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UNOCAL

January 19, 1995

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Project Manager
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Low Level Waste and Decommissioning
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Office of Nuclear Material Safety and
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Washington, D.C. 20555-0001

SITE CHARACTERIZATION REPORT
MOLYCORP, WASHINGTON, PA

Dear Mr. Person

Enclosed is the Site Characterization Report for the Molycorp, Inc., Washington, PA facility.

Sincerely,

Barbara K. Dankmyer
Resident Manager

xc. J. Yusko- PA DER
J. Malviya - PADER (w/o attachments)
J. Kinneman - NRC Region I (w/o attachments)
D. Shoemaker - Molycorp

28A

MOLYCORP, Inc.
A UNOCAL 76 COMPANY

Site Characterization Report

for

License Termination

of the

Washington, PA Facility

Volume 1 of 3

January 1995

FOSTER WHEELER ENVIRONMENTAL CORPORATION

MOLYCORP, INC.
SITE CHARACTERIZATION REPORT

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1.0 INTRODUCTION

The Molycorp, Inc. Site Characterization Report (SCR) details and documents the results of a site characterization program conducted on the Molycorp, Inc., Washington, Pennsylvania site. The SCR is submitted pursuant to Source Materials License SMB-1393, Amendment No. 1 Section 14C (Docket 40-08778), and the schedule provided therein, modified and agreed to with the United States Nuclear Regulatory Commission (NRC). The SCR is based on an approved (August 5, 1993) Site Characterization Plan (SCP) and revisions to the SCP as requested by the NRC in their letter of December 1, 1993.

The SCP was prepared in response to the listing of the Molycorp, Inc. Washington plant site under the NRC's 1990 Site Decommissioning Management Plan (SDMP). The SDMP was instituted by the NRC to develop a comprehensive strategy to deal with sites that required closure; that is, to assure that closure on decommissioning issues at a site was attained in a timely manner.

In the case of Molycorp, Inc., the Washington, Pennsylvania facility produced a ferrocolumbium alloy from Brazilian ore (pyrochlore) between 1964 and 1970. While the use of pyrochlore was commonplace by that time, this particular ore contained thorium as an accessory metal. The thorium was also in concentrations which required Molycorp to acquire a Source Materials License (December 19,1963). The operation resulted in the production of a thorium-bearing slag, some of which was used as fill over portions of the site.

Currently, much of the slag produced from this operation is relocated in a stabilized, soil capped pile on the southern portion of the site. There is also a smaller pile in the northern portion of the site. Ferrocolumbium slag is also mixed with soils at various locations on the site.

The majority of the field effort in support of the SCR was conducted in the spring, summer and fall of 1994. Field studies were conducted to understand the hydrogeology of the site (including surface water); the nature, extent and distribution of the thoriated slag; the demography of the area immediately surrounding the site; and other components required to fully characterize the thoriated material and to determine its effect, if any, on the local population and environment.

Importantly, the slag material does not represent a threat to the public health and safety or to the environment. Additionally, while low concentrations of thorium are present in the slag mixed with site soils, there is no evidence that any of the thorium is migrating off the site.

1.1 OBJECTIVES OF THE CHARACTERIZATION OF THE SITE

The objectives of this site characterization reflect the objectives presented in the SCP (which were in turn based on the 1992 Branch Technical Position on Site Characterization for Decommissioning) as well as the objectives presented in the November 1994 Branch Technical

Position on Site Characterization for Decommissioning. Specifically, the objectives for this site were:

- To determine the extent of the distribution of thoriated residues on the site, in the structures and in the environmental media.
- To determine the rate(s) of migration, if any, of thorium or its daughters through various pathways to man.
- To assess associated non-radiological constituents and determine their effects on the radiological constituents and potential impacts on decommissioning.
- To quantify parameters that affect potential human exposure to existing site radiological materials.
- To support evaluation of alternative decommissioning actions and detailed planning of a preferred approach for decommissioning, decontamination, and waste disposal.

As is evident in the report, the work on the site has kept pace with the evolving SDMP requirements and has met the above objectives.

While the aforementioned objectives have been met, it has also become evident that the characterization reported in subsequent sections of this report is not at an endpoint. The complexity and heterogeneity of the waste material and its distribution will be taken into account in the formulation of the decontamination and decommissioning (D&D) alternatives. It is expected that real-time characterization will continue during execution of any D&D alternative to ensure proper remediation, minimize volume and provide cost savings.

1.2 RELEVANT NRC GUIDELINES

The following guidance documents were used as the basis of the SCP and to form the framework for the ultimate decommissioning of the site.

- Options 1 and 2 of the Branch Technical Position "Disposal or Onsite Storage of Thorium or Uranium Wastes from Past Operations," 46 FR 52601, October 23, 1981.
- "Termination of Byproduct, Source and Special Nuclear Material Licenses," Policy and Guidance Directive FC 83-23, Division of Industrial and Medical Nuclear Safety, November 4, 1983.
- "Termination of Operating Licenses for Nuclear Reactors," Regulatory Guide 1.80, June 1974.

- Letter to Stanford University from James R. Miller, Chief, Standardization and Special Projects Branch, Division of Licensing, Office of Nuclear Reactor Regulation, NRC Docket No. 50-141, April 21, 1982.

- "National Primary Drinking Water Standards," 40 CFR 141.

- "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings," 40 CFR 192.

It should be noted that Molycorp, Inc. and their contractor Foster Wheeler Environmental Corporation (FWENC) are fully aware of the NRC's efforts in establishing a proposed rule for "Radiological Criteria for (FWENC) Decommissioning" and the parallel effort undertaken by EPA. This includes the proposed 15 mrem/year Total Effective Dose Equivalent Standard and the guidance and documents associated with this proposal rule, including:

- NUREG-1500, "Work Draft Regulatory Guide on Release Criteria for Decommissioning: NRC Staff's Draft for Comment," August 1994.

- NUREG-1496 Vol. 1 and Vol. 2, "Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for Decommissioning of NRC-licensed Nuclear Facilities," August 1994.

- NUREG/CR-5512 Vol. 1, "Residual Radioactive Contamination from Decommissioning," October 1992.

Lastly, the guidance in NUREG/CR-5849, "Manual for Conducting Radiological Surveys in Support of License Termination," June 1992 was used in support of the SCP.

SECTION 2.0

2.0 GENERAL INFORMATION

2.1 SITE BACKGROUND

The Molycorp, Inc. project site (the site) is located in southwestern Pennsylvania in Washington County approximately 35 miles southwest of Pittsburgh. The region is generally comprised of towns located close to transportation corridors surrounded by agricultural lands and open areas. The precise location of the site, the adjacent property owners, and a description of the surrounding development are provided below. A history and photographs of the site and its activities since the early 1900s are presented in Section 2.1.2, Site History.

2.1.1 Site Location and Description

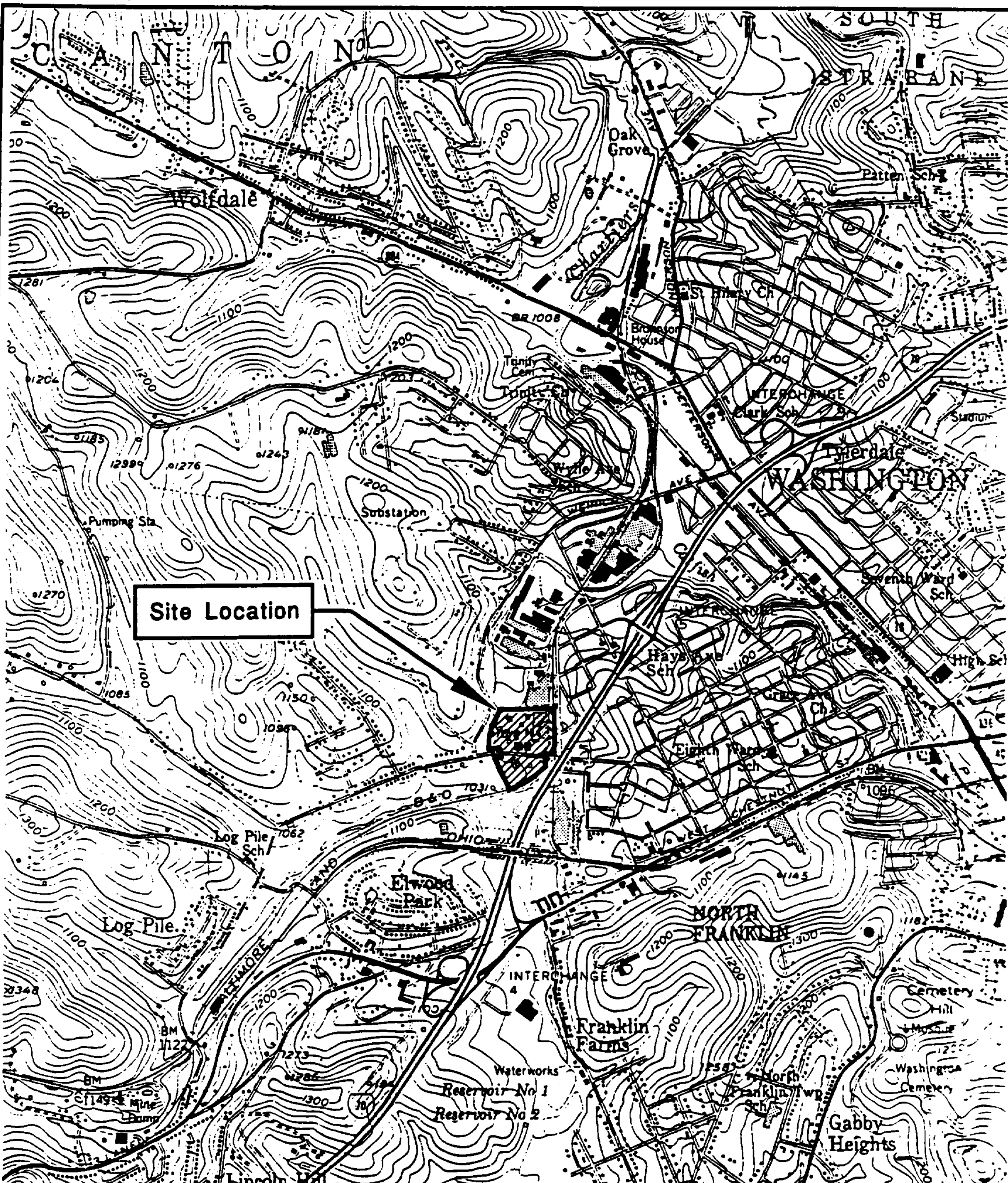
The site is situated on the outskirts of the City of Washington -- Washington County's largest population center and the seat of the County government. Although the Molycorp, Inc. facility is in close proximity to the City's urbanized area, it is separated from the populated City neighborhoods by the ramps and structures associated with Interstate 70 (I-70). From I-70, Molycorp, Inc. has excellent access to points in all directions throughout the region. Access to I-70 is less than 2,000 feet from the plant site via Exit 5, which is also known as the Jessop Place Exit.

2.1.1.1 Location and Use

The site consists of approximately 20 acres, which represents the fenced portion of the 59-acre parcel owned by Molycorp, Inc. in this area of Pennsylvania. The plant, which began ferroalloy manufacturing operations in the 1920s, is located at 300 Caldwell Avenue, Washington, Pennsylvania, 15301. The site lies entirely within Canton Township less than one-half mile from the City of Washington (see Figure 2-1, Site Location, which is based on the Washington West USGS seven and one-half minute quadrangle map, 1969). Currently, the site is in an extended standby mode with a small active area leased to a vendor. Purchasing and reselling alloys, maintenance, and decommissioning are the principal current site activities. The site will continue to be used for some heavy industrial use in the future (see Section 4.6 for additional land use information).

2.1.1.2 Legal Land Description and Adjacent Property Owners

The Molycorp, Inc. land holdings in Washington, PA are comprised of eight land parcels with a total acreage of 55 acres. Molycorp, Inc.'s legal boundaries are presented on Figure 2-2, entitled Adjacent Property Owners. The boundary of the site is also delineated in this figure. A legal description and verification for the fenced areas are included in Appendix A of this report. The fenced area is situated between 1,010 and 1,045 feet above mean sea level with relatively flat topography. The surveyor's topographic map of the project site (1:240 scale) can be found in Appendix B.



SOURCE: U.S.G.S. 7.5 MINUTE TOPOGRAPHIC MAP
WASHINGTON WEST, PA QUADRANGLE

0 2000 4000

SCALE IN FEET

QUADRANGLE LOCATION

N

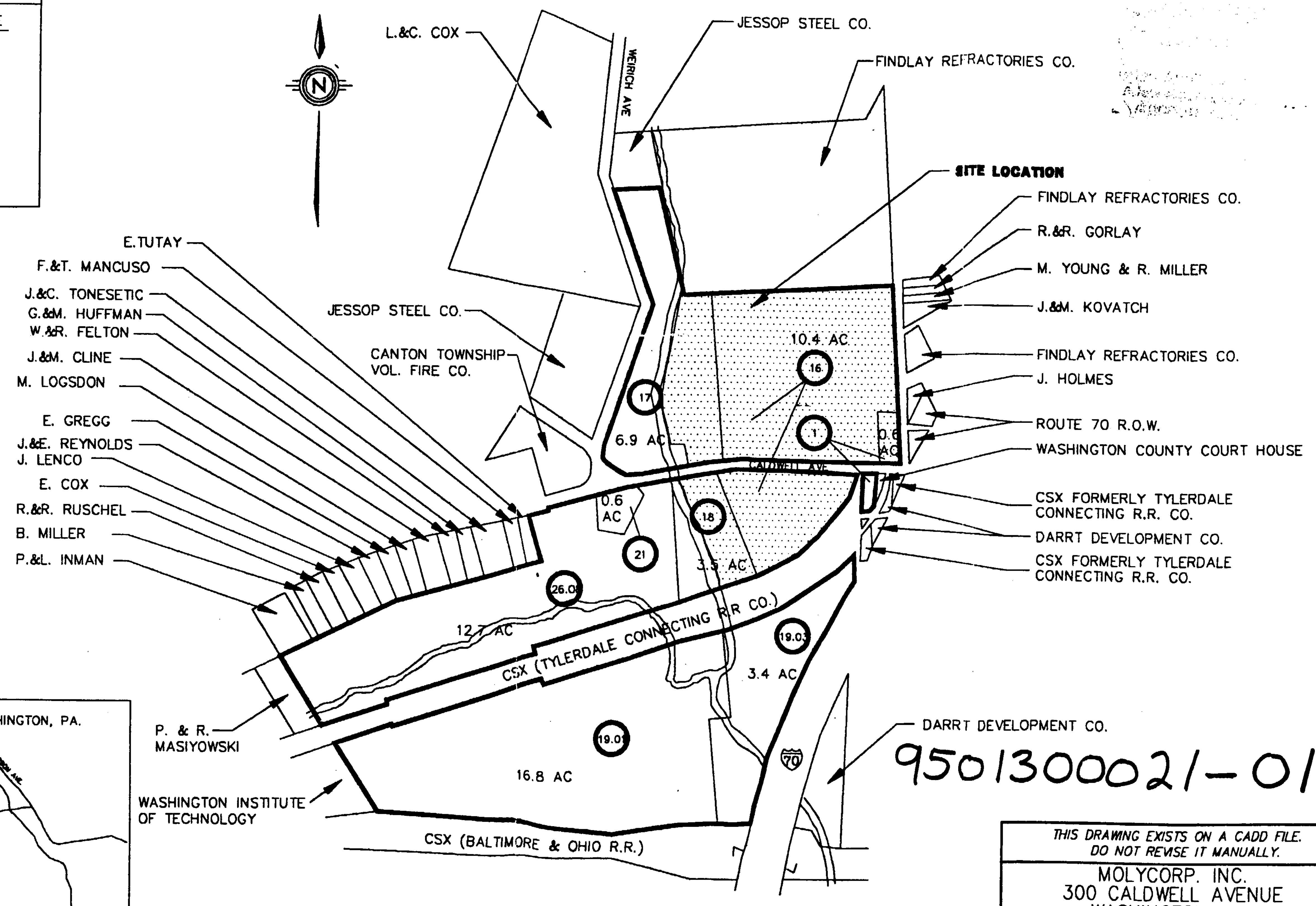
MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE 2-1

SITE LOCATION

FOSTER WHEELER ENVIRONMENTAL CORPORATION

MOLYCORP, INC. ACREAGE	
LOT #	ACREAGE
1	0.6
16	10.4
17	6.9
18	3.5
19.01	16.8
19.03	3.4
21	0.6
26.08	12.7
TOTAL:	54.9



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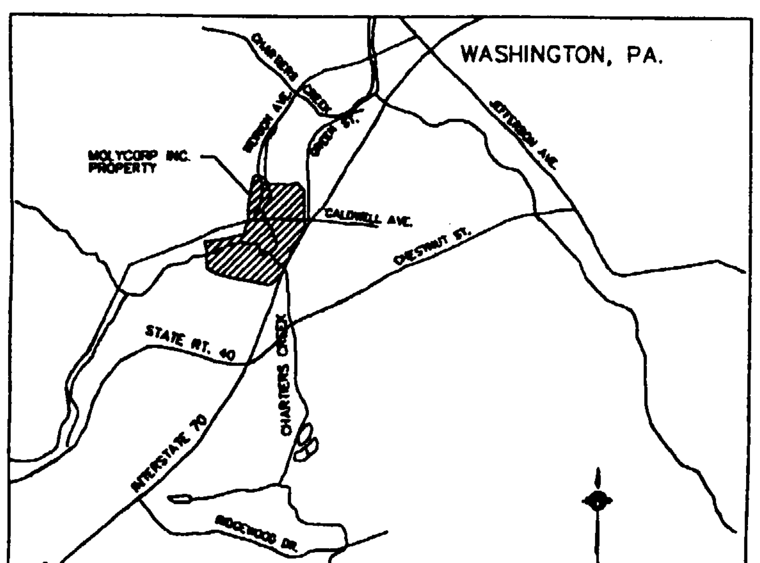

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THIS DRAWING EXISTS ON A CADD FILE. DO NOT REVISE IT MANUALLY.

MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA.

FIGURE 2-2

ADJACENT PROPERTY OWNERS

FOSTER WHEELER ENVIRONMENTAL CORPORATION

11X17

Molycorp, Inc.'s property has frontage along two dedicated public streets in Canton Township -- Caldwell Avenue and Weirich Avenue. The site is traversed by Chartiers Creek which meanders through the property from the south to the north. The property is served by the CSX railroad via two lines which were formerly owned by the Tylerdale Connecting Railroad Company (a.k.a. the Tyler Connecting Railroad) and the Baltimore and Ohio Railroad. CSX operates both lines with service provided three times per week.

Adjacent property owners can be classified into three major categories based on the current use of the land -- residential, industrial and public. The residential property lies to the east of the site on Green Street and to the west along Weirich Avenue. The industrial property is located predominately north of the site and includes property under the ownership of the Findlay Refractories Company and Allegheny Ludlum Corporation. Darrt Development Company owns several smaller scattered parcels located to the south and east of the project site. Land under public ownership includes the Canton Township Volunteer Fire Company property, the right-of-way for Interstate 70, and other public streets. The Washington Institute of Technology owns a 38-acre parcel with a commercial building adjacent to the southwestern property line. This building was used as a mining education and training facility. However, it has not been used for this purpose for some time and has fallen into a state of disrepair and, therefore, is considered a vacant parcel.

