by second growth successional trees and shrubs. Silver maple was most common along the railroad, and black locust and black cherry co-dominated the trees along Ninth Street.

A wooded wetland occurred along the east side of the site. This extended from the base of the landfill eastward across the site boundary. This wooded swamp had 0-8 in. standing of standing water and was connected to two dry channels draining the landfill and the railroad berm area. The Fish and Wildlife Service classification for this area is PFOIA--palustrine broad leaved forest flooded temporarily. The swamp was not connected by surface water channel to Marsh Run. A levee along the northern bank separated the swamp from the stream. This levee may be breached during heavy storm events, permitting an exchange of surface waters. The swamp was dominated by silver maple.

Wildlife

The two major habitats available onsite were wooded areas (upland and wetland) and adjacent open grassland area. The latter provides food and cover for hedgerow species such as rabbit, chipmunk, squirrel, woodchuck, mice, and other small mammals, small snakes and songbirds. Upland game birds such as pheasant, quail and grouse may find limited habitat here as well. All of this upland area (landfill and railroad berm) has been filled and graded which lowers habitat quality for burrowing species such as woodchuck, rabbit, and fox. The woodland and open field may periodically be used for forage grounds by hawks and owls. No dens or burrows were noted during the field investigations. The only wildlife observed during the field investigations were black-capped chickadees in the brush adjacent to the open grass area.

The wooded wetland and adjacent stream provide food and cover for a variety of amphibians, reptiles, birds, and small mammals. Species which might use this habitat include: various salamanders and frogs, boxturtle, snapping turtle, water snake, various herons and ducks, woodcock, kingfisher, various woodpeckers, flicker, songbirds, muskrat, opossum, and raccoon. Other species which may periodically use the site due to its proximity to adjacent marsh and wooded tracts and the Susquehanna River include: deer, mink, otter, skunk, and migratory waterfowl.

6.6.1.2 Aquatic Habitat

The major aquatic habitat in the vicinity of the site is Marsh Run Creek, a small perennial stream which flows through the length of the depot and crosses the site along the southern border of the site. After entering the site, the stream flows due east and then north paralleling Marsh Run Road and to the east of the marsh area adjacent to the site. Marsh Run Creek enters the Susquehanna River northeast of the site through two large tunnels that cut beneath the railroad tracks running parallel to the river. Marsh Run Creek is classified as a warmwater fishery (WWF) by the Pennsylvania Department of Environmental Resources. Marsh Run is a

small, second order freshwater tributary to the Susquehanna River in New Cumberland, Pennsylvania. Marsh Run drains much of NCAD as well as the Marsh Run Field and low density residential and commercial development.

A qualitative environmental survey of fish and benthic invertebrate communities, physical habitat assessment and water quality was conducted in that part of Marsh Run which flows through the site on 21 November 1989. The sampling station for this study was located at the southeast corner of the property, beginning at the eastern side of the landfill access road bridge and extending downstream for 100 meters into the adjacent property. From the upstream station boundary Marsh Run flows east, then northeast into the Susquehanna River.

Water quality was sampled 20 ft downstream of the upstream station boundary. Water temperature at 10:20 a.m. on 21 November 1989 was 3.7 C. Selected physicochemical characteristics were measured and found to be within normal ranges (pH was 6.0, dissolved oxygen was 11.8 mg/L, and conductivity was 558 µmho/cm). Weather on the sampling date was windy with light snow flurries and an ambient air temperature of about -2°C.

Substrate composition was determined by pebble counts, a method of sampling coarse river-bed material (Wolman, 1954). The stream substrate was composed largely by small cobble (64-128 mm), large cobble (128-256 mm), and very coarse gravel (32-64 mm). In addition, there was a considerable amount of fine materials ($\leq$ 0.062 mm) distributed in the stream channel. This bimodal substrate composition (Figure 6-1) indicates that a continuing source of excess fine sediment is being transported to the stream. Under normal conditions, fine sediment would be present as a function of the dominant particle size and a normal distribution. When excess fine sediments are supplied to a stream, a bimodal distribution is observed with one peak representing the normal dominant particle size and a second peak representing the added fine component of the substrate.

An instream flow transect was selected at the top of the sampling station to measure stream depth and stream flow velocities. From these measurements the stream discharge of Marsh Run was calculated to be 3.8 cfs (cubic ft per second).

Benthos

Benthic macroinvertebrates were qualitatively sampled on 21 November 1989 from the stream station at Marsh Run and Marsh Run Road. A kick net and dip net were used to collect samples from three habitat types; riffle, pool and undercut banks/roots. Samples were preserved in the field with 10 percent buffered formalin and returned to the laboratory for processing.

Samples were rinsed through a NO. 35 (500µ) sieve to remove the formalin. The samples were then sorted using a white enamel gridded pan from which random sub-samples of 100 organisms were removed. The sub-samples of 100 organisms were identified to taxa using the procedure described in the Rapid Bioassessment Protocols and ranked according to relative abundance. (Table 6-19). The community present is indicative of an invertebrate

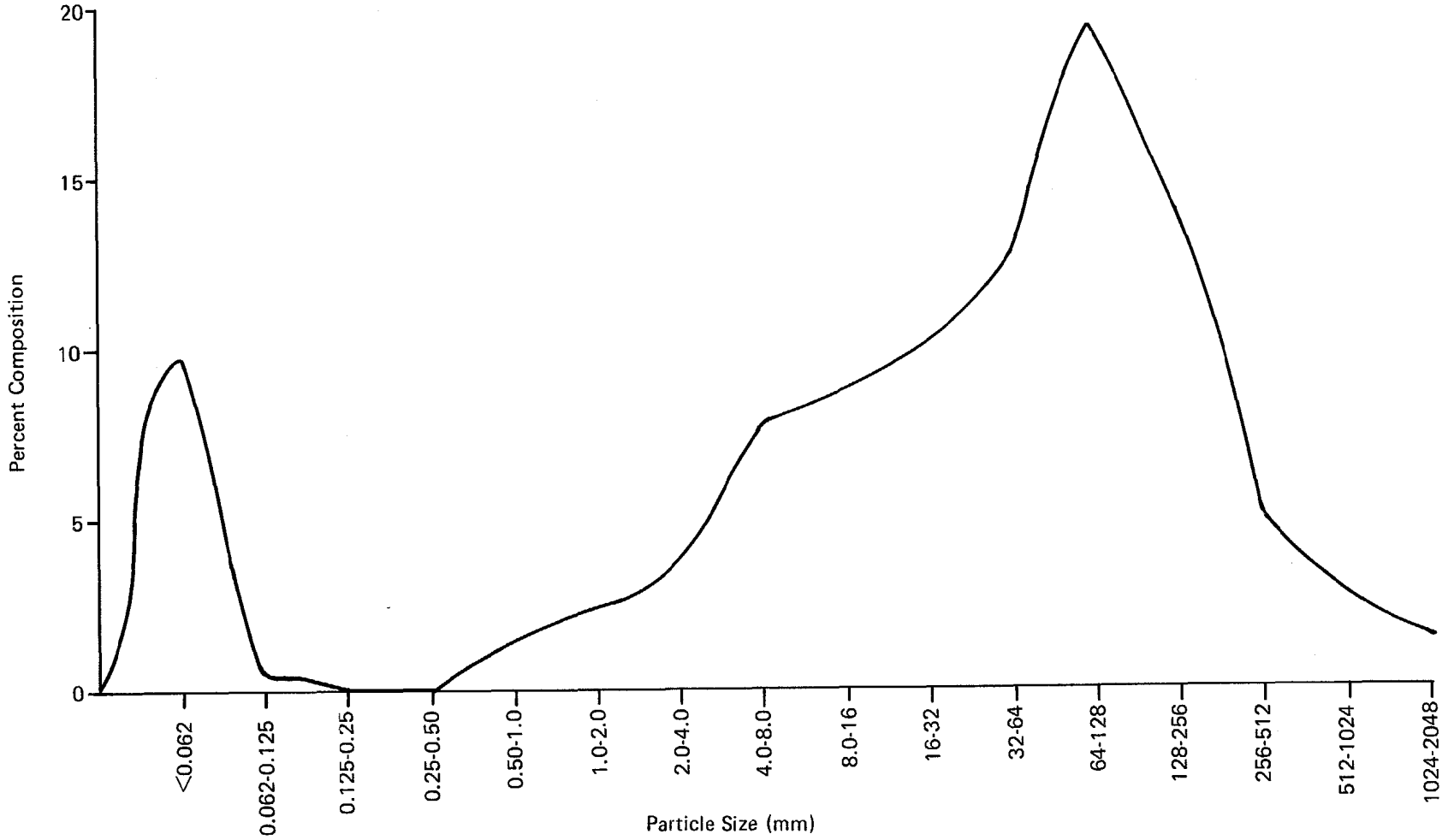


Figure 6-1. Substrate composition of Marsh Run stream station sampled 21 November 1989.

TABLE 6-19 SPECIES LIST AND RELATIVE ABUNDANCE FOR BENTHIC MACROINVERTEBRATE SAMPLES COLLECTED FROM THE MARSH RUN FIELD SITE, NOVEMBER 1989

Taxa	Abundance
Platyhelminthes	
Rhabdocoela	C
Tricladida	R
Mollusca	
Gastropoda	
Physidae	
Physella	R
Planorbidae	R
Pelecypoda	
Corbiculidae *Corbicula*	R
Pisidiidae	C
Annelida	
Oligochaeta	A
Hirundinea	
Glossiphoniidae	
Placobdella papillifera	R
Arthropoda	
Crustacea	
Amphipoda	
Gammaridae	
Crangonyx	A
Gammarus fasciatus	A
Isopoda	
Asellidae	
Asellus	A
Insecta	
Trichoptera	
Hydropsychidae	
Cheumatopsyche	A
Hydropsyche betteni	A
Philopotamidae	
Chimarra	R
Wormaldia	R
Diptera	
Chironomidae	A
Simuliiddae	C
Tabanidae	
Chrysops	R
Tipulidae	
Tipula	R

Note:
R = rare (<3)
C = common (3-9)
A = abundant (>10)

community subject to poor water quality. The depauperate community observed is likely the result of stresses resulting from the excess sediment load discussed earlier and the contaminant concentrations discussed in Sections 6.6.3-6.6.5.

Fish

Fish were sampled using standard electrofishing methods. The location of the 100-meter long station was selected to include all major habitat types (riffle, run, pool). Block nets with 0.125-in. mesh were placed across the stream at the upstream and downstream bounds of the station. The station was sampled upstream from the block nets toward the bridge using a backpack-mounted pulse DC electrofishing unit. A representative sample of fish collected was kept in live boxes until sampling of the 100-meters was completed. Collected fish were measured for length. A few fish of each species were preserved for taxonomic verification; all others were released. Ten species of fish were identified in the survey and are listed in Table 6-20. Gizzard shad was the most common species.

6.6.2 Potential Routes of Exposure

6.6.2.1 Terrestrial Population

Terrestrial biota could potentially be exposed to contaminants buried at the Marsh Run site through ingestion, dermal contact, or inhalation. However, because the contaminants are covered with fill material, it is unlikely that complete exposure routes to terrestrial biota exist. Additionally, because of the inaccessible nature of the site, the number of potentially exposed species and the number of individuals in any one species is very low. Accordingly, the potential risk to terrestrial biota is sufficiently low so as not to warrant further consideration.

6.6.2.2 Aquatic Population

Studies of ground-water flow detailed in Section 3.1.7 indicate that Marsh Run Creek is a secondary sink (with respect to the Susquehanna River) for contaminated ground water. Contaminated sediments are, however, unlikely to enter the creek from this site because the site is capped and the existing plant cover prevents significant erosion of soil into Marsh Run Creek. An upstream source of sediment has been implicated as the cause for turbidity and observed sediment deposits, but has not been further identified. Depending on the chemical and physical properties of the individual compounds, contaminants entering Marsh Run Creek may enter the water column directly or be sorbed to sediments. Water column organisms may be exposed directly to contaminants dissolved in the water column or by consumption of benthic organisms which may accumulate contaminants directly from contaminated sediments.

Benthic organisms may be exposed to contaminants by directly ingesting contaminated sediments or by being exposed to contaminants dissolved in interstitial pore water. A complete, and potentially significant,

TABLE 6-20 LIST OF FISH COLLECTED FROM MARSH RUN AT THE NEW CUMBERLAND ARMY DEPOT, IN DECREASING ORDER OF ABUNDANCE.

Scientific Name	Common Name	Size Range (inches)/(mm)	Relative Abundance
Dorosoma cepedianum	Gizzard shad	1.9-5.1/75-200	A
Notemigonus crysoleucas	Golden shiner	0.64-3.8/25-150	A
Notropis spilopterus	Spot Fin shiner	0.64-2.5/25-100	C
Notropis volucellus	Mimic shiner	0.64-2.5/25-100	C
Notropis simus	Bluntnose shiner	1.3-1.9/50-75	C
Lepomis macrochirus	Bluegill	1.9-2.5/75-100	R
Lepomis gibbosus	Pumpkin seed	1.3-3.8/50-150	R
Lepomis cyanellus	Green sunfish	1.3-2.5/50-100	R
Campostoma anomalum	Common stoneroller	1.9-3.8/75-150	R
Lepomis hybrid	Green sunfish x Pumpkin seed	1.3-2.5/50-100	R

Relative abundance key:
A - abundant >50 specimens
B - common 10-50 specimens
C - rare <10 specimens

exposure pathway therefore exists between contaminants measured at the referenced stations on the site and benthic and water column aquatic species.

6.6.3 Identification of Chemicals of Concern

Surface water and sediment samples were collected and analyzed for potential contaminants by Woodward-Clyde (1988) as detailed in Section 1.2.3 and by EA as detailed in Sections 2.1.4 and 2.1.5 of this report. Woodward-Clyde collected surface water samples at a single background control station immediately upstream of the site and at one station immediately adjacent to the site. They also collected sediment samples from two stations in Marsh Run, a control station upstream of the site, and a station immediately adjacent to the site. Sediments were also sampled by Woodward-Clyde from the head of a small drainage swale along the northern boundary of the site and from the marsh area between the site and Marsh Run. All surface water and sediment samples were analyzed for total inorganics (including trace metals), volatile organics, and total petroleum hydrocarbons. The results of the 1988 sampling are detailed in Woodward-Clyde (1988).

The locations of the sediment and surface water samples collected by EA are detailed in Section 2.1.4 and 2.1.5. All samples collected by EA were analyzed for volatile and semivolatile organics, pesticides, PCBs, and total inorganics. The results of these analyses are found in Section 4.3. Figure 6-2 indicates the locations of the Woodward-Clyde and EA surface water and sediment samples.

The results of the surface water and sediment sampling indicate that the concentrations of several trace metals in one or more of the surface water or sediment samples were high enough to justify detailed examination. The only organics to be detected in notable quantities were DDT and its metabolites which were detected in water samples from station SWS-5, a background station on Marsh Run Creek upstream from the site. This apparent contamination is unrelated to the site and will not be considered further.

6.6.4 Comparison of Measured Concentrations of Trace Metals to State and Federal Water Quality Criteria

The observed concentrations of trace metals in surface water samples were compared to Pennsylvania's Water Quality Criteria for Toxic Substances (Title 25, Chapter 6, Water Quality Toxics Management Strategy as published in the Pennsylvania Bulletin 19:1059-1092, March 11, 1989) and the U.S. Environmental Protection Agency's Quality Criteria for Water 1986 (U.S. EPA 1986). Water quality criteria for many trace metals are hardness-dependent; therefore, individual hardness values were calculated for each surface water sample from the measured concentrations of calcium and magnesium (Method 314A--Standard Methods, APHA, 1985). Sample-specific chronic criteria were calculated using the more stringent of the state or federal criteria and compared to measured concentrations of the trace metal.

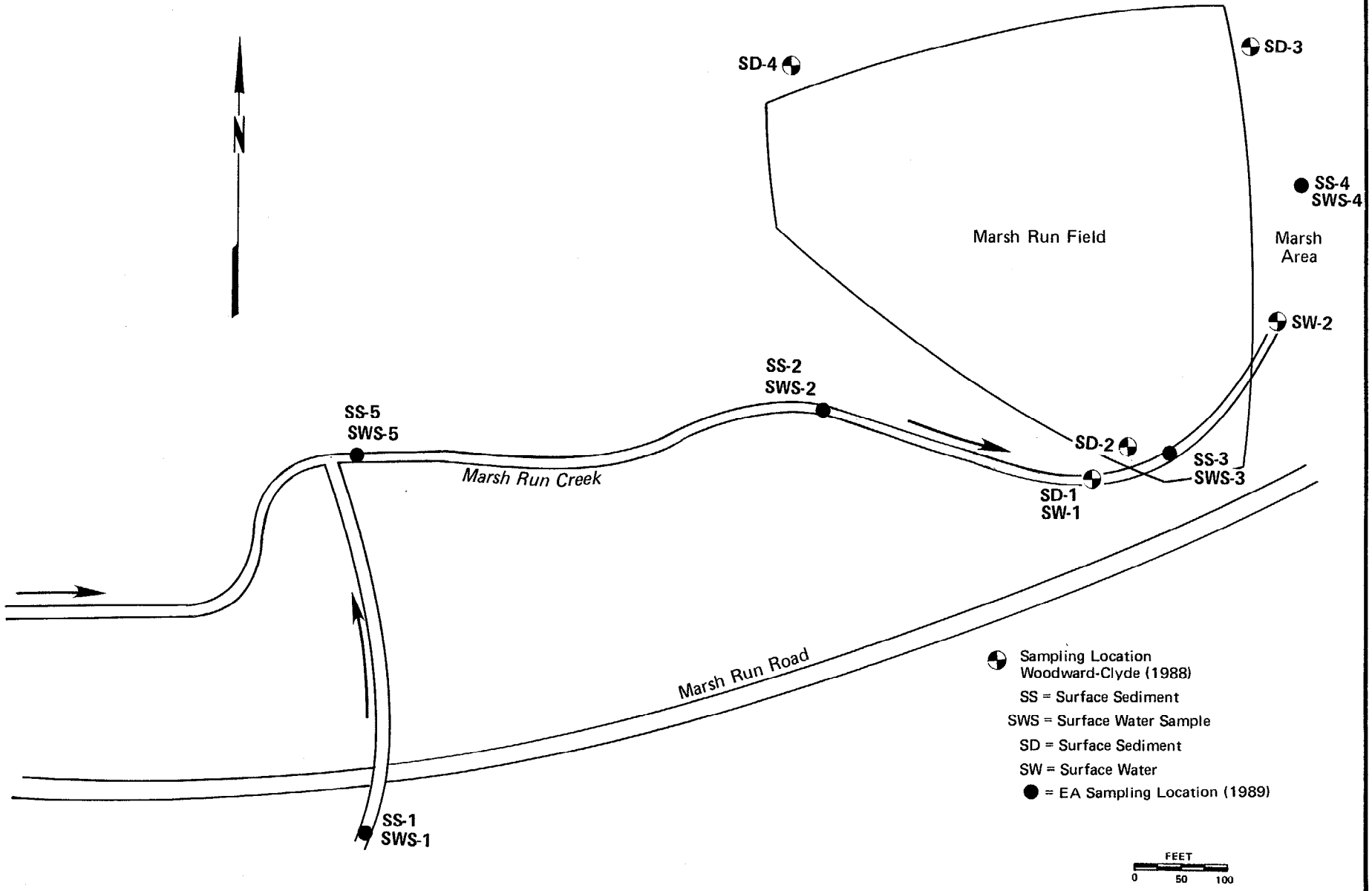


Figure 6-2. Location of surface water and sediment sampling stations.

As detailed in Table 6-14, aluminum concentrations at all stations except SWS-2 exceeded the U.S. EPA chronic criterion of 87 µg/L and in some cases the acute criterion of 750 µg/L. The background station SWS-5 had the highest measured aluminum concentration followed by the marsh station SWS-4.

Copper (see Table 6-15) was observed to exceed the chronic criterion in only one sample, SW-2. This sample also had the lowest hardness value.

The concentration of iron in several background samples (SW-1, SWS-5, and SWS-5 Dup) exceeded the 1,000 µg/L U.S. EPA acute criterion (Table 6-16), as did a single sample from Marsh Run (SW-2) and a single sample from the marsh adjacent to the site (SWS-4). In a similar manner, as shown in Table 6-17, background samples SWS-1, SWS-5, and SWS-5 Dup exceed the state chronic criteria for lead, as did a single sample (SW-2) from Marsh Run.

Mercury concentrations of 2.1 µg/L in sample SWS-2 from Marsh Run exceeded the federal and state chronic criteria by three orders of magnitude, but the duplicate sample from the same station (SWS-2 Dup) had an undetectable concentration of mercury. Mercury was also detected in the water sample collected from the marsh (SWS-4) and in one of the background samples (SWS-1 Dup) (see Table 6-18).

Concentrations of zinc in background samples and samples taken in the immediate vicinity of the site were all below the state and federal chronic criteria (Table 6-19). As shown in Table 6-20, other trace metals were not detected in surface water samples (e.g., antimony, beryllium, cadmium, cobalt, nickel, selenium, silver, and thallium) or were detected at concentrations below applicable criteria (i.e., arsenic). Several trace metals (e.g., barium, chromium (total), magnesium, manganese, vanadium, and boron) were detected but have no applicable acute or chronic criteria.

6.6.5 Comparison of Trace Metals Concentrations from Site and Background Sediment Samples

Table 6-21 compares the highest concentration of trace metals detected in sediment samples from the immediate vicinity of the site with trace metal concentrations from the background site (SS-1) and background concentration of trace metals typical for southeastern Pennsylvania. In only four cases (i.e., arsenic, cadmium, mercury, and selenium) was the highest concentration in sediments from the site higher than background concentration. In each case these trace metals were detected from the same sample, SS-4, collected from the marshy area between the site and Marsh Run.

6.6.6 Conclusions and Recommendations

Evaluating the potential contribution of contaminants from the abandoned waste site to the observed elevations of trace metals in surface waters and sediments is difficult as a result of one or more apparent offsite sources of contamination upstream of the site. Aluminum, iron, and lead

TABLE 6-21 COMPARISON OF BACKGROUND AND SITE CONCENTRATIONS OF TRACE METALS IN SEDIMENTS

Trace Metal	Southeastern[1] Pennsylvania Background Concentration (mg/kg)	Site Background (SS-1; mg/kg)	Highest Concentration Onsite	
			Concentration (mg/kg)	Sampling Location
Arsenic	6.5	11.8	32.4*	SS-4
Beryllium	1-15	0.32	1.1	SS-2
Cadmium	<1-1[2]	U	1.8*	SS-4 Dup
Chromium	50-70	9.9	24.9	SS-2
Cobalt	15-70	8.5	11.7	SS-3
Copper	50-150	8.9S	32.7S	SS-4 Dup
Lead	30-100	13.2S	75.8	SS-4
Mercury	0.082-0.13	U	0.24S*	SS-4
Nickel	30-200	8.2	18.6	SS-2
Selenium	0.5	U	0.84*	SS-4
Silver	NR	U	U	
Thallium	NR	U	U	
Vanadium	150-500	26.3	34.1	SS-4 Dup
Zinc	74-510	75.2S	157	SS-4 Dup

* - Concentration is above site background concentration and typical background concentration
U - undetected
S - indicates compound detected at <5 times the concentration detected in associated trip or rinsate blank
1 - Source: Shacklette and Boerngen (1984)
2 - Source: Conner and Shacklette (1975)

concentrations in background surface water samples were elevated compared to concentrations from Marsh Run Creek and the marsh located between Marsh Run and the site. Elevated concentrations of DDT and metabolites in background sample SWS-5 (and SWS-5 Dup) indicate that upstream sources may also contribute organic contaminants to Marsh Run.

The highest concentrations of trace metals contaminants in the immediate vicinity of the site were detected in the surface water and sediment samples collected from the marsh area between Marsh Run Creek and the site. Given the ground-water flow patterns and the site geography, it is more likely that contaminants detected in the marsh area are more directly associated with the leaching of contaminants from the site rather than offsite locations.

It should also be noted that all of the surface water and sediment trace metal analyses were total determination, which includes both dissolved and bound fractions. Significant fractions of the observed trace metals may be bound to particulates and therefore not bioavailable to aquatic organisms.

7. SUMMARY AND CONCLUSIONS

7.1 SUMMARY

The results of the Remedial Investigation at the Marsh Run Field site are summarized in the following discussions. The purpose of this RI was to identify potential source(s) of contamination, define the nature and extent of contamination at the site, as well as immediate offsite impacts to ground water, surface water, and air. Downgradient ground-water impacts and downstream surface water quality have also been evaluated and assessed in terms of human health and environmental risks associated with the potential routes of exposure.

To assess the impact of the landfill on ground water, surface water, and ambient air at the site, the following investigations and samplings were completed:

- Installation of ground-water monitoring wells during a first and second phase (saturated overburden and bedrock), and sample collection and analysis
- Slug test
- Stream surface water and sediment sample collection and analysis
- Residential supply well sampling

7.1.1 Source Identification

Based on data collected during this study and from previous investigations conducted on NCAD property and at Marsh Run Field, it appears as if contamination derived from the fill placed at Marsh Run Field is contributing to the local contamination of ground water and potentially to surface waters of Marsh Run Creek. Specifically, low-level concentrations of the volatile organic compounds trichloroethene (TCE), vinyl chloride, 1,2-dichloroethene (total), 1,1-dichloroethene, 1,1,2,2-tetrachloroethane were detected in monitoring wells installed peripheral to the fill and well points installed in the fill. Based on the inferred ground-water flow paths and hydrogeologic conditions, the presence of these compounds in the shallow overburden wells strongly suggests that the landfill materials are the source of these volatile organic compounds. Elevated trace metals in the total phase (undissolved) of ground water collected from site monitoring wells, especially the overburden wells, indicate a potential site-specific source of trace metals contamination. The analytical data indicate that most of the elevated trace metal constituents are in the total (i.e., suspended solid) phase and are therefore relatively immobile in the bedrock aquifer. Based on peripheral analysis (i.e., monitoring well soil and water samples), other compounds detected in monitoring well samples that may be present in the fill are polynuclear aromatic hydrocarbons (PAHs), typical constituents of asphaltic substances or heavy oils.

Review of data from previous investigations conducted at various solid waste management units (SWMUs) on NCAD property has indicated that other potential offsite contaminant sources of trace metals, pesticides, PAHs, volatiles, and PCBs exist in relative close proximity to Marsh Run Field. Examination of physical and chemical data obtained from this investigation suggests that if an offsite source of volatiles is contributing to the volatile contamination of the ground water beneath Marsh Run Field it is not readily apparent. Although the possibility exists that an undetected source of volatile organics is present offsite, however unlikely, the present monitoring system appears to be adequate to identify such a source. The exception would be a deeper, yet undefined component of ground-water flow responsible for contaminant transport. However, this situation, based on present knowledge, is an unlikely scenario.

Conversely, elevated metal concentrations in offsite monitoring wells indicate a potential source of trace metals west of Marsh Run Field. Based on inferred ground-water flow paths, an offsite source and onsite source would not be likely to interact or communicate (to the depth of aquifer investigated) due to Marsh Run Creek's role as a hydraulic barrier. Whether or not any offsite sources of organics or inorganics are contributing to the ground-water contamination beneath and downgradient of Marsh Run Field via Marsh Run Field appears to be at least contributing to the localized volatile contamination of the ground water.

Other indirect, nonintrusive sampling techniques (i.e., geophysics) were utilized to define boundaries of the "waste fill" material. The results of the geophysics generally defined a "waste fill" outer boundary. The exact nature of the waste material was not directly investigated by test pits or soil borings.

7.1.1.1 Ground-Water Contamination

The Triassic Gettysburg sandstone/shale Formation comprises the regional aquifer in the site vicinity. Regional ground-water flow patterns in this aquifer roughly trend south to north. Ground water flows from the Triassic highlands immediately south and southeast of the site to the north where it discharges as base flow to the Susquehanna River.

Monitoring well water level data indicate that the perennial flowing Marsh Run Creek which borders the site to the southwest, south, and east serves as an intermediate ground-water discharge point that intercepts base flow from the bedrock aquifer (to at least the depth of aquifer investigated, 50 ft) south and east of the site and also a portion of the ground water beneath Marsh Run Field which flows radially south to Marsh Run Creek. It is speculated that in deeper zones of the aquifer the regional south to north flow trend is resumed and ground-water underflow of Marsh Run Creek occurs. All of the existing residences, based on topographic position, are hydraulically upgradient of the site. Consequently, if at depth ground-water underflow of Marsh Run were to occur trending along a regional flow pattern, these residences would still be upgradient of the site with respect to regional hydraulic gradients. In effect, the residences' topographic position and the presence of Marsh

Run Creek prevent potential contaminant migration from beneath Marsh Run Field to these residences under current conditions.

Data collected from site monitoring wells indicate VOCs to be present in the bedrock aquifer at low concentration levels [i.e., less than 400 µg/L (ppb)] beneath the site. Two sampling rounds spaced approximately 6 months apart revealed similar concentration levels of trichloroethene, 1,2-dichloroethene (total), and several other industrial solvent-related compounds in the bedrock aquifer. Several of the aforementioned VOCs exceeded their respective MCLs by 1 to 80 times. Subsequently, shallow monitoring wells installed in the unconsolidated overburden around the perimeter of Marsh Run Field revealed low levels of VOCs during the second round of sampling. Compounds such as vinyl chloride, trichloroethene, 1,2-dichloroethene and several other VOCs were detected at low levels (i.e., less than 110 µg/L) in the saturated overburden. Several of the respective volatile compounds' MCLs were exceeded in samples collected from the overburden wells during the second round. No VOCs were detected in the overburden monitoring wells during the first sampling event.

Based on the available monitoring well sampling data, water level data, aquifer testing, and ground-water modeling, it appears as if Marsh Run Field is a potential source of VOCs detected in the ground water. As previously discussed in Section 7.1.1, Source Characterization, the potential exists, although unlikely, that an offsite source may be contributing to the VOC contamination detected in the site monitoring wells. However, during this investigation, ground-water samples collected from upgradient monitoring wells were found not to contain detectable levels of VOCs similar to those encountered beneath or downgradient of the site.

Trace metal contamination is not as well defined. It appears, based on monitoring well data, that elevated trace metals in ground water (arsenic, cadmium, chromium, lead) in the total phase (i.e., suspended solids, undissolved) are potentially attributable to the fill material at Marsh Run Field. However, offsite upgradient wells MW-5A and MW-5 exhibited similar elevated trace levels which may be indicative of an offsite source. Review of historical documents and analytical results of previous NCAD environmental investigation has revealed other sites that have been documented as contributing contamination to the area on the depot adjacent to Marsh Run Creek. Elevated trace metals are primarily restricted to the total phase which makes these constituents much less mobile than if they were in the dissolved phase.

Any potential ground-water contamination, whether site (Marsh Run Field) derived or from an offsite (upgradient source) will migrate north towards the Susquehanna River or intermediately discharge to Marsh Run Creek. Ground-water modeling of the site demonstrated that the ground-water contamination will migrate northward or be emptied into the Susquehanna via Marsh Run Creek. The residences are not in the predicted migration path of contamination detected in the aquifer.

7.1.1.2 Residential Wells

Data from the residences' supply wells sampled during this investigation and previously by PaDER have revealed no apparent site-related contamination. Based on ground-water modeling results, the residences southeast and east of the site are not in the predicted migration path of potential site-related contamination. Marsh Run Creek and the relative topographic position of the residences with respect to Marsh Run Field further preclude contaminant migration to these residences.

7.1.1.3 Surface/Sediment Water Impacts

The interaction between Marsh Run Creek and the ground-water system was investigated during this investigation. Water level data, ground-water monitoring, surface water sampling and analysis, and modeling of the hydrologic conditions at the site were conducted. Results of the modeling indicate that Marsh Run Creek receives perennial base flow from the bedrock aquifer and saturated overburden, both from the site and on the other side of the creek. To the depth investigated (i.e., 50 ft below the ground surface) Marsh Run Creek receives base flow from the bedrock aquifer and acts as an intermediate discharge point. Marsh Run Creek surface water and sediment sampling upstream of the site at SWS-5, SS-5 revealed low-level (i.e., <10 µg/L) volatile contaminants trichloroethene and 1,1,2,2-tetrachloroethane in the stream water and low-level PAH contamination in the stream sediments. Surface water sampling adjacent to and downstream from Marsh Run Field SWS-2 and SWS-3 also revealed low-level volatile compounds trichloroethene and 1,2-dichloroethene similar to the concentration detected upstream. Based on the distribution of volatile contamination in Marsh Creek, an upstream source of volatile compounds is suspected as contributing to volatile contamination in Marsh Run Creek. Previous water quality studies of Marsh Run Creek on the depot also detected similar concentration and species of volatiles and pesticides upstream of Marsh Run Field. Ground-water modeling and inferred ground-water flow paths suggest that there is a potential that some low-level volatiles from Marsh Run Field may migrate towards Marsh Run Creek; however, this has not been confirmed by the MW-7 bedrock well which is situated between Marsh Run Field and Marsh Run Creek. The primary source of volatiles to Marsh Run Creek appears to be an upstream source unrelated to Marsh Run Field. Figure 1-5 and Table 1-4 detail previous investigation sampling results and locations to support this equation.

7.1.1.4 Air Emissions

In light of the dense grass ground cover, fugitive dust emission is not a significant contaminant transport mechanism or exposure pathway. The cover topsoil was sampled and analyzed by both the U.S. EPA and the U.S. Corps of Engineers, Omaha District. No significant detection of contamination was observed.

7.1.2 Fate and Transport

In summary, the "waste fill" distributed at Marsh Run Field is a potential source of low-level volatiles and inorganics to the ground-water system. The "waste fill" is not a contaminant migration pathway but serves rather as a source term to the bedrock aquifer. Volatile organic compounds detected in the site monitoring wells are reflective of typical industrial solvents used for paint stripping, degreasing, and metals fabrication. The parent VOCs trichloroethene, 1,1,2,2-tetrachloroethene, and possibly tetrachloroethene are apparently undergoing and have undergone microbial and/or abiotic transformation to more environmentally persistent VOCs, such as 1,2-dichloroethene (total) and possibly vinyl chloride. Vinyl chloride may itself be a parent compound. The age of the onset of volatile contamination is uncertain as is the mechanism of source loading (i.e., solvent-laden soil, corroding barrels, etc.). Consequently, fate and transport dynamics were modeled using the known site hydrologic conditions (i.e., hydraulic gradient, hydraulic conductivity), and assuming other unknown but theoretically plausible parameters (i.e., depth of bedrock aquifer source strength and size). The assumed parameters used in modeling directly effect the total predicted source loading versus the actual contaminant flux to the environment; however, the migration direction, rate and dissemination effects of the aquifer on contaminant transport are considered valid, based on the present knowledge of the site. Results of modeling were used to predict the approximate duration necessary to achieve steady state plume dynamics (i.e., source in = contaminant flux out), direction and rate of migration and the qualitative comparisons of contaminant distribution in both the saturated overburden and bedrock aquifer. Modeling results compare favorably with observed conditions with respect to water balance, contaminant distribution, and migration pathways. The model results indicate that the residences are not in the contaminant migration pathway. Analytical results of the residences' wells confirm this indication.

The mobility of semivolatile compounds which were detected in monitoring well soil samples and at very low levels (i.e., near detection limit) in several monitoring wells, specifically PAH compounds, is low in ground water and is not considered a threat to the ground water. Although there appear to be elevated trace metal concentrations in the ground water, this contamination is not mobile due to the propensity of metals to be in an undissolved phase (suspended solids). Based on the fate and transport scenario developed for the site, only future supply wells installed north of the site and west of the north-south trending segment of Marsh Run Creek would potentially be in the contaminant migration path.

7.1.3 Risk Assessment Conclusions

The risk assessment completed for Marsh Run Field included both human health and environmental toxicity concerns. The exposure routes considered in the risk assessment included ground water, surface water (and sediment), air, and direct contact.

Ground-water exposure points addressed in the assessment included data from both the perimeter monitoring wells and the domestic wells nearest

the site. The type of exposure considered for the ground water was ingestion. Environmental impacts at the site were assessed in terms of downstream surface water quality impacts. The types of exposure which would be of primary concern for surface water include the use of surface water as a source of drinking water and recreation (i.e., play).

7.1.3.1 Applicable or Relevant and Appropriate Requirements

The applicable or relevant and appropriate requirements (ARARs) considered in the risk assessment included MCLs, SMCLs, and lifetime health advisories (HAs).

7.1.3.2 Risk Characterization

Evaluation of risks associated with the past use of Marsh Run Field as a soccer field leads to the conclusion that this use resulted in very little risk to the children using the field. Evaluation of the current use scenario of children playing in Marsh Run Creek and evaluation of the future use scenario of children playing on Marsh Run Field both indicate that there is little cause for concern.

Evaluation of the risk from ingestion of onsite ground water indicates that there would be potential risk associated with this exposure pathway in ground water. This is a highly unlikely exposure scenario since residential development is not likely to occur on the site.

Evaluation of the offsite residential wells in the neighboring area showed that these wells did not contain contaminants and hence posed no risk from the ingestion of water from the residential wells. Groundwater monitoring described in Section 4 and modeling in Section 5 indicate that current residents are not downgradient of the site and that contaminants from the site are not likely to reach residential wells, indicating that there is no risk to current residents in the vicinity of Marsh Run Field.

7.1.3.3 Ecological Assessment

The purpose of this ecological assessment is to determine whether or not releases of contaminants from Marsh Run Field have the potential to cause direct harm to plants or animals in the immediate vicinity of the site. A contaminant entering the environment surrounding Marsh Run Field will potentially cause adverse effects. The random distribution of elevated levels in the marsh and stream sediment both on or adjacent to the site and upstream give no clear and concise pattern. Several metals of concern with regard to toxicity to biota are potentially related to the site and potential offsite source(s). In addition, since sediment/surface water were analyzed for total metals, much of the metals bound to particulate matter are not bioavailable.

7.2 CONCLUSIONS

Based on the above analysis, there are no risks identified with the site's existing conditions. Potential risks may exist, however, if domestic water supply wells were to exist north of the site. It is highly unlikely that domestic wells will be installed in this proximity, since the area north of the site is wetlands, which are prone to flooding.

7.2.1 Remedial Objectives

Based on the limited risks presently associated with the site, the primary objectives for any remedial activities are to provide adequate closure remedies. Appropriate landfill closure procedures should be implemented to further reduce leachate generation and mitigate contaminant transport to the regional aquifer at the site.

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APPENDIX A

BORING LOGS

JOB # 388
JULY 31, 1989

E. A. ENGINEERING
MARSH RUN SITE
WELL LOCATIONS

	ELEVATIONS			COORDINATES			
		CASING				NORTH	WEST
WELL #	GROUND	INNER	OUTER	NORTH	EAST	LATITUDE	LONGITUDE
MW-1	304.52	306.58	306.86	317,085.77	2,227,191.75	40*12'00.147"	76*49'25.985"
MW-1A	303.79	306.02	306.74	317,065.74	2,227,184.13	40*11'59.950"	76*49'26.086"
MW-2	300.16	301.70	301.70	316,805.32	2,227,817.86	40*11'57.311"	76*49'17.955"
MW-2A	300.02	302.50	302.95	316,816.44	2,227,817.77	40*11'57.421"	76*49'17.954"
MW-3A	301.16	303.42	304.48	316,613.34	2,227,686.13	40*11'55.427"	76*49'19.678"
MW-4	303.88	305.85	306.38	317,094.15	2,227,634.77	40*12'00.184"	76*49'20.275"
MW-4A	302.89	305.04	305.56	317,086.01	2,227,653.31	40*12'00.102"	76*49'20.037"
MW-5	300.35	302.75	302.94	316,403.76	2,227,545.71	40*11'53.371"	76*49'21.516"
MW-5A	301.97	304.31	304.92	316,385.23	2,227,542.75	40*11'53.188"	76*49'21.557"
MW-6	299.16	301.11	301.01	317,113.49	2,226,833.23	40*12'00.458"	76*49'30.602"
MW-6A	301.33	303.34	304.93	317,105.85	2,226,847.76	40*12'00.381"	76*49'30.416"
MW-7	299.90	302.02	302.02	316,689.48	2,227,291.29	40*11'56.221"	76*49'24.756"
MW-7A	299.84	301.92	301.61	316,709.80	2,227,314.63	40*11'56.419"	76*49'24.453"
WP-1	302.20	304.53	305.10	316,818.80	2,227,460.38	40*11'57.481"	76*49'22.560"
WP-2	301.97	304.71	304.73	316,619.36	2,227,577.05	40*11'55.498"	76*49'21.083"
WP-3	302.25	304.34	305.08	316,811.36	2,227,612.75	40*11'57.392"	76*49'20.597"
SS-2	292.77			316,745.94	2,227,026.03		
SS-3	292.75			316,474.03	2,227,645.37		
SS-4	293.53			316,481.25	2,227,726.64		

Horizontal Datum: Pennsylvania Plane Coordinates South Zone NAD 1983
Vertical Datum: NGVD 1929
Monuments used: Horizontal Fishing & Fishing Azumuth
Vertical Fishing RM-1 & RM-2

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF SOIL BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-1
Coordinates:N 317085.77; E2227191.75

Location: NCAD
Job No. 10424.22
Client: ACE
Drilling Method: B-61, HSA, 2 man crew, 8"OD, 4"ID

Surface Elevation: 304.52
Casing Above Surface:2.06
Reference Elevation: 306.58
Reference Description:Top of PVC

Sampling Method: SS, 140 lb. hammer, 30" drop. Continuous sampling first 1o ft., 5 ft. intervals thereafter to bedrock

Start Date:1/16/89 Completion Date:1/16/89

SAMP TYPE	IN DRVN	IN RCVD	SAMP NO.	SAMP DPTH	BLOWS/6"	HNU PPM	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS Flat, grass covered / SOIL DESCRIPTION
SS	24	20	1	1	3-4-7			ML	Dk. bn. clayey silt, moist
SS	24	22	2	2.5	3-4-4			ML	Med. bn., clayey silt, moist, increasing clay content occ. large asphalt/ gravel fill debris increasing plasticity
SS	24	12	3	5.5	4-3-4-7		5	CL	Med. red-bn. clayey silt with a little gravel, moist
SS	24	8	4	7.5	12-35-32-33			Fill / SP	Mottled bn. cg sand and gravel with abundant quartz fragments might be a highly weathered SS bed, moist
SS	24	6	5	9.5	32-13-14-3-4		10	SP	Moisture on spoon. Not very wet, Lt. bn., very cg sand with Weathered gravel, cobble frags of SS, moist-wet
SS	10	10	6	15	13-51/4		15	Sap	Moisture on spoon SS refusal at 15 1/2 Med. dk. red shale, weathered powdery H.C. odor from sample Bedrock at 15.5 ft., begin coring at 15 ft.
							20		

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER
DEN-DENISON CORE BARREL SAMPLER
SPT-STANDARD PENETRATION TEST (ASTM D 1586-84)

GROUND-WATER DEPTH BELOW GRADE
AT COMPL 11.14 FT.
AFTER 22 HRS. 10.07 FT.
AFTER 24 HRS. FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF CORE BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-1

Coordinates:

Surface Elevation:
Casing Above Surface:
Reference Elevation:
Reference Description:

Location: NCAD
Job No. 10424.22
Client: ACE
Drilling Method: Mob-B-61 Nx wire line split barrel coring device 10" long
Core Bit Size:Nx Inclination:0

Start Date: 1/20/89 Completion Date:1/20/89

RUN NO.	RQD (%)	RCOVERY (%)	BEDDING INCLIN	FRACTRS INCLIN	RUN LENGTH (FT.)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS: LITHOLOGIC LOG	DRILLING LOG
1	30	70	Massive			20		Gravel at top, red shale in bit. washed out, no recovery	10:26-10:30 Resume at 21.5 10:30- Jam/11:01-11:08
					5 ft.			Finely laminated red siltstone with shale parting	11:08-11:21 11:21-11:27 11:27-11:31 (pulled core)
2	90	98	Massive			25			11:47-11:52 11:52-11:55 11:55-11:59 11:59-12:03
					10 ft.	30		Gradational conatact red siltstone to fg red sandstone	12:03-12:07 12:11-12:15 12:15-12:19 12:19-12:22 Taking water 40-50 gal. 12:22-12:25
3	100	100	Massive			35		Fg red sandstone	12:25-12:28 12:50-12:53 12:53-12:56 12:57-12:59 12:59-13:02 13:02-13:05
						40			

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER
DEN-DENISON CORE BARREL SAMPLER
SPT-STANDARD PENETRATION TEST (ASTM D 1586-84)

GROUND-WATER DEPTH BELOW GRADE
AT COMPLETION FT.
AFTER HRS. FT.
AFTER 24 HRS. FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF CORE BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-1
Coordinates:

Surface Elevation:
Casing Above Surface:
Reference Elevation:
Reference Description:

Location: NCAD
Job No. 10424.22
Client: ACE
Drilling Method: Mobile B-61 Nx wire line split barrel casing device 10" long
Core Bit Size: Nx Inclination: 0

Start Date: 1/20/89 Completion Date: 1/20/89

RUN NO.	RQD (%)	RCOVERY (%)	BEDDING INCLIN	FRACTRS INCLIN	RUN LENGTH (FT.)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS: LITHOLOGIC LOG	DRILLING LOG
						40			
					10 ft.			Red sandstone with uncommon oblique fractures, some calcite(?) filled veins	13:09-13:12
									13:12-13:15
									13:15-13:18
									13:18-13:21
						45			13:21-13:24
4	100	100	Massive						13:43-13:46
									13:46-13:50
									13:50-13:53
									13:53-13:56
						50		Bottom of boring 50 ft.	13:56-14:00
						55			
						60			

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER

GROUND-WATER DEPTH BELOW GRADE
AT COMPLETION FT.
AFTER HRS. FT.
AFTER 24 HRS. FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF SOIL BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-2

Coordinates: N 316805.32; E 2227817.86

Location: NCAD
Job No. 10424.22
Client: USCOE
Drilling Method: 12" O.D., 8 1/2" I.D. hollow stem auger

Surface Elevation: 300.16
Casing Above Surface: 1.54
Reference Elevation: 301.70
Reference Description: Top of PVC

Sampling Method: SS, 140 lb. hammer W/30" drop

Start Date: 7/19/89 Completion Date: 7/20/89

SAMP TYPE	IN DRVN	IN RCVD	SAMP NO.	SAMP DPTH	BLOWS/6"	HNU PPM	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS Flat, grassy area, slightly muddy but stable SOIL DESCRIPTION
SS	24	10	1	1	2-3-5-8-4	0		SM	Black, moist, silty fine sand with some granules loose 50% fine sand 20% granule
								Fill	30% silt or finer
SS	24	7	2	3.0	3-4-5-1	0			Organic matter, asphalt odor cinders, ash fill (Some silty sand past 3.0 ft.) Grading to green-brown, moist
SS	24	24	3	5.0	2-3-5-2		5		Silt and clay with trace of fine sand
								CL	Brown/Green, moist, silt and clay with a trace of fine sand, organ
SS	24	19	4	7.0	5-7-19-11				matter interspersed, soft, medium plasticity - CL ,In-situ materia
									Encountered watered at 6.0 ft. +,- 1ft.
								CL	Green wet silt and clay
SS	20	18	5	9.0	16-22-50/2"				Medium stiff, med. plasticity
							10	ML/SM	Grading to stiff past 8.0 ft. Brown silt with some fine sand, trace of clay dense low plasiticit 50% fine, 50% fine sand and granule
									At 10 ft. 12" auger would not advance, changed drill rig over to a rotary 8 1/2" roller bit
									Hit rock at 11 ft. at 11:30
							15		
							20		

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER
DEN-DENISON CORE BARREL SAMPLER
SPT-STANDARD PENETRATION TEST (ASTM D 1586-84)

GROUND-WATER DEPTH BELOW GRADE

AT COMPL		4.06	FT.
AFTER	HRS.		FT.
AFTER 24	HRS.	4.36	FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF CORE BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-2

Coordinates:

Surface Elevation:
Casing Above Surface:
Reference Elevation:
Reference Description:

Location: MCAD
Job No. 10424.22
Client: USCOE
Drilling Method: Split inner barrel, 10 ft. Nx wire line core barrel, mobile B-81
Core Bit Size: Nx Inclination: 0

Start Date: 7/19/89 Completion Date: 7/20/89

RUN NO.	RQD (%)	RCOVERY (%)	BEDDING INCLIN	FRACTRS INCLIN	RUN LENGTH (FT.)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS LITHOLOGIC LOG	DRILLING LOG
						10	ML		Min.
1	10	20			5 ft.			Maroon siltstone and fine sand stone interbedded with red shale - fissil- SST bedding indescript and massive Hematile cement Run #1 poor recovery due to shale washing	2.5 2.25 3.5 3.0
						15			3.0
2	0	20			10 ft.			Maroon fine sandstone and siltstone, interlayed shale beds High shale content in run # 2 Run #2 poor recovery	Water loss less than 10 gallon 2.5 2.3 3.0
						20			3.0 2.5 3.0 3.25 2.5
						25			3.0
3	50	75			4 ft.			Maroon siltstone, fine sand-stone, interlayed W/ shale	3.0 2.75 3.3 3.3
						30			4.2 20 gallons lost

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER
DEN-DENISON CORE BARREL SAMPLER
SPT-STANDARD PENETRATION TEST (ASTM D 1586-84)

GROUND-WATER DEPTH BELOW GRADE
AT COMPLETION FT.
AFTER HRS. FT.
AFTER 24 HRS. FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF CORE BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-2

Coordinates:

Surface Elevation:
Casing Above Surface:
Reference Elevation:
Reference Description:

Location: NCAD
Job No. 10424.22
Client: USCOE
Drilling Method: Split inner barrel, 10 ft.
Nx wire-line core barrel, Mobile B-81
Core Bit Size: Nx Inclination: 0

Start Date: 7/19/89 Completion Date: 7/20/89

RUN NO.	RQD (%)	RCOVERY (%)	BEDDING INCLIN	FRACTRS INCLIN	RUN LENGTH (FT.)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS: LITHOLOGIC LOG	DRILLING LOG
						30			
4	95	100	25 deg.					Maroon, massive bedded silt-stone	Min. 2.2
									3.3
								Fracture at 33 ft.	3.0
								Predominantly siltstone Seams of shale	3.0
					10 ft.	35			3.5
								Bedding non-descript Styolites healed	3.5
								Predominant water zone at 33 ft.	3.25
									3.6
							Silt Stone		3.25
						40			2.7
5	55	55	20 deg.					Maroon siltstone Massive non-descript Bedding interbedded with shale	< 20 gallons water loss 2.5
									2.5
								Grading to fine silty sandston Low angle fracture Mostly healed	2.5
									3.0
					10 ft.	45		Past 41 ft. maroon fine-med. gravel, massive bedding silty sandstone- Lithic quartz rock frag.,	3.2
									2.5
									2.25
									3.8
									At 48ft. core barrel clogged no water return Stopped coring at 48 ft. Directed driller to stop corin and reem to 50 ft. W/6" bit No apparent water loss
						50		Bottom of boring 50 ft.	

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER
DEN-DENISON CORE BARREL SAMPLER
SPT-STANDARD PENETRATION TEST (ASTM D 1586-84)

GROUND-WATER DEPTH BELOW GRADE
AT COMPLETION FT.
AFTER HRS. FT.
AFTER 24 HRS. FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF SOIL BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-4
Coordinates:N 317094.15; E 2227634.77

Surface Elevation: 303.88
Casing Above Surface:1.98
Reference Elevation: 305.85
Reference Description:Top of PVC

Start Date:1/13/89 Completion Date:1/13/89

Location: NCAD
Job No. 10424.22
Client: ACE
Drilling Method: B-61,HSA, 8" O.D. 4" I.D., 2 man crew

Sampling Method: SS, 140 lb. hammer 30" drop. First 10 ft. continuous 5 ft. intervals thereafter

SAMP TYPE	IN DRVN	IN RCVD	SAMP NO.	SAMP DPTH	BLOWS/6"	HNU PPM	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS Muddy ground, flat / SOIL DESCRIPTION
SS	24	18	1		2-2-3			CL	Dk. red-bn. silty clay ,moist
SS	24	5	2		4-2-51/3			CL	Dk. red-bn., silty clay, wet
SS	24	24	3		12-17-20			Fill	
SS	24	16	4		23-7-16-17		5	CL	Med. red-bn. clay with mg sand and some gravel, moist. Duplicate sample taken Water on the spoons 6ft.
SS	24	1	5		15-10-16-22-25			SC	Red-bn. cg clayey sand with gravel,moist Lost first sample, spoon wet; Second sample- sandy clay wet, red-bn. Too wet for spoon to hold, need a trap
							10	SC	Trying to auger to 15 ft.,very slow, hitting resistant SS ledges.
SS	5	4	6		51/5		15	SP	Dk. red-bn., cg sand, wet Cored from 24 1/2- 29 1/2, got 5ft. of red SS. Note: Offset well drilled to 32 ft. Coring resumed at this depth.
SS	8	4	7		35-51/2		20	SW	Dk. red-bn., SS saprolite

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER
DEN-DENISON CORE BARREL SAMPLER
SPT-STANDARD PENETRATION TEST (ASTM D 1586-84)

GROUND-WATER DEPTH BELOW GRADE

AT COMPL		13.27	FT.
AFTER	HRS.		FT.
AFTER 24	HRS.	12.22	FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF SOIL BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-4

Coordinates:

Surface Elevation:
Casing Above Surface:
Reference Elevation:
Reference Description:

Start Date:1/13/89 Completion Date:1/13/89

Location: NCAD
Job No. 10424.22
Client: ACE
Drilling Method: B61, HSA, 8"OD, 4"ID, 2 man crew

Sampling Method: SS, 140 lb. hammer, 30" drop.
First 10 ft. continuous, 5ft. int. thereafter to bedrock.

SAMP TYPE	IN DRVN	IN RCVD	SAMP NO.	SAMP DPTH	BLOWS/6"	HNU PPM	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS
									SOIL DESCRIPTION
N/A	N/A	N/A	N/A		N/A		20	SM	
									Weathered shale, alternating weathered shale and moderately weathered fine sandstone
									Silt/sanstone
									Same (no split spoons taken)
							25		Hard to very hard augering
							30		Hit competent rock at 30 feet
									(See attached core log)
							35		
							40		

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER
DEN-DENISON CORE BARREL SAMPLER
SPT-STANDARD PENETRATION TEST (ASTM D 1586-84)

GROUND-WATER DEPTH BELOW GRADE
AT COMPLETION FT.
AFTER HRS. FT.
AFTER 24 HRS. FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF CORE BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-4

Coordinates:

Surface Elevation:
Casing Above Surface:
Reference Elevation:
Reference Description:

Location: NCAD
Job No. 10424.22
Client: ACE
Drilling Method: Mobile B-61, NX wire line split barrel casing device 10" long
Core Bit Size:NX Inclination:0

Start Date: 1/23/89 Completion Date:1/23/89

RUN NO.	RQD (%)	RCOVERY (%)	BEDDING INCLIN	FRACTRS INCLIN	RUN LENGTH (FT.)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS LITHOLOGIC LOG	DRILLING LOG
						30			
1	85	100	Massive					Red shale	9:04-9:09
									9:09-9:14 Made connection 9:14-9:26
						35			
					10 ft.			Gradational contact with increasing silt content	9:26-9:31
									9:31-9:36
								Red siltstone	9:36-9:42
								Red fg sandstone uncommon oblique fractures	9:50-9:54 Made connection 9:54-10:02
						40			
									10:02-10:07
2	80	100	Massive					Red ufg-fg sandstone	10:07-10:12
									10:34-10:39
									10:39-10:44 Made connection 10:44-10:50
						45			
					8 ft.				10:50-10:54
								Gradational contact between uf SS and siltstone	10:54-10:58
									10:58-11:02
									11:02-11:07
						50		Bottom of boring 50 ft.	

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER
DEN-DENISON CORE BARREL SAMPLER
SPT-STANDARD PENETRATION TEST (ASTM D 1586-84)

GROUND-WATER DEPTH BELOW GRADE
AT COMPLETION FT.
AFTER HRS. FT.
AFTER 24 HRS. FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF SOIL BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-4A
Coordinates: N 317086.01; E 2227653.31

Surface Elevation: 302.89
Casing Above Surface: 2.15
Reference Elevation: 305.04
Reference Description: Top of PVC

Start Date: 1/13/89 Completion Date: 1/13/89

Location: NCAD
Job No. 10424.22
Client: ACE
Drilling Method: B-61, HSA, 2 man crew

Sampling Method: SS, 140 lb. hammer, 30" drop. Continuous first 10 ft., 5 ft. int. thereafter until bedrock

SAMP TYPE	IN DRVN	IN RCVD	SAMP NO.	SAMP DPTH	BLOWS/6"	HNU PPM	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS Muddy ground, flat / SOIL DESCRIPTION
SS	24	12	1		3-3-2	0		ML	Dk. red-bn., clayey silt, moist
SS	24	4	2		1-3			CL	Dk. red silty clay, wet, water on spoon
SS	24	10	3		50"/1				Dk. red sandy clay with gravel (fill?), moist
SS	24	16	4		10-13-17			CL	Dk. red clay with cg sand and gravel, moist
							5		
SS	24	18	5		23-18-14-15			SP	Dk. reddish bn. fg-cg sand with gravel & chunks of red SS, saprolite, moist
SS	23	16	6		16-11-12-12-51/5			SC	Dk. reddish bn., clayey mg sand with large SS rh frag. saprolite of red SS/Sh, moist
							10		
SS	5	4	7		51/5		15	SW	Dk. red bn., cg sand, wet, contact with bedrock
							20		

Bottom of boring 15 ft.

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER
DEN-DENISON CORE BARREL SAMPLER
SPT-STANDARD PENETRATION TEST (ASTM D 1586-84)

GROUND-WATER DEPTH BELOW GRADE

AT COMPL		7.92	FT.
AFTER	HRS.		FT.
AFTER	24 HRS.	8.07	FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF SOIL BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-5

Coordinates: N 316385.23; E 2227542.75

Surface Elevation: 300.35
Casing Above Surface: 2.40
Reference Elevation: 302.75
Reference Description: Top of PVC

Start Date: 1/11/89 Completion Date: 1/11/89

Location: NCAD
Job No. 10424.22
Client: ACE
Drilling Method: B-61, HSA, 2 man crew

Sampling Method: SS, 140 lb. hammer, 30" drop. Continuos first 10 ft., every 5 ft. thereafter

SAMP TYPE	IN DRVN	IN RCVD	SAMP NO.	SAMP DPTH	BLOWS/6"	HNU PPM	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS Snow covered, sloping slightly SW SOIL DESCRIPTION
SS	24	6	1		3-7-9			ML	Dk. bn. clayey silt with some ang. mg sand, moist (fill)
SS	24	12	2		4-4-4-4			ML	Dk. bn. silt with some clay, moist
SS	24	14	3		2-2-2-1		5	Fill ML	As above but grading into gravelly silt with some mg sand, wet
SS	24	18	4		1-2-4-3			CL	Dk. red-bn., gravelly clay, wet Split with ACE
SS	24	20	5		3-2-2			CL	Dk. bn.-rd. silty clay with some mg sand, wet
							10		
SS	10	7	6		7-50/4	9	15	SM	50 blows over 4" HNU reading taken in the hole after auger pulled, about 6" in hol
							20		

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER
DEN-DENISON CORE BARREL SAMPLER
SPT-STANDARD PENETRATION TEST (ASTM D 1586-84)

GROUND-WATER DEPTH BELOW GRADE

AT COMPL		4.89	FT.
AFTER	HRS.		FT.
AFTER	24 HRS.	5.27	FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF CORE BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-5
Coordinates:

Surface Elevation:
Casing Above Surface:
Reference Elevation:
Reference Description:

Location: NCAD
Job No. 10424.22
Client: ACE
Drilling Method: Mobile B-61 Nx wire line split barrel coring device 10" long
Core Bit Size: Nx Inclination: 0

Start Date: 1/24/89 Completion Date: 1/24/89

RUN NO.	RQD (%)	RECOVERY (%)	BEDDING INCLIN	FRACTRS INCLIN	RUN LENGTH (FT.)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS: LITHOLOGIC LOG	SURFACE CONDITIONS: DRILLING LOG
						10			
1	10	30	Massive		5 ft.	15		Dark maroon very fine to fine hematile cementel sanstone/ siltstone interlayed with red soft shale intervals	22 sec. 4 min. 3.5 min. 4.4 min. 3.8 min. 55 sec.
2	40	90			5 ft.	20		Oblique fractures 40-60 Deg. inclination Minor Fe-Oxide infilling Red fine maroon silty sand-stone with alternating shale layers 6"-12" thick massive bedding no major fracture infilling	Lost 25 gallons 6 min. 1.5 min. 5 min. 7 min. 7 min. 3 min. Lost 50 gallons Finished Run 2 @ 16:00
						25			
						30			

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER
DEN-DENISON CORE BARREL SAMPLER
SPT-STANDARD PENETRATION TEST (ASTM D 1586-84)

GROUND-WATER DEPTH BELOW GRADE
AT COMPLETION FT.
AFTER HRS. FT.
AFTER 24 HRS. FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF CORE BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-5

Coordinates:

Location: NCAD
Job No. 10424.22
Client: ACE
Drilling Method: B-61, Nx wire line split barrel casing device 10" long
Core Bit Size: Nx Inclination: 0

Surface Elevation:
Casing Above Surface:
Reference Elevation:
Reference Description:

Start Date: 1/24/89 Completion Date: 1/24/89

RUN NO.	RQD (%)	RECOVERY (%)	BEDDING INCLIN	FRACTRS INCLIN	RUN LENGTH (FT.)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS: LITHOLOGIC LOG	SURFACE CONDITIONS: DRILLING LOG
						20			
						25			
3	68	95	Massive						10:28-10:31
									10:31-10:36
								Red shaly siltstone	10:36-10:42
									10:42-10:46
					10 ft.	30			Made a correction 10:46-10:49 Core barrel jam 30.5
								Red siltstone	10:53- Jam 11:19-11:23
									11:23-11:28
									11:28-11:32
								Gradational contact Siltstone/sandstone	11:32-11:34 Made a conncetion 11:34-11:38
						35			
4	75	90	Massive					Red v. fine grained sandstone	11:38-11:44
									11:44-11:47
					5 ft.				11:47-11:49
									11:49-11:52 Made a connection 11:52-11:54 1/2 way
						40			

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER
DEN-DENISON CORE BARREL SAMPLER
SPT-STANDARD PENETRATION TEST (ASTM D 1586-84)

GROUND-WATER DEPTH BELOW GRADE

AT COMPLETION		FT.
AFTER	HRS.	FT.
AFTER	24 HRS.	FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF CORE BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-5

Coordinates:

Surface Elevation:
Casing Above Surface:
Reference Elevation:
Reference Description:

Location: NCAD
Job No. 10424.22
Client: ACE
Drilling Method: B-61, Nx wire line split barrel casing device 10" long
Core Bit Size: Nx Inclination: 0

Start Date: 1/24/89 Completion Date: 1/24/89

RUN NO.	RQD (%)	RECOVERY (%)	BEDDING INCLIN	FRACTRS INCLIN	RUN LENGTH (FT.)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS: LITHOLOGIC LOG	SURFACE CONDITIONS: DRILLING LOG
4	90	100	Massive			40			
									12:11-12:14
									12:14-12:16
								Red, v. fine sandstone	12:16-12:18 Made connection
					10 ft.	45			12:18-12:20
									12:20-12:24
									12:24-12:27
									12:27-12:29
									12:29-12:32
						50		Bottom of boring 50 ft.	12:32-12:35
						55			
						60			

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER
DEN-DENISON CORE BARREL SAMPLER
SPT-STANDARD PENETRATION TEST (ASTM D 1586-84)

GROUND-WATER DEPTH BELOW GRADE
AT COMPLETION FT.
AFTER HRS. FT.
AFTER 24 HRS. FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF SOIL BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-5A
Coordinates:N 316385.23; E 2227542.75

Surface Elevation: 301.97
Casing Above Surface:2.34
Reference Elevation: 304.31
Reference Description:Top of PVC

Start Date:1/11/89 Completion Date:1/11/89

Location: NCAD
Job No. 10424.22
Client: ACE
Drilling Method: B-61, HSA, 2 man crew

Sampling Method: SS, 140 lb. hammer, 30" drop, First 10 ft. continu
5 ft. interval thereafter until bedrock

SURFACE CONDITIONS
Snow covered, slightly sloping to the SW

SAMP TYPE	IN DRVN	IN RCVD	SAMP NO.	SAMP DPTH	BLOWS/6"	HNU PPM	DEPTH FEET	GRAPH LOG	SOIL DESCRIPTION
SS	24	12	1		3-4-7			SM	Black, dk. bn., silty sand with cinders and gravel, fill? moist
SS	24	8	2		9-6-5-5			PT	Med. bn., clay with abundant plant material, wet,swamp peat?
SS	24	10	3		5-4-3-2	5	5	CL	Reddish-bn., gravelly clay with some ang. fg sand, wet
SS	24	1	4		2-2-2			CL	Very wet, bn. gravelly clay as above almost no recovery
SS	24	24	5		2-2-3-2-2		10	CL	Dark red-bn., silty clay, wet Duplicate made
SS	6	4	6		50/6	0	15	SW	Med. reddish SS& Sh, bedrock 50 blows over 6" Bottom of boring 15 ft.
							20		

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER
DEN-DENISON CORE BARREL SAMPLER
SPT-STANDARD PENETRATION TEST (ASTM D 1586-84)

GROUND-WATER DEPTH BELOW GRADE

AT COMPL		4.46	FT.
AFTER	HRS.		FT.
AFTER	24 HRS.	4.38	FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF SOIL BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-6

Coordinates: N 317113.49; E 2227542.75

Location: NCAD
Job No. 10424.22
Client: USCOE
Drilling Method: 8" O.D., 4 3/4" I.D. hollow stem auger

Surface Elevation: 299.16
Casing Above Surface: 1.95
Reference Elevation: 301.11
Reference Description: Top of PVC

Sampling Method: SS 2" O.D., 1 3/8" I.D. split spoon 140 lb. hammer, 30" drop- 24" sample

Start Date: 7/21/89 Completion Date: 7/24/89

SAMP TYPE	IN DRVN	IN RCVD	SAMP NO.	SAMP DPTH	BLOWS/6"	HNU PPM	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS 12 ft. offset from MW-6A to NW SOIL DESCRIPTION
SS	24	15	1	1.0	6-10-10-10-6	0		ML Fill	Brown silt and fine sand with a trace of clay, gravel, low plasticit stiff (Fill) ML Gradational, mottled
SS	24	22	2	3.0	10-12-16-20	0		ML	Red brown, moist, silt and fine sand trace to a little clay (in-situ material)-ML
SS	24	14	3	5.0	11-15-16-9	0	5	ML	Medium brown moist , silt with a little clay and trace to a little fine sand with granules, low plasticity, stiff-ML grading to varicolored clayey sand
SS	22	14	4	7.0	22-30			SC	Encountered water at 7.0 ft. Varicolored wet fine sand with some clay and silt, low plasticity, D
SS	3	1	5		50/4"-50/3"			SST	SST in top of SS #4 Maroon moderately weathered, silty fine sandstone, hematile cement
							10		Weathered fine silty sandstone No SS #5 recovery for dhemical ananlysis Hard augering past 9.5 ft., No more split spoon samples
									Auger w/o sampling to 15 ft. very hard past 13 ft.
								SST	
							15		Begin Nx core at 15 ft.
							20		

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER
DEN-DENISON CORE BARREL SAMPLER
SPT-STANDARD PENETRATION TEST (ASTM D 1586-84)

GROUND-WATER DEPTH BELOW GRADE

AT COMPL		5.97	FT.
AFTER	HRS.		FT.
AFTER		6.01	FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF CORE BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-6

Coordinates:

Surface Elevation:
Casing Above Surface:
Reference Elevation:
Reference Description:

Location: NCAD
Job No. 10424.22
Client: USCOE
Drilling Method: Mobile B-81 double barrel split inner barrel core barrel, Nx wire line
Core Bit Size: Nx Inclination: 0

Start Date: 7/21/89 Completion Date: 7/24/89

RUN NO.	RQD (%)	RECOVERY (%)	BEDDING INCLIN	FRACTRS INCLIN	RUN LENGTH (FT.)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS: LITHOLOGIC LOG	SURFACE CONDITIONS: DRILLING LOG
						10			
1	25	50	20 deg.			15			
					5 ft.			Maroon fine sandstone and silt stone interlayed with red shale- fissil, weathered	
								Low RQD, shales, beds fracture	Run #1 negligable water loss
								slight, weathered sandstone-lithic	Set 6" casing to 20 ft.
						20			
2	50	75	25 deg.					Maroon, fine to coarse sandstone with silt, lithic sandstone, quartz angular to subangular	Min. 2.5
									3.5
								Interbedded fissil, shale-hematile cement	3.25
								Bedding nondescript, massive	3.0
					8 ft.	25			2.5
								Water bearing fracture at 26 ft.	3.0
								Finer more even grained past 26 ft.	3.0
3								Abundant rock fragments at 27 ft. (intraclasts)	2.75 Core barrel clogged at 28 ft. Stopped Run #2 at 28 ft. 25 gallons water loss at 28 ft
						30		(Run #3 Next sheet)	

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER
DEN-DENISON CORE BARREL SAMPLER
SPT-STANDARD PENETRATION TEST (ASTM D 1586-84)

GROUND-WATER DEPTH BELOW GRADE
AT COMPLETION FT.
AFTER HRS. FT.
AFTER 24 HRS. FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF CORE BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-6

Coordinates:

Surface Elevation:
Casing Above Surface:
Reference Elevation:
Reference Description:

Location: NCAD
Job No. 10424.22
Client: USCOE
Drilling Method: Mobile B-81 double barrel split inner barrel core barrel, Nx wire line
Core Bit Size: Nx Inclination: 0

Start Date: 7/21/89 Completion Date: 7/24/89

RUN NO.	RQD (%)	RECOVERY (%)	BEDDING INCLIN	FRACTRS INCLIN	RUN LENGTH (FT.)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS: LITHOLOGIC LOG	DRILLING LOG
						30			
3	68	78	25 deg.					Maroon, fine-medium lithic sandstone with silt thin inter bedded fissil shale seams	29 ft. 2.75 Min. 30 ft. 3.0 Min. 3.0
								Lithology becomes finer grained and more equi-grained past 26 ft.	3.25
					10 ft.				2.75
									2.5
						35			3.25
									3.0
								Water bearing zone at 37 ft.	3.0
4	100	100	35 deg.						3.0
								Maroon silty fine sandstone-lithic	50 gallons water loss at Run#3 4.0
						40		Bedding massive, non-descript Small (< 1/4") irregular quartz and rock fragment intra clast	3.75
									3.0
									3.0
								Bedding steepens at 43 ft.	3.25
					10 ft.				4.25
						45			3.5
									3.5
									2.75
									3.0
						50		Bottom of boring 50 ft.	50 gal. water lost during Run# Did not core 48-50 ft. but had ream w/6" bit to 50 ft.