A ten-acre parcel of vacant land under the ownership of L. and C. Cox on Weirich Avenue between Comfort Lane and Point View Drive (behind Allegheny Ludlum) may be the site of future commercial development. The property owner has formally requested that the zoning be changed from R-2 Residential to General Commercial. Although Canton Township denied this request in 1994, the Township is conducting a Comprehensive Plan on the portion of the Township which contains the Cox property and several neighboring parcels. The zoning may be changed at some time in the future depending upon the outcome of the Township's planning studies.

2.1.2 Site History

Molycorp, Inc., formerly the Molybdenum Corporation of America until 1974, has owned and operated a plant on the outskirts of Washington, Pennsylvania in Canton Township for over 70 years. The active site consists of approximately 20 acres, as shown previously on Figure 2-2. The main process buildings are located on the north side of Caldwell Avenue, while employee vehicle parking, equipment and miscellaneous storage areas are located on the south side.

This section presents a summary of significant historical information about the facility, along with historical photographs and site development maps, and presents an historical perspective on the extent of site contamination and activities performed to address it. Site investigations that were conducted, a summary of monitoring records, and incidents of release, inspections and permits obtained will also be discussed.

2.1.2.1 Physical Site Development and Processes

The Molybdenum Corporation of America was formed from the Electric Reduction Company in Washington, Pennsylvania on June 16, 1920. As seen in Photograph #1, rolling agricultural fields and woodlands surrounded it. Figure 2-3 shows an historic map of the structures located at the site in 1925. The facility was purchased to manufacture ferroalloys. Production continued into the 1940s and expanded, as evident in Photograph #2 and on Figure 2-4 that show the Molycorp, Inc. buildings and the Findlay Clay Products Co. directly north of it. The two stacks or towers, however, were not constructed until shortly after 1953. Interstate Route 70 was built even later, in the 1960s.

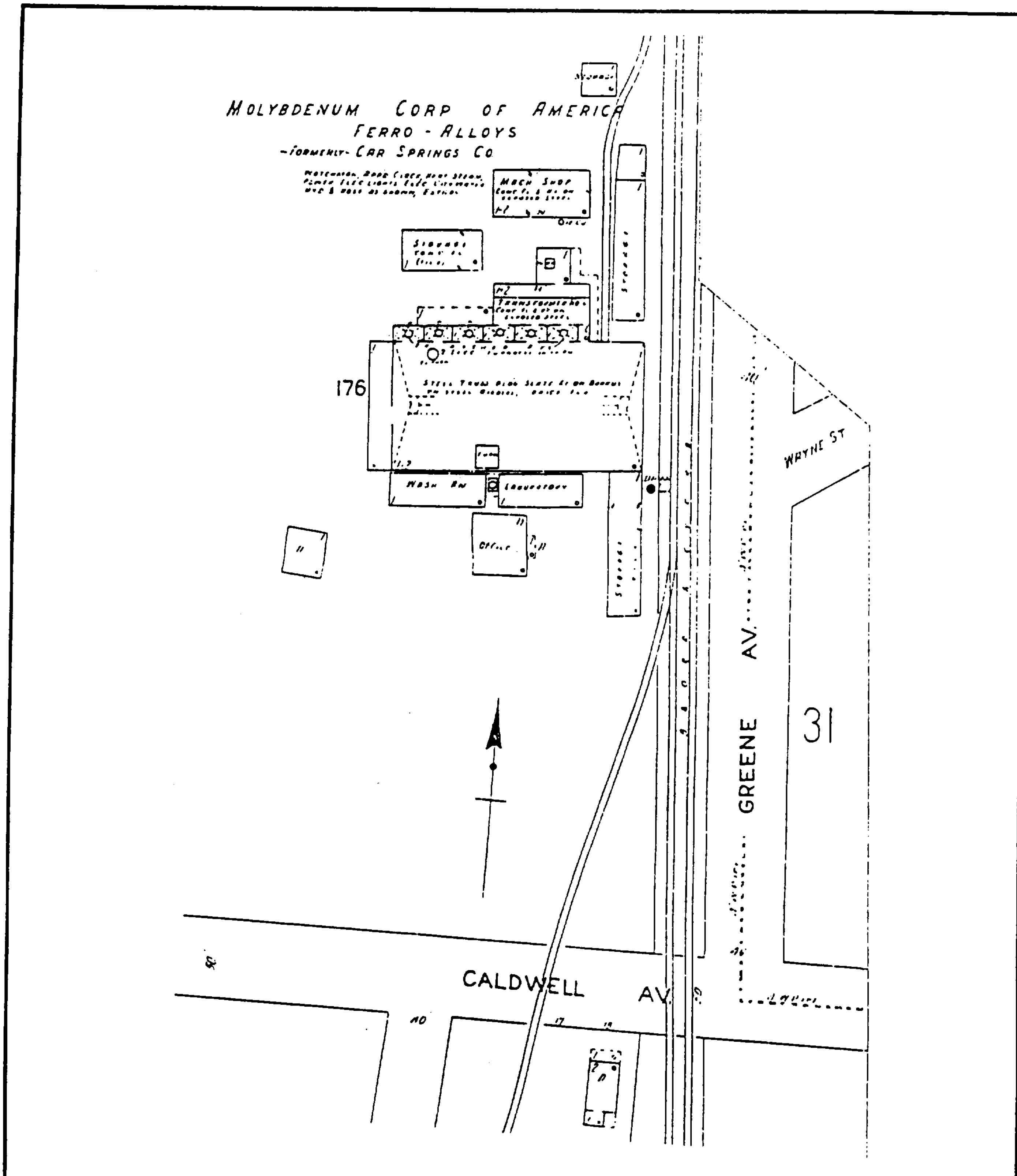
Molybdenum manufacturing was begun in the 1920s. Processing of this material was idled in 1991. Although primarily manufacturing molybdenum products, the plant also produced ferrocolumbium (FeCb, 1964 to 1971), as well as other ferroalloys, e.g., tungsten. Waste slags from the ferro-alloy operations, some of which contained natural thorium, were retained on the plant site, along with the larger quantity of ferromolybdenum slags that were normally used as landfill on the plant property. In 1972 some of the thoriated material from the site was disposed of at the West Valley, New York, burial site. Additionally, Molycorp, Inc. performed cleanup operations to segregate and stabilize some of the thoriated slag and soil located at the Washington site. The segregated material was placed in a capped pile containing about 27,700 cubic yards of slag on the south property. An 8-foot steel security fence surrounds the area south of Caldwell Avenue which contains the pile. Appropriate warning signs are posted on the fence by the pile and on the pile. Figure 2-5 shows the configuration of the plant in 1969.

A view of the active plant site dated from the 1970s but before 1978 is presented in Photograph #3. New additions to the facility, built in the 1960s, are the eight surface impoundments and a large thickener. In 1978 one of two molybdenum roasting furnaces was shut down as part of a consent decree with the Pennsylvania Department of Environmental Resources (PADER) Air Quality Agency due to exceedences of SO_2 standards. All remaining processing continued. Ferrocolumbium slag cleanup at the site was concentrated in the early to mid-1970s time frame. Numerous investigations, studies and surveys were undertaken from 1970 to today to comply with regulatory requirements of the U.S. Nuclear Regulatory Commission (NRC), as described in Section 2.1.2.2.

Photograph #4 shows the Molycorp, Inc. facility as it appears today (photograph taken in 1991). The changed appearance including additional buildings, such as the molybdenum roaster/acid plant complex, can be traced on the site layout plan (Figure 2-6) prepared in the late 1970s and indicates what structures remain from that time period. The review of potential and/or actual contamination under these structures or land will be presented from an historical perspective in the next section.

MOLYBDENUM CORPORATION OF AMERICA IN THE 1920'S
LOOKING WEST TOWARD WEIRICH AVENUE FROM THE
BALTIMORE & OHIO R.R. LINE

PHOTO 1



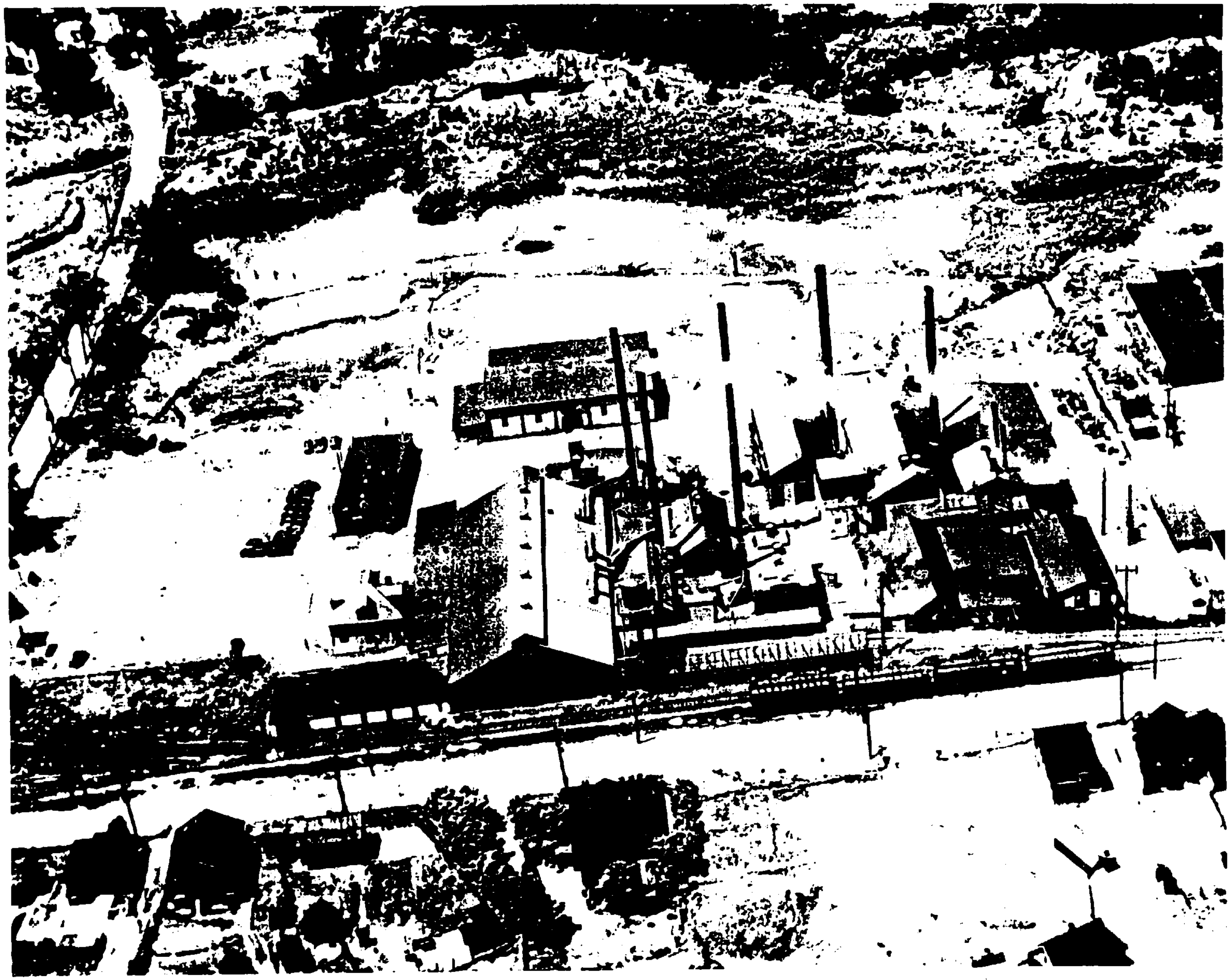
SOURCE: SANBORN MAPPING & GEOGRAPHIC INFORMATION SERVICE/ERIIS, 1991.

MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE 2-3

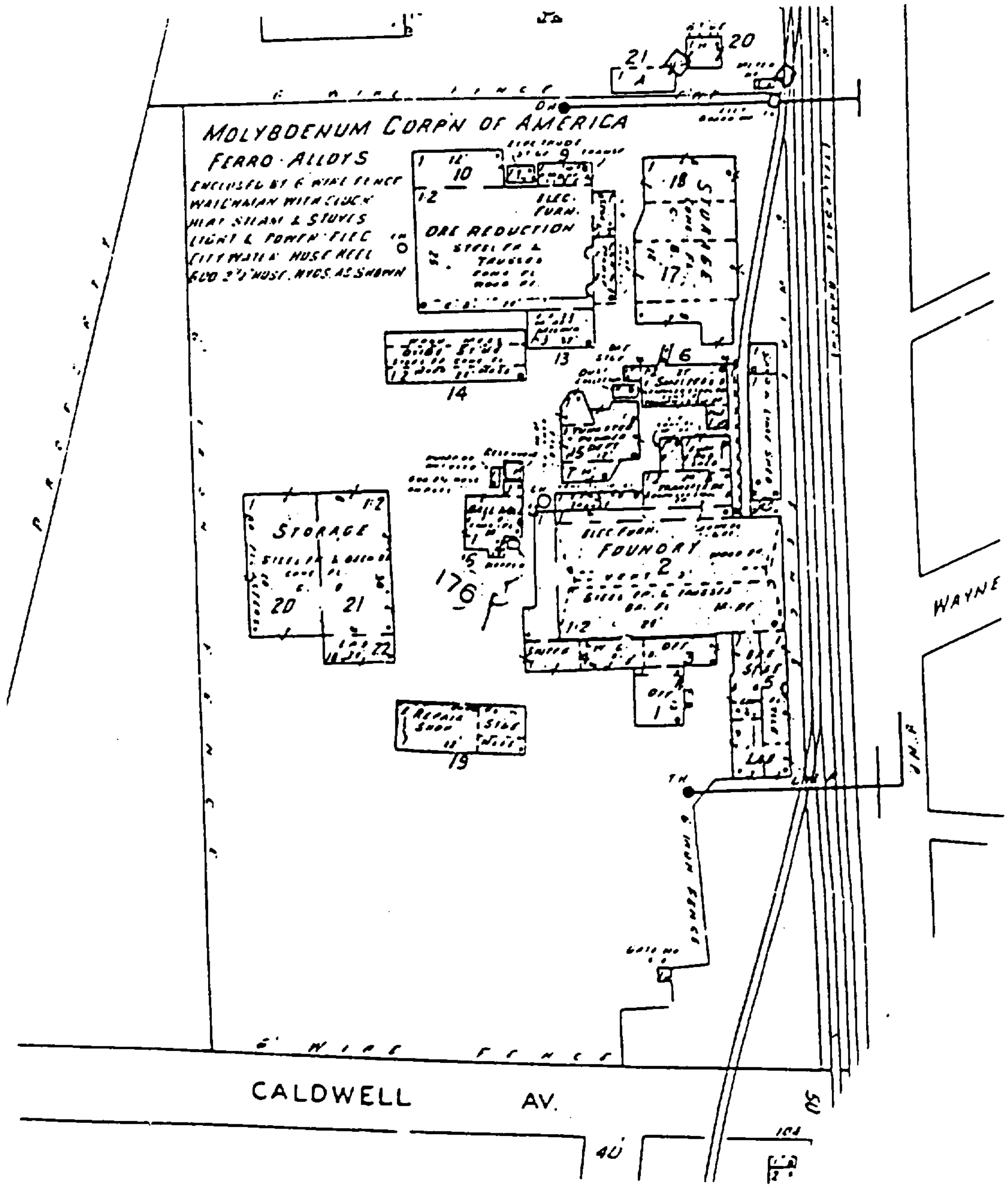
MOLYCORP, INC. SITE-1925
(SANBORN MAP)

FOSTER WHEELER ENVIRONMENTAL CORPORATION



MOLYCORP, INC. FACILITY IN 1940's
LOOKING WEST TOWARD CHARTIERS CREEK AND
WEIRICH AVENUE

PHOTO 2



SOURCE: SANBORN MAPPING & GEOGRAPHIC INFORMATION SERVICE/ERIIS, 1991.

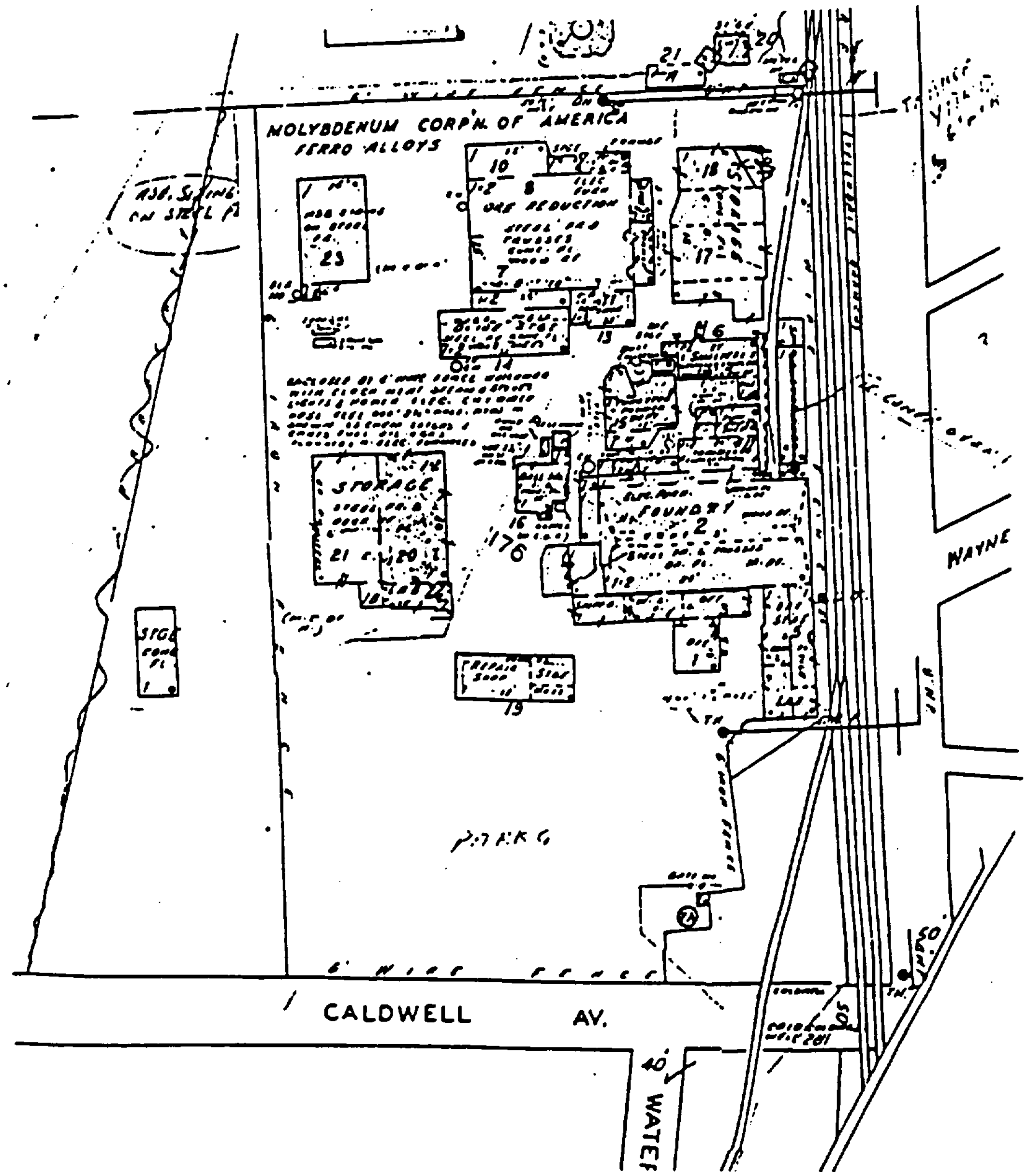
N

MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

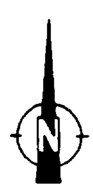
FIGURE 2-4

MOLYCORP, INC. SITE-1947
(SANBORN MAP)

FOSTER WHEELER ENVIRONMENTAL CORPORATION



SOURCE: SANBORN MAPPING & GEOGRAPHIC INFORMATION SERVICE/ERIIS, 1991.