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER
DEN-DENISON CORE BARREL SAMPLER
SPT-STANDARD PENETRATION TEST (ASTM D 1586-84)

GROUND-WATER DEPTH BELOW GRADE
AT COMPLETION FT.
AFTER HRS. FT.
AFTER 24 HRS. FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF SOIL BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-6A
Coordinates: N 317105.85; E 2226847.76

Location: NCAD
Job No. 10424.22
Client: USCOE
Drilling Method: 8" OD, 4 3/4" ID Hollow stem auger

Surface Elevation: 301.33
Casing Above Surface: 2.01
Reference Elevation: 303.34
Reference Description: Top of PVC

Sampling Method: SPT

Start Date: 7/20/89 Completion Date: 7/21/89

SAMP TYPE	IN DRVN	IN RCVD	SAMP NO.	SAMP DPTH	BLOWS/6"	HNU PPM	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS Inside depot off road to north 180 ft. west of guard house SOIL DESCRIPTION
								ML Fill	Brown moist silt with trace of clay and fine sand medium stiff ML upper(fill)
SS	24	14	1	1.5	5-5-3-10-5				
SS	24	16	2	3.0	8-12-15-4			ML	Medium brown mottled gray, moist, silt with a little clay and trace fine sand low plasticity- stiff, ML
SS	24	22	3	5.5	10-14-20-12		5		Light brown to varicolored silt and clay, trace of fine sand, low plasticity, very stiff ML/CL
SS	24	15	4	7.5	14-27-50/3"			SC	Gradational to more sand Water encountered at 7.0 ft. Gray and brown clay and fine to medium sand with weathered residnum,
SS	3	3	5	--	------			SST	Tip of SS #5 red fine-med. weathered sandstone spoon refused at 8.4
				No	Samples		10		Hard augering to 15 ft. sandstone
								SST	
							15		Bottom of boring 15 ft.
							20		

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER
DEN-DENISON CORE BARREL SAMPLER
SPT-STANDARD PENETRATION TEST (ASTM D 1586-84)

GROUND-WATER DEPTH BELOW GRADE

AT COMPL		9.8	FT.
AFTER	HRS.		FT.
AFTER	24 HRS.	3.8	FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF SOIL BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-7

Coordinates: N 316689.48; E 2227291.29

Surface Elevation: 299.90
Casing Above Surface: 2.12
Reference Elevation: 302.02
Reference Description: Top of PVC

Location: NCAD
Job No. 10424.22
Client: USCOE
Drilling Method: 8" O.D. 4 3/4" I.D. hollow stem auger
Mobile B-81 Drill rig
Sampling Method: SS- 2" O.D., 1 3/8" I.D. split spoon 140 lb. hammer, 30" drop driven 24 inches

Start Date: 7/25/89 Completion Date: 7/28/89

SAMP TYPE	IN DRVN	IN RCVD	SAMP NO.	SAMP DPTH	BLOWS/6"	HNU PPM	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS 4 Ft. off of NCAD perimeter road, south of perimeter road, in grassed shoulder SOIL DESCRIPTION
								SM	Black, moist, cinders, as and silty loam
SS	24	19	1	1.0	3-8-12-10-4			Fill	
								ML	Light brown, silt and fine sand trace of clay, low plasticity-very stiff Ml
								Fill	Grading to gray silty clay
SS	24	22	2	3.0	7-12-16-6				Organic layer silty loam at 2.8 ft.
								CL	Gray- brown, silty and clay trace of fine sand, medium plasticity, very stiff
								ML	Brown silt and fine sand
SS	24	21	3	5.0	9-12-18-9		5		Fill to 3 ft.
									Brown, moist, silt and fine sand, low plasticity, very stiff ML
SS	24	19	4	7.0	19-21-30-9			ML	
									Water encountered at 7.2 ft.
								SC	Tan clayey sand and gravel- angular SC
									Red to maroon, weathered fine sandstone- saprolite
SS	24	16	5	9.0	12-16-22-20			WR	
							10		Severely weathered, maroon to brown, wet fine to coarse sandstone
								SAP	Coarse Sandy seams- saprolite
									Spoon refused at 10.8 ft.
									Auger refused at 14.0 ft. at 11:40 changed to core barrel(Nx)
							15		
								SST	
							20		

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER
DEN-DENISON CORE BARREL SAMPLER
SPT-STANDARD PENETRATION TEST (ASTM D 1586-84)

GROUND-WATER DEPTH BELOW GRADE

AT COMPL		5.18	FT.
AFTER	HRS.		FT.
AFTER 24	HRS.	4.99	FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF CORE BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-7

Coordinates:

Location: NCAD
Job No. 10424.22
Client: USCOE
Drilling Method: Mobile B-81

Surface Elevation:
Casing Above Surface:
Reference Elevation:
Reference Description:

Core Bit Size: Nx Inclination: 0

Start Date: 7/25/89 Completion Date: 7/28/89

RUN NO.	RQD (%)	RCOVERY (%)	BEDDING INCLIN	FRACTRS INCLIN	RUN LENGTH (FT.)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS LITHOLOGIC LOG	DRILLING LOG
						10			
1					6 ft.	15		Maroon fine silty sandstone interbedded with fissil shale Bedding massive sandstone, 50% shale	Water loss (50 gal.)
2	20	60	45 deg.		5 ft.	20		Maroon fine silty sandstone Low RQD, rock broken, grading to shale Inudated fissil shale inter-layed w/ fine silt sandstone	Min. 3.5 4.0 4.25 3.75
3	42	80	45 deg.		5 ft.	25 30		Maroon fine silty sandstone Non-descript massive bedding	5.5 Lost circulation core, barrel Run #2 had to pull barrel at 2 Negligable water loss

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER
DEN-DENISON CORE BARREL SAMPLER
SPT-STANDARD PENETRATION TEST (ASTM D 1586-84)

GROUND-WATER DEPTH BELOW GRADE
AT COMPLETION FT.
AFTER HRS. FT.
AFTER 24 HRS. FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF CORE BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-7

Coordinates:

Surface Elevation:
Casing Above Surface:
Reference Elevation:
Reference Description:

Location: NCAD
Job No. 10424.22
Client: USCOE
Drilling Method: Mobile B-81

Core Bit Size: Nx Inclination: 0

Start Date: 7/25/89 Completion Date: 7/28/89

RUN NO.	RQD (%)	RECOVERY (%)	BEDDING INCLIN	FRACTRS INCLIN	RUN LENGTH (FT.)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS: LITHOLOGIC LOG	DRILLING LOG
						30			
4	75	85	45 deg.					Maroon fine sandstone fissil siltstone	Min. 3.0
									3.25
									3.5
									3.25
					10 ft.	35			2.75
									3.5
								Water bearing zone at 37 ft.	3.5
									4.0
									3.75
						40			
5	54	87	45 deg.					Maroon, fine sandstone-lithic indescript bedding	3.5 Water loss of 50 gal. @ 37 ft.
									3.0
									3.0
								Thin interbedded fissil shale seams	3.5
									2.75
					10 ft.	45			3.5
									4.0
									4.25
									4.0
									3.75
						50		Bottom of boring 50 ft.	3.75 (water loss

Finished coring at 14:00, re

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER
DEN-DENISON CORE BARREL SAMPLER
SPT-STANDARD PENETRATION TEST (ASTM D 1586-84)

GROUND-WATER DEPTH BELOW GRADE
AT COMPLETION FT.
AFTER HRS. FT.
AFTER 24 HRS. FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LOG OF SOIL BORING

15 LOVETON CIRCLE SPARKS, MARYLAND 21152 TELE: 301-771-4950

BORING NO. MW-7A
Coordinates: N 316709.80; E 2227314.63

Surface Elevation: 299.84
Casing Above Surface: 2.08
Reference Elevation: 301.92
Reference Description: Top of PVC

Location: NCAD
Job No. 10424.22
Client: USCOE
Drilling Method: 8" OD, 4 1/2 ID hollow stem auger

Sampling Method: SPT

Start Date: 7/20/89 Completion Date: 7/20/89

SURFACE CONDITIONS
Near NCAD access road 5 ft. offset from NCAD fence

SAMP TYPE	IN DRVN	IN RCVD	SAMP NO.	SAMP DPTH	BLOWS/6"	HNU PPM	DEPTH FEET	GRAPH LOG	SOIL DESCRIPTION
SS	24	12	1	1.5	1-2-5-4-4			ML Fill	Brown moist silt with a litle fine sand and trace of clay, low plas. medium stiff organic debris(grass, roots, etc.) Loam fill
SS	24	16	2	3.0	8-15-18-5			ML Fill	Light brown, moist silt with a little clay and fine sand, low-medium Plasticity, stiff ML/CL (Fill) Grading to Red brown]
SS	24	18	3	6.0	8-16-15-1		5	ML	Reddish brown mottled moist silt witha a little to trace of clay anu sand ML- stiff low plasticity grading to gray clay and silt
SS	24	18	4	7.5	10-16-22-8			CL	Gray and brown silt and clay with little fine sand, medium plasticit Encountered water at 7.5 ft. +,- 0.5 ft.
SS	24	10	5	9	10-20-33			SC	Gray fine/medium sand and clay
							10	Sap SST	Red weathered fine-medium sandstone with silt and hematile cement Drilling difficult past 11 ft.
								SST	Very hard augering past 12.0 ft.
SS	4	0	6		50/4"				Split spoon refusal at 13 ft. Red sandstone shale
							15		Bottom of boring 15.0 ft.
							20		

SAMPLER TYPE
SS-DRIVEN SPLIT SPOON
SH-PRESSED SHELBY TUBE
OST-OSTENBURG PISTON SAMPLER
DEN-DENISON CORE BARREL SAMPLER
SPT-STANDARD PENETRATION TEST (ASTM D 1586-84)

GROUND-WATER DEPTH BELOW GRADE

AT COMPL		7.5	FT.
AFTER	HRS.		FT.
AFTER 24	HRS.	7.37	FT.

APPENDIX A (Cont.)

WOODWARD-CLYDE CONSULTANTS
BORING AND TEST PIT LOGS

LOG of BORING No. MW-1A

DATE 3/11/87 SURFACE ELEVATION 87.50 LOCATION N5414.99 E4875.76

DEPTH, ft.	S.S. SAMPLES	SAMPLING RESISTANCE, RECOVERY	DESCRIPTION NOTES: Proportions used: trace = 0-10%, little = 10-20%, some = 20-35% and =35-50%	HNU SOIL (ppm)	U.S.C.S.
0		7,22"	Reddish-brown silty fine SAND with trace fine GRAVEL, moist		
2			- increasing CLAY fraction	0	
		6,15"			CL
4				0	
		12,23"			
6			- increasing coarse SAND and GRAVEL content	0	
		29,12"			
8				0	
		25*,0"			
10			- spoon wet	0	
		14,14"			
12				0	
		20,20"			
14			- turns light to medium brown (tan), some oxidation	0	
		32,8"	- red shale/fine sandstone, hard, dry		SP-SM
16			* used 300 lb. hammer with 24" drop Note: Borehole advance with 8" O.D. HSA by a CME-45C operated by Walt Ketter of Empire Soils Investigating, inspected by WCC Geologist Timothy Glazar. Water level at the time of drilling. Elevation and coordinates referenced to on-site monuments		

Completion Depth 15.15 Feet Water Depth ∿ 10 Date 3/27/87

Project Name New Cumberland Army Depot Project Number 86C8554E

Woodward-Clyde Consultants

FIGURE:

LOG of BORING No. MW-2A

DATE 3/12/87 SURFACE ELEVATION 83.92 LOCATION N4747.84 E4758.19

DEPTH, ft.	S.S. SAMPLES	SAMPLING RESISTANCE, RECOVERY	DESCRIPTION NOTES: Proportions used: trace = 0-10%, little = 10-20%, some = 20-35%, and =35-50%	HNU SOIL (ppm)	U.S.C.S.
0			Reddish-brown fine SANDY SILTY CLAY/CLAYEY SILT with trace fine GRAVEL (TOPSOIL)		
		4,19"	Dark brown/black silty coarse to fine SAND with trace fine GRAVEL, wood fragments, carbonaceous fragments, moist (FILL)	0	
2		2,12"			
4			Medium gray/reddish fine sandy SILTY CLAY/CLAYEY SILT no gravel, moderately to very cohesive, moist	0	
		4,18"			OL
6				0	
		12,6"			
8				0	
			Medium brown/tan silty coarse to fine SAND and GRAVEL, some ocidation, moist		
		30,6"	Red shale/fine sandstone, hard, dry		SW-SM
10				0	
		109/4",*			
12			* used 300 lb. hammer with 24" drop Note: Borehole advanced with 8" O.D. HSA by a CME-45C operated by Walt Ketter of Empire Soils Investigations inspected by WCC Geologist Timpthy Glazar. Elevation and coordinates referenced to onsite monuments.		
14			DTB - Dry at Time of Boring, water level measured at 13.3' below ground surface 1½ hrs. after drilling		
16					

Completion Depth 16.5 Feet Water Depth DTB Date 3.27.87

Project Name New Cumberland Army Depot Landfill Project Number 86C8554E

Woodward-Clyde Consultants

FIGURE:

LOG of BORING No. MW-3A

DATE 3/12/87 SURFACE ELEVATION 84.94 LOCATION N4837.58 E4534.48

DEPTH, ft.	S.S. SAMPLES	SAMPLING RESISTANCE, RECOVERY	DESCRIPTION NOTES: Proportions used: trace = 0-10%, little = 10-20%, some = 20-35%, and =35-50%	HNU SOIL (ppm)	U.S.C.S.
0			Medium brown fine sandy SILTY CLAY/CLAYEY SILT with trace fine GRAVEL (TOPSOIL)		
		7,18"	Black silty coarse to fine SAND with little fine to coarse GRAVEL, red brick fragments, carbonaceous fragments, moist (FILL)		
2				0	
		4,0"			
4				0	
		9.24"	Medium brown (reddish) fine sandy SILTY CLAY/CLAYEY SILT with trace fine GRAVEL, moist, moderately cohesive, moderately soft		CL
6				0	
		16,24"	- decrease in moisture content, increas in hardness		
8				0	
		35,24"	Medium brown (reddish) silty coarse to fine SAND and GRAVEL		
10			- wet	0	
		15,18"			GW
12		91/6*,6"	Red shale/fine sandstone, hard, dry	0	

* used 300 lb. hammer with 24" drop

Note: Borehole advanced to 12½' with 8" O.D. HSA by a CME-45C operated by Walt Ketter of Empire Soils Investigations, inspected by WCC Geologist Timothy Glazar. Water level at the time of drilling. Elevation and coordinates referenced to on-site monuments. At 12½' switch to air rotary drilling method using a 3 7/8" tri-cone roller bit to 16'.

Completion Depth 16 Feet Water Depth ~ 10 Date 3/27/87

Project Name New Cumberland Army Depot Landfill Project Number 86C8554E

Woodward-Clyde Consultants

FIGURE:

LOG of TEST PIT No. TP-1

DATE 4/13/87 SURFACE ELEVATION 94.85 LOCATION N5471.96 E5060.88

DEPTH, ft.	S.S. SAMPLES	CHEMICAL SAMPLE & STRATUM DEPTH	DESCRIPTION NOTES: Proportions used: trace = 0-10%, little = 10-20%, some = 20-35%, and =35-50%	HNU SOIL (ppm)	U.S.C.S.
0			Reddish brown clayey SILT, trace gravel and cobbles, organic material (0-14")		
		"A"		ND	
2					CL
4					
		"B"	- increased clay fraction	ND	
6					
8					
10				ND	
12			ND = Not Detected Note: Test pit excavated with backhoe operated by John Straw of Continental Vanguard, Inc., inspected by WCC Geologist Timothy Glazar. Elevation and location referenced to on-site monuments.		

Completion Depth 11 Feet Water Depth DRY Date 6/22/87

Project Name New Cumberland Army Depot Landfill Project Number 86C8554E

Woodward-Clyde Consultants

FIGURE:

LOG of TEST PIT No. TP-2

DATE 4/13/87 SURFACE ELEVATION 91.05 LOCATION N5412.70 E5006.00

DEPTH, ft.	SS SAMPLES	CHEMICAL SAMPLE & STRATUM DEPTH	DESCRIPTION NOTES: Proportions used: trace = 0-10%, little = 10-20%, some = 20-35%, and =35-50%	HNU SOIL (ppm)	U.S.C.S.
0			Reddish-brown clayey SILT, trace fine to coarse gravel, organic material (0-12")		
		"A"		ND	
2					CL
4					
		"B"		ND	
6					
8					
				ND	
10			ND = Not Detected Note: Test pit excavated with backhoe operated by John Straw of Continental Vanguard, Inc. inspected by WCC Geologist Timothy Glazar. Elevation and location referenced to on-site monuments.		
12					

Completion Depth 10 Feet Water Depth DRY Date 6/22/87

Project Name New Cumberland Army Depot Landfill Project Number 86C8554E

Woodward-Clyde Consultants

FIGURE:

LOG of TEST PIT No. TP-3

DATE 4/14/87 SURFACE ELEVATION 85.56 LOCATION N5251.39 E4750.51

DEPTH, ft.	SS. SAMPLES	CHEMICAL SAMPLE & STRATUM DEPTH	DESCRIPTION NOTES: Proportions used: trace = 0-10%, little = 10-20%, some = 20-35%, and =35-50%	HNU SOIL (ppm)	U.S.C.S.
0			Medium brown fine sandy SILT with little fine to coarse gravel, roots (0-6") (topsoil)		GL
1		"A"		ND	
2			Black silty sandy FILL with some fine to coarse gravel, metal, wood, red brick fragments, black cindery material, pasty white material		
3		"B"		ND	GM
4					
5				ND	
6			ND = Not Detected Note: Test pit excavated with backhoe operated by John Straw of Continental Vanguared, Inc., inspected by WCC Geologist Timothy Glazar. Elevation and location referenced to on-site monumnets.		

Completion Depth 5 Feet Water Depth 4½ Date 6/22/87

Project Name New Cumberland Army Depot Landfill Project Number 86C8554E

Woodward-Clyde Consultants

FIGURE:

LOG of TEST PIT No. TP-4

DATE 4/14/87 SURFACE ELEVATION 85.54 LOCATION N4883.54 E4731.10

DEPTH, ft.	S.S. SAMPLES	CHEMICAL SAMPLE & STRATUM DEPTH	DESCRIPTION NOTES: Proportions used: trace = 0-10%, little = 10-20%, some = 20-35%, and =35-50%	HNU SOIL (ppm)	U.S.C.S.
0			Medium brown fine sandy SILT with little fine to coarse gravel, roots (topsoil)		CL
1		"A"	Dark gray/black silty sandy FILL with some fine to coarse gravel, wood, glass, red brick fragments oxidation present	ND	
2					GM
3		"B"		ND	
4					
5				ND	

ND = Not Detected

Note: Test pit excavated with backhoe operated by John Straw of Continental Vanguard, Inc., inspected by WCC Geologist Timothy Glazar. Elevation and location referenced to on-site monuments.

Completion Depth 4½ Feet Water Depth 4 Date 6/22/87

Project Name New Cumberland Army Depot Landfill Project Number 86C8554E

Woodward-Clyde Consultants

FIGURE:

LOG of TEST PIT No. TP-5

DATE 4/14/87 SURFACE ELEVATION 85.53 LOCATION N5153.23 E4630.06

DEPTH, ft.	S.S. SAMPLES	CHEMICAL SAMPLE & STRATUM DEPTH	DESCRIPTION NOTES. Proportions used: trace = 0-10%, little = 10-20%, some = 20-35%, and =35-50%	HNU SOIL (ppm)	U.S.C.S.
0			Medium brown fine sandy SILT with little fine to coarse gravel, roots (topsoil)		CL
1		"A"	Black silty sandy FILL some fine to coarse gravel, red brick fragments, glass, wood, rubber, some white/gray powdery material	ND	
2					GM
3		"B"		ND	
4				ND	
5			ND = Not Detected Note: Test pit excavated with backhoe operated by John Shaw of Continental Vanguard, Inc., inspected by WCC Geologist Timothy Glazar. Elevation and location referenced to on-site monuments.		

Completion Depth 4 Feet Water Depth 4 Date 6/22/87

Project Name New Cumberland Army Depot Landfill Project Number 86C8554E

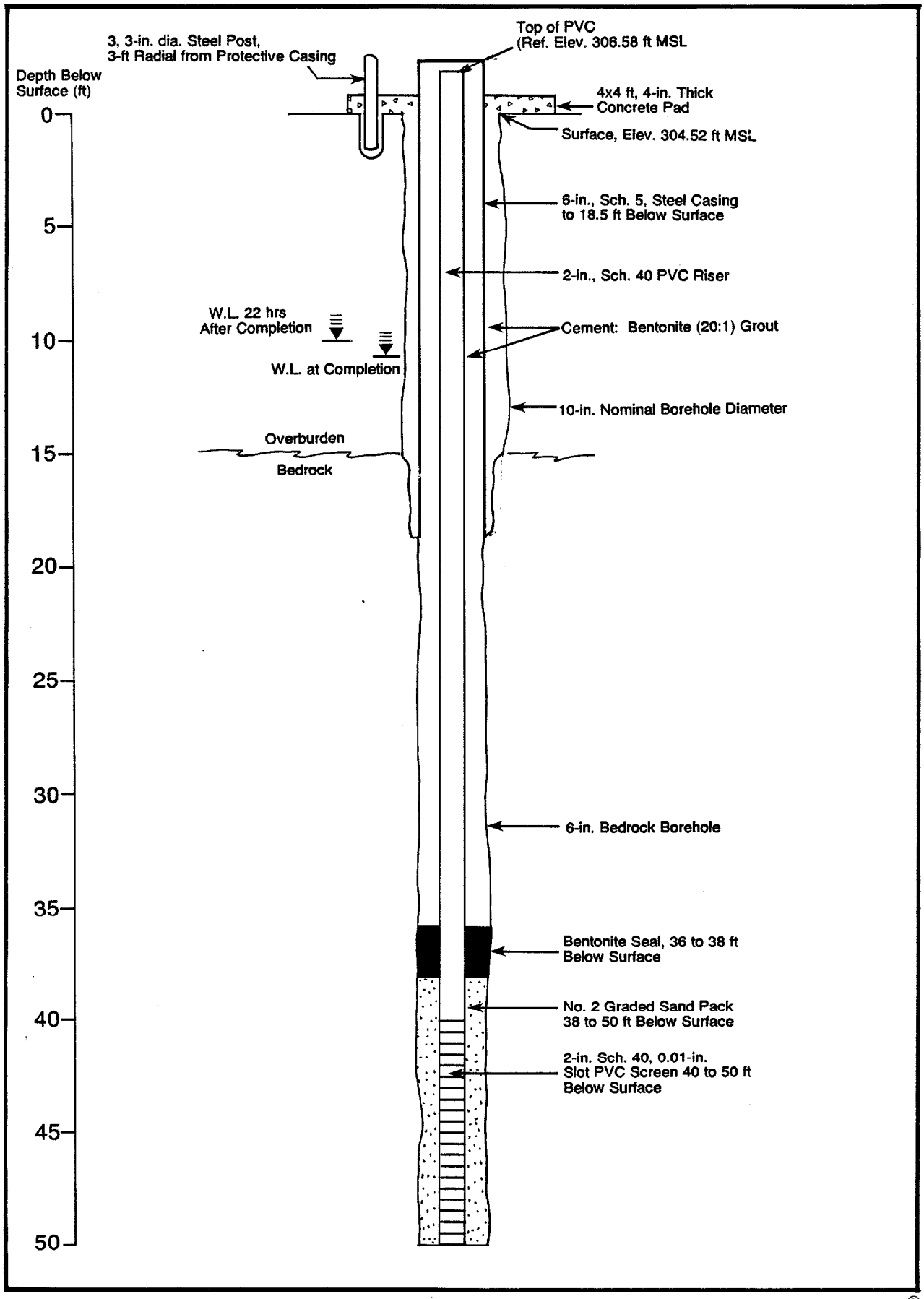
Woodward-Clyde Consultants

FIGURE:

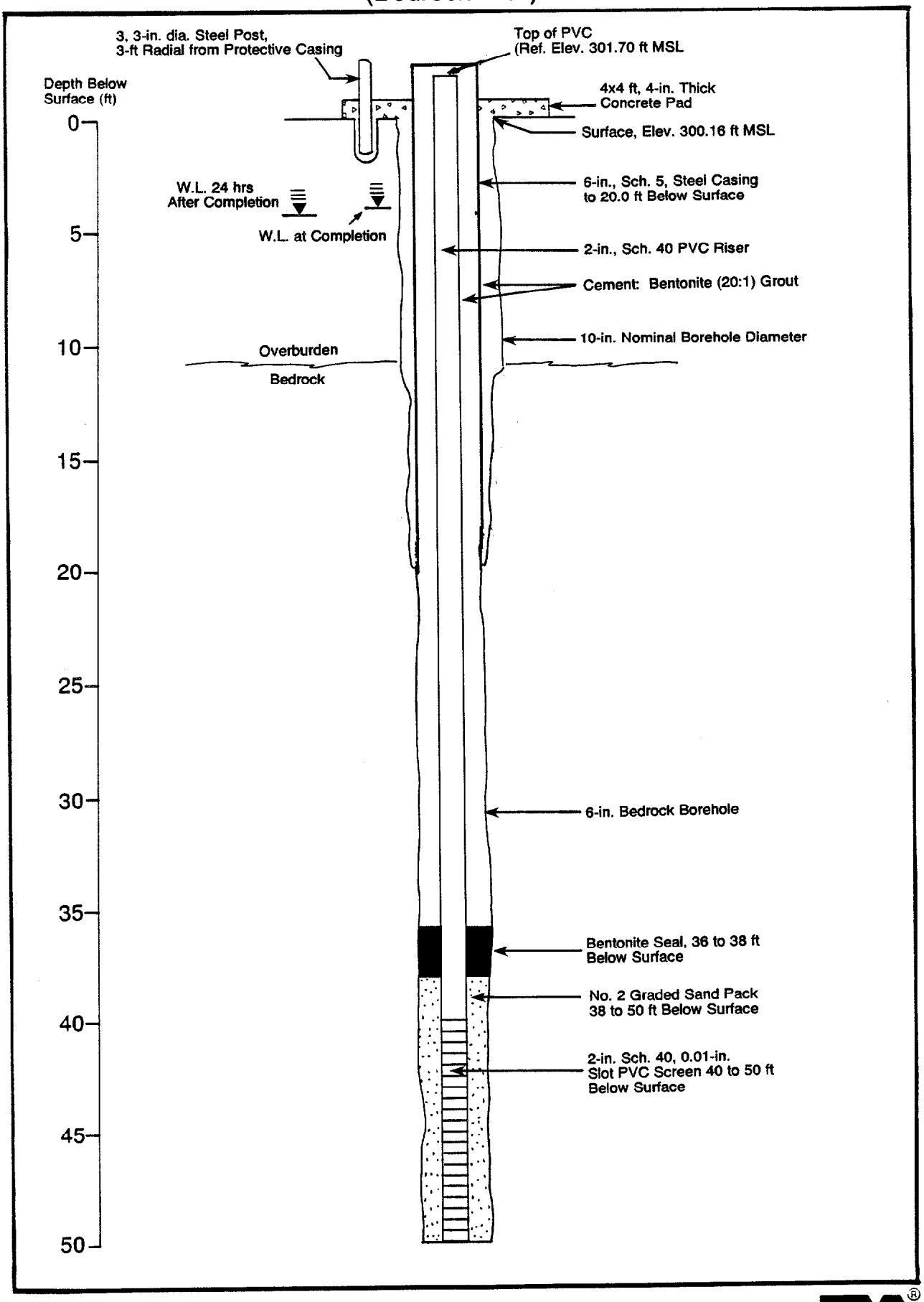
APPENDIX B

WELL CONSTRUCTION DIAGRAMS

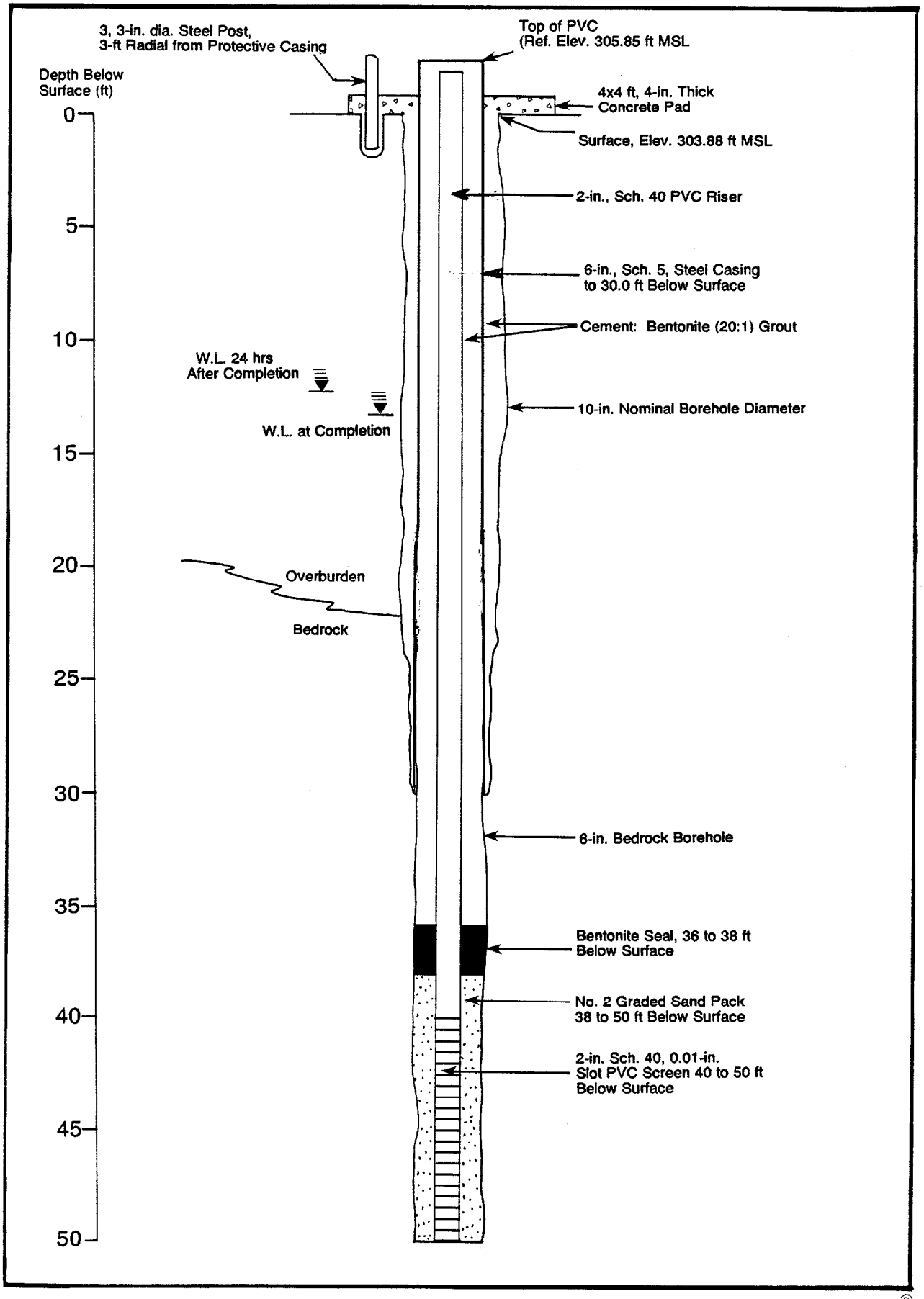
MW-1
(Bedrock Well)



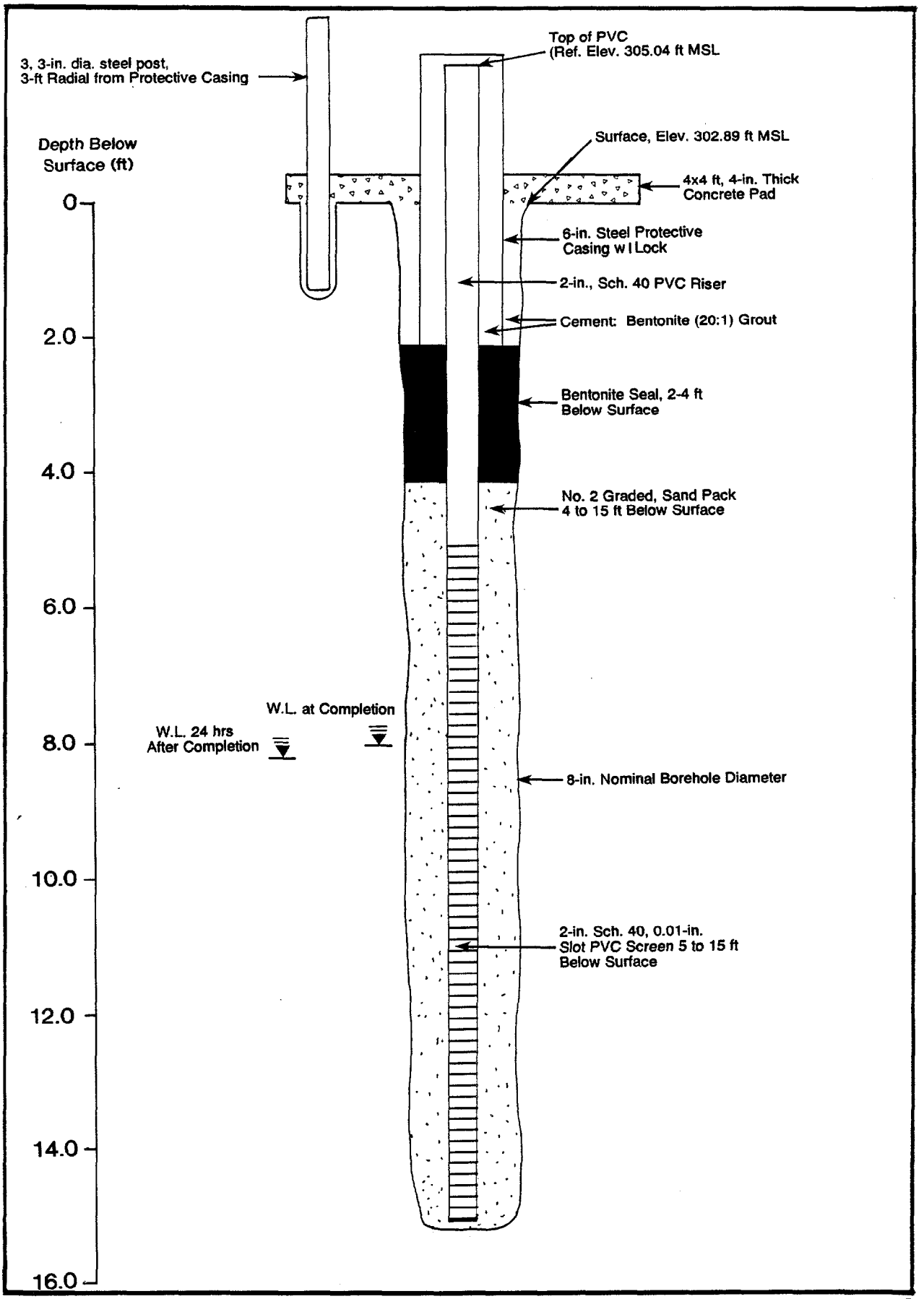
MW-2
(Bedrock Well)



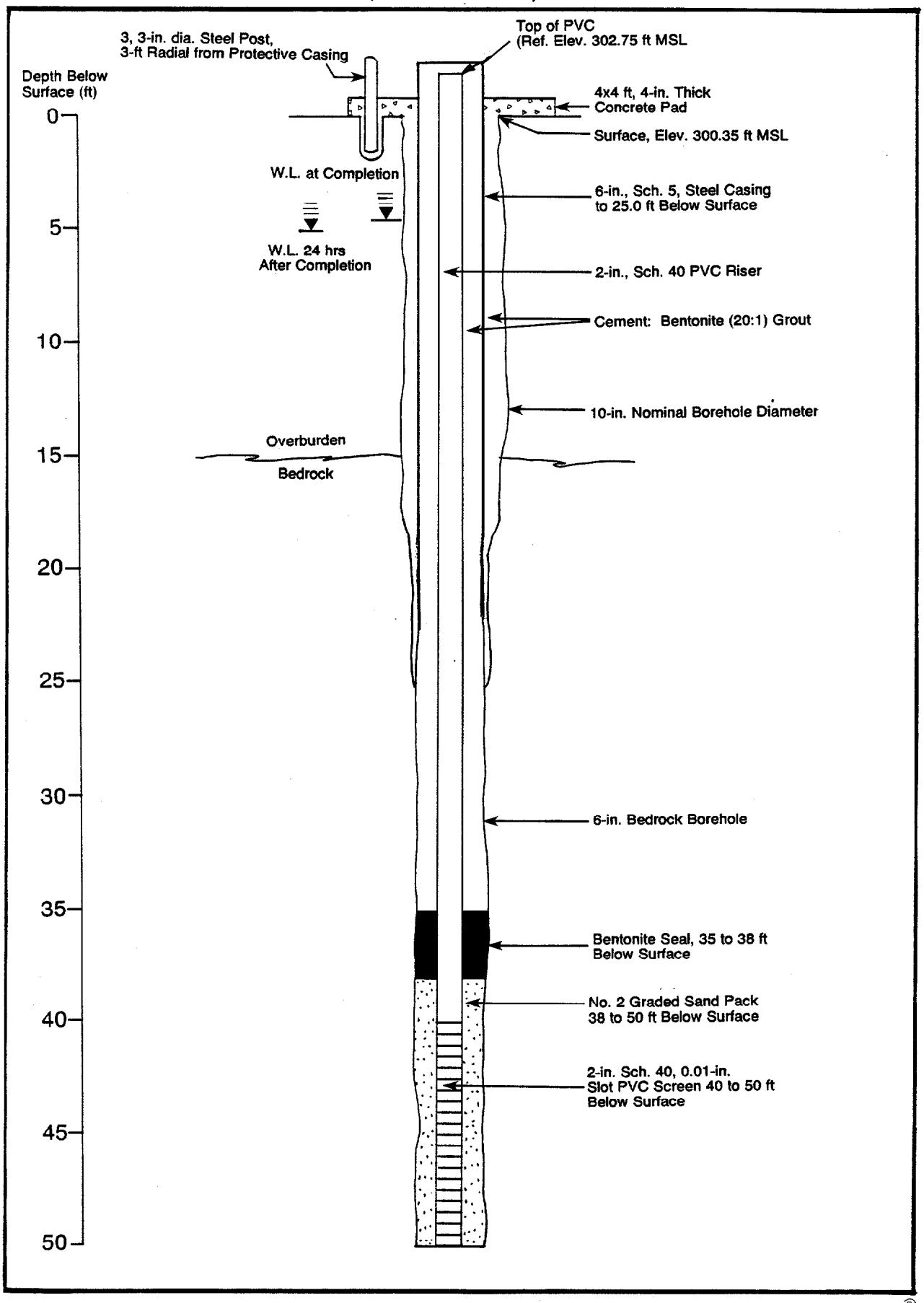
MW-4
(Bedrock Well)



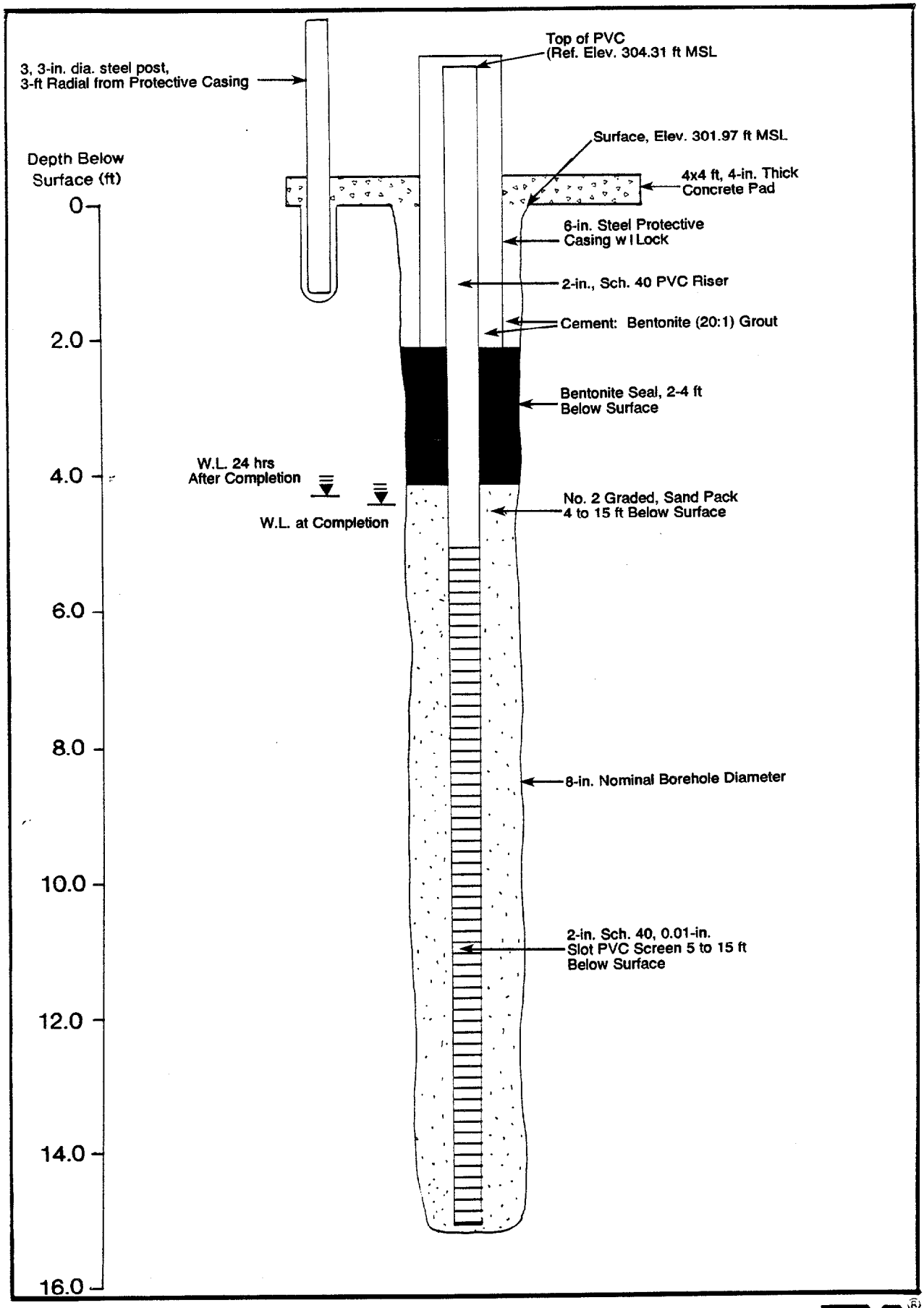
MW-4A
(Overburden Monitoring Wells)



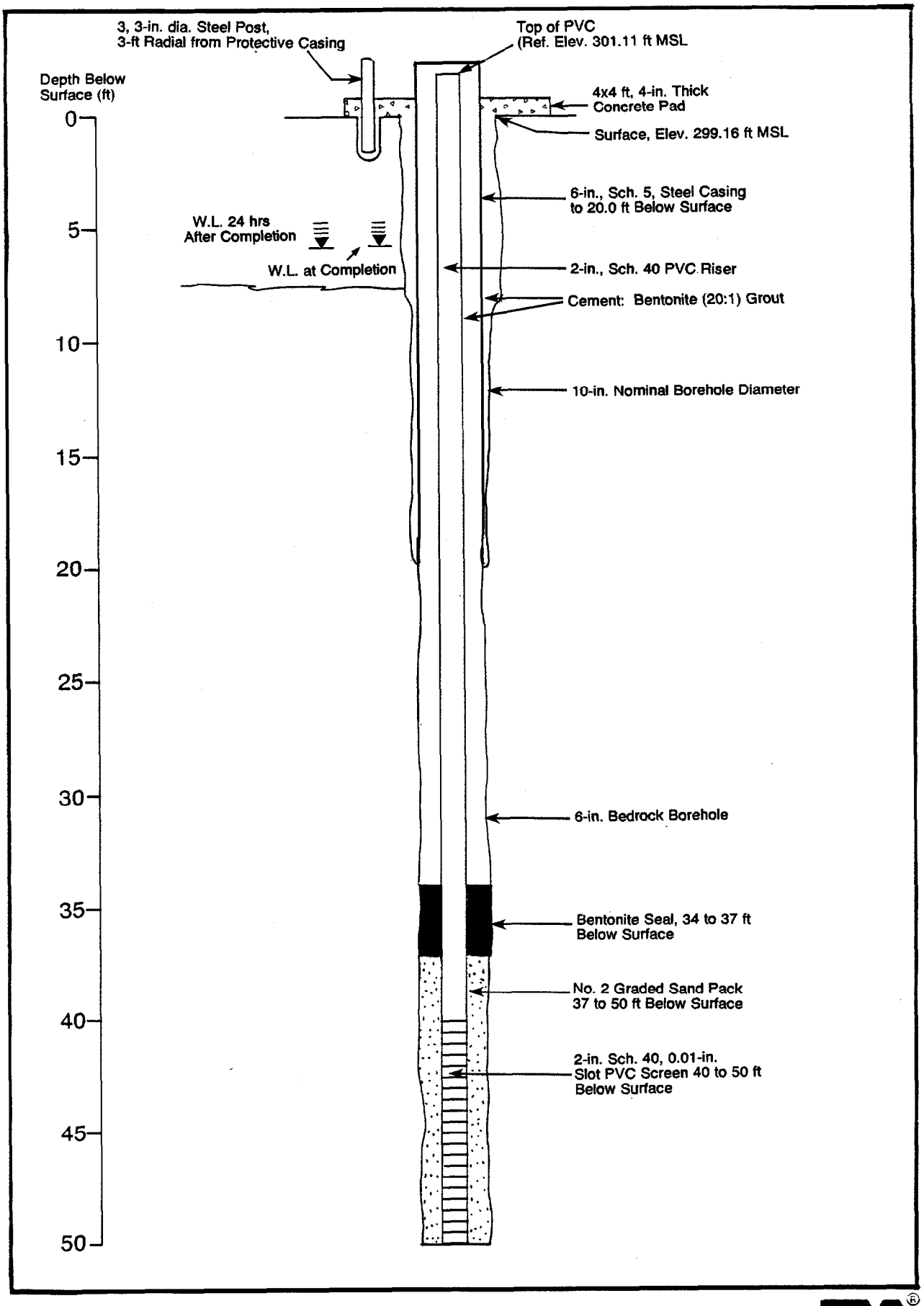
MW-5
(Bedrock Well)



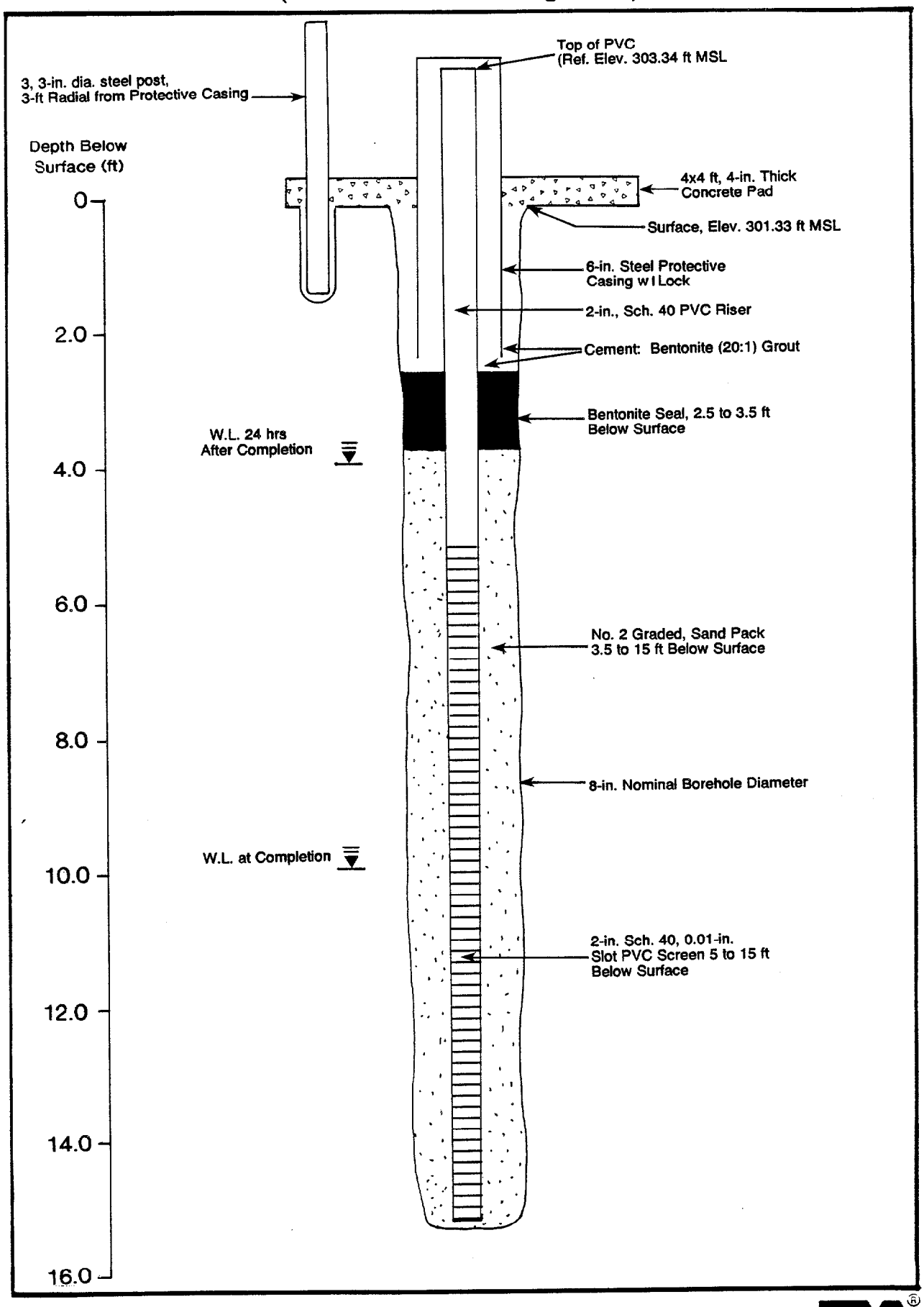
MW-5A
(Overburden Monitoring Wells)



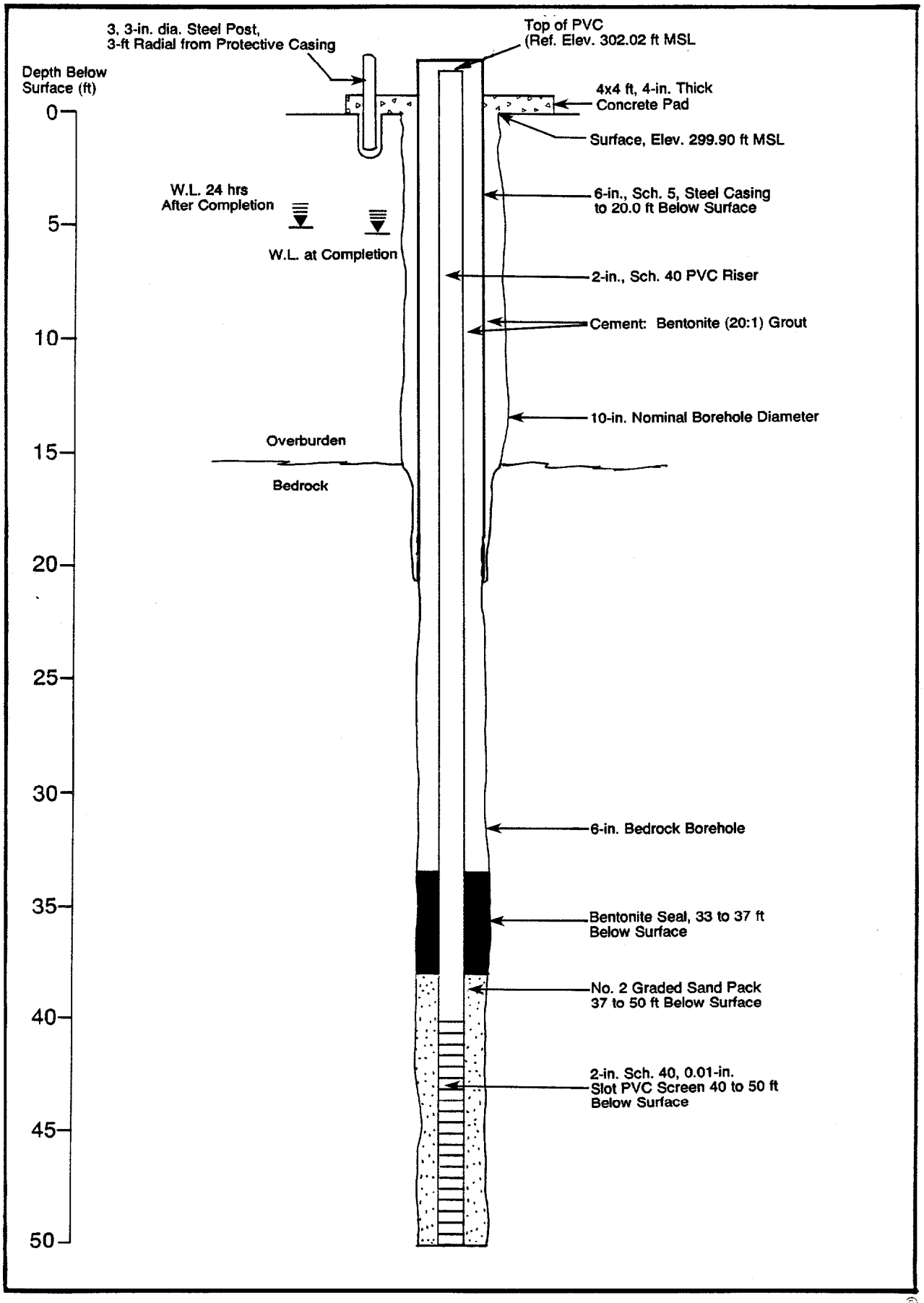
MW-6
(Bedrock Well)



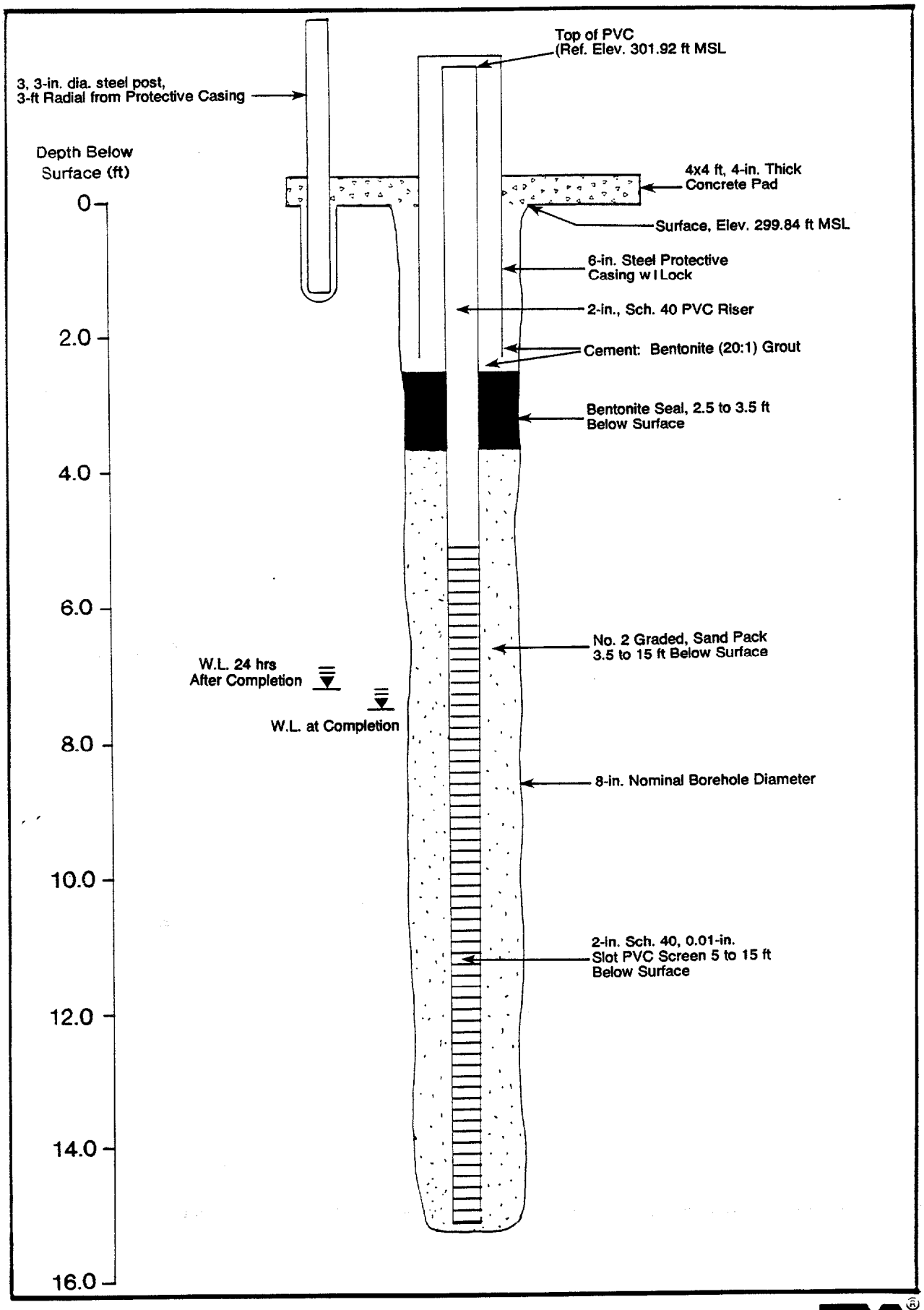
MW-6A
(Overburden Monitoring Wells)

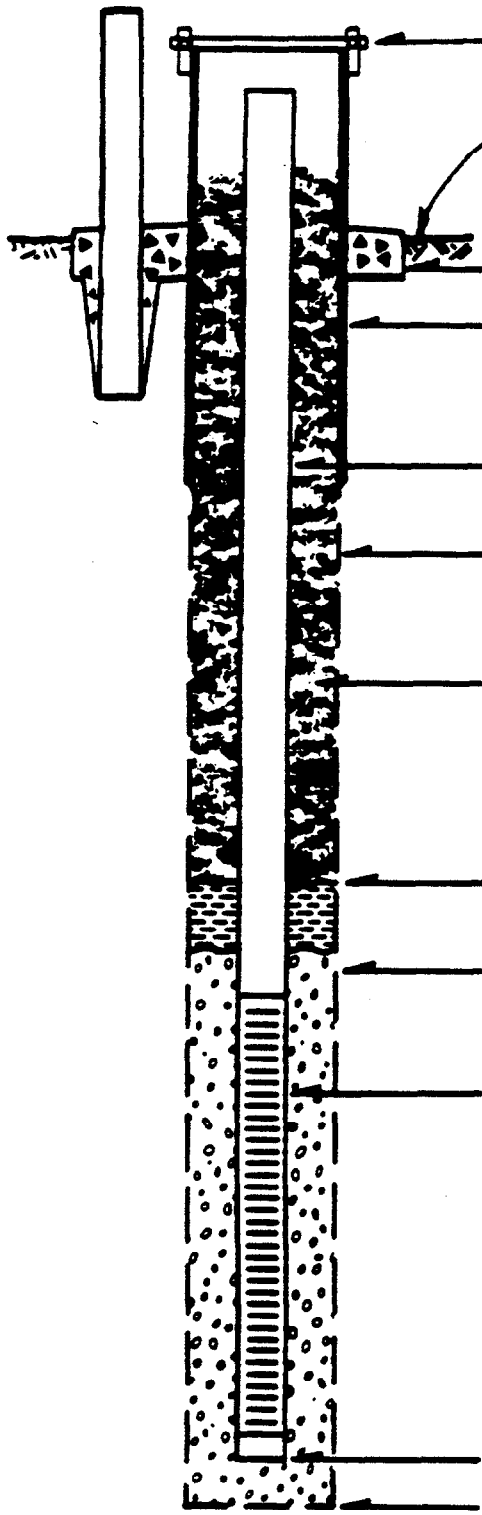


MW-7
(Bedrock Well)



MW-7A
(Overburden Monitoring Wells)



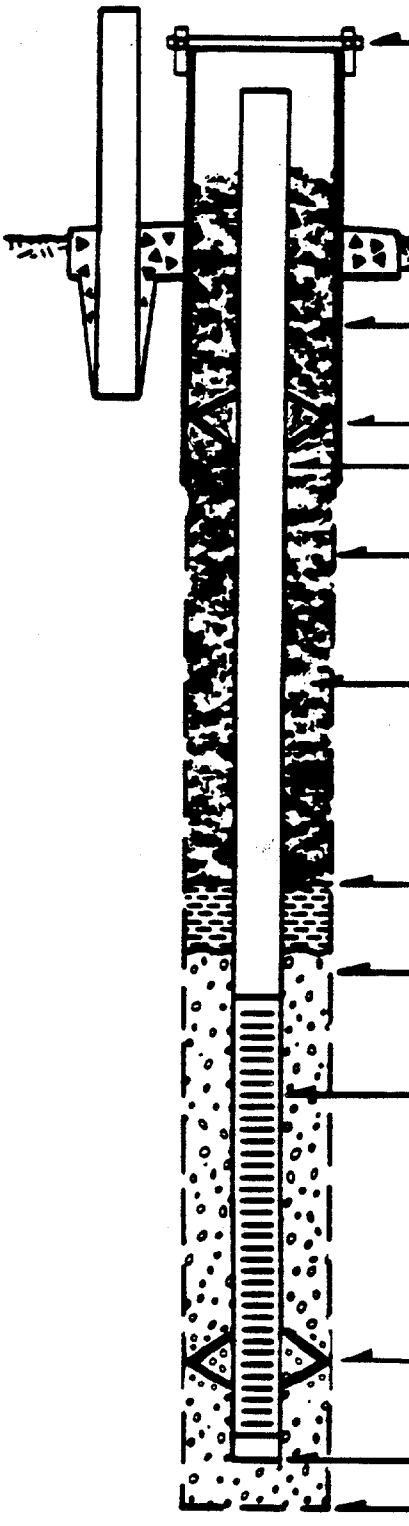


Elevation of top of casing *	90.48
Ground Elevation *	87.50
*(Elevations relative to onsite monuments)	
Concrete pad with steel posts	
I.D./O.D. of surface casing	6"/6.5"
Type of surface casing	Steel
I.D./O.D. of riser pipe	2"/2.3"
Type of riser pipe	PVC Blank
Diameter of borehole	8"
Type of backfill	Cement, 7 gallons of water to 1-bag cement
Type of seal	Bentonite Pellets
Depth to top of seal	2'
Depth to top of sand pack	3'
Depth to top of screen	5.25'
Type of screened section	2" PVC SCH 40 10 Slot
I.D./O.D. of screened section	2"/2.3"
Type of sand pack	Grade 1 Sand (SP)
Depth to bottom of well	15.25'
Depth of borehole	15.25'

Note: Well drilled with a CME-45C by Walt Ketter of Empire Soils Investigations, inspected by WCC geologist, Timothy Glazar

REPORT OF MONITORING WELL NO. MW-1A

DRN.BY: D.G.	CKD.BY:	PROJECT: NO: 86C8554E, NCAD	DATE: 3/27/87	FIGURE: MW-1

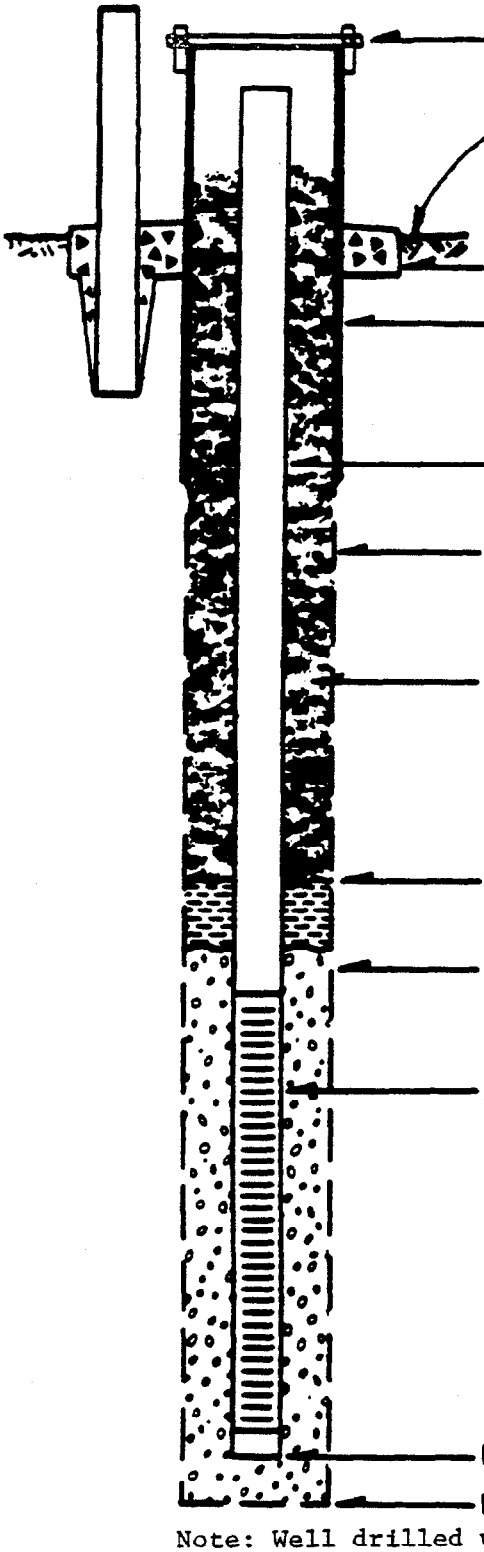


Elevation of top of casing *	86.73
Ground Elevation *	83.92
*(Elevations relative to onsite monuments)	
Concrete pad with steel posts	
I.D./O.D. of surface casing	6"/6.5"
Type of surface casing	Steel
Centralizer	
I.D./O.D. of riser pipe	2"/2.3"
Type of riser pipe	PVC Blank
Diameter of borehole	8"
Type of backfill	Cement, 7 gallons of water to 1-bag cement
Type of seal	Bentonite Pellets
Depth to top of seal	½'
Depth to top of sand pack	1½'
Depth to top of screen	3'
Type of screened section	PVC SCH 40 Factory milled 10 Slot
I.D./O.D. of screened section	2"/2.3"
Type of sand pack	Grade 1 Sand (SP)
Centralizer	
Depth to bottom of well	13'
Depth of borehole	16½'

Note: Well drilled with a CME-45C by Walt Ketter of Empire Soils Investigations, inspected by WCC geologist Timothy Glazar

REPORT OF MONITORING WELL NO. MW-2A

DRN.BY: D.G.	CKD.BY: TDG	PROJECT NO: 86C8554E, NCAD	DATE: 3/27/87	FIGURE: MW-2



Elevation of top of casing * 88.23

Ground Elevation * 84.94

*(Elevations relative to onsite monuments)

Concrete pad with steel posts

I.D./O.D. of surface casing 6"/6.5"

Type of surface casing Steel

I.D./O.D. of riser pipe 2"/2.3"

Type of riser pipe PVC Blank

Diameter of borehole 8"

Type of backfill Cement, 7 gallons of water to 1-bag cement

Type of seal Bentonite Pellets

Depth to top of seal 2'

Depth to top of sand pack 3'

Depth to top of screen 4½'

Type of screened section PVC SCH 40 Factory milled 10 Slot

I.D./O.D. of screened section 2"/2.3"

Type of sand pack Grade 1 Sand (SP)

Depth to bottom of well 14½'

Depth of borehole 16'

Note: Well drilled with a CME-45C by Walt Ketter of Empire Soils Investigations, inspected by WCC geologist, Timothy Glazar

REPORT OF MONITORING WELL NO. MW-3A

DRN.BY: D.G.	CKD.BY: TDG	PROJECT: NO. 86C8554E, NCAD	DATE: 3/27/87	FIGURE: MW-3

APPENDIX C

MARSH RUN FIELD
SLUG TEST DATA

3E1000B
Environmental Logger
02/13 10:51

Unit# 03004 Test# 4

INPUT 1: Level (F) TOC

Reference 7.95
Scale factor 50.38
Offset 0.00

Step# 0 02/09 13:08

Elapsed Time Value

IN-SITU INC. HERMIT DATA MANAGEMENT PACKAGE

MW5.SLUG

DRAWDOWN TABLE

Reference Value : 7.95 (Ft)