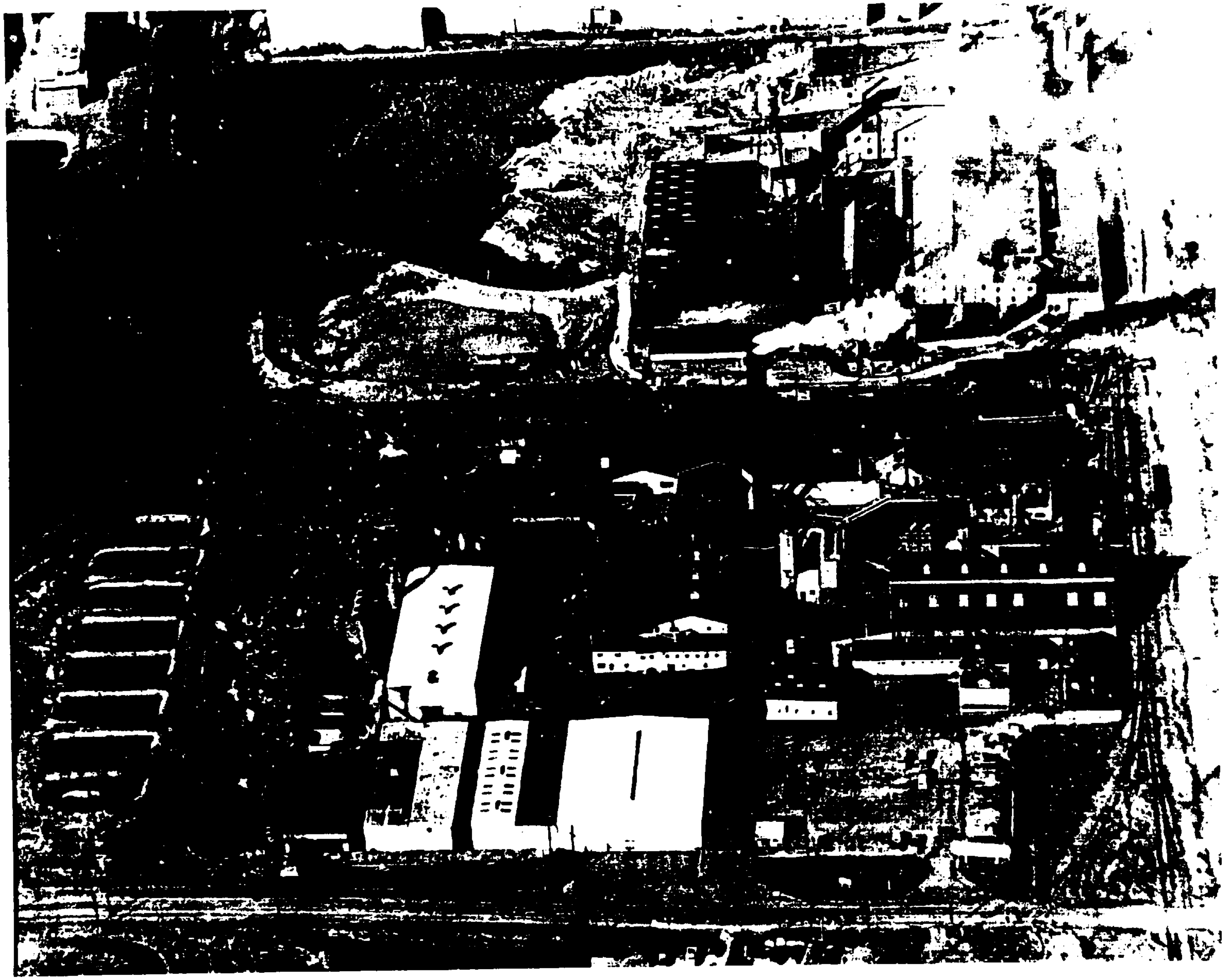


MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE 2–5

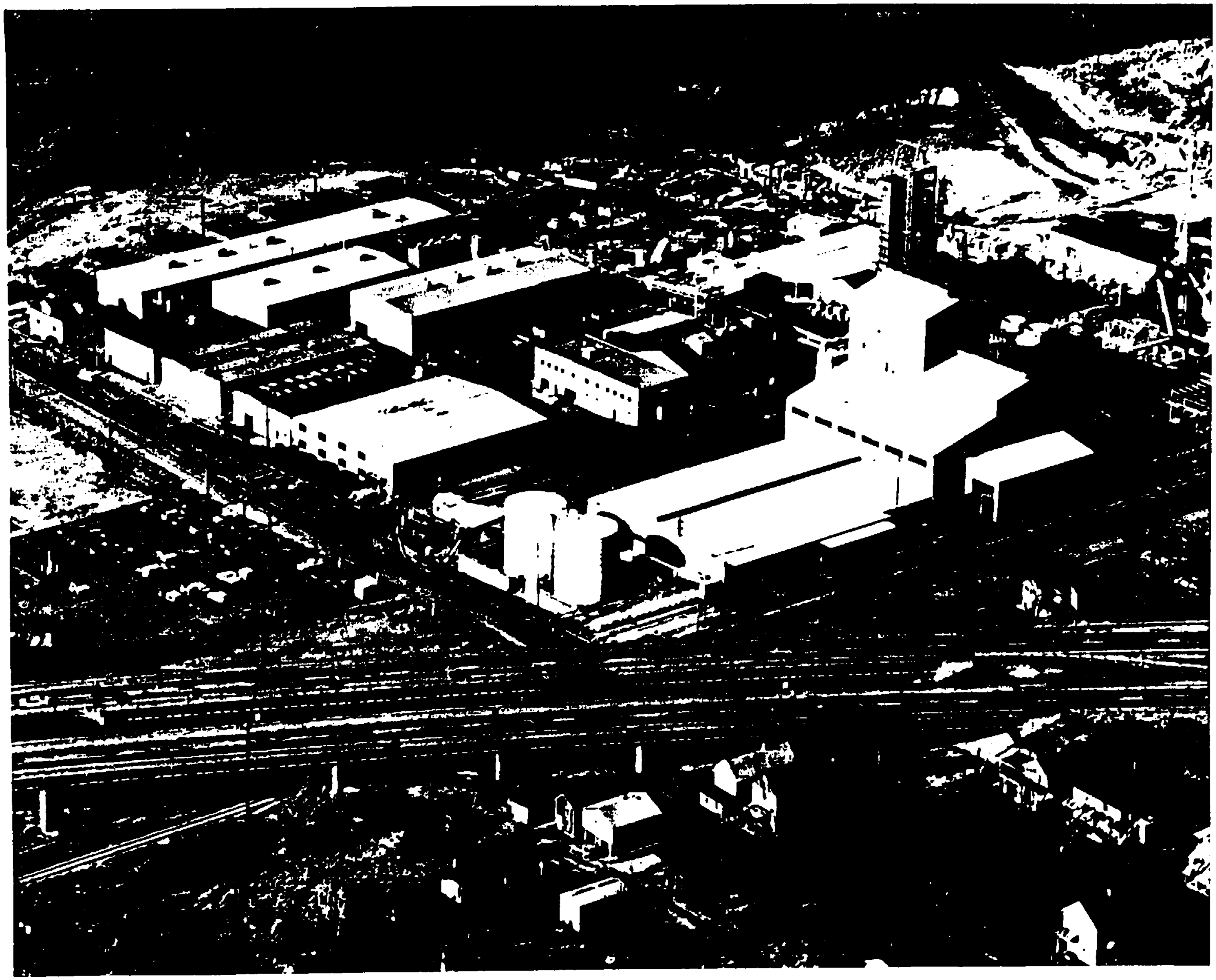
MOLYCORP, INC. SITE–1969
(SANBORN MAP)

FOSTER WHEELER ENVIRONMENTAL CORPORATION



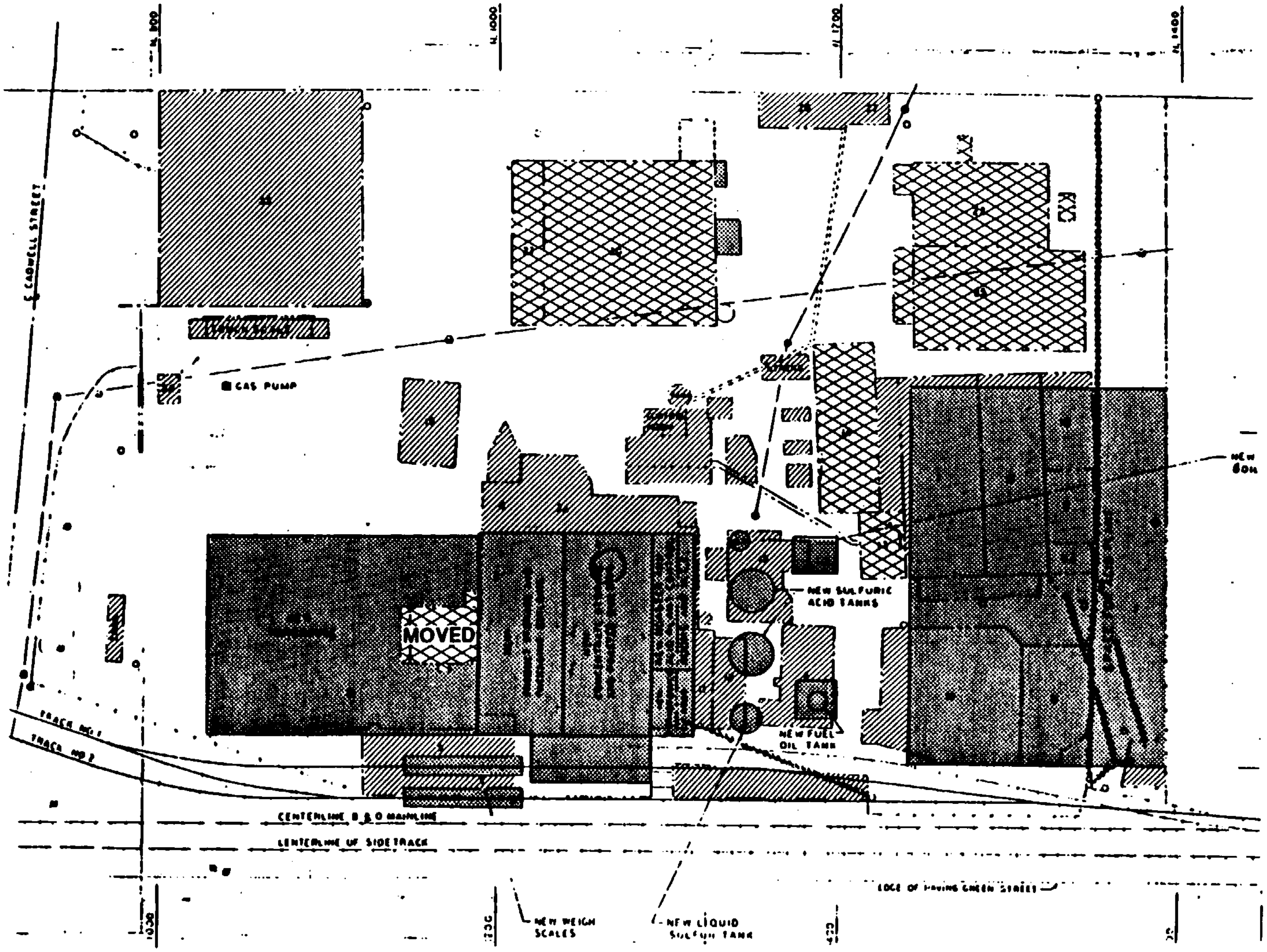
MOLYCORP, INC. FACILITY IN 1970's
LOOKING NORTH FROM CALDWELL AVENUE

PHOTO 3



MOLYCORP, INC. FACILITY IN 1991
LOOKING NORTHWEST FROM I-70 NEAR THE
INTERSECTION OF CALDWELL AVENUE & THE CSX R.R. LINE

PHOTO 4



SOURCE: MOLYCORP, INC. RENOVATIONS DRAWING FILE.

LEGEND

- STRUCTURES EXISTING IN 1970
- NEW CONSTRUCTION–LATE 1970'S
- STRUCTURES (1970 OR EARLIER) STILL STANDING 1994

NOT TO SCALE

MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE 2–6

LATE 1970'S SITE LAYOUT

FOSTER WHEELER ENVIRONMENTAL CORPORATION

2.1.2.2 Historical Perspective on Site Contamination

This section reviews the activities that have occurred in addressing contamination from the ferro-columbium process at the site. Field investigations and long-term monitoring have been conducted over time, and will be summarized below.

- *Site Investigations Conducted, Licenses and Permits*

In parallel with the changing physical site development, various investigations were undertaken to address changing United States Atomic Energy Commission (USAEC or AEC) requirements almost immediately upon receiving a Source Materials License in late 1963 (December 19, 1963). The processing of certain types of ore concentrates for ferrocolumbium (FeCb) necessitated a Source Materials License, i.e., ore concentrates or materials containing 0.05 percent (or greater) by weight of uranium, thorium or a combination of both. Most of this material was a pyrochlore which originated from the Companhia Brasileira de Metalugia e Mineracao's Araxa mine whose ore contained thorium as an accessory mineral above the 0.05 percent limit. The slag which resulted from the aluminothermic production of ferrocolumbium alloys was in a refractory glass/ceramic form containing an average of 1.2 percent thorium. This slag, initially segregated and retained on site, continued to be generated through 1970.

In 1966 Molybdenum Corporation of America (Molycorp, Inc.'s predecessor) initiated several meetings with the Pennsylvania Department of Health's Industrial Wastes Section and AEC personnel in pursuit of an on-site burial permit. A formal application was submitted in 1967. About this time period, Molycorp, Inc.'s consultant, Applied Health Physics, Inc., conducted a series of leaching studies on the FeCb slags (1970). These studies indicated that the radioactive materials were fixed and would not leach into the groundwater in excess of prescribed limits. Nonetheless no action was taken by the state or the AEC on the request for an on-site burial permit.

In June of 1971 an AEC compliance inspection revealed that thorium-bearing slags had been inadvertently buried on-site in violation of the terms and conditions of their license and AEC regulations. It was speculated that the burial occurred during a large scale clean-out of settling basins and regrading of the plant site by a private contractor who was totally unaware of the restrictions on landfilling FeCb slags.

The AEC issued a Notice of Violation and requested remedial action be taken by Molycorp, Inc. to excavate these materials and dispose of them in accordance with AEC regulations and guidance documents. Molycorp, Inc. contracted with Applied Health Physics, Inc. to perform a thorough radiological survey of the site and to provide health physics and waste disposal services necessary to comply with AEC's requests. Levels to 1.2 mR/hr were reported in some areas.

In 1972 Molycorp, Inc. authorized these materials to be dug, sampled, concentrated as much as possible, and shipped in bulk form to an AEC-licensed waste disposal facility operated by Nuclear

Fuel Services, Inc. in West Valley, New York. Disposal was terminated when New York State officials determined the slag was "of insignificant contamination and too large a volume to bury and waste valuable burial area" (Applied Health Physics, 1975). The solution implemented in 1973 was consolidating and placing the thorium slag source material into a 27,700 yd^3 pile covered with vegetation at the south end of the site, which was in compliance with Federal and state regulations as well as Molycorp, Inc.'s Source Material License SMB-744. The 1975 Applied Health Physics, Inc. report and analysis of activity by gamma spectrometry indicated that the average concentration of Th-232 in the slag contained in the pile was 1,250 pCi/g, with exposures within the 0.2 mR/hr NRC (note in 1974 AEC was reorganized to the NRC and ERDA-Energy Research and Development Authority) maximum level allowed at that time.

An NRC contractor, Oak Ridge Associated Universities, conducted a radiological survey of the site in 1985, which identified elevated (twice background or greater) levels of thorium in the dikes which separated the surface impoundments, and indicated the potential of subsurface thoriated slags in the western portion of the site. Figure 2-7 shows the areas on-site found to have elevated contact radiation levels.

In 1990, RSA, Inc. conducted a sub-surface survey for Molycorp, Inc. to characterize the thorium contamination across the western portion of the site (i.e., the impoundment area), and the area immediately to the north, west, and northwest. Thirty-two holes were drilled on the site and radiation measurements were logged at every six inches of depth from the surface down to bedrock, both above and below the water table. Radiation levels were also logged in monitoring wells previously drilled on the site. In addition to the subsurface measurements, RSA, Inc. conducted a scintillometer survey of the radiation exposure rates inside the study area. The surface study consisted of approximately 400 measurements of the gamma radiation field at a height of one meter above ground level. Findings revealed that, in general, the subsurface concentrations of thorium were above those in the surface soils in almost every hole drilled. A general pattern was that the underground radiation levels decreased to background at a depth of about ten feet. While a majority of the holes exhibited concentrations of greater than 0.01 percent thorium, in only a few holes did the thorium content exceed an average of 0.05 percent thorium at some point below the surface of the ground (Wrenn, Appendix I, 1990, page 6).

In October 1992, Molycorp, Inc.'s license (SMB 1393) was renewed. This license renewal included an amendment incorporating a schedule for decommissioning the site. In November 1992, Molycorp, Inc. submitted a Site Characterization Plan (SCP) to the NRC for approval.

In addition to the Source Materials License, Molycorp, Inc. obtained the following permits that covered its operations:

Air Quality - Roasting Furnace (1970); Roasting Furnace/Acid Plant (1982-1991); Ore Dryer/Tube Furnace (1970-1991); Oxide Dryer/Lead Leach (1984-1986); Ferromolybdenum/ Aluminothermic Process (1970-1991); Crushing/Screening System (1970 to present); Temporary Vanadium (1987) and Temporary Nickel (1988).