ELAPSED TIME (Min)	REAL TIME (hh:mm)	VALUE (Ft)	DRAWDOWN (Ft)
.00	DAY 1 13:08	6.80	-1.15
.00	13:08	6.80	-1.15

.01	13:08	6.80	-1.15
.01	13:08	6.80	-1.15
.01	13:08	6.80	-1.15
.02	13:08	6.79	-1.16
.02	13:08	6.80	-1.15
.02	13:08	6.80	-1.15
.03	13:08	6.82	-1.13
.03	13:08	6.80	-1.15
.03	13:08	6.83	-1.12
.05	13:08	6.80	-1.15
.07	13:08	6.80	-1.15
.08	13:08	6.80	-1.15
.10	13:08	6.80	-1.15
.12	13:08	6.80	-1.15
.13	13:08	6.80	-1.15
.15	13:08	6.80	-1.15
.17	13:08	6.80	-1.15
.18	13:08	6.79	-1.16
.20	13:08	6.79	-1.16
.22	13:08	6.80	-1.15
.23	13:08	6.79	-1.16
.25	13:08	6.79	-1.16
.27	13:08	6.79	-1.16
.28	13:08	6.79	-1.16
.30	13:08	6.79	-1.16
.32	13:08	6.79	-1.16
.33	13:08	6.79	-1.16
.42	13:08	6.77	-1.18
.50	13:08	6.77	-1.18
.58	13:08	6.79	-1.16
.67	13:08	6.80	-1.15
.75	13:08	6.79	-1.16
.83	13:08	6.80	-1.15
.92	13:08	6.80	-1.15
1.00	13:09	6.79	-1.16
1.08	13:09	6.77	-1.18
1.17	13:09	6.79	-1.16
1.25	13:09	6.79	-1.16
1.33	13:09	6.79	-1.16
1.42	13:09	6.79	-1.16
1.50	13:09	6.79	-1.16
1.58	13:09	6.79	-1.16
1.67	13:09	6.79	-1.16
1.75	13:09	6.79	-1.16
1.83	13:09	6.79	-1.16
1.92	13:09	6.80	-1.15
2.00	13:10	6.80	-1.15
2.50	13:10	6.80	-1.15
3.00	13:11	6.80	-1.15
3.50	13:11	6.83	-1.12
4.00	13:12	6.85	-1.10
4.50	13:12	6.85	-1.10
5.00	13:13	6.87	-1.08
5.50	13:13	6.88	-1.07
6.00	13:14	6.90	-1.05
6.50	13:14	6.90	-1.05
7.00	13:15	6.91	-1.04
7.50	13:15	6.93	-1.02
8.00	13:16	6.94	-1.01
8.50	13:16	6.96	-.99
9.00	13:17	6.98	-.97
9.50	13:17	6.99	-.96
10.00	13:18	6.99	-.96
12.00	13:20	7.06	-.89
14.00	13:22	7.10	-.85
16.00	13:24	7.15	-.80

18.00	13:26	7.18	-.77
20.00	13:28	7.23	-.72
22.00	13:30	7.28	-.67
24.00	13:32	7.33	-.62
26.00	13:34	7.36	-.59
28.00	13:36	7.41	-.54
30.00	13:38	7.45	-.50
32.00	13:40	7.48	-.47
34.00	13:42	7.53	-.42
36.00	13:44	7.56	-.39
38.00	13:46	7.61	-.34

SE1000B
Environmental Logger
02/13 10:54

Unit# 03004 Test# 2

INPUT 1: Level (F) TOC

Reference	12.30
Scale factor	50.38
Offset	0.00

Step# 0 02/08 17:32

Elapsed Time Value

IN-SITU INC. HERMIT DATA MANAGEMENT PACKAGE

MW1 SLUG

DRAWDOWN TABLE

Reference Value : 12.30 (Ft)

ELAPSED TIME (Min)	REAL TIME (hh:mm)	VALUE (Ft)	DRAWDOWN (Ft)
.00	DAY 1 17:32	7.79	-4.51
.00	17:32	7.66	-4.64

.01	17:32	7.71	-4.59
.01	17:32	7.72	-4.58
.01	17:32	7.74	-4.56
.02	17:32	7.77	-4.53
.02	17:32	7.77	-4.53
.02	17:32	7.82	-4.48
.03	17:32	7.83	-4.47
.03	17:32	7.85	-4.45
.03	17:32	7.90	-4.40
.05	17:32	8.01	-4.29
.07	17:32	8.14	-4.16
.08	17:32	8.26	-4.04
.10	17:32	8.37	-3.93
.12	17:32	8.50	-3.80
.13	17:32	8.61	-3.69
.15	17:32	8.71	-3.59
.17	17:32	8.82	-3.48
.18	17:32	8.91	-3.39
.20	17:32	9.01	-3.29
.22	17:32	9.12	-3.18
.23	17:32	9.21	-3.09
.25	17:32	9.29	-3.01
.27	17:32	9.39	-2.91
.28	17:32	9.47	-2.83
.30	17:32	9.55	-2.75
.32	17:32	9.63	-2.67
.33	17:32	9.69	-2.61
.42	17:32	10.02	-2.28
.50	17:32	10.29	-2.01
.58	17:32	10.53	-1.77
.67	17:32	10.74	-1.56
.75	17:32	10.91	-1.39
.83	17:32	11.06	-1.24
.92	17:32	11.17	-1.13
1.00	17:33	11.28	-1.02
1.08	17:33	11.36	-.94
1.17	17:33	11.45	-.85
1.25	17:33	11.52	-.78
1.33	17:33	11.58	-.72
1.42	17:33	11.63	-.67
1.50	17:33	11.68	-.62
1.58	17:33	11.71	-.59
1.67	17:33	11.76	-.54
1.75	17:33	11.77	-.53
1.83	17:33	11.82	-.48
1.92	17:33	11.83	-.47
2.00	17:34	11.87	-.43
2.50	17:34	11.96	-.34
3.00	17:35	12.03	-.27
3.50	17:35	12.07	-.23
4.00	17:36	12.10	-.20
4.50	17:36	12.12	-.18
5.00	17:37	12.14	-.16
5.50	17:37	12.15	-.15
6.00	17:38	12.17	-.13
6.50	17:38	12.18	-.12
7.00	17:39	12.18	-.12
7.50	17:39	12.20	-.10
8.00	17:40	12.20	-.10
8.50	17:40	12.20	-.10
9.00	17:41	12.22	-.08
9.50	17:41	12.22	-.08
10.00	17:42	12.22	-.08
12.00	17:44	12.25	-.05
14.00	17:46	12.26	-.04
16.00	17:48	12.26	-.04

18.00	17:50	12.26	-.04
20.00	17:52	12.26	-.04

SE1000B
Environmental Logger
02/13 10:56

Unit# 03004 Test# 1

INPUT 1: Level (F) TOC

Reference	10.70
Scale factor	50.38
Offset	0.00

Step# 0 02/08 16:48

Elapsed Time Value

IN-SITU INC. HERMIT DATA MANAGEMENT PACKAGE

MW4A SLUG

DRAWDOWN TABLE

Reference Value : 10.70 (Ft)

ELAPSED TIME (Min)	REAL TIME (hh:mm)	VALUE (Ft)	DRAWDOWN (Ft)
.00	DAY 1 16:48	9.87	-.83
.00	16:48	9.68	-1.02

.01	16:48	9.76	-.94
.01	16:48	9.81	-.89
.01	16:48	9.90	-.80
.02	16:48	9.81	-.89
.02	16:48	9.95	-.75
.02	16:48	10.00	-.70
.03	16:48	10.01	-.69
.03	16:48	10.03	-.67
.03	16:48	10.03	-.67
.05	16:48	10.08	-.62
.07	16:48	10.09	-.61
.08	16:48	10.12	-.58
.10	16:48	10.14	-.56
.12	16:48	10.16	-.54
.13	16:48	10.14	-.56
.15	16:48	10.14	-.56
.17	16:48	10.16	-.54
.18	16:48	10.16	-.54
.20	16:48	10.16	-.54
.22	16:48	10.16	-.54
.23	16:48	10.16	-.54
.25	16:48	10.16	-.54
.27	16:48	10.16	-.54
.28	16:48	10.17	-.53
.30	16:48	10.17	-.53
.32	16:48	10.17	-.53
.33	16:48	10.17	-.53
.42	16:48	10.17	-.53
.50	16:48	10.17	-.53
.58	16:48	10.17	-.53
.67	16:48	10.19	-.51
.75	16:48	10.19	-.51
.83	16:48	10.19	-.51
.92	16:48	10.19	-.51
1.00	16:49	10.20	-.50
1.08	16:49	10.20	-.50
1.17	16:49	10.20	-.50
1.25	16:49	10.22	-.48
1.33	16:49	10.22	-.48
1.42	16:49	10.22	-.48
1.50	16:49	10.22	-.48
1.58	16:49	10.23	-.47
1.67	16:49	10.23	-.47
1.75	16:49	10.23	-.47
1.83	16:49	10.23	-.47
1.92	16:49	10.23	-.47
2.00	16:50	10.25	-.45
2.50	16:50	10.25	-.45
3.00	16:51	10.27	-.43
3.50	16:51	10.28	-.42
4.00	16:52	10.30	-.40
4.50	16:52	10.31	-.39
5.00	16:53	10.33	-.37
5.50	16:53	10.35	-.35
6.00	16:54	10.36	-.34
6.50	16:54	10.38	-.32
7.00	16:55	10.38	-.32
7.50	16:55	10.39	-.31
8.00	16:56	10.41	-.29
8.50	16:56	10.43	-.27
9.00	16:57	10.43	-.27
9.50	16:57	10.43	-.27
10.00	16:58	10.44	-.26
12.00	17:00	10.46	-.24
14.00	17:02	10.49	-.21
16.00	17:04	10.50	-.20

18.00	17:06	10.52	-.18
20.00	17:08	10.52	-.18
22.00	17:10	10.55	-.15
24.00	17:12	10.55	-.15
26.00	17:14	10.58	-.12
28.00	17:16	10.58	-.12
30.00	17:18	10.60	-.10
32.00	17:20	10.60	-.10

SE1000B
Environmental Logger
02/13 10:58

Unit# 03004 Test# 0

INPUT 1: Level (F) TOC

Reference	13.60
Scale factor	50.38
Offset	0.00

Step# 0 02/08 16:32

Elapsed Time Value

IN-SITU INC. HERMIT DATA MANAGEMENT PACKAGE

MW4 SLUG

DRAWDOWN TABLE

Reference Value : 13.60 (Ft)

ELAPSED TIME (Min)	REAL TIME (hh:mm)	VALUE (Ft)	DRAWDOWN (Ft)
.00	DAY 1 16:32	13.07	-.53
.00	16:32	13.18	-.42

.01	16:32	13.15	-.45
.01	16:32	13.20	-.40
.01	16:32	12.88	-.72
.02	16:32	12.75	-.85
.02	16:32	12.66	-.94
.02	16:32	12.91	-.69
.03	16:32	12.75	-.85
.03	16:32	12.64	-.96
.03	16:32	12.77	-.83
.05	16:32	12.77	-.83
.07	16:32	12.79	-.81
.08	16:32	12.82	-.78
.10	16:32	12.83	-.77
.12	16:32	12.86	-.74
.13	16:32	12.88	-.72
.15	16:32	12.90	-.70
.17	16:32	12.91	-.69
.18	16:32	12.94	-.66
.20	16:32	12.96	-.64
.22	16:32	12.98	-.62
.23	16:32	12.99	-.61
.25	16:32	13.01	-.59
.27	16:32	13.02	-.58
.28	16:32	13.04	-.56
.30	16:32	13.06	-.54
.32	16:32	13.07	-.53
.33	16:32	13.09	-.51
.42	16:32	13.13	-.47
.50	16:32	13.18	-.42
.58	16:32	13.23	-.37
.67	16:32	13.26	-.34
.75	16:32	13.31	-.29
.83	16:32	13.33	-.27
.92	16:32	13.36	-.24
1.00	16:33	13.37	-.23
1.08	16:33	13.39	-.21
1.17	16:33	13.40	-.20
1.25	16:33	13.42	-.18
1.33	16:33	13.44	-.16
1.42	16:33	13.45	-.15
1.50	16:33	13.47	-.13
1.58	16:33	13.47	-.13
1.67	16:33	13.48	-.12
1.75	16:33	13.48	-.12
1.83	16:33	13.50	-.10
1.92	16:33	13.50	-.10
2.00	16:34	13.50	-.10
2.50	16:34	13.52	-.08
3.00	16:35	13.55	-.05
3.50	16:35	13.55	-.05
4.00	16:36	13.56	-.04
4.50	16:36	13.56	-.04
5.00	16:37	13.56	-.04
5.50	16:37	13.56	-.04
6.00	16:38	13.58	-.02
6.50	16:38	13.58	-.02
7.00	16:39	13.58	-.02
7.50	16:39	13.60	.00
8.00	16:40	13.58	-.02
8.50	16:40	13.60	.00
9.00	16:41	13.60	.00
9.50	16:41	13.60	.00
10.00	16:42	13.60	.00
12.00	16:44	13.60	.00

MW-5A

SE1000B
Environmental Logger
02/13 10:52

Unit# 03004 Test# 3

INPUT 1: Level (F) TOC

Reference	7.50
Scale factor	50.38
Offset	0.00

Step# 0 02/09 12:50

Elapsed Time	Value	DRAWDOWN (ft.)	Drawdown (ft.)
0.0000	6.94	-0.56	- 0.56
0.0033	6.94	"	
0.0066	6.94	"	
0.0099	6.92	-0.58	- 0.58
0.0133	6.92	"	
0.0166	6.92	"	
0.0200	6.91	-0.59	- 0.59
0.0233	6.91	"	
0.0266	6.91	"	
0.0300	6.91	"	
0.0333	6.91	"	
0.0500	6.91	"	
0.0666	6.91	"	
0.0833	6.91	"	
0.1000	6.91	"	
0.1166	6.91	-	
0.1333	6.92	-0.58	- 0.58
0.1500	6.92	"	
0.1666	6.92	"	
0.1833	6.92	"	

0.2000	6.94	-0.56	-0.56
0.2166	6.94	"	
0.2333	6.94	"	
0.2500	6.94	"	
0.2666	6.94	"	
0.2833	6.94	"	
0.3000	6.94	"	
0.3166	6.96	-0.54	-0.54
0.3333	6.96	"	
0.4167	6.96	"	
0.5000	6.97	-0.53	-0.53
0.5833	6.99	-0.51	-0.51
0.6667	7.00	-0.5	-0.50
0.7500	7.02	-.48	-0.48
0.0333	7.02	"	
0.9167	7.05	-0.45	-0.45
1.0000	7.05	"	
1.0833	7.07	-0.43	-0.43
1.1667	7.08	-0.42	-0.42
1.2500	7.08	-0.42	-0.42
1.3333	7.10	-0.4	-0.40
1.4166	7.11	-0.39	
1.5000	7.11	-0.39	-0.39
1.5833	7.13	-0.37	-0.37
1.6667	7.15	-0.35	-0.35
1.7500	7.15	-0.35	
1.8333	7.16	-0.34	-0.34
1.9167	7.18	-0.32	-0.32
2.0000	7.18	-0.32	
2.5000	7.23	-0.27	-0.27
3.0000	7.26	-0.24	-0.24
3.5000	7.29	-0.21	-0.21
4.0000	7.38	-0.12	-0.12
4.5000	7.35	-0.15	-0.15
5.0000	7.37	-0.13	-0.13
5.5000	7.38	-0.12	-0.12
6.0000	7.40	-0.10	-0.10
6.5000	7.42	-0.08	-0.08
7.0000	7.43	-0.07	-0.07
7.5000	7.43	-0.07	
8.0000	7.45	-0.05	-0.05
8.5000	7.45	-0.05	
9.0000	7.45	-0.05	
9.5000	7.46	-0.04	-0.04
10.0000	7.46	-0.04	
12.0000	7.48	-0.02	-0.02
14.0000	7.50	.000	

END

SE1000B
Environmental Logger
08/21 10:59

Unit# 04000 Test# 0

INPUT 1: Level (F) TOC

Reference 6.55
Scale factor 49.92
Offset 0.06

Step# 0 08/17 12:30

Elapsed Time Value

IN-SITU INC. HERMIT DATA MANAGEMENT PACKAGE

MW7A SLUG

DRAWDOWN TABLE

Reference Value : 6.55 (Ft)

ELAPSED TIME (Min)	REAL TIME (hh:mm)	VALUE (Ft)	DRAWDOWN (Ft)
.00	DAY 1 12:30	4.06	-2.49
.00	12:30	4.06	-2.49
.01	12:30	4.06	-2.49
.01	12:30	4.04	-2.51
.01	12:30	4.00	-2.55
.02	12:30	4.01	-2.54
.02	12:30	4.03	-2.52
.02	12:30	4.04	-2.51
.03	12:30	4.04	-2.51
.03	12:30	4.04	-2.51
.03	12:30	4.04	-2.51
.05	12:30	4.06	-2.49
.07	12:30	4.08	-2.47
.08	12:30	4.11	-2.44
.10	12:30	4.12	-2.43
.12	12:30	4.14	-2.41
.13	12:30	4.15	-2.40
.15	12:30	4.19	-2.36
.17	12:30	4.20	-2.35
.18	12:30	4.22	-2.33
.20	12:30	4.23	-2.32
.22	12:30	4.25	-2.30
.23	12:30	4.26	-2.29
.25	12:30	4.28	-2.27
.27	12:30	4.30	-2.25
.28	12:30	4.31	-2.24
.30	12:30	4.33	-2.22
.32	12:30	4.34	-2.21
.33	12:30	4.36	-2.19

.42	12:30	4.41	-2.14
.50	12:30	4.47	-2.08
.58	12:30	4.52	-2.03
.67	12:30	4.56	-1.99
.75	12:30	4.59	-1.96
.83	12:30	4.64	-1.91
.92	12:30	4.67	-1.88
1.00	12:31	4.72	-1.83
1.08	12:31	4.75	-1.80
1.17	12:31	4.78	-1.77
1.25	12:31	4.81	-1.74
1.33	12:31	4.85	-1.70
1.42	12:31	4.88	-1.67
1.50	12:31	4.91	-1.64
1.58	12:31	4.94	-1.61
1.67	12:31	4.96	-1.59
1.75	12:31	4.99	-1.56
1.83	12:31	5.00	-1.55
1.92	12:31	5.03	-1.52
2.00	12:32	5.07	-1.48
2.50	12:32	5.19	-1.36
3.00	12:33	5.30	-1.25
3.50	12:33	5.41	-1.14
4.00	12:34	5.51	-1.04
4.50	12:34	5.57	-.98
5.00	12:35	5.65	-.90
5.50	12:35	5.71	-.84
6.00	12:36	5.77	-.78
6.50	12:36	5.82	-.73
7.00	12:37	5.87	-.68
7.50	12:37	5.92	-.63
8.00	12:38	5.96	-.59
8.50	12:38	5.99	-.56
9.00	12:39	6.03	-.52
9.50	12:39	6.07	-.48
10.00	12:40	6.09	-.46
12.00	12:42	6.20	-.35
14.00	12:44	6.28	-.27
16.00	12:46	6.32	-.23
18.00	12:48	6.37	-.18

SE10008
Environmental Logger
08/21 10:57

Unit# 04000 Test# 1

INPUT 1: Level (F) TOC

Reference 6.85
Scale factor 49.72
Offset 0.06

Step# 0 08/17 13:16

Elapsed Time Value

IN-SITU INC. HERMIT DATA MANAGEMENT PACKAGE

MW2 SLUG

DRAWDOWN TABLE

Reference Value : 6.85 (Ft)

ELAPSED TIME (Min)	REAL TIME (hh:mm)	VALUE (Ft)	DRAWDOWN (Ft)
.00	DAY 1 13:16	5.57	-1.28
.00	13:16	5.59	-1.26
.01	13:16	5.65	-1.20
.01	13:16	5.62	-1.23
.01	13:16	5.62	-1.23
.02	13:16	5.63	-1.22
.02	13:16	5.67	-1.18
.02	13:16	5.71	-1.14
.03	13:16	5.74	-1.11
.03	13:16	5.78	-1.07
.03	13:16	5.81	-1.04
.05	13:16	5.92	-.93
.07	13:16	6.00	-.85
.08	13:16	6.06	-.79
.10	13:16	6.11	-.74
.12	13:16	6.14	-.71
.13	13:16	6.18	-.67
.15	13:16	6.22	-.63
.17	13:16	6.23	-.62
.18	13:16	6.28	-.57
.20	13:16	6.29	-.56
.22	13:16	6.31	-.54
.23	13:16	6.34	-.51
.25	13:16	6.36	-.49
.27	13:16	6.37	-.48
.28	13:16	6.39	-.46
.30	13:16	6.40	-.45
.32	13:16	6.42	-.43
.33	13:16	6.44	-.41

.42	13:16	6.48	-.37
.50	13:16	6.51	-.34
.58	13:16	6.55	-.30
.67	13:16	6.56	-.29
.75	13:16	6.59	-.26
.83	13:16	6.61	-.24
.92	13:16	6.62	-.23
1.00	13:17	6.64	-.21
1.08	13:17	6.64	-.21
1.17	13:17	6.66	-.19
1.25	13:17	6.66	-.19
1.33	13:17	6.67	-.18
1.42	13:17	6.67	-.18
1.50	13:17	6.69	-.16
1.58	13:17	6.69	-.16
1.67	13:17	6.69	-.16
1.75	13:17	6.70	-.15
1.83	13:17	6.70	-.15
1.92	13:17	6.70	-.15
2.00	13:18	6.72	-.13
2.50	13:18	6.73	-.12
3.00	13:19	6.75	-.10
3.50	13:19	6.77	-.08
4.00	13:20	6.78	-.07
4.50	13:20	6.80	-.05
5.00	13:21	6.80	-.05
5.50	13:21	6.81	-.04
6.00	13:22	6.81	-.04
6.50	13:22	6.81	-.04
7.00	13:23	6.81	-.04
7.50	13:23	6.81	-.04
8.00	13:24	6.81	-.04
8.50	13:24	6.81	-.04
9.00	13:25	6.83	-.02
9.50	13:25	6.83	-.02
10.00	13:26	6.83	-.02

SE1000B
Environmental Logger
08/21 10:56

Unit# 04000 Test# 2

INPUT 1: Level (F) TOC

Reference 8.45
Scale factor 49.92
Offset 0.06

Step# 0 08/17 15:05

Elapsed Time Value

IN-SITU INC. HERMIT DATA MANAGEMENT PACKAGE

MW6SLUG

DRAWDOWN TABLE

Reference Value : 8.45 (Ft)

ELAPSED TIME (Min)	REAL TIME (hh:mm)	VALUE (Ft)	DRAWDOWN (Ft)
.00	DAY 1 15:05	6.76	-1.69
.00	15:05	6.75	-1.70
.01	15:05	6.87	-1.58
.01	15:05	6.86	-1.59
.01	15:05	6.82	-1.63
.02	15:05	6.82	-1.63
.02	15:05	6.81	-1.64
.02	15:05	6.81	-1.64
.03	15:05	6.81	-1.64
.03	15:05	6.81	-1.64
.03	15:05	6.81	-1.64
.05	15:05	6.81	-1.64
.07	15:05	6.81	-1.64
.08	15:05	6.81	-1.64
.10	15:05	6.81	-1.64
.12	15:05	6.81	-1.64
.13	15:05	6.82	-1.63
.15	15:05	6.82	-1.63
.17	15:05	6.82	-1.63
.18	15:05	6.82	-1.63
.20	15:05	6.82	-1.63
.22	15:05	6.84	-1.61
.23	15:05	6.84	-1.61
.25	15:05	6.84	-1.61
.27	15:05	6.84	-1.61
.28	15:05	6.86	-1.59
.30	15:05	6.86	-1.59
.32	15:05	6.86	-1.59
.33	15:05	6.86	-1.59

.42	15:05	6.87	-1.58
.50	15:05	6.87	-1.56
.58	15:05	6.90	-1.55
.67	15:05	6.92	-1.53
.75	15:05	6.93	-1.52
.83	15:05	6.93	-1.52
.92	15:05	6.95	-1.50
1.00	15:06	6.97	-1.48
1.08	15:06	6.97	-1.48
1.17	15:06	6.98	-1.47
1.25	15:06	6.98	-1.47
1.33	15:06	7.00	-1.45
1.42	15:06	7.00	-1.45
1.50	15:06	7.01	-1.44
1.58	15:06	7.03	-1.42
1.67	15:06	7.03	-1.42
1.75	15:06	7.04	-1.41
1.83	15:06	7.04	-1.41
1.92	15:06	7.06	-1.39
2.00	15:07	7.06	-1.39
2.50	15:07	7.11	-1.34
3.00	15:08	7.15	-1.30
3.50	15:08	7.19	-1.26
4.00	15:09	7.22	-1.23
4.50	15:09	7.25	-1.20
5.00	15:10	7.28	-1.17
5.50	15:10	7.31	-1.14
6.00	15:11	7.34	-1.11
6.50	15:11	7.38	-1.07
7.00	15:12	7.41	-1.04
7.50	15:12	7.42	-1.03
8.00	15:13	7.45	-1.00
8.50	15:13	7.47	-.98
9.00	15:14	7.49	-.96
9.50	15:14	7.52	-.93
10.00	15:15	7.55	-.90
12.00	15:17	7.63	-.82
14.00	15:19	7.71	-.74
16.00	15:21	7.78	-.67
18.00	15:23	7.85	-.60
20.00	15:25	7.89	-.56
22.00	15:27	7.96	-.49
24.00	15:29	7.99	-.46
26.00	15:31	8.04	-.41
28.00	15:33	8.08	-.37

SE1000B
Environmental Logger
08/21 10:50

Unit# 04000 Test# 3

INPUT 1: Level (F) TOC

Reference 8.00
Scale factor 49.92
Offset 0.06

Step# 0 08/17 15:37

Elapsed Time Value

IN-SITU INC. HERMIT DATA MANAGEMENT PACKAGE

MW-6A SLUG

DRAWDOWN TABLE

Reference Value : 8.00 (Ft)

ELAPSED TIME (Min)	REAL TIME (hh:mm)	VALUE (Ft)	DRAWDOWN (Ft)
.00	DAY 1 15:37	7.81	-.19
.00	15:37	7.82	-.18
.01	15:37	7.81	-.19
.01	15:37	7.81	-.19
.01	15:37	7.81	-.19
.02	15:37	7.81	-.19
.02	15:37	7.81	-.19
.02	15:37	7.81	-.19
.03	15:37	7.81	-.19
.03	15:37	7.79	-.21
.03	15:37	7.79	-.21
.05	15:37	7.79	-.21
.07	15:37	7.79	-.21
.08	15:37	7.79	-.21
.10	15:37	7.79	-.21
.12	15:37	7.79	-.21
.13	15:37	7.81	-.19
.15	15:37	7.81	-.19
.17	15:37	7.81	-.19
.18	15:37	7.81	-.19
.20	15:37	7.81	-.19
.22	15:37	7.81	-.19
.23	15:37	7.81	-.19
.25	15:37	7.81	-.19
.27	15:37	7.82	-.18
.28	15:37	7.82	-.18
.30	15:37	7.82	-.18
.32	15:37	7.82	-.18
.33	15:37	7.82	-.18

.42	15:37	7.84	-.16
.50	15:37	7.85	-.15
.58	15:37	7.88	-.12
.67	15:37	7.92	-.08
.75	15:37	7.92	-.08
.83	15:37	7.92	-.08
.92	15:37	7.92	-.08
1.00	15:38	7.92	-.08
1.08	15:38	7.92	-.08
1.17	15:38	7.92	-.08
1.25	15:38	7.92	-.08
1.33	15:38	7.92	-.08
1.42	15:38	7.92	-.08
1.50	15:38	7.92	-.08
1.58	15:38	7.92	-.08
1.67	15:38	7.92	-.08
1.75	15:38	7.92	-.08
1.83	15:38	7.92	-.08
1.92	15:38	7.92	-.08
2.00	15:39	7.92	-.08
2.50	15:39	7.93	-.07
3.00	15:40	7.93	-.07
3.50	15:40	7.95	-.05
4.00	15:41	7.95	-.05
4.50	15:41	7.95	-.05
5.00	15:42	7.95	-.05
5.50	15:42	7.95	-.05
6.00	15:43	7.95	-.05
6.50	15:43	7.96	-.04
7.00	15:44	7.96	-.04
7.50	15:44	7.95	-.05
8.00	15:45	7.95	-.05
8.50	15:45	7.95	-.05
9.00	15:46	7.96	-.04
9.50	15:46	7.96	-.04
10.00	15:47	7.96	-.04
12.00	15:49	7.96	-.04
14.00	15:51	7.98	-.02

3E1000B
Environmental Logger
08/21 10:49

Unit# 04000 Test# 4

INPUT 1: Level (F) TOC

Reference 6.40
Scale factor 49.92
Offset 0.06

Step# 0 08/17 15:59

Elapsed Time Value

IN-SITU INC. HERMIT DATA MANAGEMENT PACKAGE

MW7 SLUG

DRAWDOWN TABLE

Reference Value : 6.40 (Ft)

ELAPSED TIME (Min)	REAL TIME (hh:mm)	VALUE (Ft)	DRAWDOWN (Ft)
.00	DAY 1 15:59	5.40	-1.00
.00	15:59	5.44	-.96
.01	15:59	5.42	-.98
.01	15:59	5.44	-.96
.01	15:59	5.45	-.95
.02	15:59	5.47	-.93
.02	15:59	5.50	-.90
.02	15:59	5.50	-.90
.03	15:59	5.51	-.89
.03	15:59	5.53	-.87
.03	15:59	5.55	-.85
.05	15:59	5.61	-.79
.07	15:59	5.67	-.73
.08	15:59	5.72	-.68
.10	15:59	5.75	-.65
.12	15:59	5.78	-.62
.13	15:59	5.83	-.57
.15	15:59	5.84	-.56
.17	15:59	5.88	-.52
.18	15:59	5.91	-.49
.20	15:59	5.92	-.48
.22	15:59	5.95	-.45
.23	15:59	5.97	-.43
.25	15:59	5.99	-.41
.27	15:59	6.00	-.40
.28	15:59	6.02	-.38
.30	15:59	6.03	-.37
.32	15:59	6.05	-.35
.33	15:59	6.06	-.34

.42	15:59	6.11	-.29
.50	15:59	6.16	-.24
.58	15:59	6.19	-.21
.67	15:59	6.21	-.19
.75	15:59	6.24	-.16
.83	15:59	6.25	-.15
.92	15:59	6.27	-.13
1.00	16:00	6.28	-.12
1.08	16:00	6.30	-.10
1.17	16:00	6.30	-.10
1.25	16:00	6.32	-.08
1.33	16:00	6.32	-.08
1.42	16:00	6.33	-.07
1.50	16:00	6.33	-.07
1.58	16:00	6.33	-.07
1.67	16:00	6.35	-.05
1.75	16:00	6.35	-.05
1.83	16:00	6.35	-.05
1.92	16:00	6.35	-.05
2.00	16:01	6.36	-.04
2.50	16:01	6.38	-.02
3.00	16:02	6.38	-.02
3.50	16:02	6.40	.00
4.00	16:03	6.41	.01
4.50	16:03	6.41	.01
5.00	16:04	6.41	.01
5.50	16:04	6.41	.01
6.00	16:05	6.41	.01
6.50	16:05	6.43	.03
7.00	16:06	6.43	.03
7.50	16:06	6.43	.03
8.00	16:07	6.43	.03
8.50	16:07	6.43	.03
9.00	16:08	6.43	.03
9.50	16:08	6.43	.03
10.00	16:09	6.43	.03

SE1000B
Environmental Logger
08/21 10:48

Unit# 04000 Test# 5

INPUT 1: Level (F) TOC

Reference 6.35
Scale factor 49.92
Offset 0.06

Step# 0 08/17 16:28

Elapsed Time Value

IN-SITU INC. HERMIT DATA MANAGEMENT PACKAGE

WP1 SLUG

DRAWDOWN TABLE

Reference Value : 6.35 (Ft)

ELAPSED TIME (Min)	REAL TIME (hh:mm)	VALUE (Ft)	DRAWDOWN (Ft)
.00	DAY 1 16:28	6.36	.01
.00	16:28	6.38	.03
.01	16:28	6.38	.03
.01	16:28	6.38	.03
.01	16:28	6.38	.03
.02	16:28	6.38	.03
.02	16:28	6.38	.03
.02	16:28	6.38	.03
.03	16:28	6.38	.03
.03	16:28	6.38	.03
.03	16:28	6.38	.03
.05	16:28	6.38	.03
.07	16:28	6.38	.03
.08	16:28	6.39	.04
.10	16:28	6.38	.03
.12	16:28	6.38	.03
.13	16:28	6.38	.03
.15	16:28	6.38	.03
.17	16:28	6.38	.03
.18	16:28	6.39	.04
.20	16:28	6.39	.04
.22	16:28	6.38	.03
.23	16:28	6.38	.03
.25	16:28	6.39	.04
.27	16:28	6.39	.04
.28	16:28	6.39	.04
.30	16:28	6.38	.03
.32	16:28	6.38	.03
.33	16:28	6.38	.03

.42	16:28	6.38	.03
.50	16:28	6.38	.03
.58	16:28	6.38	.03
.67	16:28	6.36	.01
.75	16:28	6.36	.01
.83	16:28	6.36	.01
.92	16:28	6.36	.01
1.00	16:29	6.36	.01
1.08	16:29	6.36	.01
1.17	16:29	6.36	.01
1.25	16:29	6.36	.01
1.33	16:29	6.36	.01
1.42	16:29	6.36	.01
1.50	16:29	6.35	.00
1.58	16:29	6.36	.01
1.67	16:29	6.36	.01
1.75	16:29	6.36	.01
1.83	16:29	6.36	.01
1.92	16:29	6.36	.01
2.00	16:30	6.36	.01
2.50	16:30	6.36	.01
3.00	16:31	6.36	.01
3.50	16:31	6.36	.01
4.00	16:32	6.36	.01
4.50	16:32	6.36	.01
5.00	16:33	6.36	.01
5.50	16:33	6.35	.00
6.00	16:34	6.35	.00
6.50	16:34	6.35	.00
7.00	16:35	6.35	.00
7.50	16:35	6.35	.00
8.00	16:36	6.36	.01
8.50	16:36	6.35	.00
9.00	16:37	6.35	.00
9.50	16:37	6.35	.00
10.00	16:38	6.35	.00
12.00	16:40	6.36	.01
14.00	16:42	6.36	.01
16.00	16:44	6.36	.01

Project MARSH Run Field — Project No. 10424.22

Subject SLUG TEST MW-1 — Sheet No. 1 of 1

Drawing No.

Computed by JPC — Date 2/9/89 — Checked by Comp — Date 1/26/90

$r_w = 0.25$ ft.

$L_e = 12$ ft.

$y_o = 4.51$ ft.

$y_t = 1$

$t = 0.92$ min

$L_w = 40$ ft.

$C = 2.7$

$r_c = 0.083$

1). $K = \frac{r_c^2 \ln(R_e/r_w)}{2 L_e} \frac{1}{t} \ln y_o/y_t$

$\ln y_o/y_t = \ln \frac{4.51}{1} = 1.5$

$\ln R_e/r_w = \frac{1}{\frac{1.1}{\ln(40/0.25)} + \frac{2.7}{(12/0.25)}}$

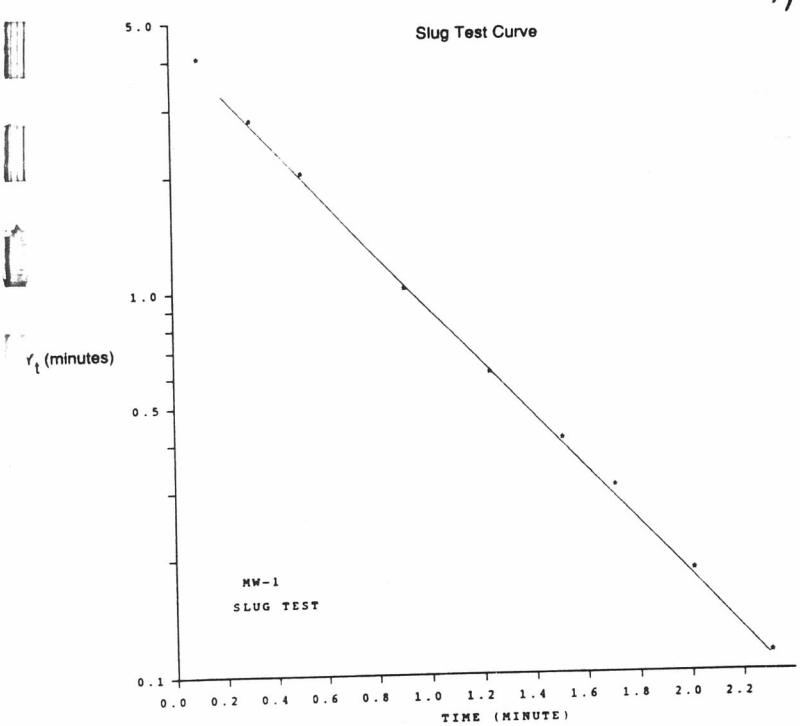
$\ln R_e/r_w = \frac{1}{0.216 + 0.056}$

$= 3.67$

$K = \frac{(0.083)^2 (3.67)}{24} (1.08)(1.5)$

$K = \frac{0.229}{24} (1.08)(1.5) = 1.7 \times 10^{-3}$ ft./min

$= 8.6 \times 10^{-4}$ cm/sec



Project NCAD Project No. 10424.22

Subject SLUG TEST MW-2 Sheet No. 1 of 1

Drawing No.

Computed by JRC Date 8/17/89 Checked by Comp. Date 1/25/90

$r_w = 0.25$ ft.
$L_e = 14$ ft.
$y_0 = 1.0$ ft.
$y_t = 0.3$
$t = 0.6$ MIN.
$L_w = 46$ ft.
$C = 2.85$
$r_c = 0.083$

$$(1)\quad K = \frac{r_c^2 \ln(R_e/r_w)}{2 L_e} \frac{1}{t} \ln y_0/y_t$$

$$\ln y_0/y_t = \ln 1.0/0.3 = 1.20$$

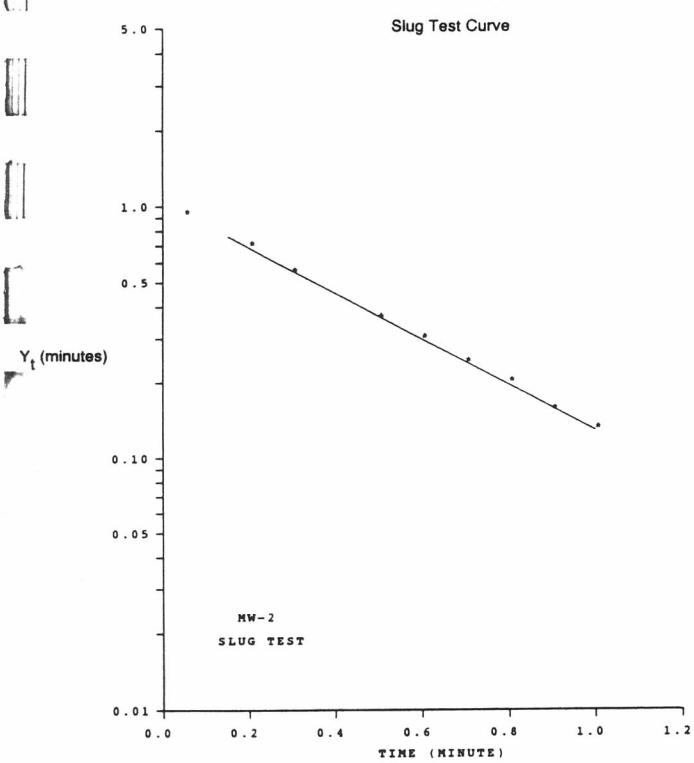
$$\ln R_e/r_w = \frac{1}{\frac{1.1}{\ln(46/0.25)} + \frac{2.85}{14/0.25}}$$

$$\ln R_e/r_w = \frac{1}{0.211 + 0.05} = 3.83$$

$$K = \frac{(0.083)^2 (3.83)}{28} (1.66)(1.20)$$

$$K = 1.8 \times 10^{-3} \text{ ft/min}$$

$$K = 9.4 \times 10^{-4} \text{ cm/sec}$$



Project NCAD Project No. 10424.22

Subject SLUG TEST MW-4 Sheet No. 1 of 1

Drawing No.

Computed by JPC Date 2/9/89 Checked by Comp. Date 1/25/90

$r_w = 0.25$ ft.

$L_e = 12$ ft.

$y_o = 0.83$ ft.

$y_t = 0.3$

$t = 0.8$ MIN.

$L_w = 39$ ft.

$C = 2.7$

$r_c = 0.083$

1) $K = \frac{r_c^2 \ln(R_e/r_w)}{2 L_e} \frac{1}{t} \ln y_o/y_t$

$\ln y_o/y_t = \ln 0.83/0.3 = 1.02$

$\ln R_e/r_w = \frac{1}{\frac{1.1}{\ln(39/0.25)} + \frac{2.7}{(12/0.35)}}$

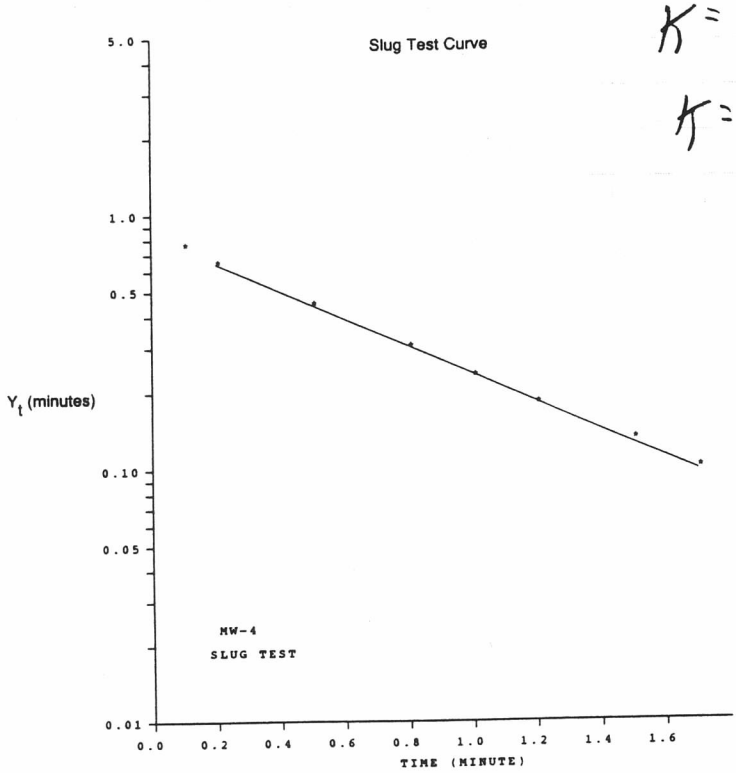
$\ln R_e/r_w = \frac{1}{0.218 + 0.056}$

$= 3.65$

$K = \frac{(0.083)^2 (3.65)}{24} (1.25)(1.02)$

$K = 1.3 \times 10^{-3}$ ft./min

$K = 6.8 \times 10^{-4}$ cm/sec



Project: Marsh Run Field — Project No. 10424.22
Subject: Slug test MW-4A — Sheet No. 1 of 1
Drawing No.
Computed by: JPC — Date: 2/9/89 — Checked by: Comp — Date: 1/26/90

$r_w = 0.33$ ft.
$L_e = 7.0$ ft
$Y_0 = .48$ ft.
$Y_t = .2$
$t = 17.5$ min
$L_w = 7$ ft.
$C = 1.75$
$r_c = 0.083$

1) $$K = \frac{r_c^2 \ln(R_e/r_w)}{2L_e} \frac{1}{t} \ln Y_0/Y_t$$

$$\ln Y_0/Y_t = \ln .48/.2 = 0.88$$

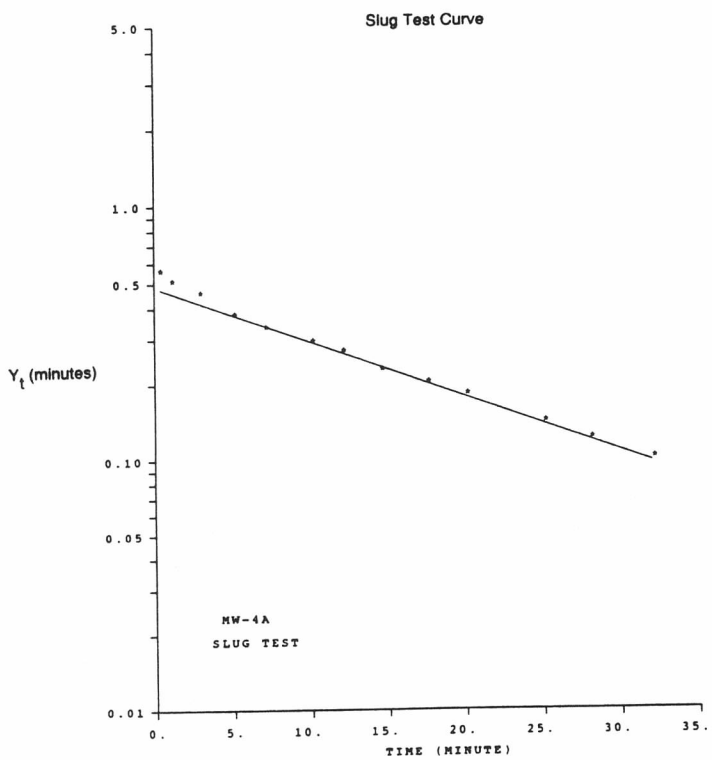
$$\ln R_e/r_w = \frac{1}{\frac{1.1}{\ln(7/0.33)} + \frac{1.75}{(7/0.33)}}$$

$$\ln R_e/r_w = \frac{1}{0.361 + 0.08} = 2.26$$

$$K = \frac{(0.083)^2 (2.26)}{14} (0.057)(0.88$$

$$K = 5.5 \times 10^{-5} \text{ ft./Min}$$

$$K = 2.8 \times 10^{-5} \text{ cm/sec.}$$



EA 0289A 7/13/89

Project: Marsh Run Field — Project No. 10424.22
Subject: Slug Test MW-5 — Sheet No. 1 of 1
Drawing No.
Computed by: JPC — Date: 2/9/89 — Checked by: Comp — Date: 1/26/90

$r_w = 0.25$ ft.
$L_e = 12$ ft.
$y_0 = 1.3$ ft.
$y_t = 0.4$
$t = 35$ min
$L_w = 45$ ft.
$C = 2.7$
$r_c = 0.083$

1) $$K = \frac{r_c^2 \ln(R_e/r_w)}{2L_e} \frac{1}{t} \ln y_0/y_t$$

$$\ln y_0/y_t = \ln \frac{1.3}{0.4} = 1.18$$

$$\ln R_e/r_w = \frac{1}{\frac{1.1}{\ln(45/0.25)} + \frac{2.7}{(12/0.25)}}$$

$$\ln R_e/r_w = \frac{1}{.212 + 0.056}$$

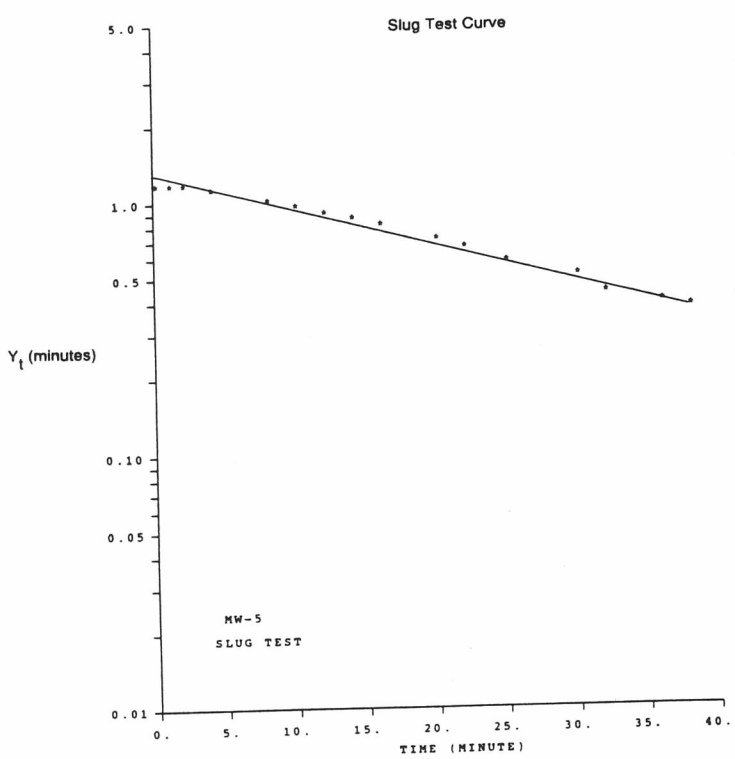
$$= 3.73$$

$$K = \frac{(0.083)^2 (3.73)}{24} (.028)(1.18)$$

$$K = \frac{.233}{24} (.033)$$

$$K = 3.5 \times 10^{-5} \text{ ft./min.}$$

$$K = 1.79 \times 10^{-5} \text{ cm/sec}$$



Project: Marsh Run Field — Project No. 10424.22
Subject: Slug Test MW-5A — Sheet No. 1 of 1
Drawing No.
Computed by: JPC — Date: 2/9/89 — Checked by: CoMD. — Date: 1/26/90

$r_w = 0.33$ ft.
$L_e = 10.0$ ft.
$y_o = .58$ ft.
$y_t = 0.2$
$t = 3.6$ MIN
$L_w = 10$ ft.
$C = 2.05$
$r_c = 0.083$

(1) $$K = \frac{r_c^2 \ln(R_e/r_w)}{2L_e} \; \frac{1}{t} \ln \frac{y_o}{y_t}$$

$$\ln \frac{y_o}{y_t} = \ln \frac{0.58}{0.2} = 1.06$$

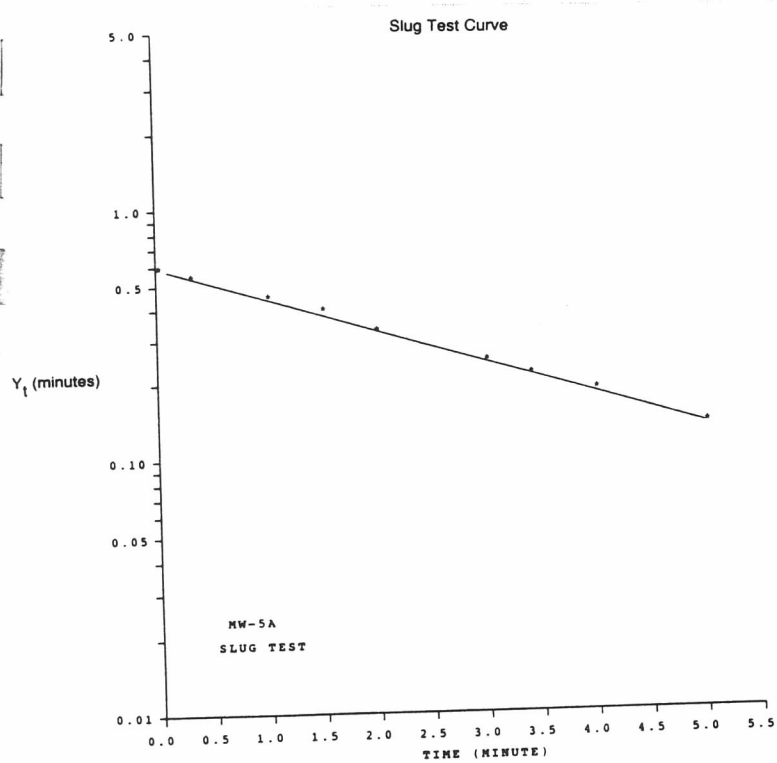
$$\ln \frac{R_e}{r_w} = \frac{1}{\frac{1.1}{\ln(10/0.33)} + \frac{2.05}{(10/0.33)}}$$

$$\ln \frac{R_e}{r_w} = \frac{1}{.322 + 0.068} = 2.56$$

$$K = \frac{(0.083)^2 (2.56)}{20} = (.277)(1.06)$$

$$K = 2.59 \times 10^{-4} \text{ ft/MIN}$$

$$K = 1.3 \times 10^{-4} \text{ cm/sec}$$



EA 0289A 7/13/89

Project: Marsh Run Field — Project No. 10424.22
Subject: Slug Test MW-6 — Sheet No. 1 of 1
Drawing No.
Computed by: JPC — Date: 2/9/89 — Checked by: Comp. — Date: 1/26/90

$r_w = 0.25$ ft.
$L_e = 13$ ft.
$Y_o = 1.50$ ft.
$Y_t = 0.7$
$t = 15$ min
$L_w = 43.5$ ft.
$C = 2.80$
$r_c = 0.083$

1.) $$K = \frac{r_c^2 \ln(R_e/r_w)}{2 L_e} \frac{1}{t} \ln \frac{Y_o}{Y_t}$$

$$\ln \frac{Y_o}{Y_t} = \ln \frac{1.50}{0.7} = 0.76$$

$$\ln \frac{R_e}{r_w} = \frac{1}{\frac{1.1}{\ln(43.5/0.25)} + \frac{2.80}{52}}$$

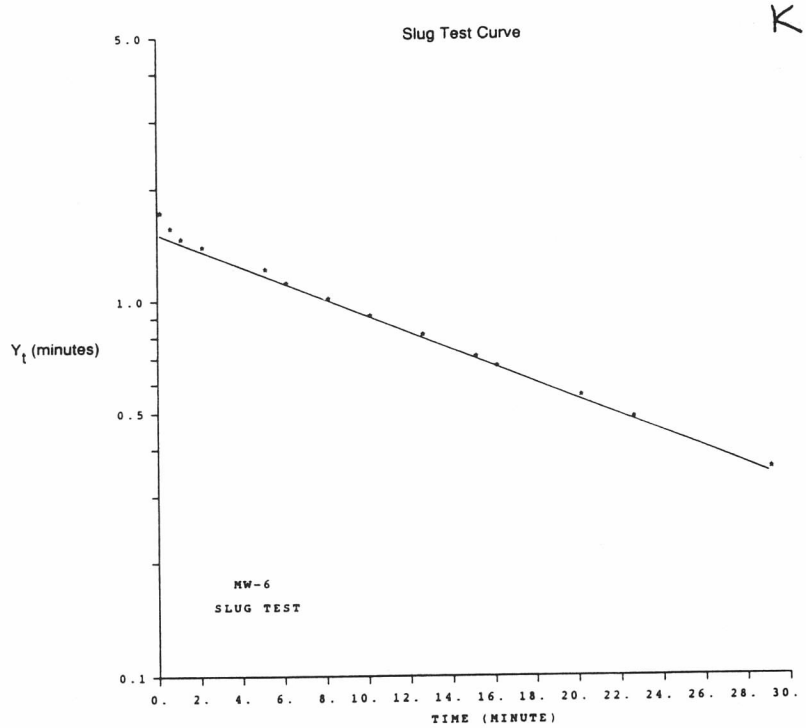
$$\ln \frac{R_e}{r_w} = \frac{1}{0.213 + .054}$$

$$\ln \frac{R_e}{r_w} = 3.75$$

$$K = \frac{(0.083)^2 (3.75)}{26} (0.066)(0.76)$$

$$K = 5 \times 10^{-5} \text{ ft./min.}$$

$$K = 2.5 \times 10^{-5} \text{ cm/sec}$$



EA 0289A 7/13/89

Project: MARSH Run Field — Project No. 10424.22
Subject: Slug Test MW-6A — Sheet No. 1 of 1
Drawing No.
Computed by: JPC — Date: 2/9/89 — Checked by: COMP — Date: 1/26/90

$r_w = 0.33$ ft.
$L_e = 9.25$ ft.
$Y_o = 0.09$ ft.
$Y_t = 0.052$
$t = 6$ min.
$L_w = 9.0$ ft.
$C = 2.0$
$r_c = 0.083$

1.) $$K = \frac{r_c^2 + \ln(R_e/r_w)}{2L_e} \frac{1}{t} \ln \frac{Y_o}{Y_t}$$

$$\ln \frac{Y_o}{Y_t} = \ln \frac{.09}{.052} = 0.55$$

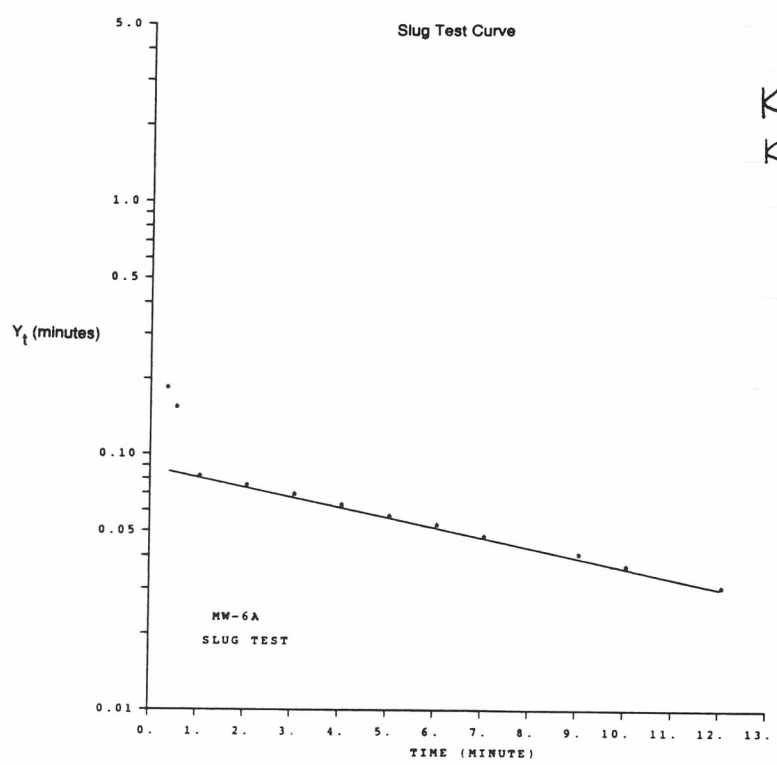
$$\ln(R_e/r_w) = \frac{1}{\frac{1.1}{\ln(9/0.33)} + \frac{2}{9.25/0.33}}$$

$$\ln(R_e/r_w) = \frac{1}{0.333 + 0.07}$$

$$\ln R_e/r_w = 2.47$$

$$K = \frac{(0.083)^2 (2.47)}{18.5} (0.167)(0.55)$$

$K = 8.4 \times 10^{-5}$ ft/min
$K = 4.26 \times 10^{-5}$ cm/sec



EA 0289A 7/13/89

Project NCAD Project No. 10424.22

Subject SLUG TEST MW-7 Sheet No. ___ of ___

Drawing No. ___

Computed by JPC Date 8/17/89 Checked by comp Date 1/25/90

$r_w = 0.25$ ft.
$L_e = 13$ ft.
$y_o = 1.0$ ft.
$y_t = 0.3$
$t = 0.4$ min
$L_w = 45.5$ ft.
$C = 2.8$
$r_c = 0.083$

1) $K = \dfrac{r_c^2 \ln(R_e/r_w)}{2 L_e} \dfrac{1}{t} \ln \dfrac{y_o}{y_t}$

$\ln y_o/y_t = \ln \dfrac{1.0}{0.3} = 1.25$

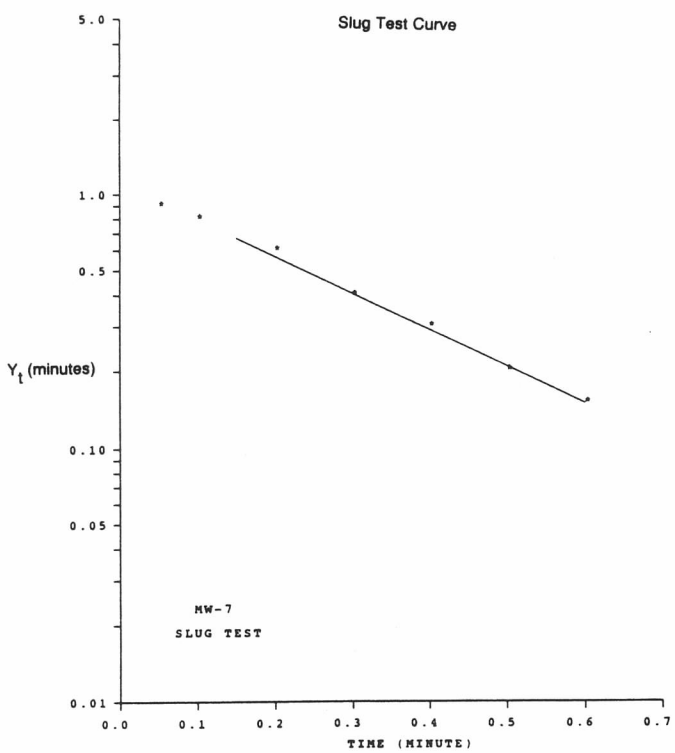
$\ln R_e/r_w = \dfrac{1}{\dfrac{1.1}{\ln(45.5/0.25)} + \dfrac{2.8}{(13/0.25)}}$

$\ln R_e/r_w = \dfrac{1}{0.211 + 0.54} = 3.77$

$K = \dfrac{(0.083)^2 (3.77)}{26} (2.5)(1.2)$

$K = 3 \times 10^{-3}$ ft/min

$K = 1.5 \times 10^{-3}$ cm/sec



Project: Marsh Run Field — Project No. 10424.22
Subject: Slug Test MW-7A — Sheet No. 1 of 1
Drawing No.
Computed by: JPC — Date: 2/9/89 — Checked by: Comp — Date: 1/26/90

$r_w = 0.33$ ft
$L_e = 11.0$ ft.
$Y_0 = 1.89$ ft
$Y_t = 0.5$
$t = 10$ min
$L_w = 10.5$ ft.
$C = 2.25$
$r_c = 0.083$

1) $$K = \frac{r_c^2 \ln(R_e/r_w)}{2L_e} \frac{1}{t} \ln \frac{Y_0}{Y_t}$$

$$\ln \frac{Y_0}{Y_t} = \ln \frac{1.89}{0.5} = 1.33$$

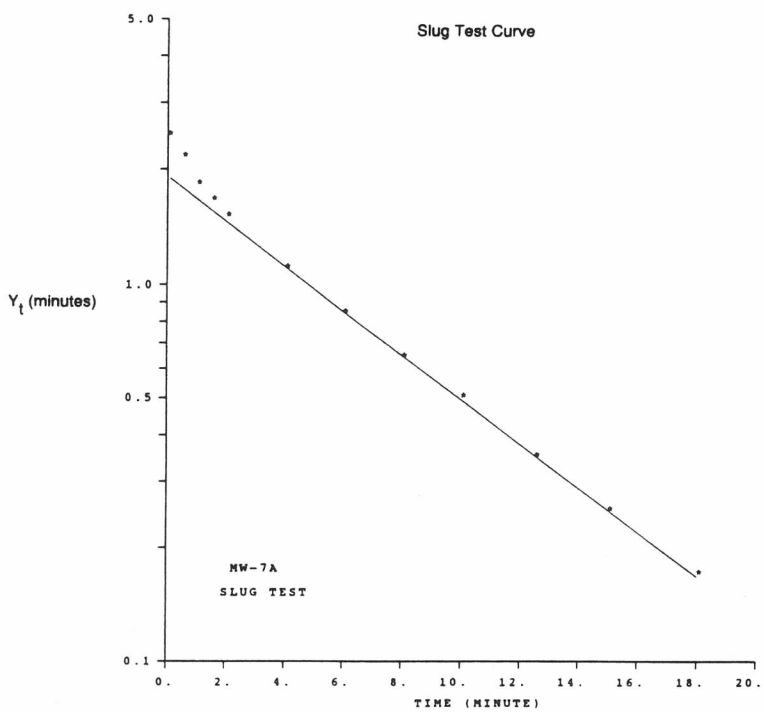
$$\ln R_e/r_w = \frac{1}{\frac{1.1}{\ln(10.5/0.33} + \frac{C}{11/0.33}}$$

$$\ln R_e/r_w = \frac{1}{0.318 + 0.068} = 2.59$$

$$K = \frac{(0.083)^2 (2.58)}{22} \cdot (0.1)(1.33)$$

$$K = 1.08 \times 10^{-4} \text{ ft/min}$$

$$K = 5.47 \times 10^{-5} \text{ cm/sec}$$



APPENDIX D

GROUND-WATER MODEL
INPUT AND OUTPUT PARAMETERS

TABLE D-1 BOUNDARY ARRAY FOR LAYER 1

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0	8	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0	9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0	10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	0
0	11	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	0
0	12	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0
0	13	-1	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0

0 = No flow boundary
1 = Variable head boundary
-1 = Constant head boundary

TABLE D-2 BOUNDARY ARRAY FOR LAYER 2

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
0	11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
0	12	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
0	13	-1	-1	1	0	0	0	0	0	0	0	0	0	0	0	0	0

0AQUIFER HEAD WILL BE SET TO 999.00 AT ALL NO-FLOW NODES (IBOUND=0)

0 = No flow boundary
1 = Variable head boundary
-1 = Constant head boundary

TABLE D-3 INITIAL HEAD FOR LAYER 1 (elev. ft.)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	1	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0
0	2	93.3	93.3	93.3	93.3	93.3	93.3	93.3	93.5	93.5	93.5	93.5	93.5	93.2	93.2	93.1	93.1
0	3	93.7	93.7	93.7	93.7	93.7	93.7	93.7	94.0	94.0	94.0	94.0	94.0	93.5	93.4	93.2	93.2
0	4	94.0	94.0	94.0	94.0	94.0	94.0	94.0	94.5	94.5	94.5	94.5	94.5	93.9	93.6	93.3	93.3
0	5	94.5	94.5	94.5	94.5	94.5	94.5	94.5	94.0	94.0	94.0	94.0	94.9	94.4	93.8	93.4	93.3
0	6	95.0	95.0	94.7	94.7	94.7	95.0	95.0	95.5	95.5	95.5	95.5	95.0	94.5	94.0	93.5	93.3
0	7	96.0	95.5	95.0	95.0	95.0	95.5	96.0	96.0	96.0	96.0	95.5	95.0	94.5	94.0	93.6	93.3
0	8	96.5	96.0	95.5	95.5	96.0	96.0	97.0	97.0	96.5	96.5	96.0	95.5	95.4	94.5	93.9	93.5
0	9	96.0	96.0	95.5	95.5	96.0	96.0	97.0	98.0	97.0	96.5	96.0	96.0	95.5	94.6	94.0	93.7
0	10	95.5	95.5	95.5	95.5	95.5	96.0	97.0	98.0	98.5	98.0	97.0	96.0	95.0	94.0	93.8	.0
0	11	94.8	94.8	94.6	94.6	94.5	95.0	96.0	96.0	97.0	97.0	96.0	95.0	94.5	93.9	95.0	.0
0	12	94.5	94.5	94.2	94.2	94.1	94.1	94.0	94.0	94.0	94.0	94.0	94.0	94.0	95.0	.0	.0
0	13	94.3	94.3	94.6	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.5	96.0	96.0	.0	.0	.0
0																	

TABLE D-4 INITIAL HEAD FOR LAYER 2 (elev. ft.)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	1	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0
0	2	93.2	93.2	93.2	93.2	93.2	93.2	93.2	93.2	93.2	93.2	93.2	93.2	93.2	93.1	93.1	93.1
0	3	93.4	93.4	93.3	93.3	93.3	93.4	93.4	93.4	93.4	93.4	93.4	93.4	93.4	93.2	93.2	93.2
0	4	93.6	93.6	93.4	93.4	93.4	93.5	93.6	93.6	93.6	93.6	93.6	93.6	93.6	93.3	93.3	93.2
0	5	93.8	93.8	93.6	93.6	93.6	93.7	93.8	93.8	93.8	93.7	93.7	93.7	93.7	93.5	93.4	93.3
0	6	94.0	94.0	93.8	93.8	93.8	93.9	94.0	94.0	94.0	94.1	94.1	94.1	94.1	93.7	93.6	93.3
0	7	94.6	94.4	94.4	94.5	94.5	94.5	94.6	94.8	94.6	94.6	94.6	94.5	94.3	94.0	93.7	93.4
0	8	94.6	94.6	94.5	94.9	95.1	95.1	95.2	95.2	95.1	95.1	95.0	94.8	94.5	94.1	93.8	93.5
0	9	94.5	94.5	94.5	95.1	95.1	95.2	95.3	95.4	95.4	95.3	95.2	95.0	94.7	94.3	94.0	93.7
0	10	94.4	94.4	94.5	94.4	95.0	95.3	95.6	95.6	95.6	95.6	95.4	95.2	94.5	94.0	93.8	94.5
0	11	94.4	94.3	94.3	94.3	94.3	94.3	95.0	95.5	96.0	95.7	95.5	95.0	94.3	93.9	95.0	95.0
0	12	94.3	94.3	94.2	94.2	94.1	94.1	94.0	94.0	94.0	94.0	94.0	94.0	94.0	95.5	95.5	95.5
0	13	94.3	94.3	94.8	94.8	94.8	94.8	95.0	95.3	95.5	95.5	95.5	95.5	95.7	95.7	95.7	95.7

0HEAD PRINT FORMAT IS FORMAT NUMBER -8 DRAWDOWN PRINT FORMAT IS FORMAT NUMBER -8
0HEADS WILL BE SAVED ON UNIT 0 DRAWDOWNS WILL BE SAVED ON UNIT 0
0OUTPUT CONTROL IS SPECIFIED EVERY TIME STEP

TABLE D-5 HYD. COND. ALONG ROWS FOR LAYER 1 (ft/day)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	1	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14
0	2	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14
0	3	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14
0	4	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14
0	5	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14
0	6	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14
0	7	.14	.14	.14	.14	.14	.14	.14	.14	2.85	2.85	.14	.14	.14	.14	.14	.14
0	8	.14	.14	.14	.14	2.85	2.85	2.85	2.85	2.85	2.85	2.85	.14	.14	.14	.14	.14
0	9	.14	.14	.14	.14	2.85	2.85	2.85	2.85	2.85	2.85	2.85	.14	.14	.14	.14	.14
0	10	.14	.14	.14	.14	.14	2.85	2.85	2.85	2.85	2.85	2.85	.14	.14	.14	.14	.00
0	11	.14	.14	.14	.14	.14	.14	.14	2.85	2.85	2.85	2.85	.14	.14	.14	.14	.00
0	12	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.00	.00
0	13	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.00	.00	.00

0 BOTTOM = 90.99999 FOR LAYER 1

0

TABLE D-6 VERT HYD COND (ft/day)/THICKNESS FOR LAYER 1 (ft)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
0	2	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058
0	3	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058
0	4	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058
0	5	.0064	.0064	.0064	.0064	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058
0	6	.0073	.0073	.0073	.0073	.0073	.0064	.0064	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.0058
0	7	.0082	.0082	.0082	.0082	.0082	.0082	.0082	.0073	.0073	.0015	.0014	.0014	.0014	.0014	.0014	.0014
0	8	.0028	.0023	.0023	.0028	.0035	.0035	.0028	.0020	.0018	.0015	.0015	.0015	.0015	.0015	.0015	.0015
0	9	.0023	.0023	.0023	.0028	.0035	.0035	.0028	.0028	.0023	.0020	.0018	.0015	.0015	.0015	.0015	.0015
0	10	.0020	.0020	.0020	.0023	.0023	.0023	.0023	.0023	.0023	.0018	.0015	.0015	.0015	.0015	.0015	.0000
0	11	.0018	.0018	.0018	.0018	.0018	.0018	.0018	.0018	.0018	.0015	.0015	.0015	.0015	.0015	.0015	.0000
0	12	.0015	.0015	.0015	.0015	.0015	.0015	.0015	.0015	.0015	.0015	.0015	.0015	.0015	.0015	.0000	.0000
0	13	.0014	.0014	.0014	.0014	.0014	.0014	.0014	.0014	.0014	.0014	.0014	.0014	.0014	.0000	.0000	.0000

TRANSMIS. ALONG ROWS = 225.0000 FOR LAYER 2

TABLE D-7 RECHARGE (ft/day)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	1	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
0	2	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
0	3	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
0	4	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
0	5	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
0	6	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
0	7	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
0	8	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
0	9	.001	.001	.001	.001	.001	.002	.002	.002	.002	.002	.001	.001	.001	.001	.001	.001
0	10	.001	.001	.001	.001	.001	.002	.002	.002	.002	.002	.001	.001	.001	.001	.001	.001
0	11	.001	.001	.001	.001	.001	.001	.001	.002	.002	.002	.001	.001	.001	.001	.001	.001
0	12	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
0	13	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001

TABLE D-8 TOTAL BUDGET PRINTOUT (ft^3/day) (CELL-BY-CELL FLOW TERM)

OOUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:

HEAD PRINTOUT	DRAWDOWN PRINTOUT	HEAD SAVE	DRAWDOWN SAVE
1	1	0	0

0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	1	COL	1	RATE	-.3225910
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	1	COL	2	RATE	-.3226407
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	1	COL	3	RATE	-.3227254
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	1	COL	4	RATE	-.3227580
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	1	COL	5	RATE	-.3225951
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	1	COL	6	RATE	-.3220404
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	1	COL	7	RATE	-.3208640
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	1	COL	8	RATE	-.3188200
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	1	COL	9	RATE	-.3165603
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	1	COL	10	RATE	-.3110845
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	1	COL	11	RATE	-.3048240
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	1	COL	12	RATE	-.2964551
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	1	COL	13	RATE	-.2853420
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	1	COL	14	RATE	-.2704473
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	1	COL	15	RATE	-.2485525
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	1	COL	16	RATE	-.0000000
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	2	COL	16	RATE	-9.372666
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	3	COL	16	RATE	-17.49929
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	4	COL	16	RATE	-24.21965
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	5	COL	16	RATE	-35.30676
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	6	COL	16	RATE	-46.15833
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	7	COL	16	RATE	-15.16358
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	8	COL	1	RATE	37.36516
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	8	COL	16	RATE	-15.36121
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	9	COL	16	RATE	-13.55688
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	10	COL	15	RATE	-16.38620
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	11	COL	14	RATE	-16.34747
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	11	COL	15	RATE	3.000933
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	12	COL	3	RATE	-8.493972
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	12	COL	4	RATE	-10.39136
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	12	COL	5	RATE	-13.50915

TABLE D-8 (Cont.)