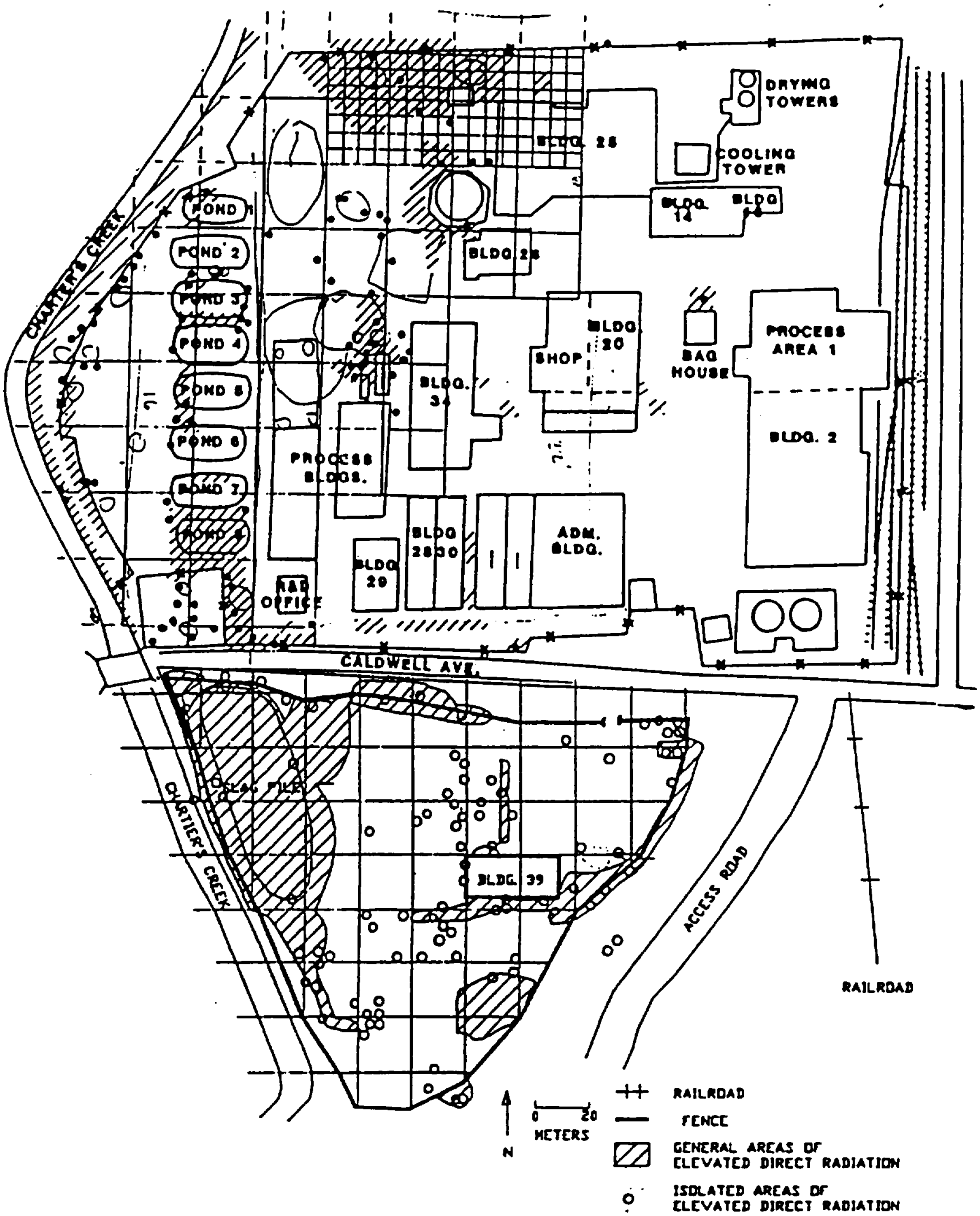


Figure 2-7 Active Plant Site and South Property with Locations of Elevated Contact Radiation Levels, 1985

Source: Oak Ridge Associated Universities, Radiological Survey of Molybdenum Corporation of America, Washington, PA 1985.

Water Quality - National Pollution Discharge Elimination System (NPDES) permit from the 1970's to present; Publicly Owned Treatment Works (POTW) Industrial Pretreatment Program permit from 1991 to present.

Solid Waste - Permits for RCRA Part A 1981 (accepted); RCRA Part B for ponds 1985 (rejected) and a general permit for above ground storage tanks (1990-95).

Landfill - Ferromolybdenum slag - area closed per PADER Approved Closure Plan 1994.

- *Summary of Site Monitoring Records*

Extensive data exists from previous groundwater and surface water on-site sampling from the last 12 years. This information could be reviewed if trends warrant further evaluation, based upon currently collected data (see Section 2.3, Contamination Overview). Additionally, records exist from various solid waste, water quality, and NRC inspections.

2.2 GENERAL PHYSICAL AND DEMOGRAPHIC SETTING

This section summarizes the general physical setting of the site as well as its proximity to individuals who could be potentially affected by any existing thorium slag or decommissioning activities.

2.2.1 Physical Site Characteristics

The site is situated in Canton Township, Washington County, southwest of Pittsburgh. It is part of the Kanawha section of the Appalachian Plateaus Province. The site area topography consists of relatively flat-topped ridges and hill tops with steep-sided valleys resulting from erosion by streams. The site consists of fill material overlying the Chartiers Creek alluvial floodplain and is situated along the east bank of Chartiers Creek, that flows northward. Ground elevations range from 1,010 to 1,045 ft-msl and slope towards the creek. Vegetation cover in the vicinity of the site is divided primarily into two types: forest cover and crops/pasture cover.

The Molycorp, Inc. facility is located in the humid continental climatic region. This region experiences distinct seasons with seasonal variations slightly moderated by the nearness of the Great Lakes and the Atlantic seaboard. Total annual precipitation of Washington County averages 38 inches, most of which occurs in April through September. Average monthly temperatures range from 30°F to 69°F.

The site is situated along the east bank of Chartiers Creek. On the site, eight water holding/recirculation impoundments were constructed as part of the facility containment system. The distance from the surface impoundments to Chartiers Creek varies from 60 to 170 feet. The site contains predominantly fill material which overlies Chartiers Creek alluvium, which overlies claystone and other sedimentary strata of Pennsylvanian and Permian ages. Site ground surface is partially covered with asphalt and/or concrete. The two water bearing zones at the site are fill and alluvium (clay, sandy clay, and clayey sand with gravel). Groundwater within the underlying alluvium of the site ranges from 8 to 15 ft-bgs. Groundwater sample analytical results from 1991 showed that molybdenum concentrations (dissolved) ranged from less than 5.0 to 1,500 mg/l.

2.2.2 General Information on Exposed Populations

The U.S. Nuclear Regulatory Commission has prepared a guidance document for the preparation of site characterization reports for decommissioning sites. The July 1992 Draft *Branch Technical Position on Site Characterization for Decommissioning Sites* (updated November 1994) was issued by the Decommissioning and Regulatory Issues Branch of the Division of Low-Level Waste Management and Decommissioning of the NRC's Office of Nuclear Material Safety and Safeguards. This guidance document establishes the need for an assessment of the potentially exposed population and, specifically, requests that information be provided about the location and characteristics of any subgroups of special concern to the particular site characterization report. This section presents a description of the general distribution and number of people in the area, the current land uses encountered in a 5 km radius, the anticipated land uses on and adjacent to the site, and a summary of existing subgroups and their location.

2.2.2.1 General Distribution and Number of People

Although population surrounding the site can be found in all three of the municipalities close to the site, it is concentrated in the City of Washington, located east of the Molycorp, Inc. facility, as evident on the Washington West topographic map and aerial photograph. The U.S. Bureau of the Census population reported for the area municipalities between 1960 and 1990 is shown in Table 2-1. It indicates that the City of Washington population showed a declining trend, while North Franklin and Canton Townships population increased slightly. The site, therefore, was not located in an area of significant growth during this period. The average median age in 1990 for these three jurisdictions was 36 years (U.S. Census, 1990) (see Section 4.7 for a detailed population analysis).

Table 2-1
Trends In Area Population Growth

Municipality	1960	1970	1980	1990	2015*	Area (mi^2)
Canton Township	7,820	8,869	10,311	9,256	10,751	14.9
North Franklin Township	3,882	4,444	4,648	4,997	5,768	7.3
City of Washington	23,545	19,827	18,363	15,864	15,827	3.0
Washington County	271,271	210,876	217,074	204,584	228,837	864

Source: U.S. Bureau of the Census, 1960-1990
*Southwestern PA Regional Planning Commission, Cycle V Forecasts, 1994.

The Southwestern Pennsylvania Regional Planning Commission (SPRPC) projects a 15 percent population increase for both Canton Township and North Franklin Township by the year 2015, and a further population decline for the City of Washington. Washington County's household population (excluding group quarters) is also expected to increase by 11 percent by the year 2015 (SPRPC, 1994).

2.2.2.2 Current Land Uses within a 5 km Radius of the Facility

The land uses in a 5 km radius of the Molycorp, Inc. facility cover portions of Canton, South Strabane, Buffalo, Chartiers, and North and South Franklin Townships, as well as the City of Washington and East Washington Borough. The land uses in this large area are generalized and presented on Figure 2-8. The land use categories consist of residential, commercial, industrial, agricultural, and other, which includes open space, forest, institutional, transportation, and vacant land uses. The map was derived utilizing the Southwestern Pennsylvania Regional Planning Commission LANDSAT (digital land cover) data by satellite taken in 1990. Since resolution was a minimum of 10-polygon acres and the fact that mixed uses (residential/commercial/industrial) were sometimes automatically combined, some of the land use areas were checked or updated somewhat during the July 1994 site verification visit.

As Figure 2-8 shows, land use patterns, primarily residential, are very dense in and around the City of Washington. Surrounding this urban area the general use changes to agricultural and vacant/wooded. Large heavy and light industrial centers can be found in Canton Township, particularly along Chartiers Creek and major roadways such as Routes 40 and 70.

Although other land uses, including schools, churches, retail businesses, and parks, are present in most communities, they are identified more accurately on smaller scale maps, such as those showing land uses in a 2 km radius (see Section 4.6.1, Existing Land Uses in the 2 km Radius).

2.2.2.3 Potential Land Use of the Site and Surroundings

It is anticipated that the project site will most likely be used for some heavy industrial purpose, the specifics of which have not been established at this time. Land adjacent to the site (see the aerial photograph, Figure 4-27 in Section 4.6) will generally continue in industrial and residential land uses.

2.2.2.4 Subgroups and their Locations

An important element in the NRC site characterization program for decommissioning sites is the identification and analysis of the potential effect on surrounding populations. In addition to the general populations identified earlier, population subgroups, or sensitive populations, also need to be considered.

LEGEND

- Residential
- Industrial
- Commercial
- Agriculture
- Other
- Project Site

950130021-02

SOURCE : SW PA REGIONAL PLANNING COMMISSION
LAND USE MAP DERIVED FROM LANDSAT 1990

0 1000 2000 3000 4000 5000
SCALE IN FEET

PENNSYLVANIA
QUADRANGLE LOCATION

MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE 2-8
5 KM GENERALIZED LAND USE

FOSTER WHEELER ENVIRONMENTAL CORPORATION

The locations of the particular subgroups of interest to the Molycorp, Inc. project include: schools, nursing homes, day care centers, group quarters, hospitals, clinics, and prisons. In the 2 km radius (referred to in this report as the "study area"), an in-depth inventory of these subgroups, based on available data, agency meetings, and field verification, resulted in the identification of the following sensitive population locations: 4 schools, 4 nursing homes, 9 day care centers, 3 group quarters and 1 clinic. For more information about, and mapping of, the subgroups, their locations, and the subgroup age levels in the 2 km radius, refer to Section 4.7.2, Sensitive Populations.

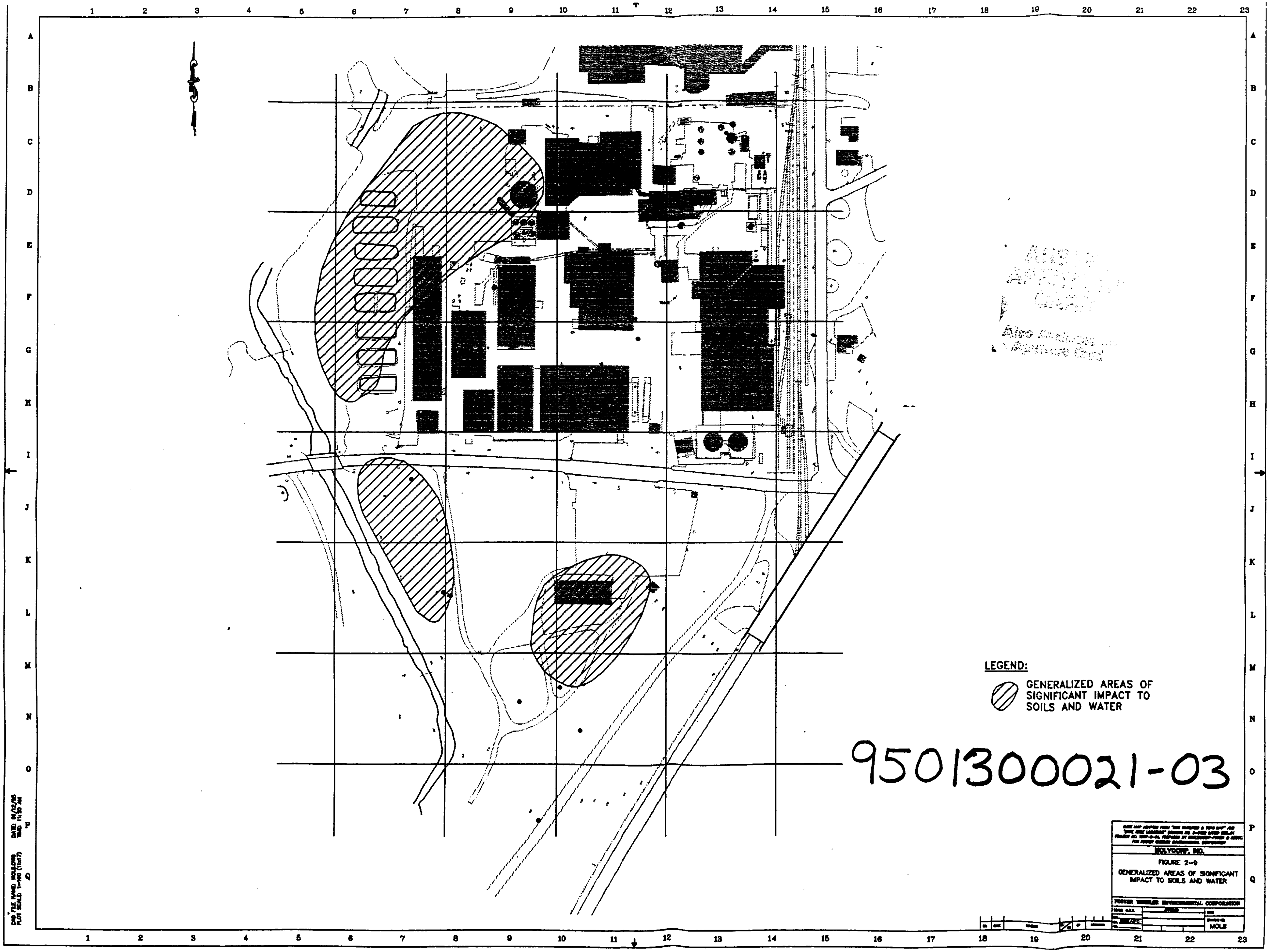
2.3 CONTAMINATION OVERVIEW

The Molycorp, Inc. site was investigated during the spring, summer and fall of 1994 and samples were taken from surface water, groundwater, and soils to assess the level and type of contamination that may exist. The level of effort involved soil sampling from 418 borings (12,499 soil samples) and on-site analysis for a significant portion for thorium-232 by NaI-based gamma spectroscopy using a downhole probe and/or sample analysis. In addition, selected soil samples were analyzed for a select portion of the Total Analyte List (TAL) metals and radionuclides at IEA Labs, Cary, North Carolina. Several stream sediment samples from Chartiers Creek and soil samples were analyzed for radionuclides and geotechnical parameters, respectively. Two rounds of approximately 30 groundwater samples and four Chartiers Creek water samples were analyzed for TAL metals and radionuclides.

Radium (Ra-228) was detected in measurable quantities, although considerably below the prevailing NRC standards. Thorium-232, the radionuclide of primary concern, does not exceed 5 pCi/l in either ground or surface water. Figure 2-9 shows the locations of potential concentrations of contamination, based on the analytical program to date. Several TAL metals, however, exceed background concentrations.

Molybdenum has concentrations occasionally exceeding 100 mg/l in some wells, especially BR1, the only monitoring well completed in bedrock for Molycorp, Inc.'s site characterization. Molybdenum also increases slightly in Chartiers Creek from an upstream staff gauge at CR1 to a downstream staff gauge at CR4. Some TOX (total organic halogens) values in wells exceed quantification levels by a small concentration. Cadmium and selenium were detected in some wells.

Analyses of soils by both downhole and sample specific gamma spectroscopy indicated elevated Thorium-232 concentrations exceeding 50 pCi/g in areas generally in the top several feet of soil. These areas include the impound area, the northwest portion of the site around the thickener, the thorium pile and the center of Unit 2 (south of Caldwell Avenue).


LEGEND:
GENERALIZED AREAS OF SIGNIFICANT IMPACT TO SOILS AND WATER
950130021-03
MOLYCORP, INC.
FIGURE 2-9
GENERALIZED AREAS OF SIGNIFICANT IMPACT TO SOILS AND WATER
FOSTER WHEELER ENVIRONMENTAL CORPORATION

3.0 DOSE ASSESSMENT

This section presents an evaluation of the radiological consequences potentially resulting from exposure to thoriated slag/soil at the site. Radiological doses to a maximally exposed hypothetical individual living at or near the boundary of the site are estimated at selected times for up to 500 years from both direct and indirect exposure pathways using the RESRAD dose assessment code. Estimates of radon ingrowth from the decay of thorium-232 were also made for this same 500-year period.

The results of this analysis indicate which of the pathways is significant, provide an assessment of the radiological consequences if no action is taken to remediate the site, and establish a baseline for the determination of exposure scenarios, cleanup criteria, and soil guidelines for decontamination and decommissioning (D&D) of the site.

There exists low levels of radioactive contamination at various locations on this site, including surface impoundments, buildings in the northeastern and central sectors of the site, and slag piles in the southwestern and southeastern sections. This section of the report specifically addresses the radiological impacts of the totality of site contamination (i.e., spread throughout the entire 17 acre site area for conservatism) as it presently exists.

Radiological impacts were estimated using the RESRAD code, developed by the US Department of Energy (DOE) for assessing the impacts of residual radioactive soil contamination following decontamination of sites in their Formerly Utilized Sites Remedial Action Program (FUSRAP). The volume and concentration of contaminated materials were estimated from current and prior site characterization data (see Section 5.2). Other site specific and locale specific data were obtained from various Molycorp documents and permits, and various departments of the Commonwealth of Pennsylvania.

A detailed description of RESRAD input values and their sources is provided in Appendix O. Preliminary RESRAD runs were performed to estimate the maximum exposure from contaminated soils and sediment on the site. These runs were made with the waste in an unstabilized condition for both the resident farmer and industrial scenarios. The only difference in the runs is the suppression of certain exposure pathways for the industrial scenario. In short, the site is modeled as a 17 acre area having contaminated material which extends to a depth of approximately 2 feet. The assumption of surficial contamination is conservative and for modeling purposes. It does not reflect the material buried at different depths as reported in Section 5.2. Various scoping runs were performed to determine the impact of varying the depth of contaminated material, the concentration, or the volume of contaminated material on the total effective dose.

The calculated maximum total exposure rate is 917 mrem/yr for the resident farmer scenario and occurs at year 42. This result takes into account the ingrowth and decay of daughter products. For the industrial scenario, the maximum total exposure rate is 695 mrem/yr and occurs at year 53.

The ingrowth of radon was also calculated from the decay of thorium-232 out to 500 years. The results indicate that the contribution to the total effective dose equivalent by radon and its progeny for the most conservative scenario is less than three percent.

3.1 DOSE ASSESSMENT METHODS

3.1.1 Source Term Development

The first step in performing a radiological dose assessment was to develop a source term. This involved estimating the type of contamination, its horizontal and vertical extent, and its concentration in the contaminated media. These estimates were made from site characterization data as reported in Section 5.2.

The site area was surveyed on a grid system and the results were used to develop both surface and subsurface contamination data. These data were reviewed to determine the horizontal and vertical extent of soil contamination throughout the site. Details of the surface contamination in selected concentration increments are given in Section 5.2. Similar data are also given for various volumes of contaminated material associated with a specified concentration at different subsurface depths. These figures indicate that a portion of the soil contamination at the site is located at the surface and upper 2 feet extending in bands to 10 feet.

For the purposes of conservatively estimating the doses in the scenarios modeled, it was assumed that the total accumulated volume of contaminated soil associated with concentrations above 30 pCi/gm would be the volume used in the subject analysis. This volume was estimated to be approximately 1,200,000 ft^3, extending from the surface to a depth of about 2 feet.

3.1.2 RESRAD

The RESRAD code is one of several computer codes developed for DOE's FUSRAP program to model various exposure scenarios for radioactive soil contamination remaining after remediation or decontamination is completed. The code is specifically designed to model low-level contamination disposed of on site. In the present analysis, the code is used to determine the risk posed by the site to surrounding populations and environs if allowed to remain in an unremediated state.