0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	12	COL	6	RATE	-14.50994
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	12	COL	7	RATE	-16.62679
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	12	COL	8	RATE	-17.91576
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	12	COL	9	RATE	-17.84129
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	12	COL	10	RATE	-17.47200
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	12	COL	11	RATE	-16.72432
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	12	COL	12	RATE	-15.11666
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	12	COL	13	RATE	-14.38128
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	12	COL	14	RATE	2.005738
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	13	COL	1	RATE	-.5784277
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	13	COL	2	RATE	-.6788840
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	1	ROW	13	COL	3	RATE	1.647643
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	2	ROW	1	COL	1	RATE	-104.5710
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	2	ROW	1	COL	2	RATE	-104.5929
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	2	ROW	1	COL	3	RATE	-104.6307
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	2	ROW	1	COL	4	RATE	-104.6457
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	2	ROW	1	COL	5	RATE	-104.5737
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	2	ROW	1	COL	6	RATE	-104.3269
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	2	ROW	1	COL	7	RATE	-103.8026
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	2	ROW	1	COL	8	RATE	-102.8900
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	2	ROW	1	COL	9	RATE	-101.4723
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	2	ROW	1	COL	10	RATE	-99.42616
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	2	ROW	1	COL	11	RATE	-96.61320
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	2	ROW	1	COL	12	RATE	-92.84064
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	2	ROW	1	COL	13	RATE	-87.80975
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	2	ROW	1	COL	14	RATE	-81.03471
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	2	ROW	1	COL	15	RATE	-71.65693
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	2	ROW	1	COL	16	RATE	-58.05743
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	2	ROW	12	COL	1	RATE	-140.1685
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	2	ROW	13	COL	1	RATE	.0000000
0	CONSTANT	HEAD	PERIOD	1	STEP	1	LAYER	2	ROW	13	COL	2	RATE	-88.84323
1														

TABLE D-8 (Cont.)

HEAD IN LAYER 1 AT END OF TIME STEP 1 IN STRESS PERIOD 1

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	1	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0
0	2	93.7	93.7	93.7	93.7	93.7	93.7	93.7	93.7	93.7	93.7	93.7	93.6	93.6	93.6	93.5	93.1
0	3	94.1	94.1	94.1	94.1	94.1	94.1	94.1	94.1	94.1	94.1	94.0	94.0	94.0	93.9	93.8	93.2
0	4	94.4	94.4	94.4	94.4	94.5	94.4	94.4	94.4	94.4	94.4	94.4	94.3	94.3	94.2	94.1	93.3
0	5	94.7	94.7	94.7	94.7	94.7	94.7	94.7	94.7	94.7	94.7	94.6	94.6	94.5	94.4	94.3	93.3
0	6	94.9	94.9	94.9	94.9	94.9	95.0	95.0	95.0	95.0	94.9	94.9	94.8	94.7	94.6	94.5	93.3
0	7	95.1	95.1	95.1	95.1	95.1	95.1	95.1	95.1	95.3	95.6	95.7	95.7	95.6	95.5	95.3	93.3
0	8	96.5	95.6	95.6	95.6	95.5	95.5	95.6	95.7	95.7	95.8	95.8	95.8	95.7	95.6	95.4	95.5
0	9	95.6	95.6	95.6	95.5	95.5	95.7	95.8	95.9	95.9	96.0	95.9	95.9	95.8	95.7	95.4	95.7
0	10	95.5	95.6	95.6	95.6	95.7	95.9	96.0	96.0	96.0	96.1	96.0	95.9	95.8	95.7	95.6	999.0
0	11	95.4	95.5	95.5	95.6	95.7	95.8	95.8	96.1	96.1	96.1	96.0	95.8	95.7	95.9	95.0	999.0
0	12	95.2	95.3	94.2	94.2	94.1	94.1	94.0	94.0	94.0	94.0	94.0	94.0	94.0	95.0	999.0	999.0
0	13	94.3	94.3	94.6	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0
1																	

HEAD IN LAYER 2 AT END OF TIME STEP 1 IN STRESS PERIOD 1

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	1	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0
0	2	93.5	93.5	93.5	93.5	93.5	93.5	93.5	93.5	93.5	93.4	93.4	93.4	93.4	93.4	93.3	93.3
0	3	93.9	93.9	93.9	93.9	93.9	93.9	93.9	93.9	93.8	93.8	93.8	93.8	93.7	93.7	93.6	93.5
0	4	94.2	94.2	94.2	94.2	94.2	94.2	94.2	94.2	94.2	94.2	94.1	94.1	94.0	93.9	93.8	93.7
0	5	94.5	94.5	94.5	94.5	94.5	94.5	94.5	94.5	94.5	94.4	94.4	94.3	94.3	94.2	94.1	93.9
0	6	94.7	94.7	94.7	94.7	94.7	94.7	94.7	94.7	94.7	94.7	94.6	94.6	94.5	94.4	94.3	94.1
0	7	94.9	94.9	94.9	94.9	94.9	94.9	94.9	94.9	94.9	94.9	94.8	94.7	94.7	94.6	94.4	94.3
0	8	95.0	95.0	95.0	95.0	95.0	95.1	95.1	95.1	95.0	95.0	94.9	94.9	94.8	94.7	94.6	94.4
0	9	95.0	95.0	95.0	95.0	95.1	95.1	95.1	95.2	95.1	95.1	95.0	95.0	94.9	94.8	94.7	94.5
0	10	94.9	94.9	95.0	95.0	95.1	95.1	95.2	95.2	95.2	95.1	95.1	95.0	94.9	94.8	94.7	999.0
0	11	94.7	94.7	94.8	94.9	95.0	95.1	95.1	95.1	95.1	95.1	95.0	95.0	94.9	94.8	94.8	999.0
0	12	94.3	94.5	94.7	94.8	94.9	95.0	95.0	95.0	95.0	95.0	95.0	94.9	94.9	94.9	999.0	999.0
0	13	94.3	94.3	94.5	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0

TABLE D-8 (Cont.)

1

DRAWDOWN IN LAYER 1 AT END OF TIME STEP 1 IN STRESS PERIOD 1

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
0	2	-.4	-.4	-.4	-.4	-.4	-.4	-.4	-.2	-.2	-.2	-.2	-.1	-.4	-.4	-.4	.0
0	3	-.4	-.4	-.4	-.4	-.4	-.4	-.4	-.1	-.1	-.1	.0	.0	-.5	-.5	-.6	.0
0	4	-.4	-.4	-.4	-.4	-.5	-.4	-.4	.1	.1	.1	.1	.2	-.4	-.6	-.8	.0
0	5	-.2	-.2	-.2	-.2	-.2	-.2	-.2	.3	.3	.3	.4	.3	-.1	-.6	-.9	.0
0	6	.1	.1	-.2	-.2	-.2	.0	.0	.5	.5	.6	.6	.2	-.2	-.6	-1.0	.0
0	7	.9	.4	-.1	-.1	-.1	.4	.9	.9	.7	.4	-.2	-.7	-1.1	-1.5	-1.7	.0
0	8	.0	.4	-.1	.0	.5	.5	1.4	1.3	.8	.7	.2	-.3	-.3	-1.1	-1.5	.0
0	9	.4	.4	-.1	.0	.5	.3	1.2	2.1	1.1	.5	.1	.1	-.3	-1.1	-1.4	.0
0	10	.0	-.1	-.1	-.1	-.2	-.1	1.0	2.0	2.5	1.9	1.0	.1	-.8	-1.6	.0	999.0
0	11	-.6	-.7	-.9	-1.0	-1.2	-.8	.2	0.1	.9	.9	.0	-.8	-1.2	.0	.0	999.0
0	12	-.7	0.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	999.0	999.0
0	13	.0	.0	.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0

1

DRAWDOWN IN LAYER 2 AT END OF TIME STEP 1 IN STRESS PERIOD 1

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
0	2	-.3	-.3	-.3	-.3	-.3	-.3	-.3	-.3	-.3	-.2	-.2	-.2	-.2	-.3	-.2	-.2
0	3	-.5	-.5	-.6	-.6	-.6	-.5	-.5	-.5	-.4	-.4	-.4	-.4	-.3	-.5	-.4	-.3
0	4	-.6	-.6	-.8	-.8	-.8	-.7	-.6	-.6	-.6	-.6	-.5	-.5	-.4	-.6	-.5	-.5
0	5	-.7	-.7	-.9	-.9	-.9	-.8	-.7	-.7	-.7	-.6	-.5	-.5	-.4	-.7	-.7	-.8
0	6	-.7	-.7	-.9	-.9	-.9	-.8	-.7	-.7	-.7	-.6	-.5	-.5	-.4	-.7	-.7	-.8
0	7	-.3	-.5	-.5	-.4	-.4	-.4	-.3	-.1	-.3	-.3	-.2	-.2	-.4	-.6	-.7	-.9
0	8	-.4	-.4	-.5	-.1	.1	.0	.1	.1	.1	.1	.1	-.1	-.3	-.6	-.8	-.9
0	9	-.5	-.5	-.5	.1	.0	.1	.2	.2	.3	.2	.2	.0	-.2	-.5	-.7	-.8
0	10	-.5	-.5	-.5	-.6	-.1	.2	.4	.4	.4	.5	.3	.2	-.4	-.8	-.9	999.0
0	11	-.3	-.4	-.5	-.6	-.7	-.8	-.1	.4	.9	.6	.5	.0	-.6	-.9	.2	999.0
0	12	.0	-.2	-.5	-.6	-.8	-.9	-1.0	-1.0	-1.0	-1.0	-1.0	-.9	-.9	.6	999.0	999.0
0	13	.0	.0	.3	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0

TABLE D-9 VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 1 IN STRESS PERIOD 1

CUMULATIVE VOLUMES	L**3		RATES FOR THIS TIME STEP	L**3/T	
IN:			IN:		
STORAGE =	.00000		STORAGE =	.00000	
CONSTANT HEAD =	88.039		CONSTANT HEAD =	44.019	
RECHARGE =	4191.0		RECHARGE =	2095.5	
TOTAL IN =	4279.0		TOTAL IN =	2139.5	
OUT:			OUT:		
STORAGE =	.00000		STORAGE =	.00000	
CONSTANT HEAD =	4260.4		CONSTANT HEAD =	2130.2	
RECHARGE =	.00000		RECHARGE =	.00000	
TOTAL OUT =	4260.4		TOTAL OUT =	2130.2	
IN - OUT =	18.688		IN - OUT =	9.3438	
PERCENT DISCREPANCY =		.44	PERCENT DISCREPANCY =		.44

TIME SUMMARY AT END OF TIME STEP 1 IN STRESS PERIOD 1

	SECONDS	MINUTES	HOURS	DAYS	YEARS
TIME STEP LENGTH	172800.	2880.00	48.0000	2.00000	.54570E-02
STRESS PERIOD TIME	172800.	2880.00	48.0000	2.00000	.54570E-02
TOTAL SIMULATION TIME	172800.	2880.00	48.0000	2.00000	.54570E-02

TABLE D-10 LEAKAGE (ft^3/day) CELL BY CELL THROUGH CLAY LAYER

1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	11.60	11.60	11.60	11.60	11.60	11.60	11.60	11.60	11.60	17.40	17.40	11.60	11.60	11.60	11.60	-11.60
3	11.60	11.60	11.60	11.60	11.60	11.60	11.60	11.60	17.40	17.40	11.60	11.60	17.40	11.60	11.60	-17.40
4	11.60	11.60	11.60	11.60	17.40	11.60	11.60	11.60	11.60	11.60	17.40	11.60	17.40	17.40	17.40	-23.20
5	12.80	12.80	12.80	12.80	11.60	11.60	11.60	11.60	11.60	17.40	11.60	17.40	11.60	11.60	11.60	-34.80
6	14.60	14.60	14.60	14.60	14.60	19.20	19.20	17.40	17.40	11.60	17.40	11.60	11.60	11.60	11.60	-46.40
7	16.40	16.40	16.40	16.40	16.40	16.40	16.40	14.60	29.20	10.50	12.60	14.00	12.60	12.60	12.60	-14.00
8	34.50	13.80	13.80	14.00	17.50	14.00	14.00	12.00	12.60	12.00	13.50	13.50	13.50	13.50	12.00	-13.50
9	13.80	13.80	13.80	14.00	14.00	21.00	19.60	19.60	18.40	18.00	16.20	13.50	13.50	13.50	10.50	-12.00
10	12.00	14.00	12.00	13.80	13.80	18.40	18.40	18.40	18.40	18.00	13.50	13.50	13.50	12.00	-13.50	0.00
11	12.60	14.40	12.60	12.60	12.60	12.60	12.60	18.00	18.00	15.00	15.00	12.00	12.00	-13.50	3.00	0.00
12	13.50	12.00	-7.50	-9.00	-12.00	-13.50	-15.00	-15.00	-15.00	-15.00	-15.00	-13.50	-13.50	1.50	0.00	0.00
13	0.00	0.00	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

2104.00 -343.90 1760.10

TABLE D-11 STEADY STATE HEAD ELEVATIONS IN THE UPPER LAYER OF THE NEW CUMBERLAND SITE, PREDICTED BY THE SUTRA MODEL

ELEVATION (FT)

NODE ROW\COL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0
2	93.3	93.3	93.3	93.3	93.3	93.3	93.3	93.3	93.3	93.3	93.3	93.3	93.3	93.3	93.3	93.2	93.1
3	93.9	93.9	93.9	93.9	93.9	93.9	93.9	93.9	93.9	93.9	93.9	93.8	93.8	93.8	93.7	93.4	93.2
4	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.2	94.2	94.2	94.1	94.0	93.6	93.3
5	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.5	94.5	94.4	94.3	94.3	93.8	93.3
6	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.7	94.7	94.6	94.4	93.8	93.3
7	95.0	95.0	95.0	95.0	95.0	95.0	95.1	95.1	95.1	95.2	95.3	95.3	95.2	95.1	95.0	94.1	93.3
8	95.8	95.6	95.3	95.3	95.3	95.3	95.3	95.4	95.4	95.6	95.7	95.8	95.7	95.6	95.4	94.4	93.4
9	96.1	95.8	95.6	95.6	95.5	95.6	95.7	95.8	95.8	95.8	95.9	95.8	95.8	95.7	95.5	94.5	93.6
10	95.6	95.6	95.6	95.6	95.6	95.7	95.8	95.9	95.9	96.0	96.0	95.9	95.8	95.7	95.1	94.2	93.8
11	95.4	95.5	95.6	95.6	95.7	95.6	95.6	95.6	95.6	95.6	95.6	95.6	95.6	95.3	94.3	93.8	93.8
12	95.3	95.3	95.1	94.9	94.9	94.9	94.9	95.0	95.1	95.1	95.0	94.9	94.9	94.4	93.9	93.8	93.8
13	94.8	94.8	94.5	94.2	94.2	94.1	94.1	94.0	94.0	94.0	94.0	94.0	94.0	93.9	93.9	93.9	93.9
14	94.3	94.3	94.3	94.2	94.2	94.1	94.1	94.0	94.0	94.0	94.0	94.0	94.0	93.9	93.9	93.9	93.9

TABLE D-12 SOLUTE CONCENTRATION IN THE UPPER LAYER AFTER 10 YEARS AT THE NEW CUMBERLAND SITE, RELATIVE TO A 1000 UNIT SOURCE

CONCENTRATION

NODE ROW\COL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	2	4	3	0	0	0	0	0	0
7	0	0	0	0	1	3	3	4	248	595	320	3	0	0	0	0	0
8	0	0	0	0	245	578	702	687	861	744	704	234	1	0	0	0	0
9	0	0	0	0	457	778	798	745	874	1000	806	494	0	0	0	0	0
10	0	0	0	0	233	666	837	746	785	673	609	394	0	0	0	0	0
11	0	0	0	0	0	282	643	780	837	865	745	374	0	0	0	0	0
12	0	0	0	0	2	14	30	945	1000	1000	1000	719	4	0	0	0	0
13	0	0	0	0	0	0	4	26	49	52	40	20	3	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE D-13 SOLUTE CONCENTRATION IN THE UPPER LAYER AFTER 20 YEARS AT THE NEW CUMBERLAND SITE, RELATIVE TO A 1000 UNIT SOURCE

CONCENTRATION

NODE ROW\COL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	2	5	4	1	0	0	0	0	0
7	0	0	0	0	2	4	4	5	267	658	364	4	0	0	0	0	0
8	0	0	0	0	264	634	798	776	947	772	763	255	1	0	0	0	0
9	0	0	0	0	490	798	805	749	897	1000	838	546	0	0	0	0	0
10	0	0	0	0	252	691	851	760	812	693	631	423	1	0	0	0	0
11	0	0	0	0	0	308	704	732	703	731	614	321	0	0	0	0	0
12	0	0	0	0	5	36	73	1000	1000	1000	1000	1000	11	0	0	0	0
13	0	0	0	0	0	1	11	55	98	101	77	39	7	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE D-14 SOLUTE CONCENTRATION IN THE UPPER LAYER AFTER 30 YEARS AT THE NEW CUMBERLAND SITE, RELATIVE TO A 1000 UNIT SOURCE

CONCENTRATION

NODE ROW\COL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	2	5	4	1	0	0	0	0	0
7	0	0	0	0	2	4	4	5	268	663	369	4	0	0	0	0	0
8	0	0	0	0	266	638	806	783	953	772	767	257	1	0	0	0	0
9	0	0	0	0	492	798	804	747	897	1000	840	551	0	0	0	0	0
10	0	0	0	0	254	692	851	765	821	702	640	429	1	0	0	0	0
11	0	0	0	0	0	310	709	684	638	672	560	288	0	0	0	0	0
12	0	0	0	0	7	57	110	1000	1000	1000	1000	1000	16	0	0	0	0
13	0	0	0	0	0	1	15	71	120	120	91	48	9	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE D-15 SOLUTE CONCENTRATION IN THE UPPER LAYER AFTER 40 YEARS AT THE NEW CUMBERLAND SITE, RELATIVE TO A 1000 UNIT SOURCE

CONCENTRATION

NODE ROW\COL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	2	5	4	1	0	0	0	0	0
7	0	0	0	0	2	4	4	5	268	663	369	4	0	0	0	0	0
8	0	0	0	0	266	638	807	783	953	772	767	257	1	0	0	0	0
9	0	0	0	0	492	798	803	747	897	1000	840	551	0	0	0	0	0
10	0	0	0	0	254	692	852	767	824	705	642	431	1	0	0	0	0
11	0	0	0	0	0	309	709	661	616	654	546	276	0	0	0	0	0
12	0	0	0	0	9	78	140	1000	1000	1000	1000	1000	20	0	0	0	0
13	0	0	0	0	0	2	18	79	127	127	96	51	10	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE D-16 STEADY STATE HEAD ELEVATIONS IN THE LOWER LAYER AFTER AT THE NEW CUMBERLAND SITE, PREDICTED BY THE SUTRA MODEL

ELEVATION (FT)

NODE ROW\COL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0	93.0
2	93.5	93.5	93.5	93.5	93.5	93.5	93.4	93.4	93.4	93.4	93.4	93.4	93.4	93.4	93.3	93.3	93.3
3	93.9	93.9	93.9	93.9	93.9	93.9	93.9	93.9	93.9	93.9	93.8	93.8	93.8	93.7	93.7	93.6	93.5
4	94.2	94.2	94.2	94.2	94.2	94.2	94.2	94.2	94.2	94.2	94.2	94.1	94.1	94.0	93.9	93.8	93.8
5	94.5	94.5	94.5	94.5	94.5	94.5	94.5	94.5	94.5	94.5	94.5	94.4	94.4	94.3	94.2	94.1	94.0
6	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.7	94.7	94.6	94.5	94.4	94.2	94.2
7	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0	94.9	94.9	94.8	94.7	94.6	94.4	94.4
8	95.2	95.1	95.1	95.1	95.2	95.2	95.2	95.2	95.1	95.1	95.1	95.0	94.9	94.8	94.7	94.6	94.6
9	95.2	95.2	95.2	95.2	95.2	95.2	95.3	95.3	95.2	95.2	95.2	95.1	95.0	94.9	94.9	94.8	94.7
10	95.1	95.1	95.2	95.2	95.2	95.3	95.3	95.3	95.3	95.3	95.2	95.2	95.1	95.0	94.9	94.8	94.8
11	95.0	95.0	95.1	95.1	95.2	95.2	95.2	95.3	95.3	95.2	95.2	95.2	95.1	95.0	94.9	94.9	94.9
12	94.8	94.9	94.9	95.0	95.1	95.1	95.2	95.2	95.2	95.2	95.1	95.1	95.1	95.0	95.0	94.9	94.9
13	94.5	94.6	94.7	94.8	95.0	95.0	95.1	95.1	95.1	95.1	95.1	95.1	95.0	95.0	95.0	95.0	94.9
14	94.3	94.3	94.3	94.8	94.9	95.0	95.1	95.1	95.1	95.1	95.1	95.1	95.0	95.0	95.0	95.0	95.0

TABLE D-17 SOLUTE CONCENTRATION IN THE LOWER LAYER AFTER 10 YEARS AT THE NEW CUMBERLAND SITE, RELATIVE TO A 1000 UNIT SOURCE

CONCENTRATION

NODE ROW\COL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0	0	1	2	4	7	10	14	18	19	17	12	7	3	1	0	0
2	0	0	1	3	6	9	13	19	25	27	23	17	9	4	1	0	0
3	0	0	2	5	10	16	22	31	42	46	41	29	15	7	3	1	0
4	0	0	2	8	18	27	36	50	72	84	74	49	25	11	4	2	0
5	0	0	3	14	32	50	62	82	126	156	132	81	40	17	6	2	1
6	0	0	3	22	62	97	110	133	214	288	239	134	63	25	8	3	1
7	0	0	3	33	122	203	222	232	387	563	429	210	95	32	9	2	0
8	0	0	2	37	274	502	524	511	609	711	600	359	120	32	8	2	0
9	0	0	1	35	381	721	732	716	674	643	693	458	122	29	6	1	0
10	0	0	3	35	239	576	752	722	710	703	708	438	110	25	6	1	0
11	0	0	4	30	101	296	456	610	787	772	754	446	97	23	4	0	0
12	0	0	6	27	75	146	202	254	319	295	241	156	62	13	1	0	0
13	0	1	7	18	31	41	49	59	68	60	45	28	12	3	0	0	0
14	0	1	7	10	8	7	5	4	4	3	3	2	1	0	0	0	0

TABLE D-18 SOLUTE CONCENTRATION IN THE LOWER LAYER AFTER 20 YEARS AT THE NEW CUMBERLAND SITE, RELATIVE TO A 1000 UNIT SOURCE

CONCENTRATION

NODE ROW\COL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1	3	10	25	46	66	86	108	129	137	126	103	70	41	22	12	9
2	0	2	11	28	52	76	97	121	145	153	141	117	80	46	25	16	11
3	0	2	12	34	66	97	122	150	182	196	187	153	100	58	32	21	13
4	0	2	13	43	88	130	161	191	239	275	260	202	129	73	40	25	15
5	0	1	13	53	121	181	214	243	315	378	353	263	168	97	49	29	15
6	0	0	12	64	172	262	288	315	410	527	501	351	216	118	55	28	12
7	0	0	9	78	255	408	445	458	593	808	728	456	264	123	50	23	9
8	0	0	7	84	439	761	804	794	859	960	899	624	288	117	44	18	6
9	0	0	6	83	573	987	979	966	919	871	952	715	284	106	39	15	4
10	0	0	12	90	403	808	980	935	919	915	960	691	264	96	41	12	1
11	0	1	16	78	214	471	649	818	1000	1000	1000	723	245	105	39	6	0
12	0	2	24	109	253	420	531	637	734	721	663	495	254	86	19	1	0
13	1	8	49	118	170	209	237	270	296	275	228	162	85	27	5	0	0
14	2	11	65	96	68	62	50	42	35	32	30	24	14	6	1	0	0

TABLE D-19 SOLUTE CONCENTRATION IN THE LOWER LAYER AFTER 30 YEARS AT THE NEW CUMBERLAND SITE, RELATIVE TO A 1000 UNIT SOURCE

CONCENTRATION

NODE ROW\COL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1	5	21	53	94	135	168	197	223	232	222	197	151	100	65	48	41
2	1	5	21	54	99	142	175	204	232	240	230	207	158	105	68	55	45
3	0	4	21	60	115	166	202	233	265	282	278	247	179	119	76	65	50
4	0	3	21	70	140	203	246	277	324	366	357	302	215	141	87	71	50
5	0	2	20	79	176	258	299	326	396	463	450	363	260	173	100	74	47
6	0	1	18	90	231	342	371	400	484	604	602	457	315	197	107	68	39
7	0	0	14	103	316	490	532	551	665	880	832	561	361	195	95	57	31
8	0	0	12	112	507	850	894	890	941	1000	993	726	378	184	85	50	25
9	0	0	12	115	652	1000	1000	1000	991	939	1000	806	372	169	79	47	19
10	0	0	21	132	485	888	1000	994	976	971	1000	785	350	156	97	42	9
11	1	5	28	104	249	498	661	822	1000	1000	1000	803	323	195	110	25	1
12	0	2	33	164	377	596	727	860	960	982	980	815	498	222	65	9	0
13	1	15	98	252	350	424	470	529	571	548	488	382	232	91	21	2	0
14	5	21	160	266	182	181	146	125	106	98	94	81	55	28	8	1	0

TABLE D-20 SOLUTE CONCENTRATION IN THE LOWER LAYER AFTER 40 YEARS AT THE NEW CUMBERLAND SITE, RELATIVE TO A 1000 UNIT SOURCE

CONCENTRATION

NODE ROW\COL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	2	7	27	67	119	168	206	235	259	267	259	239	194	139	99	87	81
2	1	6	26	67	121	172	209	238	263	271	262	245	197	140	97	94	85
3	0	5	25	73	137	194	235	265	294	309	309	284	216	153	104	103	89
4	0	4	25	83	162	231	278	308	353	394	389	338	253	177	116	108	87
5	0	3	24	91	198	287	328	356	422	488	480	397	298	211	130	110	80
6	0	1	22	101	254	369	398	428	508	627	632	492	353	236	136	101	69
7	0	0	18	116	339	517	559	579	687	901	861	594	397	230	120	89	61
8	0	0	15	127	533	877	919	917	965	1000	1000	756	412	217	110	84	55
9	0	0	15	132	682	1000	1000	1000	1000	959	1000	832	405	199	106	85	45
10	0	0	27	157	525	919	1000	1000	994	986	1000	810	380	181	143	85	24
11	1	9	41	120	252	485	637	791	998	991	1000	784	327	244	196	60	6
12	0	3	32	168	409	642	775	919	1000	1000	1000	1000	705	385	143	25	1
13	2	18	120	344	482	586	647	729	784	772	726	618	423	197	56	9	0
14	7	21	242	449	304	336	270	239	206	195	190	172	127	72	27	5	0

TABLE D-21 STEADY STATE HEADS IN THE VERTICAL ORIENTATION AT THE NEW CUMBERLAND SITE, PREDICTED BY THE SUTRA MODEL

ELEVATION (FT)

NODE ROW\COL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	94.0	97.7	97.7	97.7	97.7	97.7	97.6	97.5	97.3	97.1	96.9	96.6	96.5	96.0	95.9	95.6	95.4	95.1	94.9	94.6	94.3	93.9	93.7	93.0
2	94.0	97.7	97.7	97.7	97.7	97.7	97.6	97.5	97.3	97.1	96.9	96.6	96.5	96.0	95.8	95.6	95.4	95.1	94.8	94.5	94.3	93.9	93.6	93.0
3	94.0	97.7	97.7	97.7	97.7	97.7	97.6	97.5	97.3	97.1	96.9	96.6	96.5	96.0	95.8	95.6	95.3	95.1	94.8	94.5	94.2	93.9	93.6	93.0
4	94.7	97.5	97.5	97.5	97.5	97.5	97.4	97.3	97.2	96.9	96.8	96.6	96.4	95.9	95.8	95.5	95.3	95.0	94.8	94.5	94.2	93.9	93.6	93.0
5	95.4	97.3	97.3	97.3	97.3	97.3	97.2	97.1	97.0	96.8	96.7	96.5	96.3	95.9	95.7	95.5	95.2	95.0	94.7	94.4	94.1	93.8	93.5	93.0
6	96.1	97.1	97.1	97.1	97.1	97.1	97.0	96.9	96.8	96.6	96.5	96.4	96.2	95.8	95.7	95.4	95.2	94.9	94.7	94.4	94.1	93.8	93.4	93.0
7	96.8	96.9	96.9	96.9	96.9	96.8	96.8	96.7	96.6	96.5	96.3	96.2	96.0	95.8	95.6	95.4	95.1	94.9	94.6	94.3	94.0	93.7	93.4	93.0
8	96.8	96.9	96.9	96.9	96.9	96.8	96.8	96.7	96.6	96.4	96.3	96.2	96.0	95.8	95.6	95.4	95.1	94.9	94.6	94.3	94.0	93.7	93.4	93.0
9	96.8	96.9	96.9	96.9	96.9	96.8	96.7	96.7	96.6	96.4	96.3	96.2	96.0	95.8	95.6	95.4	95.1	94.9	94.6	94.3	94.0	93.7	93.4	93.0
10	96.8	96.9	96.9	96.9	96.8	96.8	96.7	96.7	96.6	96.4	96.3	96.2	96.0	95.8	95.6	95.3	95.1	94.9	94.6	94.3	94.0	93.7	93.3	93.0
11	96.8	96.9	96.9	96.9	96.8	96.8	96.7	96.7	96.6	96.4	96.3	96.1	96.0	95.8	95.6	95.3	95.1	94.8	94.6	94.3	94.0	93.7	93.3	93.0
12	96.8	96.9	96.9	96.9	96.8	96.8	96.7	96.6	96.5	96.4	96.3	96.1	96.0	95.8	95.6	95.3	95.1	94.8	94.6	94.3	94.0	93.7	93.3	93.0
13	96.8	96.9	96.9	96.9	96.8	96.8	96.7	96.6	96.5	96.4	96.3	96.1	96.0	95.8	95.6	95.3	95.1	94.8	94.6	94.3	94.0	93.7	93.3	93.0
14	96.9	96.9	96.9	96.9	96.8	96.8	96.7	96.6	96.5	96.4	96.3	96.1	96.0	95.8	95.6	95.3	95.1	94.8	94.6	94.3	94.0	93.7	93.3	93.0
15	96.9	96.9	96.9	96.9	96.8	96.8	96.7	96.6	96.5	96.4	96.3	96.1	96.0	95.8	95.6	95.3	95.1	94.8	94.6	94.3	94.0	93.7	93.3	93.0
16	96.9	96.9	96.9	96.9	96.8	96.8	96.7	96.6	96.5	96.4	96.3	96.1	96.0	95.8	95.6	95.3	95.1	94.8	94.6	94.3	94.0	93.7	93.3	93.0
17	96.9	96.9	96.9	96.9	96.8	96.8	96.7	96.6	96.5	96.4	96.3	96.1	96.0	95.8	95.6	95.3	95.1	94.8	94.6	94.3	94.0	93.7	93.3	93.0

Notes:
Rows 1, 2, and 3 represent saturated overburden of variable thickness.
Rows 4, 5, 6, and 7 are 1.25 ft thick each and represent clay layer.
Rows 8 through 17 are 10 ft thick each and represent bedrock aquifer.
Each cell is 50 ft horizontal length (i.e., length between each column).