The scenario upon which the RESRAD model is based is that of the resident farmer intruder. At some unspecified time in the future (after the site is abandoned), the intruder moves onto the site and constructs a house and self-sufficient farm. The family grows food, raises meat and produces dairy products on the site. A water well is constructed at the downgradient edge of the site and the family obtains its drinking water from the well.

Permanent residents, rather than individuals exposed by activities not associated with residential living, have been chosen as the primary critical population group because the exposure for permanent residents is more likely to be long term and will generally involve exposure by more pathways. Construction workers are the nonresident group most likely to receive significant exposure. The exposure of construction workers or scavengers is unlikely to last longer than a few months and will generally be limited to working hours. The lifetime exposure for the permanent onsite resident thus brackets the totality of likely scenarios and exposures. The basic dose limit for members of the general public from all sources of radiation, except natural background and radiation received as a patient, is 100 mrem/year (10 CFR 20). Exposure of workers in onsite industrial or commercial buildings may also occur; however, this exposure will in most cases be less than that of residents due to the fact that the exposure will be limited to working hours and will not include contributions from ingestion of foods grown on site. Therein lies the rationale for the utilization of the resident farmer and industrial scenarios in the present analysis.

RESRAD calculates total effective dose equivalent (hereinafter referred to as dose) and effective dose equivalent from various pathways to the individual that inhabits the farm. Dose calculations are made for various times, with appropriate corrections for the ingrowth and decay of uranium and thorium and their progeny. The pathways analyzed are as follows:

- Direct external radiation from exposure to source
- Inhalation of radioactive dusts (without radon)
- Ingestion of
    - plant foods
    - meat
    - milk
    - aquatic foods
    - drinking water
    - soil
- Radon

An exposure pathway diagram is provided as Figure 3-1.

The external exposure pathway is a result of direct exposure to the radioactive material. Shielding factors for cover materials are used to attenuate the direct radiation. The shielding factor is corrected over time to account for the erosion of the cover material. RESRAD also calculates the ingrowth and decay of daughter products, so that exposure from progeny is accounted for in the yearly dose equivalent calculations.

The dose equivalent due to the inhalation of airborne radioactive particulate material arises from the dusts that are created when the source is exposed. The inhalation pathway calculations are performed in two segments. The first segment links the source with the production of airborne radioactive dusts over the contaminated zone. The second segment calculates a dose equivalent to individuals from the inhalation of the airborne dusts over the contaminated area.

The ingestion pathway is categorized into three principal pathway segments, including the food pathway, the water pathway and the soil pathway. The radiation dose from ingestion and inhalation of radionuclides has been systematically evaluated by the ICRP (Publication 30; ICRP

EXPOSURE PATHWAY DIAGRAM

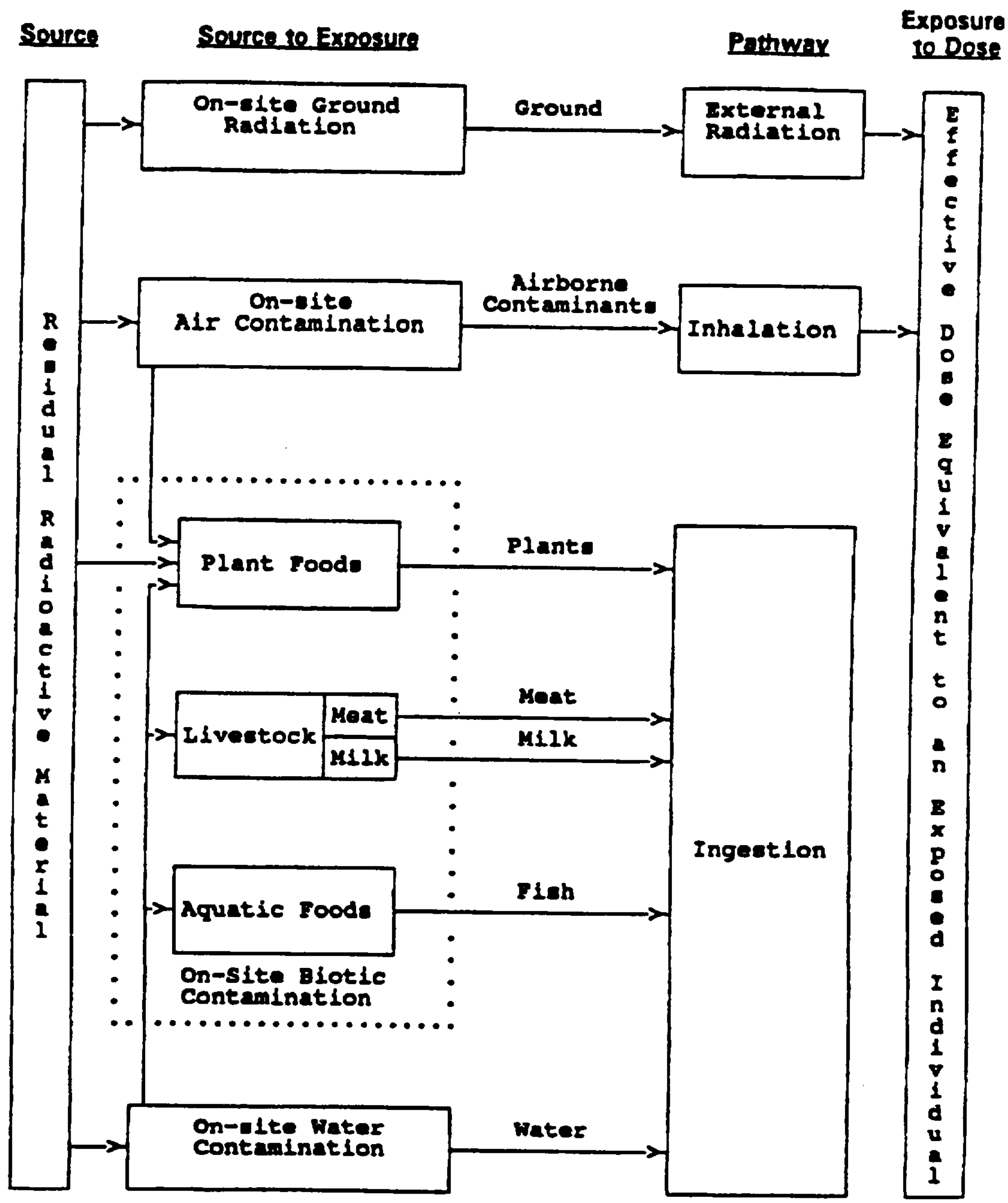


FIGURE 3-1

1979-1982). Dose equivalence in organs or tissues of the body are calculated with models that (1) describe the entrance of materials into the body (respiratory and gastrointestinal tract) and the deposition and subsequent retention of the radionuclides in body organs (referred to as metabolic models) and (2) estimate the energy deposition in tissues of the body.

The radon exposure pathway is included in RESRAD because radon and its decay products can accumulate to high concentrations in homes located on radium-contaminated sites. Radon-222, for example, and its decay products are usually singled out as the most important sources of radiation exposure to the general public from naturally occurring radioactivity. The typical estimated annual dose equivalent to the bronchial epithelium from inhaled alpha-emitted radionuclides approaches 2,500 mrem/yr, due almost entirely to the short-lived radon progeny. This translates to an effective dose equivalent of about 200 mrem/yr.

Calculation of the effective dose equivalents (EDEs) from airborne radon and radon decay products requires an estimate of (1) the radon exhalation from the ground surface, (2) the radon concentration in the air that results from this flux, and (3) the airborne concentration of radon decay products associated with a specific concentration. At a radium contaminated site, the radon release rate varies with the local distribution of radium, soil type, moisture content, and meteorological factors. Covering the contaminated area with soil and clay during remedial action or with a concrete floor when a house is being constructed can substantially reduce the radon emission rate. This is particularly significant for the radon of concern on this site (radon-220).

3.2 POTENTIALLY EXPOSED POPULATIONS

In determining if a site should be released for unrestricted use, the dose assessment performed for the Site Characterization Report (SCR) requires information on the physical characteristics of the site as well as the potentially exposed populations. While Section 4.0 of this report presents these data in greater detail, this section specifically identifies the demographic parameters utilized in dose assessment and highlights the residences and sensitive population groups that exist near the site.

3.2.1 Demographic Parameters

Demographic parameters are utilized in the dose assessment process for estimating the total external and internal individual dose from all exposure pathways including ingestion, inhalation, radon and direct exposure. With respect to demographics, the potentially exposed individuals and critical population groups must be analyzed. The parameters involved with their identification consist of the following:

- Residences located up to 1/2 km from the site
- Population and age group distribution adjacent to the site, and extended to the 1/2 km and 2 km radii

- Sensitive population groups (schools, nursing homes, day care centers, group quarters, hospitals, clinics, prisons)

- Land use adjacent to the site and extending to 2 km

- Future land use (zoning) at the site and up to 1/2 km from the site and also population projections

To determine ingestion by the potentially exposed population, additional parameters were identified relating to consumption of food and liquids produced and/or available around the site region. They include the following:

- Fruits, vegetables and grain
- Leafy vegetables
- Milk cows
- Meat and poultry
- Fish and other seafood
- Soil
- Drinking water

3.2.2 Residence Locations

In the dose assessment a residence is defined as a house, dwelling, or living unit inhabited by one or more persons on a permanent basis. The number of residences within a 1/2 km radius of the Molycorp, Inc. facility has been determined to be 178, with a total residential population of 470 persons. The detailed methodology as well as the residence locations analysis for the 1/2 km and 2 km radii can be found in Sections 4.7.3 and 4.7.1, respectively.

3.2.3 Sensitive Populations

It is important that the dose assessment identifies the sensitive population groups, particularly those immediately surrounding the site, since they could be directly impacted by any health hazard posed by Molycorp, Inc.'s decommissioning activities. Sensitive populations are largely those population groups that are young (16 years or younger) and the elderly (65 years and older) who are gathered together for educational, day care, or nursing care purposes. The facilities they utilize were identified in Section 3.2.1. For the dose assessment, the facilities' locations, usage and age groups were identified for the 1/2 km and 2 km radii. In the 1/2 km radius from the site there is only one location of a sensitive population group, a small family day care center on Scott Avenue (see Section 4.7.3).

3.3 SCENARIOS MODELED

3.3.1 No Action Alternative

Initial RESRAD runs were made with the waste in an unstabilized condition using mostly default input parameters. This was done merely as a scoping exercise and to determine what the magnitude of the expected dose would be. These runs were repeated (with the waste in an unstabilized condition) using site specific data to calculate exposures for a no action alternative. Proceeding in this manner results in the realization of the maximum doses from direct exposure, inhaled dusts, ingestion of food and water, and the ingrowth and decay of the daughter products of the principle radionuclide of interest.

The first run was made utilizing the resident farmer scenario with all of the unstabilized waste volume corresponding to a concentration greater than 30 pCi/g evenly distributed in the top 2 feet of soil covering the entire site. While it is recognized that this scenario is not likely, it was selected to establish a conservative or bounding scenario for this and any subsequent analysis.

Results of the first run indicate that most of the exposure would be due to direct exposure to the radioactive material and ingestion from plants grown on the site. The maximum exposures are realized after the contaminated material has been in place for about 42 years.

The resultant exposure rates then decrease with time as the layer of contamination is eroded away and removed by other natural processes. This process is completed in 300 to 500 years, during which time the contamination is dispersed into the environment.

The highest dose, which occurs in year 42, is summarized by its significant pathways in the following table:

Pathway	Dose Rate	Percent
Ground (direct)	596.40 mrem/yr	65.0
Inhalation	70.55 mrem/yr	7.7
Plant (ingestion)	205.80 mrem/yr	22.4
Meat (ingestion)	10.30 mrem/yr	1.1
Milk (ingestion)	8.05 mrem/yr	0.9
Soil (ingestion)	3.77 mrem/yr	0.4
Radon	22.83 mrem/yr	2.5
TOTAL	917.70 mrem/yr	100.0

The second RESRAD run modeled the total volume of unstabilized waste previously described using the industrial scenario. This run was made because industrial utilization of this site is the most plausible scenario, given its past history and foreseeable future use.

It is interesting to note that the water pathway does not impact either calculation. This is a strong indication and confirmation that there is no groundwater contamination on the site. The highest exposures from the industrial scenario are due to direct exposure and inhalation from dust. Intuitively, one would expect this result, given that for this scenario there is no ingestion of foodstuffs, nor is water drawn from an intruding well that exists on the site.

The maximum dose for this scenario is 695 mrem/yr and occurs at year 53. More than 96 percent of the contribution to the maximum dose is attributable to direct gamma (86%) and inhalation (10.2 %).

The dose for this scenario is summarized by its significant pathways in the following table:

Pathway	Industrial Scenario Dose Rate	Percent
Ground (direct)	597.80 mrem/yr	86.0
Inhalation	70.59 mrem/yr	10.2
Plant (ingestion)	0.00 mrem/yr	0.0
Meat (ingestion)	0.00 mrem/yr	0.0
Milk (ingestion)	0.00 mrem/yr	0.0
Soil (ingestion)	3.78 mrem/yr	0.5
Radon	22.92 mrem/yr	3.3
TOTAL	695.09 mrem/yr	100.0

3.3.1.1 Radon

Ordinarily radon-222 and its daughters pose a greater health hazard than radon-220 and its daughters, primarily because the much shorter half-life of radon-220 makes decay more likely prior to release into the atmosphere (Faw and Shultis, 1993). Globally, the mean annual effective dose equivalent due to radon-220 daughters is estimated to be about 20 mrem.

RESRAD calculations performed for both the resident farmer and industrial scenarios bear out the above observations. In fact, even in the most conservative case the total contribution to the effective dose by radon-220 and its daughters (23 mrem/yr) is about 2.5 percent of the total dose and about equal to the contribution from natural background.

Results for the industrial scenario are similar (22.92 mrem/yr) lending additional credence to the assertion that radon-220 is not a health hazard at the site, even in its present unremediated state.

3.4 CONCLUSIONS

The no action alternative presents the most conservative conditions for the Molycorp site. Two critical populations have been considered (1) the resident farmer, and (2) the industrial worker. Results using this alternative clearly show that leaving the waste in its present untreated, unstabilized condition in a layer on top of the ground gives a direct exposure and an inhalation exposure that contribute to a total effective dose that exceeds current regulatory standards.

Any proposed method of stabilizing the contamination at the site will have some impact on the final radiological conditions and doses. Thus, one conclusion is that the site may have to be remediated and alternatives to the no action case thoroughly examined in the D&D Plan. Next, an applicable alternative must be selected and implemented in order to mitigate any potential health hazard(s) posed by existing site conditions.

Included in the thorium-232 decay chain is the radioactive gas thoron (radon-220). The possibility of radon emissions from site contamination is a legitimate albeit minor concern. While it is true that some emissions will take place, the associated dose is such that thoron gas from the site (given the present unstabilized condition of the waste) poses no health risk to the critical population of concern nor to the surroundings.

Finally, the present analysis reaffirms the sampling analysis which indicated that the groundwater pathway was not contaminated and initial intuitive assumptions which stated that the most significant contributors to the total effective dose equivalent were most likely due to direct gamma and the inhalation pathway.

SECTION 4.0

4.0 PHYSICAL AND DEMOGRAPHIC SITE CHARACTERISTICS

This section provides an overview of the physical and demographic site characteristics of the region and how they relate to the Molycorp, Inc. project site (the site). The physical site characteristics that are included, along with respective mapping, are surface features and vegetation, meteorology and climatology, surface water hydrology, geology and hydrogeology.

The demographic characteristics are presented in terms of local and regional land use and demography.

4.1 SURFACE FEATURES AND VEGETATION

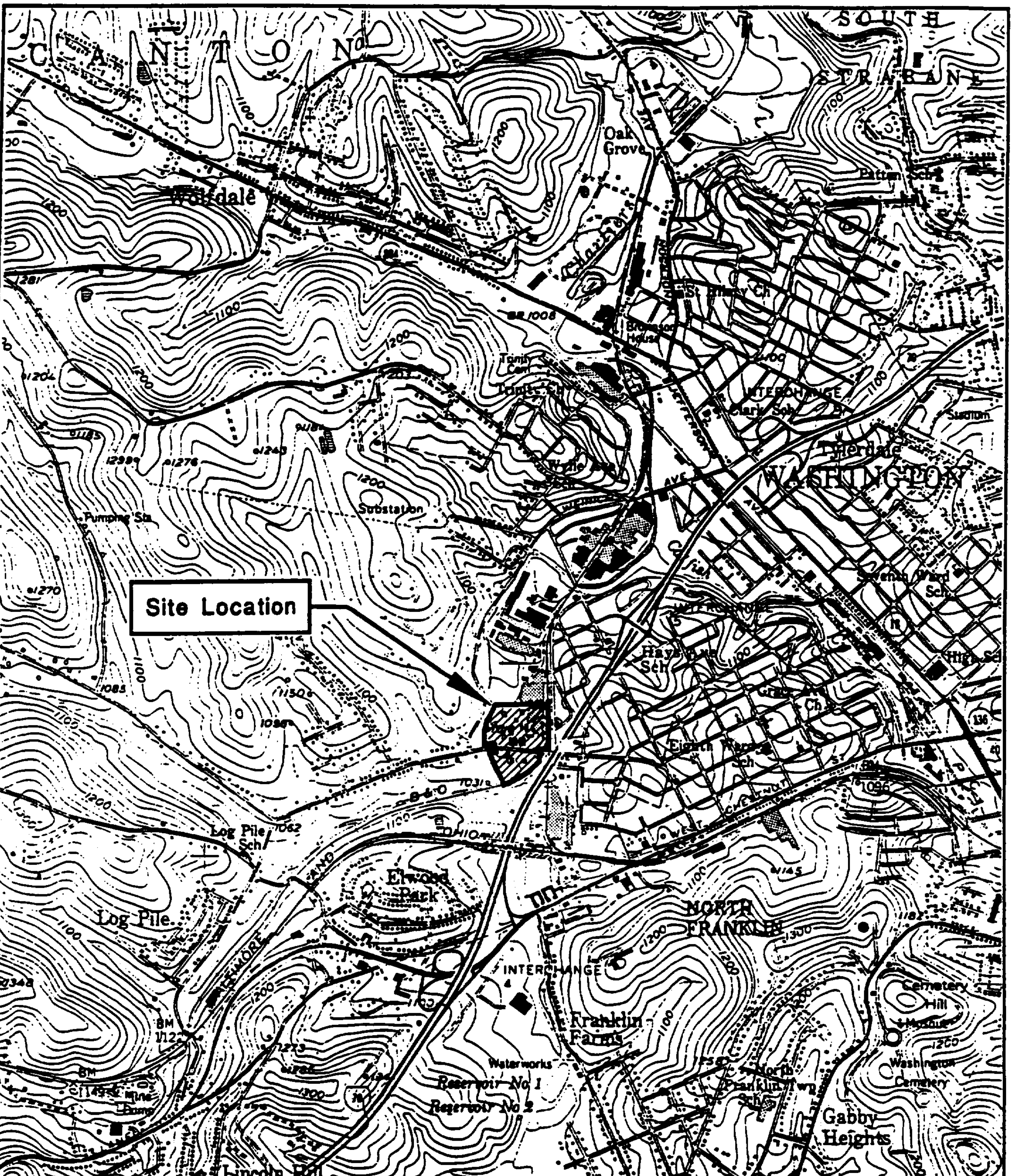
The site is situated in Canton Township, Washington County, which is located south-southwest of Pittsburgh, the major industrial and population center of the region. The regional topography consists of relatively flat-topped ridges and hilltops with steep-sided valleys resulting from erosion by streams. Topographic relief typically exceeds 100 feet within 1,000 feet of Chartiers Creek.

Figure 4-1 presents the site location and Figure 4-2 presents a map of the site.

Vegetation cover in the region is divided primarily into two types. The first is oak-hickory and aspen-birch within the well drained soils that occur on moderate to steeply sloping hills throughout the region. The second type is elm-ash-red maple and maple-beech-birch forest associations that occur in lowland areas that border streams and rivers in the region. Forest cover throughout Washington and Greene Counties comprises approximately 44 percent of the land area, while crops and pasture cover (agricultural uses) comprise about 38 percent. The majority of the remaining portions (18 percent) are unvegetated to sparsely vegetated urban areas (Seibert et al., 1983).

The majority of the agricultural land in the region is used for permanent pasture (approximately 53 percent), while row crops comprise approximately five percent and orchards make up less than one percent. The remaining portions of the agricultural land (41 percent) are used in other farming activities. Corn is the primary row crop, with grain, sorghum, potatoes and similar crops also grown in smaller amounts. Wheat and oats are the main grain crops grown, while apples are the main orchard crop in the region.

Vegetation cover on the active site is sparse. The site consists of fill material overlying the Chartiers Creek alluvial floodplain. East of the site across Greene Street, the topography slopes upward across Interstate I-70 (see Appendix B, Surveyor's Topographic Map). The site is situated along the east bank of Chartiers Creek at ground elevations ranging from 1,010 to 1,045 ft-msl and sloping towards the creek. Chartiers Creek is at an elevation of approximately 1,010 ft-msl (Remcor, Inc., 1991).



SOURCE: U.S.G.S. 7.5 MINUTE TOPOGRAPHIC MAP
WASHINGTON WEST, PA QUADRANGLE

0 2000 4000

SCALE IN FEET

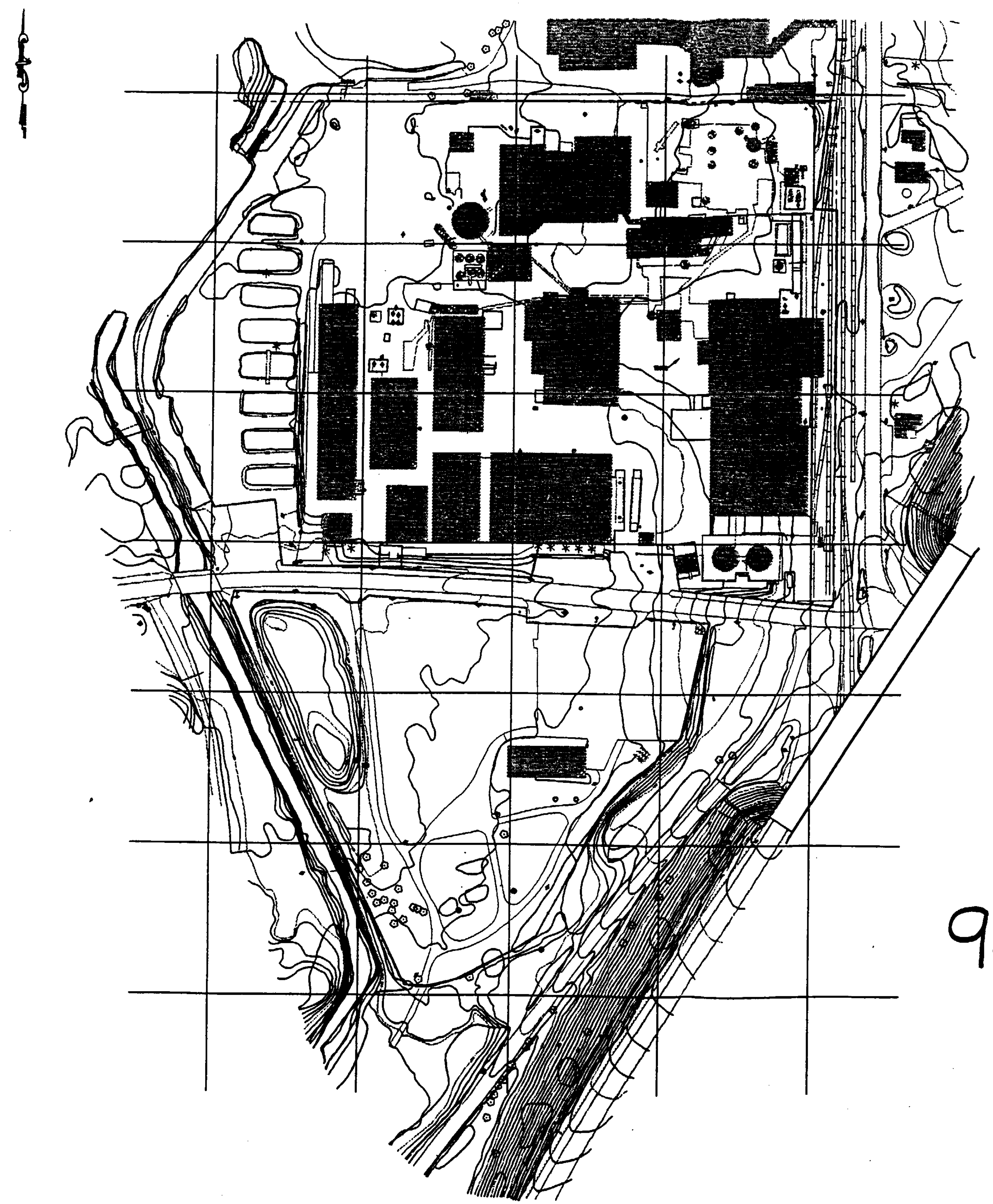
QUADRANGLE LOCATION

MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE 4-1

SITE LOCATION

FOSTER WHEELER ENVIRONMENTAL CORPORATION



9501300021-04

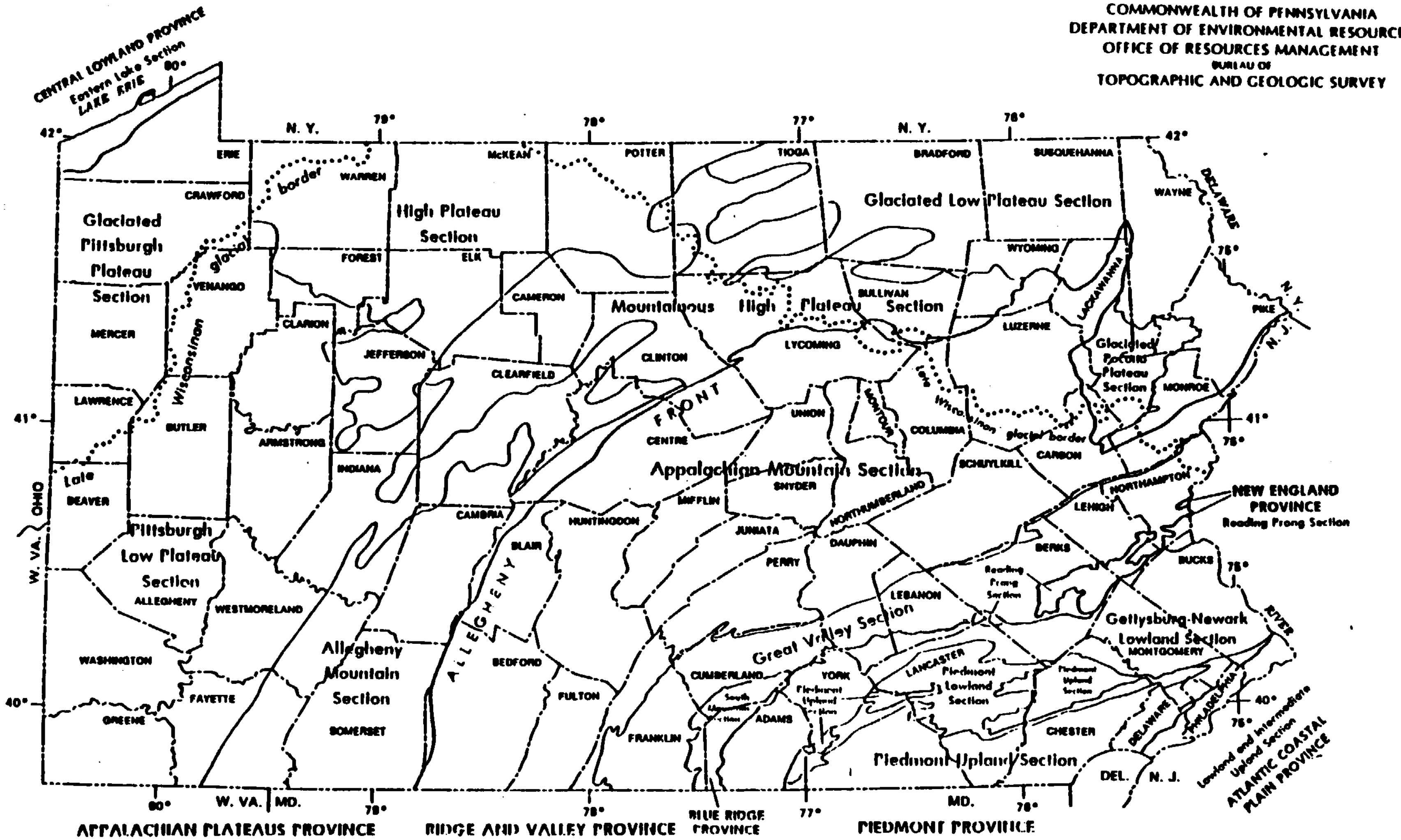
MOLYCORP, INC.

FIGURE 4-2

SITE MAP

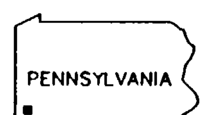
FOSTER WHEELER ENVIRONMENTAL CORPORATION

CAD FILE NAME: MLYTA1.DWG DATE: 1/19/95
PLOT SCALE: 1=60 TIME: 3:17 PM



From Berg, T. M., and others (1989), *Physiographic provinces of Pennsylvania*, Pennsylvania Geological Survey, 4th ser., Map 13, 2nd ed., © 1989 by Commonwealth of Pennsylvania.

SCALE 1:2,000,000



KEY

MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE 4-3

PHYSIOGRAPHIC PROVINCES OF PENNSYLVANIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

4.2 METEOROLOGY AND CLIMATOLOGY

The Molycorp, Inc., Washington facility is located in the humid continental climatic region. This region experiences distinct seasons with temperature, cloud cover and precipitation affected by the Great Lakes.

The summer season is generally mild but frequently humid because of invasions of tropical air from the Gulf of Mexico. The winter months are brisk with occasional periods of extreme cold. Cloud cover is persistent during the winter because of the frequent passage of moisture-laden air masses from the Great Lakes and the region's location in the path of west-to-east migratory storms. However, lake-effect precipitation is not significant. Spring and fall are transitional seasons with moderate-to-cool temperatures. Rapid and wide variations in day-to-day weather conditions are common during the spring and fall (U.S. DOE, 1983).

Total annual precipitation in Washington County averages 38 inches, most of which occurs in April through September. Average seasonal snowfall is 31 inches. Average monthly temperatures range from 30°F to 69°F (Remcor, Inc., 1991 and Seibert et al., 1983).

4.3 GEOLOGY

The Washington County area is part of the Pittsburgh Low Plateau Section of the Appalachian Plateaus Physiographic Province. This section consists of flat-lying to gently folded sedimentary stratigraphy which has been regionally elevated and dissected by dendritic stream erosion. The site is located predominantly on fill material which overlies Chartiers Creek alluvium which overlies claystone and other sedimentary strata of Pennsylvanian and Permian ages. Figure 4-3 presents the physiographic provinces of Pennsylvania.

4.3.1 Regional Geology

Figure 4-4 presents the bedrock geologic structure of the region. This region lies within the Appalachian Plateaus Physiographic Province of the Mountain system and consists of flat-lying sedimentary units varying between sandstone, shale, limestone, claystone and conglomerate. These units contain rich coal seams and numerous natural gas and oil deposits, which represent the major natural resources of the region. Washington County is the leading coal producing county in Pennsylvania (U.S. DOE, 1983).

The Washington County area, along with the adjacent Greene County area, is part of the Pittsburgh Low Plateau section of the Appalachian Plateaus Province. To the east of the site is a mature upland plateau with strong relief, which constitutes the Allegheny Mountain section of the Appalachian Plateaus Province. The Pittsburgh Low Plateau section, in most places, consists of rounded hills and ridges, that are products of the submature dissection of a plain whose character is suggested by the few flat summit areas. North of Washington, Pennsylvania, the interstream crests, or upland remnants, reach an elevation between 1,200 and 1,250 feet above sea level and

SOURCE: FROM COAL RESOURCES OF
WASHINGTON COUNTY, PA. V. SKEMA, PA
1987 MINERAL RESOURCES REPORT NO. 93

MOLYCORP. INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE 4-4
REGIONAL STRUCTURAL GEOLOGY FROM
COAL CROP LINES
AND STRUCTURE CONTOURS

FOSTER WHEELER ENVIRONMENTAL CORPORATION

mark a slightly undulating surface. South and west of Washington, to the corner of the state, the ridges become sharp and locally uneven in elevation, although they increase progressively in elevation and attain a maximum of about 1,600 feet in Greene County. This area is also more deeply dissected and less maturely rounded, a relief of 500 to 650 feet being common even in headwater localities (Seibert et al., 1983).

The sedimentary rock formations which crop out in the area range in geologic age from the Middle Conemaugh Formation of Pennsylvanian age in the north to the youngest Permian beds in the Greene Formation in southwestern Greene County. Recent alluvium is in, and adjacent to, streambeds consisting of unconsolidated clay, silt, sand, gravel, and cobbles. Landslide deposits consisting of unconsolidated, slumped, hummocky masses of soil and rock are scattered throughout the two counties. Unconsolidated material of the Carmichaels Formation is on the terraces and valleys of the Monongahela Valley and in southern Greene County. These deposits consist of silts, sands, some varved (finely laminated) clay, quartz pebbles, and hard rounded sandstone boulders which are Pleistocene in age.

In northern Washington County, the rocks in the middle Conemaugh Group of middle Pennsylvanian age consist of shales, Ames limestone, Morgantown and Connellsville sandstones and siltstones, and several thin local coal seams. The Pittsburgh coal separates the Conemaugh and Monongahela groups. It is the thickest coalbed and is the only zone that is continuous over the entire area.

The Pittsburgh Formation in the Monongahela Group consists of the massive Pittsburgh sandstone overlain by limestone, claystone, and siltstone and of the Redstone, Fishpot, and the Sewickley coalbeds. The Uniontown Formation of the Upper Monongahela and Upper Pennsylvanian has the Uniontown coalbed at the base overlain by shale and thick sandstone and by limestone and siltstone.

The Waynesburg coalbed (locally thin to absent north of the site) separates the Pennsylvanian system from the transitional Pennsylvanian and Permian systems. The thick Waynesburg sandstone overlies the coal along with a limestone shale and siltstone which underlie the Waynesburg "A" coalbed. The middle member of the Waynesburg Formation, composed of siltstone, sandstone, some locally thin layers of calcareous shale, and limestone, is overlain by the Waynesburg "B" coalbed. The Little Washington coalbed is at the base of the Upper Waynesburg member. It is overlain by shale and sandstone. The top of this member is comprised of clay and mudstone with ironstone nodules.

The Washington coalbed is at the base of the Lower Permian Washington Formation of the Dunkard Group. Limestone, sandstone with some local cross-bedded sandstone, shale, and siltstone overlie the Washington coal. The Upper Washington "A" coalbed is overlain by shale, siltstone, and sandstone and the Jellytown coal seam. The Greene Formation of the Dunkard Group is the youngest exposed formation and consists of shales, sandy shales and siltstone, calcareous and carbonaceous shale, some cross-bedded fine grained sandstone, claystone, mudstone, and an occasional thin limestone bed. Several thin local coal seams and blossoms are located throughout this section.

The layered rock sequence in the survey area has a slight general slope to the southwest. In addition to the southwest slope, the rock beds of this area have been buckled into a series of long, narrow northeast-southwest trending folds. When contoured on the base of the Pittsburgh coal, a consistent marker of low ridges (anticlines) and troughs (synclines) is formed. Some of the major folds, from west to east, are the West Middletown syncline, Claysville anticline, Finney syncline, Washington anticline, Nineveh syncline, Amity anticline, Waynesburg syncline, Bellinevnon anticline, and Whiteley syncline. The east-west trending Cross Creek syncline is in the northern part of Washington County. North of this syncline are two small domes, the Aunt Clara and Candor domes. South of the Cross Creek syncline is the Gillespie dome and the Westland dome (Seibert et al., 1983). Figure 4-4 presents the geologic structure of the Washington West topographic quadrangle (Skema, 1987) based upon regional coal crop lines. The site is located on the west side of the Washington anticline. The topographic contours depict the dendritic erosional pattern that has been imposed on these structures. The Waynesburg "A" coalbed may have been encountered during installation of bedrock monitoring well BR-1 on site (Table 4-1).

Figures 4-5 and 4-6 present geologic cross-sections in Washington County that are several miles to the east and several miles to the south of the site, respectively. The generally flat-lying stratigraphic conditions with subtle structural folds are demonstrated.

Figure 4-7 presents the bedrock geology in the immediate site area. Figure 4-8 presents a geologic cross-section approximately two miles south of the site. The legend for Figures 4-7 and 4-8 is presented on Figure 4-9. The bedrock stratigraphic column for this quadrangle is presented in detail on three pages on Figure 4-10.

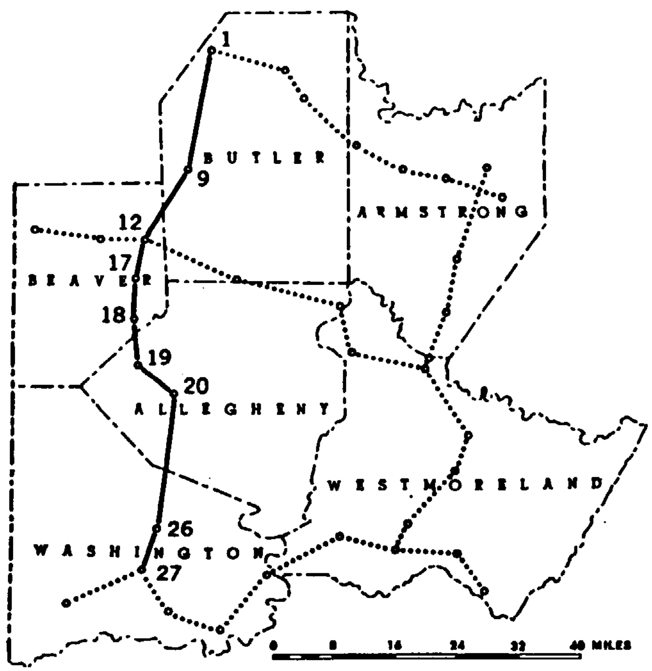
4.3.2 Site-Specific Geology

The portion of the site comprising the main manufacturing area (north of Caldwell Avenue), is situated on an alluvial floodplain that has been built up (with fill materials) over the life of the facility. Much of the site ground surface is covered with asphalt and/or concrete (Remcor, Inc., 1991).