TABLE D-22 SOLUTE CONCENTRATION IN THE VERTICAL ORIENTATION AFTER 10 YEARS AT THE NEW CUMBERLAND SITE, RELATIVE TO A 1000 UNIT SOURCE

CONCENTRATION

NODE ROW\COL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	18	8	470	944	935	911	891	874	878	815	767	804	500	26	9	6	4	2	2	1	1	1	1	0
2	21	9	462	899	875	871	861	850	863	802	751	784	501	46	17	11	7	5	3	2	2	1	1	0
3	24	9	454	864	840	851	846	839	856	796	744	775	496	63	29	18	12	8	6	4	3	2	2	0
4	28	19	438	832	815	824	819	810	824	755	707	738	486	85	41	26	17	12	8	6	5	4	3	1
5	31	31	419	795	786	793	787	776	786	708	663	694	477	116	60	38	25	18	13	10	7	6	4	3
6	32	45	402	759	758	762	755	741	746	662	619	645	474	155	85	53	36	26	19	14	11	9	7	6
7	32	64	382	720	726	727	718	701	699	610	565	597	461	224	122	78	54	38	29	22	17	14	10	11
8	42	106	371	645	675	674	667	648	645	582	524	539	474	301	180	117	81	58	43	33	25	20	16	15
9	33	122	347	562	607	607	603	585	579	536	481	479	453	337	224	151	107	78	58	44	34	27	21	19
10	22	107	305	470	522	528	526	511	505	476	431	419	412	340	249	177	128	95	72	56	43	35	27	24
11	12	77	243	371	424	436	439	430	425	408	376	361	360	320	253	191	144	109	84	66	52	42	33	28
12	6	46	171	271	321	340	348	347	345	336	318	305	306	286	242	194	152	119	94	75	59	48	38	33
13	2	24	102	177	222	246	260	266	269	268	261	253	255	247	222	188	154	125	101	82	66	54	43	37
14	1	10	50	100	138	164	182	195	204	209	210	208	211	211	199	177	152	127	105	87	71	58	47	40
15	0	3	19	47	76	101	123	139	153	163	170	173	177	181	178	166	148	128	108	90	74	61	49	42
16	0	1	5	18	39	63	85	104	121	134	144	150	156	162	163	157	144	127	109	92	76	63	51	43
17	0	0	2	10	27	50	72	92	110	124	135	143	149	156	158	154	143	127	109	93	77	64	52	44

TABLE D-23 SOLUTE CONCENTRATION IN THE VERTICAL ORIENTATION AFTER 20 YEARS AT THE NEW CUMBERLAND SITE, RELATIVE TO A 1000 UNIT SOURCE

CONCENTRATION

NODE ROW\COL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	59	29	531	1000	989	985	980	975	976	964	931	981	644	71	38	31	25	22	20	18	17	16	17	7
2	69	29	543	999	979	978	975	970	973	962	927	973	672	121	68	54	43	36	31	27	24	22	21	9
3	80	30	546	991	973	975	973	967	971	960	925	968	680	163	105	81	65	54	46	41	36	33	30	12
4	95	41	542	985	969	970	968	961	965	950	914	956	687	208	138	106	86	72	62	54	48	44	39	25
5	106	57	537	977	965	965	962	953	957	938	900	940	698	271	185	143	117	98	85	75	66	61	54	44
6	114	77	532	969	960	959	956	945	949	926	887	922	715	345	244	189	155	131	114	101	89	82	72	70
7	117	106	526	960	955	953	950	936	938	914	869	909	726	465	327	256	211	180	156	139	123	114	99	114
8	145	189	542	926	949	942	939	925	920	906	857	881	781	584	434	341	281	238	206	182	161	148	130	132
9	134	261	554	889	934	926	922	907	895	885	841	848	798	660	522	421	349	298	258	228	202	184	163	158
10	107	291	563	845	907	901	894	878	861	851	816	810	788	697	584	487	411	354	309	274	243	220	197	187
11	76	273	562	791	862	860	850	834	816	805	780	769	759	704	620	535	462	404	356	317	283	257	230	216
12	48	222	535	724	793	796	787	774	759	749	733	723	720	689	631	564	500	445	397	357	320	291	261	244
13	27	158	462	630	693	705	704	700	692	688	681	675	676	662	626	578	526	476	430	390	352	321	289	269
14	15	99	343	500	564	592	608	618	623	627	629	630	634	631	612	580	540	498	456	417	378	346	312	290
15	8	52	202	341	423	477	515	543	561	574	584	591	599	603	596	577	547	512	473	436	397	365	329	305
16	4	23	89	200	308	389	447	489	518	538	554	566	576	584	583	572	549	519	483	447	409	376	339	315
17	3	13	45	143	264	355	422	469	502	526	543	557	568	577	579	570	550	521	486	451	413	380	343	318

TABLE D-24 SOLUTE CONCENTRATION IN THE VERTICAL ORIENTATION AFTER 30 YEARS AT THE NEW CUMBERLAND SITE, RELATIVE TO A 1000 UNIT SOURCE

CONCENTRATION

NODE ROW\COL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	92	40	543	1000	998	997	996	995	994	996	973	1000	691	94	57	50	44	41	39	38	37	37	41	18
2	108	39	561	1000	996	996	995	994	993	996	972	1000	728	159	101	86	74	67	61	57	53	51	50	22
3	126	39	567	1000	995	995	995	993	992	995	972	1000	741	212	151	125	108	97	88	82	75	73	69	31
4	149	52	566	1000	995	995	994	992	991	993	969	1000	752	266	194	161	139	125	113	106	98	95	88	59
5	168	70	564	1000	995	994	993	991	989	991	965	1000	770	341	254	211	184	165	150	140	130	126	115	100
6	181	92	562	1000	995	993	992	989	987	989	961	1000	793	428	328	272	237	213	195	182	168	163	148	152
7	188	125	559	1000	994	992	991	988	984	987	953	1000	812	564	428	358	313	282	258	241	224	217	195	230
8	232	219	579	976	996	990	989	986	977	985	950	990	882	694	549	459	399	357	324	301	278	266	243	255
9	231	318	593	951	992	987	984	982	970	976	946	969	917	784	653	555	485	435	394	365	336	319	295	294
10	205	387	608	924	983	981	975	972	958	961	938	947	926	840	733	640	566	510	464	429	396	374	348	340
11	165	408	628	892	965	967	958	954	940	939	924	925	918	867	788	707	637	580	531	492	456	429	399	386
12	120	379	649	855	932	938	930	925	914	912	903	901	901	874	820	756	694	640	591	550	511	480	448	430
13	81	315	651	807	876	889	886	886	881	881	878	877	880	868	835	789	737	689	642	600	560	527	491	470
14	51	234	599	733	791	818	830	839	844	848	851	853	858	856	838	807	767	725	682	641	600	565	528	503
15	33	154	462	608	683	737	770	794	809	820	828	834	840	843	835	816	786	751	710	671	630	594	555	528
16	24	92	275	458	586	671	725	760	784	800	812	820	828	834	832	820	796	765	727	690	648	612	571	543
17	21	67	179	385	547	645	707	748	775	793	806	815	823	830	831	821	799	770	733	696	654	618	577	548

TABLE D-25 SOLUTE CONCENTRATION IN THE VERTICAL ORIENTATION AFTER 40 YEARS AT THE NEW CUMBERLAND SITE, RELATIVE TO A 1000 UNIT SOURCE

CONCENTRATION

NODE ROW\COL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	112	45	546	1000	999	999	999	999	997	1000	983	1000	705	102	65	59	53	51	50	49	49	50	56	25
2	132	43	565	1000	999	999	999	999	997	1000	982	1000	744	172	114	100	89	82	76	73	69	68	68	31
3	154	42	572	1000	999	999	999	999	996	1000	982	1000	758	228	169	144	128	117	108	103	97	96	92	42
4	183	55	572	1000	1000	999	999	999	996	1000	981	1000	771	286	215	183	163	149	139	132	124	123	115	80
5	207	73	571	1000	1000	998	998	999	995	1000	979	1000	790	365	280	238	213	195	181	173	162	161	149	133
6	223	96	569	1000	1000	998	998	999	994	1000	978	1000	815	455	357	304	271	249	232	221	208	206	188	197
7	233	129	567	1000	1000	998	998	999	992	1000	973	1000	836	596	463	396	354	325	303	289	272	269	244	290
8	288	224	589	984	1000	998	996	999	989	1000	972	1000	910	728	588	501	444	405	374	354	331	323	299	316
9	300	333	602	962	1000	999	994	998	986	998	973	1000	951	823	697	603	536	488	450	423	396	382	358	360
10	285	423	611	939	995	997	990	993	982	990	972	987	967	885	783	694	623	571	527	494	463	443	417	411
11	248	472	625	913	982	990	982	984	974	978	967	973	969	921	845	769	701	647	600	564	529	504	476	464
12	199	474	649	883	960	973	968	969	962	964	959	961	963	937	886	826	766	715	667	629	591	562	531	515
13	149	431	679	847	924	943	943	947	945	948	947	948	952	942	910	866	817	770	725	685	646	614	580	560
14	107	356	691	800	868	899	911	921	926	931	934	937	942	939	922	893	854	813	771	732	691	658	621	598
15	79	268	628	725	797	848	876	896	907	916	923	928	933	935	927	908	879	844	804	766	725	691	652	626
16	64	192	467	628	734	805	848	876	894	906	915	921	927	931	928	916	892	862	824	787	746	711	671	644
17	59	159	361	578	708	788	838	869	889	902	912	919	925	930	929	918	897	867	831	794	754	718	678	649

APPENDIX E

GRAIN SIZE DISTRIBUTION CURVES

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

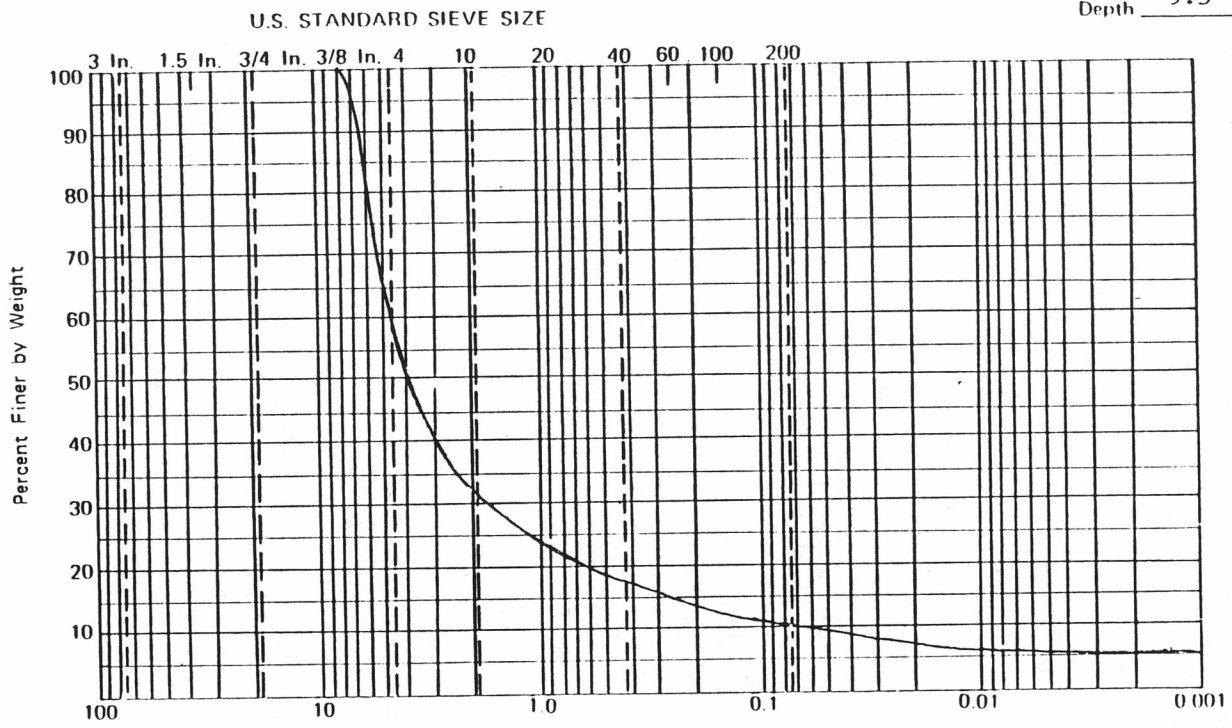
Hunt Valley/Loveton Center
15 Loveton Circle
Sparks, Maryland 21152
(301) 771-4950

GRAIN SIZE DISTRIBUTION AND LIQUID AND PLASTIC LIMIT DETERMINATIONS

Project New Cumberland #10424.22

Station No. MW 1 S5 Lab No. 89141

Depth 9.5' Elevation 295



GRAVEL		SAND			SILT OR CLAY
COARSE	FINE	COARSE	MEDIUM	FINE	

CLASSIFICATION	NAT. WC	LL	PL	PI	SPECIFIC GRAVITY
Gp-GM	6.59	*	*	*	

* Insufficient sample quantity

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

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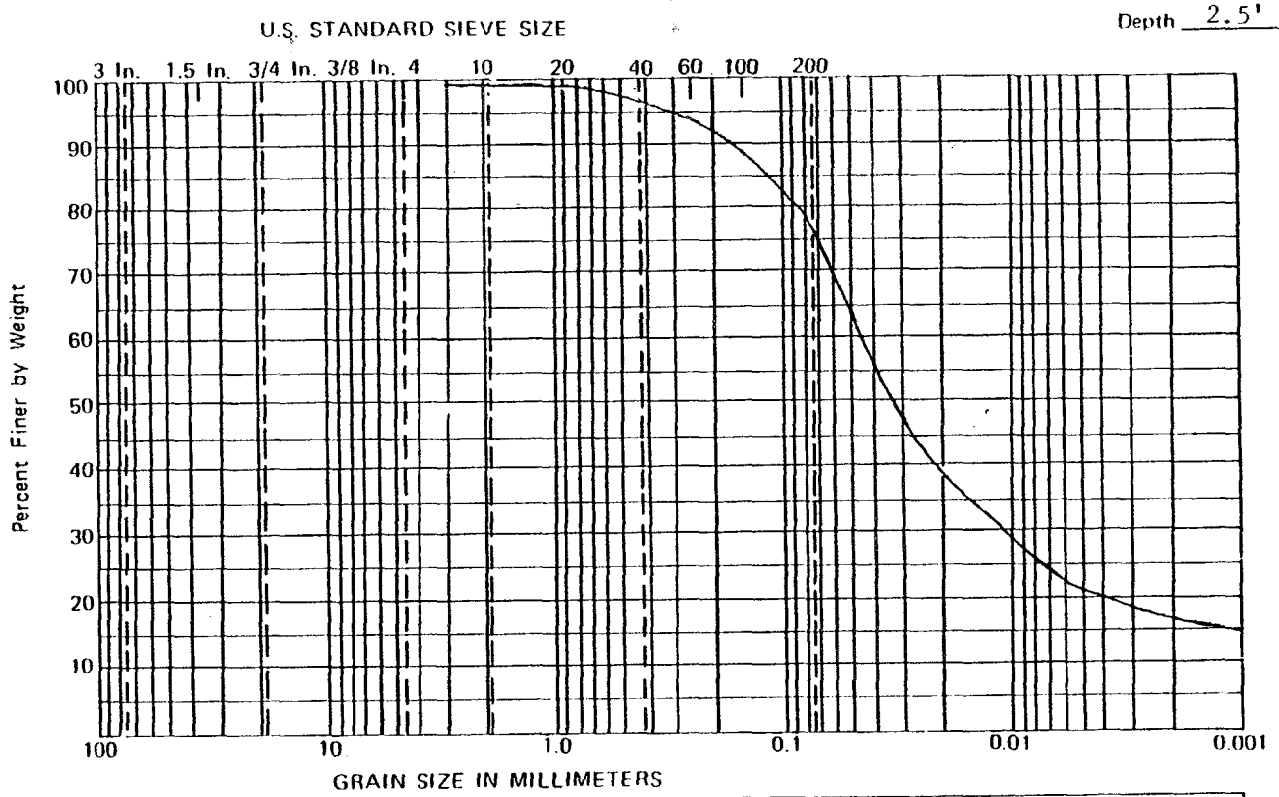
GRAIN SIZE DISTRIBUTION AND LIQUID AND PLASTIC LIMIT DETERMINATIONS

Project New Cumberland #10424.22

Station No. MW 4AS2 Lab No. 89140

Depth 2.5' Elevation 300.4



GRAVEL		SAND			SILT OR CLAY
COARSE	FINE	COARSE	MEDIUM	FINE	

CLASSIFICATION	NAT. WC	LL	PL	PI	SPECIFIC GRAVITY
CL-ML	15.82	24	17	7	N/A

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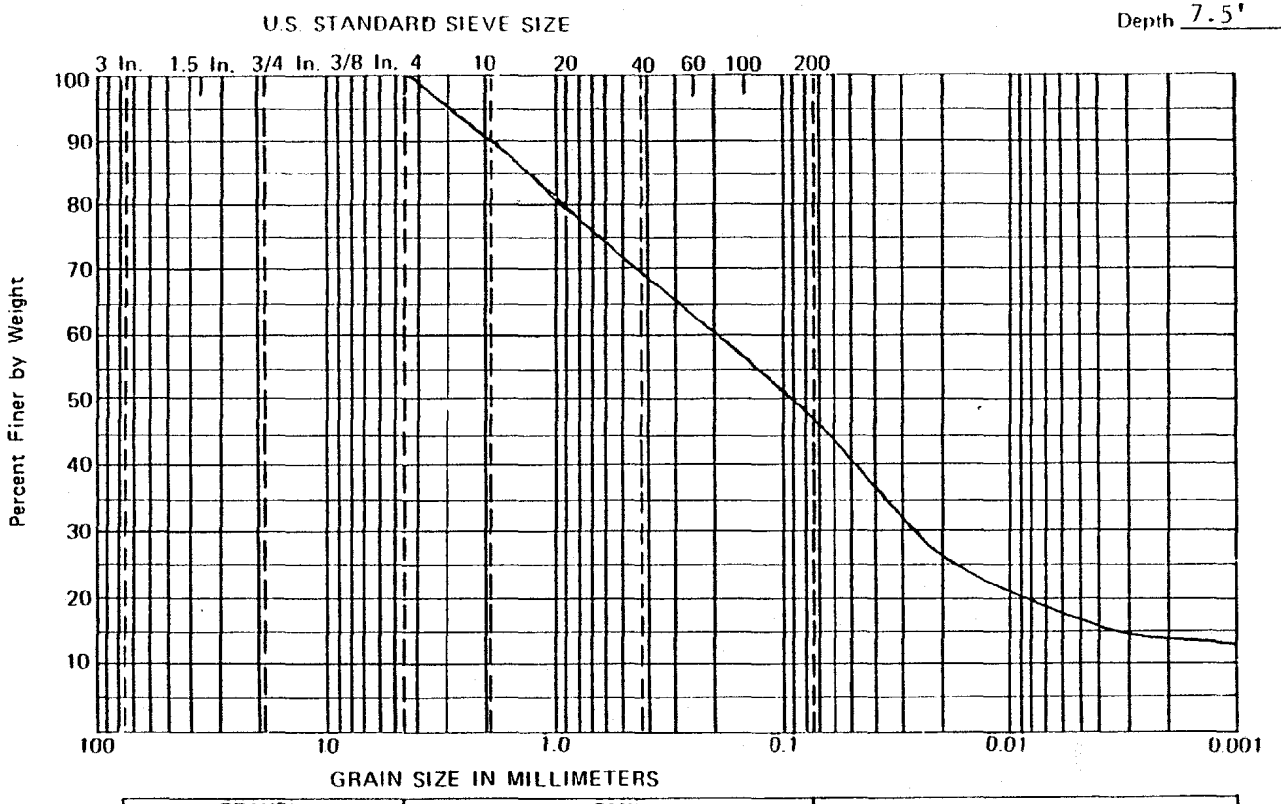
GRAIN SIZE DISTRIBUTION AND LIQUID AND PLASTIC LIMIT DETERMINATIONS

Project New Cumberland #10424.22

Station No. MW 4 S4 Lab No. 89138

Depth 7.5' Elevation 296.4



GRAVEL		SAND			SILT OR CLAY
COARSE	FINE	COARSE	MEDIUM	FINE	

CLASSIFICATION		NAT. WC	LL	PL	PI	SPECIFIC GRAVITY
	SC	10.61	25	15	10	N/A

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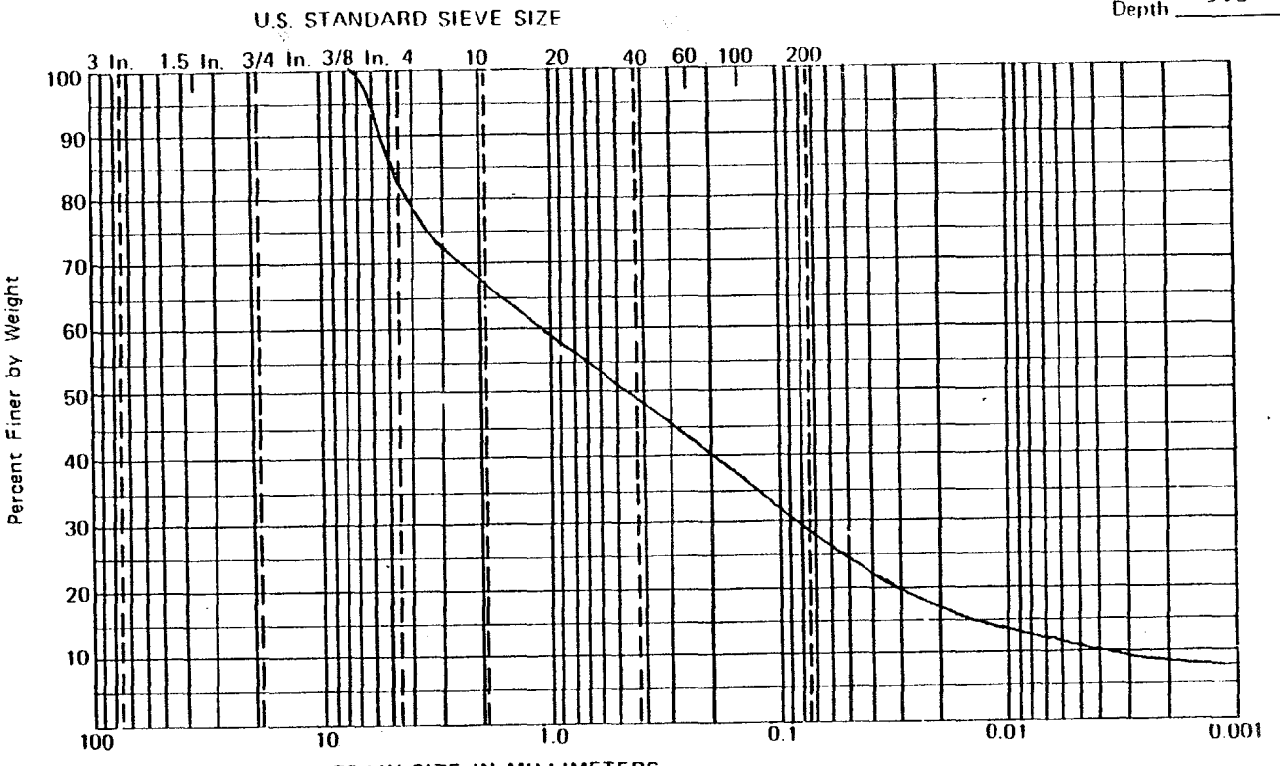
GRAIN SIZE DISTRIBUTION AND LIQUID AND PLASTIC LIMIT DETERMINATIONS

Project New Cumberland #10424.22

Station No. MW 4 S5 Lab No. 89139

Depth 9.5' Elevation 294.4



GRAVEL		SAND			SILT OR CLAY
COARSE	FINE	COARSE	MEDIUM	FINE	

CLASSIFICATION		NAT. WC	LL	PL	PI	SPECIFIC GRAVITY
	SM	8.71	17	14	3	N/A

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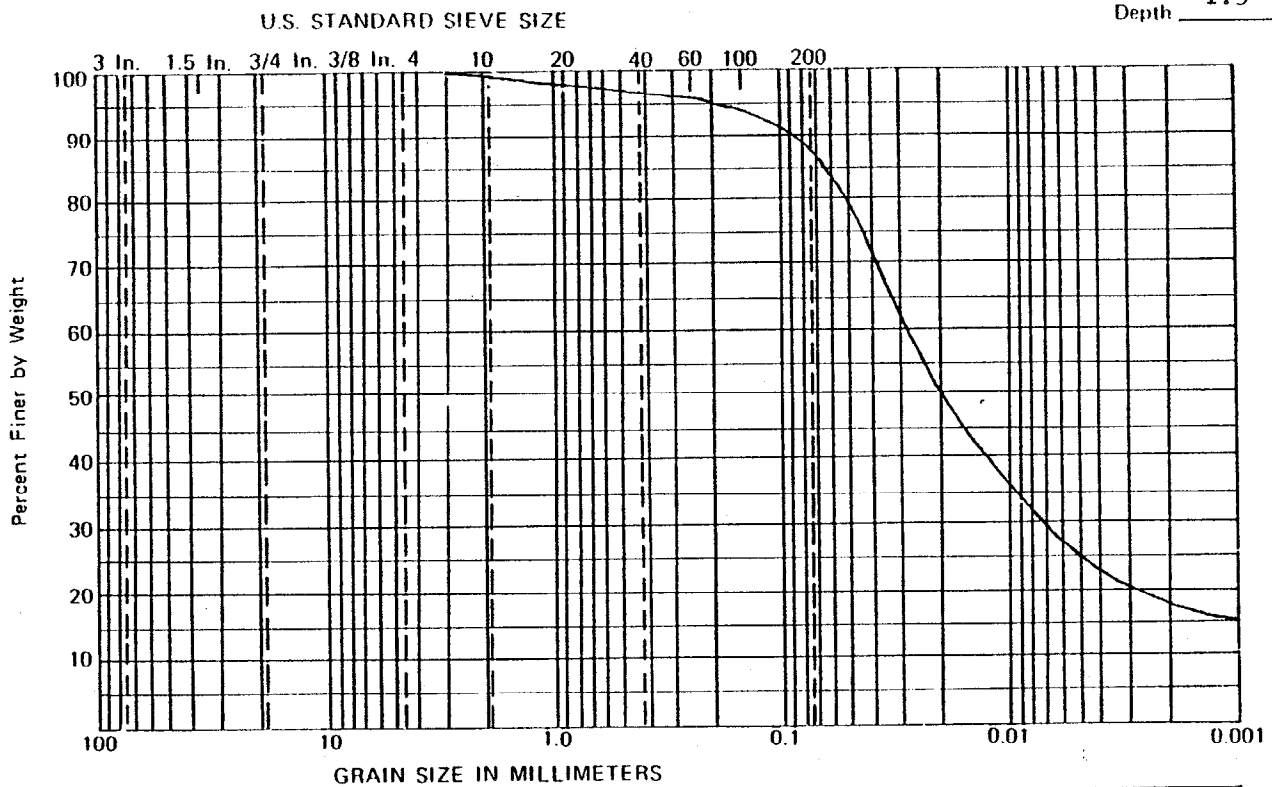
GRAIN SIZE DISTRIBUTION AND LIQUID AND PLASTIC LIMIT DETERMINATIONS

Project New Cumberland #10424.22

Station No. MW 5 S2 Lab No. 89142

Depth 1.5' Elevation 298.8



GRAVEL		SAND			SILT OR CLAY
COARSE	FINE	COARSE	MEDIUM	FINE	

CLASSIFICATION		NAT. WC	LL	PL	PI	SPECIFIC GRAVITY
	ML	27.93	45	32	13	NA

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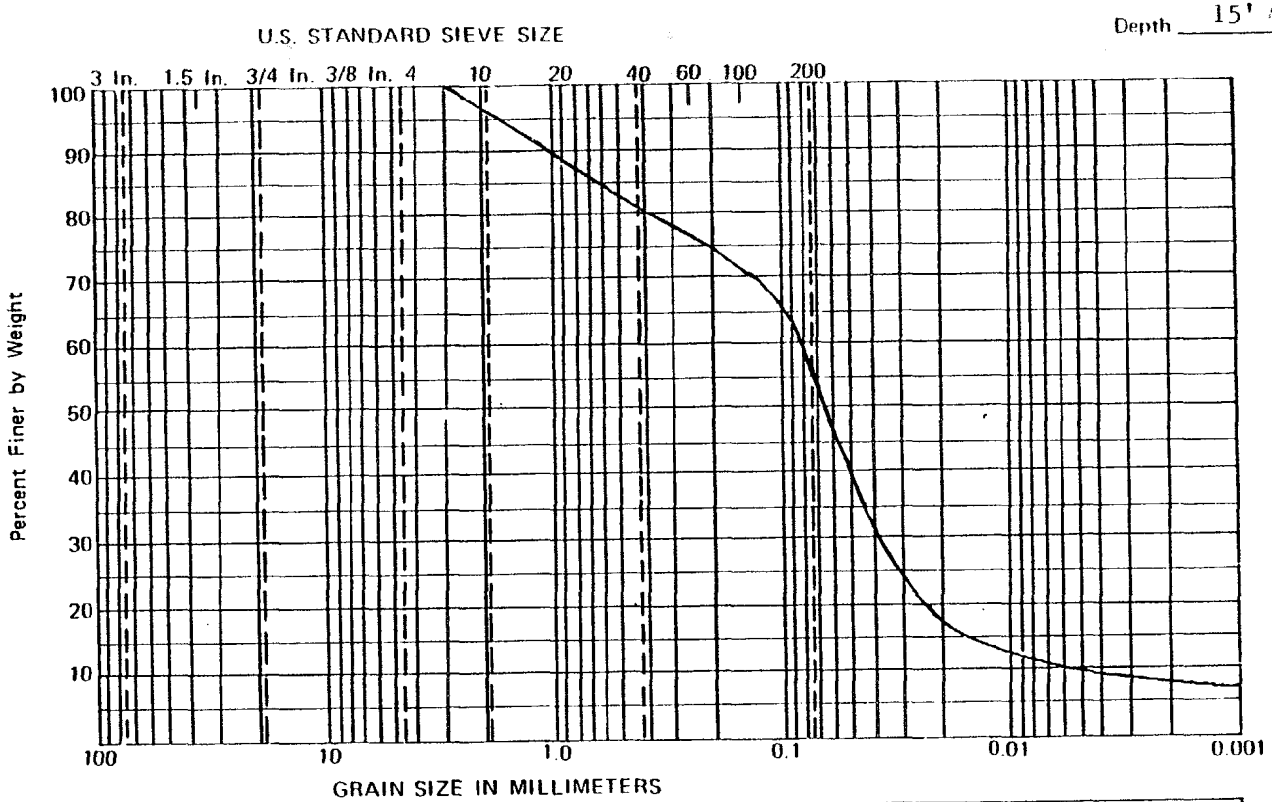
GRAIN SIZE DISTRIBUTION AND LIQUID AND PLASTIC LIMIT DETERMINATIONS

Project New Cumberland #10424.22

Station No. MW 5 S6 Lab No. 89144

Depth 15' 15' Elevation 285.4



GRAVEL		SAND			SILT OR CLAY
COARSE	FINE	COARSE	MEDIUM	FINE	

CLASSIFICATION	NAT. WC	LL	PL	PI	SPECIFIC GRAVITY
CL	11.51	24	15	9	N/A

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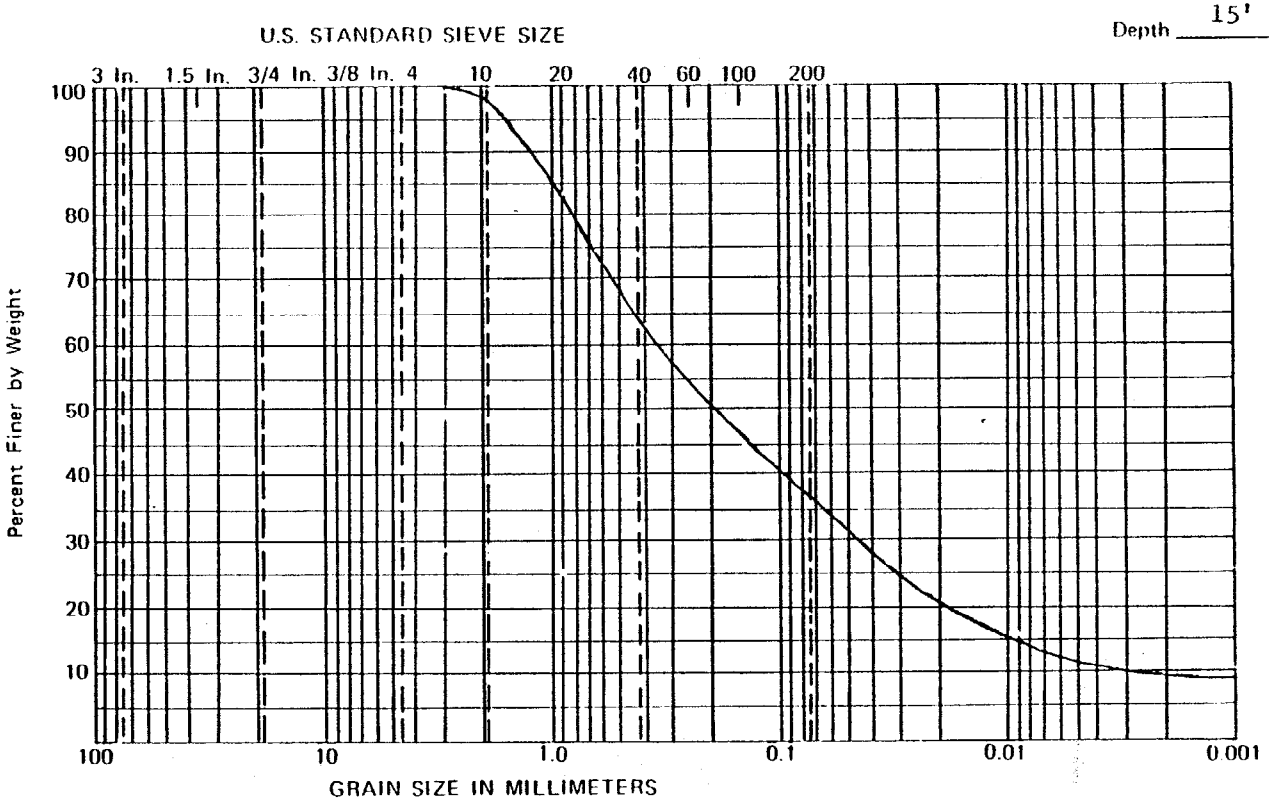
GRAIN SIZE DISTRIBUTION AND LIQUID AND PLASTIC LIMIT DETERMINATIONS

Project New Cumberland #10424.22

Station No. MW 5A S6 Lab No. 89143

Depth 15' Elevation 287



GRAVEL		SAND			SILT OR CLAY
COARSE	FINE	COARSE	MEDIUM	FINE	

CLASSIFICATION	NAT. WC	LL	PL	PI	SPECIFIC GRAVITY
SC	10.02	26	17	9	N/A