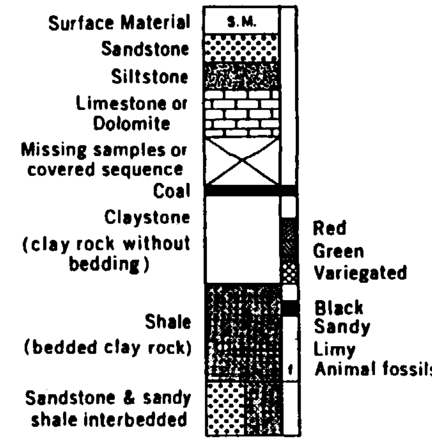
The uppermost unit at the site is fill material comprised of slags, spent refractory bricks, mixed sand, gravel, silt and clay, and miscellaneous debris, including glass. Based upon drilling records, the material tends to be loose near the surface to medium dense near the clayey unit. Fill thickness ranges from approximately 2 to 12 feet and averages 7 feet. The fill is consistently present throughout the site.

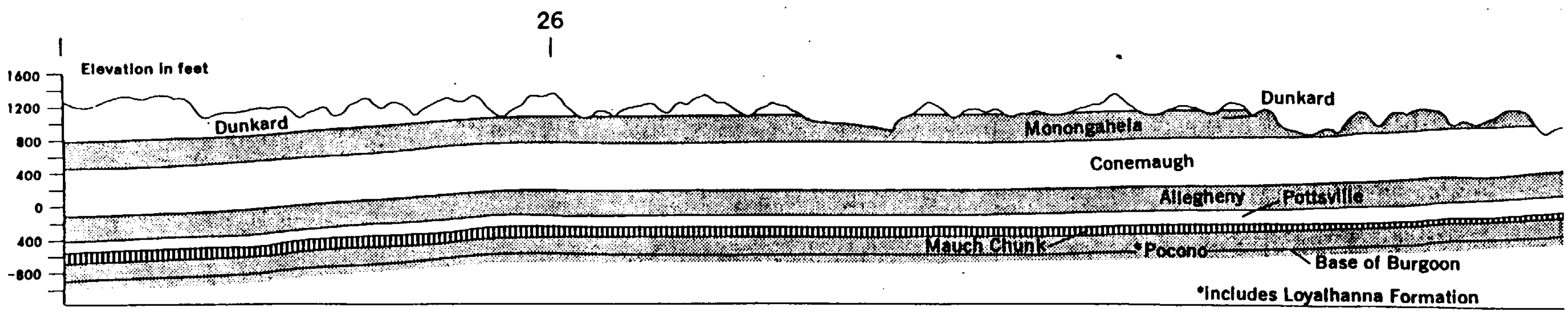
Table 4-1 Bedrock Well BR-1 Borehole Log	
Depth (feet)	Description
17.0 - 18.5	Gray clay/shale
18.5 - 24.0	Gray shale and sandstone (interlayered); fractures 23.5 - 24.0 feet
24.0 - 26.0	Coal layer
26.0 - 32.0	Gray sandstone and shale, some fractures
32.0 - 35.0	Gray sandstone, few fractures
Rock Quality Designation (RQD) 28"/216" = 13% (mostly 32.0 - 35.0 feet)	

LOCATION of SECTION



PATTERNS and COLOR in LOGS





0 1000 2000

VERTICLE SCALE 1"=2000'

0 5000 10,000

HORIZONTAL SCALE 1"=10,000'

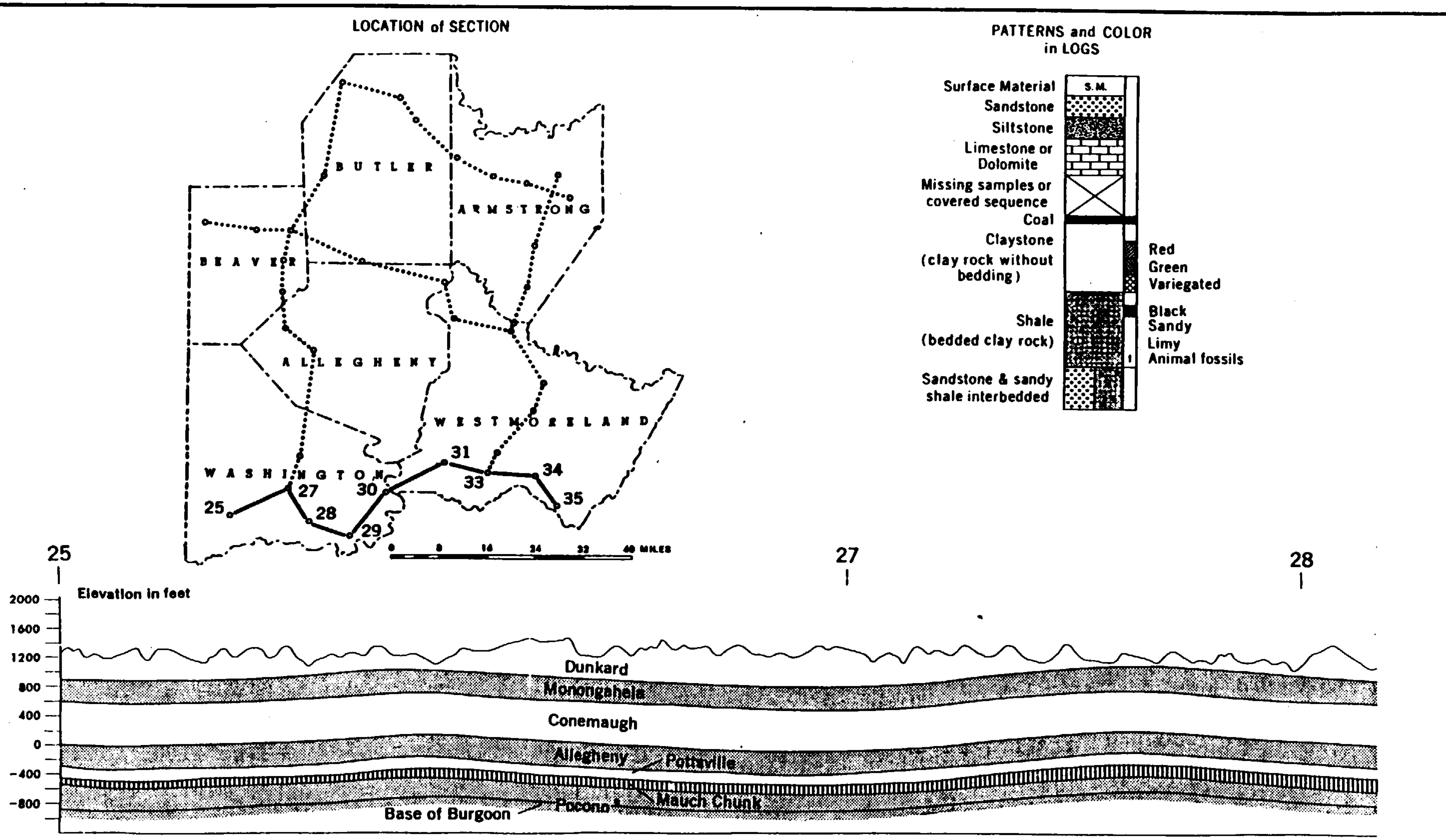
FROM GREATER PITTSBURGH REGION GEOLOGIC MAP AND CROSS SECTIONS, MAP NO. 42
PADER, WAGNER ET AL, 1975

MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE 4-5

BEDROCK GEOLOGIC CROSS SECTION SEVERAL MILES EAST OF MOLYCORP SITE

FOSTER WHEELER ENVIRONMENTAL CORPORATION



0 1000 2000

VERTICLE SCALE 1"=2000'

0 5000 10,000

HORIZONTAL SCALE 1"=10,000'

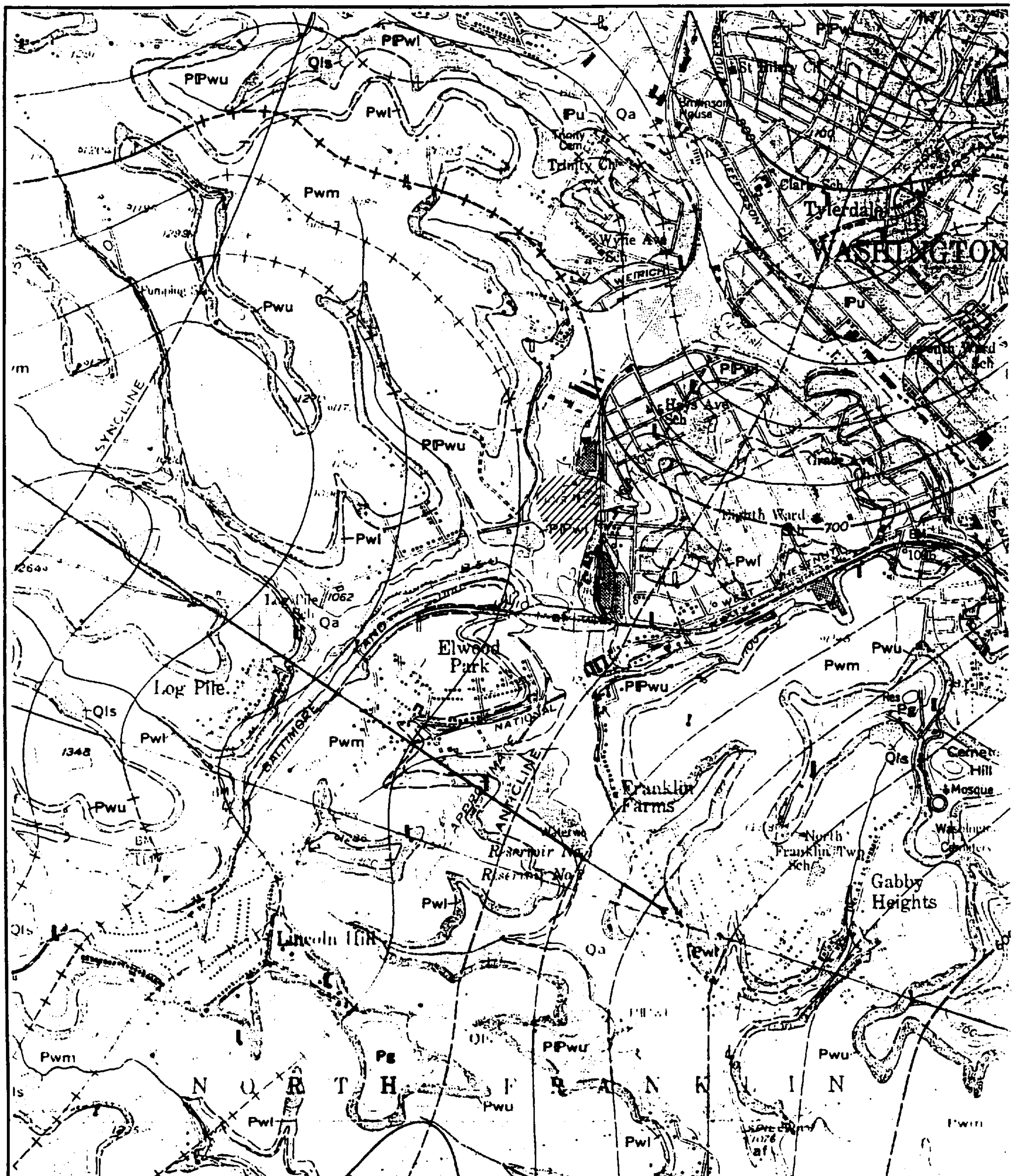
FROM GREATER PITTSBURGH REGION GEOLOGIC MAP AND CROSS SECTIONS, MAP NO. 42 PADER, WAGNER ET AL, 1975

MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE 4-6

BEDROCK GEOLOGIC CROSS SECTION · SEVERAL MILES SOUTH OF MOLYCORP SITE

FOSTER WHEELER ENVIRONMENTAL CORPORATION



SOURCE: U.S.G.S. WASHINGTON WEST, PA QUADRANGLE
BERRYHILL AND SWANSON 1964

0 2000 4000

SCALE IN FEET

PENNSYLVANIA

KEY

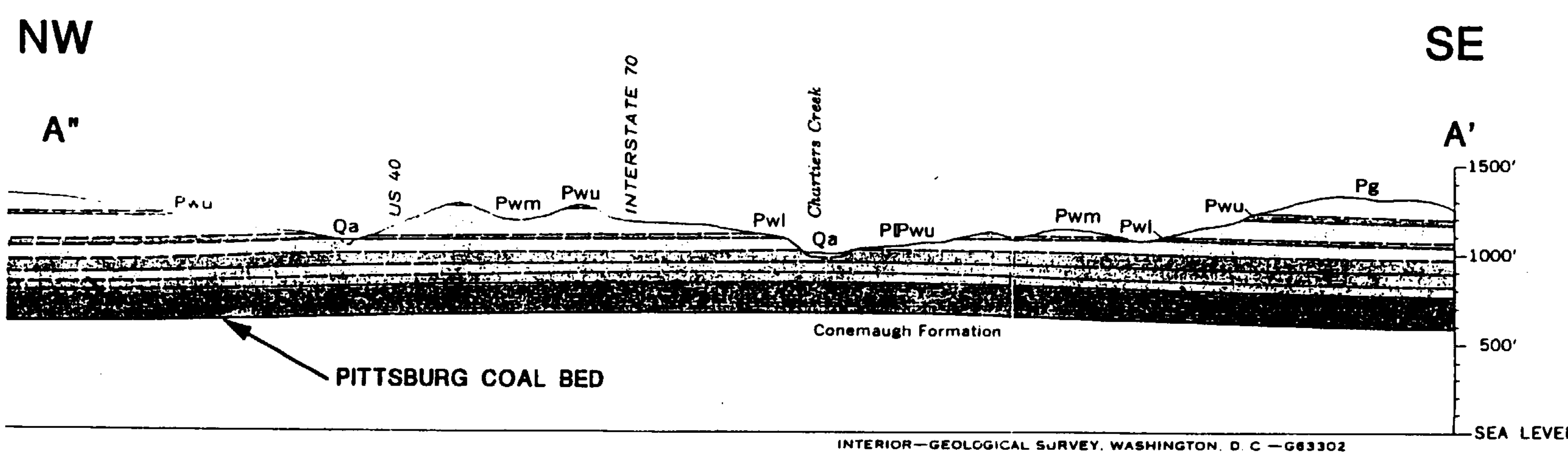
N

MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

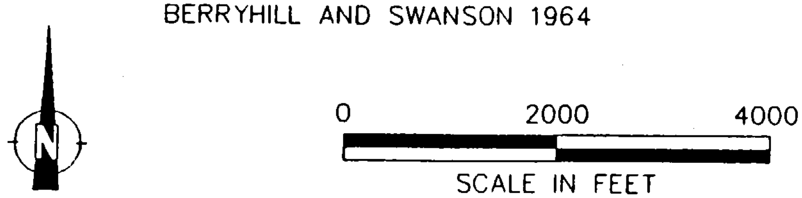
FIGURE 4-7

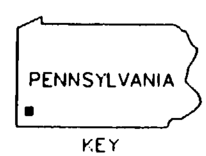
GEOLOGY OF MOLYCORP
SITE AREA

FOSTER WHEELER ENVIRONMENTAL CORPORATION



SOURCE: U.S.G.S. WASHINGTON WEST, PA QUADRANGLE
BERRYHILL AND SWANSON 1964





MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE 4-8
GEOLOGIC CROSS SECTION APPROXIMATELY TWO MILES SOUTH OF MOLYCORP SITE

FOSTER WHEELER ENVIRONMEN CORPORATION

EXPLANATION

QUATERNARY			Qa	Alluvium
			Qls	Landslide deposits
PERMIAN	*Lower Permian*	Dunkard Group	Pg	Greene Formation
			Pwu / Pwm / Pwl	Washington Formation Pwu, *upper limestone member*. Pwm, *middle member*. Pwl, *lower limestone member*
PENNSYLVANIAN AND PERMIAN	*Upper Pennsylvanian and Lower Permian*		PPwu / PPwl	Waynesburg Formation PPwu, *upper and middle members*. PPwl, *lower member*
PENNSYLVANIAN (CARBONIFEROUS)	*Upper Pennsylvanian*	Monongahela Group	Pu	Uniontown Formation
			Ppu / Ppsl	Pittsburgh Formation Ppu, *upper member*. Ppsl, *Sewickley, Fishpot, Redstone, and lower members*

af

Artificial fill

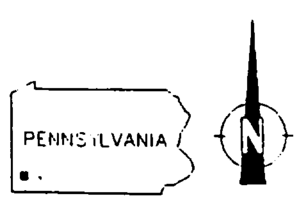
Contact

Dashed where approximately located, dotted beneath alluvium and landslide deposits. Most contacts [illegible]

SOURCE: GEOLOGY OF THE WASHINGTON WEST QUADRANGLE PENNSYLVANIA–WASHINGTON CO.

0 2000 4000

SCALE IN FEET



KEY

MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE 4-9

EXPLANATION FOR MAP AND CROSS SECTION A'-A"

FOSTER WHEELER ENVIRONMENTAL CORPORATION

SYSTEM	SERIES	GROUP	FORMATION AND MEMBER (Nomenclature that of Berryhill and Swanson, 1962)	LITHOLOGY	THICKNESS, IN FEET	DESCRIPTION
QUATERNARY					10+	Alluvium: Unconsolidated silt, sand, gravel, and cobbles in and adjacent to streams. Landslide deposits: Slumped soil with rock fragments; chiefly downslope from limestone members of the Washington Formation.
PERMIAN	Lower Permian	Dunkard	Greene Formation		195+	Chiefly sandstone, siltstone, and mudstone with thin lenticular units of limestone, clay, carbonaceous shale, and coal. Rock types generally repeated vertically in crude cyclic sequence, as follows, in descending order: Clay, light- to medium-gray, shaly; in layers as much as 1 foot thick beneath carbonaceous units and between limestone beds. Limestone, light-olive to olive-gray, argillaceous, very fine grained; in part detrital; fossils include fresh-water ostracodes, *Spirorbis*, and fish remains; some beds laminated, suggesting algal structure. Most prominent units are about 20 feet and about 170 feet above base of formation. Mudstone (as used here, a rock made up of clay-sized particles but including, in addition to clay, quartz and other minerals), generally shaly; commonly underlies limestone units and overlies carbonaceous units; thickness variable. Siltstone, micaceous; generally laminated; local cross laminations and current ripples; locally contains both ironstone and limestone nodules; occurs both above and below sandstone units and as interbeds; thickness variable. Sandstone, abundantly micaceous, friable; generally fine-grained; generally thin- to medium-bedded; locally massive; bedding variable from planar to crossbedded, including torrential, festoon, and current ripple; lenticular locally but in general sheetlike; base generally sharply defined and locally undulating. Carbonaceous shale, generally thin and lenticular; fossils include ostracodes and plant remains; persistent carbonaceous shale and siltstone unit 5 to 10 feet thick with abundance of coalified plant stems and logs, fish remains, and fresh-water ostracodes forms basal unit of formation. Coal, thin impure, lenticular; only persistent bed is 12 to 15 feet above base of formation.
			Washington Formation — Upper limestone member			Limestone, olive- to dark-gray; in beds 6 inches to 3 feet thick separated by thin layers of shaly clay; some beds laminated and seem to be algal; fossils include fresh-water ostracodes in abundance and some fish remains; dark-gray beds that weather almost white are characteristic; split into two parts by tongue of sandstone in most of western half of quadrangle.
			Washington Formation — Jollytown coal of Stevenson (1876); Middle member		140–180	In descending order: Mudstone and siltstone; sandstone and siltstone; carbonaceous shale with thin impure coal at base; siltstone and sandstone with thin impure coal or carbonaceous shale locally at base; argillaceous and in part detrital limestone; sandstone and siltstone; and impure coal and carbonaceous shale. Sandstone is micaceous, friable, and in part crossbedded, forming sheetlike bodies of variable thickness; weathers generally in beds of thin to medium thickness. Limestone sequence in middle of member is generally split into several parts by tongues of siltstone and mudstone.

SOURCE: GEOLOGY OF THE WASHINGTON WEST QUADRANGLE PENNSYLVANIA–WASHINGTON CO. BERRYHILL AND SWANSON 1964

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FIGURE 4–10 (Sheet 1 of 3)

STRATIGRAPHIC COLUMN IN WASHINGTON WEST QUADRANGLE

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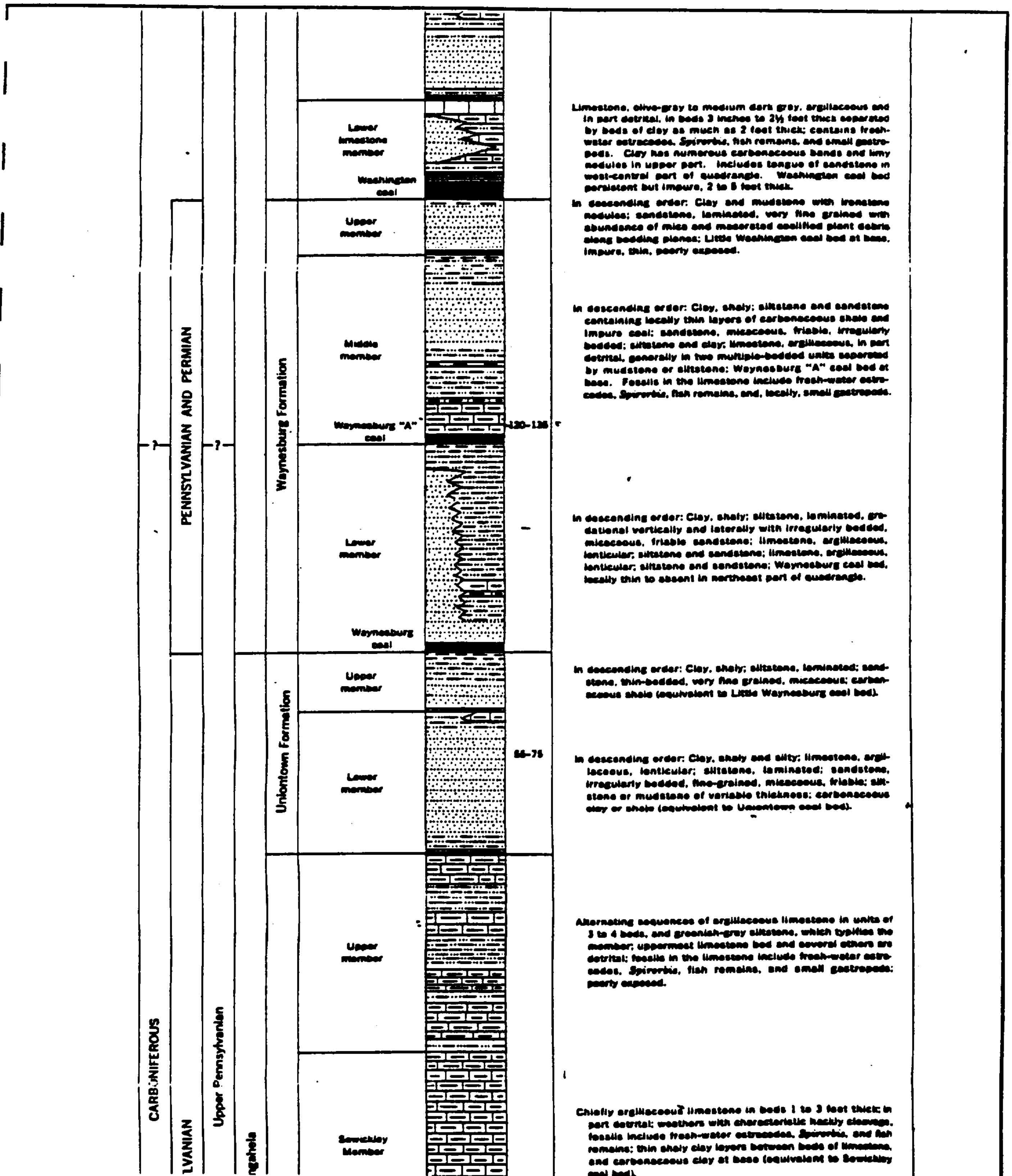

SOURCE: GEOLOGY OF THE WASHINGTON WEST QUADRANGLE PENNSYLVANIA–WASHINGTON CO. BERRYHILL AND SWANSON 1964

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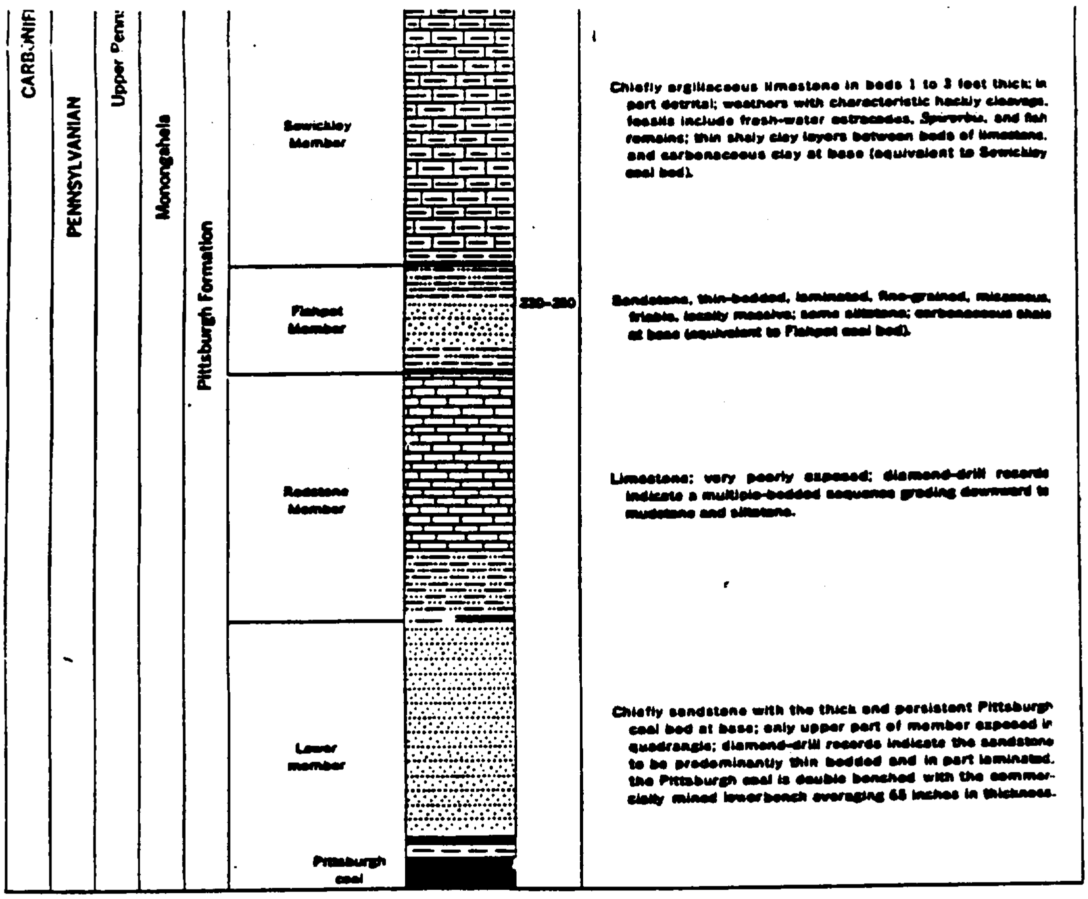
FIGURE 4–10 (Sheet 2 of 3)

STRATIGRAPHIC COLUMN IN WASHINGTON WEST QUADRANGLE

FOSTER WHEELER ENVIRONMENTAL CORPORATION



SOURCE: GEOLOGY OF THE WASHINGTON WEST QUADRANGLE PENNSYLVANIA–WASHINGTON CO. BERRYHILL AND SWANSON 1964

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FIGURE 4–10 (Sheet 3 of 3)

STRATIGRAPHIC COLUMN IN WASHINGTON WEST QUADRANGLE

FOSTER WHEELER ENVIRONMENTAL CORPORATION

Underlying the fill is 5 to 16 feet of unconsolidated deposits (alluvium) of clay, silt, sand, and gravel with a poorly sorted texture. This unit averages 8 to 9 feet in thickness. Below this unit is a clayey to silty sand with gravel which averages 2 feet in thickness.

Below the unconsolidated overburden, at depths ranging from 15 to 22 ft below ground surface and averaging 17 feet, is a grey claystone. The regional stratigraphic sequence indicates that this unit is of Permian/Pennsylvanian age from the Waynesburg Formation, of the Dunkard Group. Claystone bedrock is probably underlain by argillaceous or lenticular limestone (Remcor, Inc., 1991). Section 4.5, Site Hydrogeology, presents on-site stratigraphic cross-sections and unit maps.

The bedrock in the southwestern corner of the site (in particular the grey limestone), dips to the west-southwest at a rate of about two percent from the Washington anticline toward the Finney syncline (SRW Associates, Inc., 1980).

4.4 SURFACE WATER HYDROLOGY AND REGIONAL HYDROGEOLOGY

Chartiers Creek drains 257 square miles (to Carnegie, PA) of Appalachian plateau area, 18 square miles of which is located upgradient and south of the site. Streamflow is derived from a combination of surface runoff and the sedimentary and alluvial aquifers described below.

4.4.1 Surface Water Hydrology (Local/Regional)

The site is bounded on the west by Chartiers Creek. On the site, eight surface impoundments were constructed as part of the facility's molybdenum operations. The impoundments are lined, are approximately seven feet deep, and each encompasses a typical area of 80 by 30 feet. Rainwater is impounded within these structures at an elevation of approximately 1,020 ft-msl.

The distance from the impoundments to Chartiers Creek varies from 60 to 170 feet. The creek flows to the north at a gradient of approximately 0.001 feet per feet (ft/ft), measured during September through November 1991 (Remcor, Inc., 1991). Chartiers Creek drains an area of approximately 18 square miles of dissected plateau above the site (see Appendix C for calculated streamflow).

The entire Washington County drainage area is tributary to the Mississippi River system, the Ohio River being the immediate master stream. Chartiers Creek drains to the northeast into the Ohio River at Carnegie (Seibert et al., 1983).

Streamflow measurements and calculations are presented in Appendix C in order to quantify the site's contribution to Chartiers Creek from surface runoff and groundwater flow. Drainage basins which are larger than but analogous to the 18 square miles draining Chartiers Creek to the site area, were used to estimate, by proportioning streamflow and drainage to the site area, the drainage contribution from the site (Appendix C). Average streamflow to the site is estimated at over 8,000 gpm (gallons per minute) with approximately 28 gpm contributed by the site of which

7 to 8 gpm are baseflow, i.e., from groundwater. The baseflow contribution is estimated from the hydrographs presented in Appendix C. In addition, streamflow (Pygmy meter) measurements were conducted in Chartiers Creek adjacent to the site during a dry late summer period. Chartiers Creek flow was measured to average 224 gpm. This type of measurement is reliable for order of magnitude data. The average baseflow contributed by the site is less than 10 gpm (Appendix C). The late summer low flow for 1993 was estimated from the hydrographs at 383 gpm for the site area of which less than one gpm is contributed by the site (Appendix C).

4.4.2 Regional Hydrogeology

Groundwater in Washington County occurs in both artesian and water table aquifers; well yields range from a fraction of a gallon per minute to over 350 gpm (Newport, 1973).

A summary of the geologic and water-bearing characteristics of the different rock units in Washington County follows. The following discussion names and describes, in descending order, the formations most commonly used for water supply. The rank and classification of many of these units are similar to those used in other reports describing the geology and groundwater resources of the area. Berryhill and Swanson (1962) revised the nomenclature for Pennsylvanian and Permian age rocks in Washington County.

4.4.2.1 Alluvium

The alluvial deposits pertain to the unconsolidated material underlying the site fill material and Chartiers Creek to the west. Unconsolidated deposits (alluvium) overlie the bedrock in a few places in the major stream valleys in the county. They consist of weathered rock material that was transported and deposited by moving water. The material includes clay, silt, sand, gravel, and some boulders, and most of the particles have been rounded during transportation. Alluvium ranges in texture from poorly sorted to well sorted.

Alluvium is generally permeable and, where saturated, may yield moderate to large supplies of water to wells. However, permeability may change significantly over short distances, because of changes in the degree of sorting. Well yields depend principally upon the permeability and thickness of saturated deposits penetrated by the wells.

Few data are available for wells completed in the alluvium. Yields of two wells (200 and 350 gpm) are reported (Newport, 1973). The depths of these and other wells in the alluvium range from 28 to 63 feet. Some of the shallow wells probably do not penetrate the full thickness of the material.

Groundwater from alluvium is generally hard and has a high iron, manganese, and dissolved solids content. It also has low turbidity and generally is bacteriologically pure. The quality of water from wells changes considerably when water is induced to flow from streams into the cones of influence of the wells. When this occurs, the well water quality is intermediate in character between the quality of the surface water and groundwater. Temperature of the mixed waters will vary; they are lower during the winter and higher in the summer.

4.4.2.2 Waynesburg Formation

The Dunkard Group includes the Waynesburg Formation of Late Pennsylvanian and Early Permian age and the Washington and Greene Formations of Early Permian age. In Washington County, the Dunkard Group has a maximum thickness of approximately 900 feet. These rocks subtly change upward from more persistent coal-bearing rocks that resemble the strata of the Monongahela Group to the finer grained highly lenticular strata of the Greene Formation, which contains only thin lenses of impure coal (Berryhill, Schweinfurth and Kent, 1971).

The Waynesburg Formation pertains to the bedrock unit directly underlying the unconsolidated materials of the site.

The Waynesburg Formation is divided into three members: lower, middle and upper. The thickness of the formation ranges from 80 to 180 feet (based upon unpublished USGS data).

The lower member of the Waynesburg Formation consists chiefly of sandstone, limestone, siltstone, mudstone, and coal, and ranges in thickness from 40 to 90 feet. The Waynesburg coal bed, present in most of the county, is the basal unit of the lower member and is as much as 100 inches thick. Throughout most of the eastern half of the county, the coalbed is of minable thickness and commonly has two benches with a distinctive clay parting, which is generally 12 inches thick. In the western half of the county, the coal generally is thinner, less persistent, and confined to one bench. A light-gray, fine to coarse-grained, sometimes massive sandstone unit above the Waynesburg coalbed is the Waynesburg Sandstone (member). The sandstone is sheetlike, has tabular (foreset) and festoon crossbedding, and locally grades laterally and vertically to siltstone and shale. The sandstone is developed best in the eastern half of the county and may be as much as 65 feet thick. The limestone in the lower member is medium gray, fine-grained, argillaceous, and as much as eight feet thick. Two limestone units commonly are found in the lower member; one is at the top of the member, and the other is in the middle. The mudstone is light to dark gray and micaceous, and locally is calcareous.

The middle member consists mostly of mudstone, with some interbedded limestone, sandstone, siltstone, carbonaceous shale, and coal, and is as much as 90 feet thick. Two poorly developed coal horizons are present. These are found at the base and near the top of the member. The Waynesburg "A" coalbed is the basal unit of the middle member. The coalbed, when not represented by calcareous shale, typically is less than 24 inches thick and may have numerous clay partings. The coalbed is impure and may be represented by carbonaceous shale. The mudstone is light to dark gray and locally calcareous. The sandstone is light gray, very fine- to fine-grained, micaceous, crossbedded, and generally grades laterally and vertically to siltstone and mudstone. The siltstone is light to medium gray, micaceous, and locally is ripple bedded. The limestone is olive to dark gray, microcrystalline to finely crystalline, argillaceous, and thin to thick bedded. A thin, nonpersistent coalbed near the top of the member tentatively identified as the Waynesburg "B" coalbed has been reported in many parts of the country. The coalbed is impure and less than 12 inches thick and may be represented by carbonaceous shale. It appears to always be overlain by clastic rocks and probably is a lower split of the overlying Little Washington and Washington coal complex (Skema, 1988).

The upper member of the Waynesburg Formation is separated from the middle member by the Little Washington coalbed. The upper member is as much as 25 feet thick and consists of sandstone, siltstone, mudstone, and carbonaceous shale. The basal Little Washington coalbed, where present, is typically thin and may be represented by grayish-black, carbonaceous shale.

The Waynesburg Formation's hydrogeologic characteristics are comparable to those of the other overlying members of the Dunkard Group. The small size and scarcity of fractures limits the well yields. The mean reported yield of wells tapping the Waynesburg Formation is 10 gpm. The reported yields of 30 wells range from 0.5 to 60 gpm. The specific capacities range from 0.18 to 2.8 (gpm)/ft. Yields from 16 springs range from 1.0 to 18.4 gpm.

4.4.2.3 Monongahela Group

The Monongahela Group, which is divided into the Pittsburgh (lower) and Uniontown (upper) Formations, consists of limestone, shale, sandstone, and coal. The upper portion of the Uniontown appears to correlate with the Waynesburg Formation based upon state documents (from 1975). The limestones are dense and massive to thin bedded. The shales and sandstones are discontinuous. There are several coalbeds in the group, including the Pittsburgh, Redstone, Fishpot, Sewickley, Uniontown, and Little Waynesburg coals.

Most of the porosity and permeability in limestone is the result of enlargement of the fractures through the solution and removal of minerals by moving groundwater. Permeability of sandstone ranges greatly, according to grain size, degree of sorting, and amount of cementing material. Secondary porosity may be developed by solution and removal of cementing material or by fracturing. Shale is a fine-grained, rather impermeable rock, but generally contains water in fracture or joint systems.

The yields of wells in the Monongahela Group are low because of the smallness and scarcity of fractures. Well yields range from 0.1 to 50 gpm, and the median yield is about 1 gpm. Yields greater than those required for domestic purposes are very difficult to obtain from this group. Large-diameter wells in this formation will yield larger volumes of water than small-diameter wells for short periods, because the amount of stored water is greater in the large-diameter wells. Aside from the storage factor, the drilling of deeper wells in the Monongahela Group does not increase the potential yield of wells. The low yields are partly the result of dewatering of the rocks due to coal mining. Well depths range from 50 to 400 feet, and most of the wells are over 100 feet deep.

Groundwater in the Monongahela Group is largely of the calcium bicarbonate type. Where the unit lies within approximately 100 feet below major streams, chloride concentrations are high. The dissolved solids content ranges from 330 to 1,120 mg/l. Iron content ranges from 0.07 to 0.22 mg/l.

4.5 SITE HYDROGEOLOGY

An intensive soil boring, monitoring well and piezometer installation program was conducted to characterize the site surface fill and subsurface overburden units for physical extent, the presence of thorium, and hydrogeologic properties.

The physical extent of the units was determined by geological logging of the boreholes. The presence of thorium was determined using a downhole gamma logger and mass spectrometry analysis of soils collected during drilling (Section 5.2). Hydrogeological testing included slug testing on wells in three hydrogeologic units, two pumping tests in the fill aquifer, two infiltration tests in the vadose zone, and surface water measurements. These data are used as inputs to the MODFLOW program to further define the site hydrogeology and to characterize contaminant flow and transport conditions. The surveyed site topography with buildings and boundaries and the locations of all sampling points, can be found in Appendix B in Figures B-1 and B-2, respectively. However, Figures 4-11 and B-3 show all the soil borings and monitoring well locations, as well as building and topography on one drawing. Elevations, coordinates, stratigraphic horizons and water levels are compiled in Table E-7 in Appendix E.

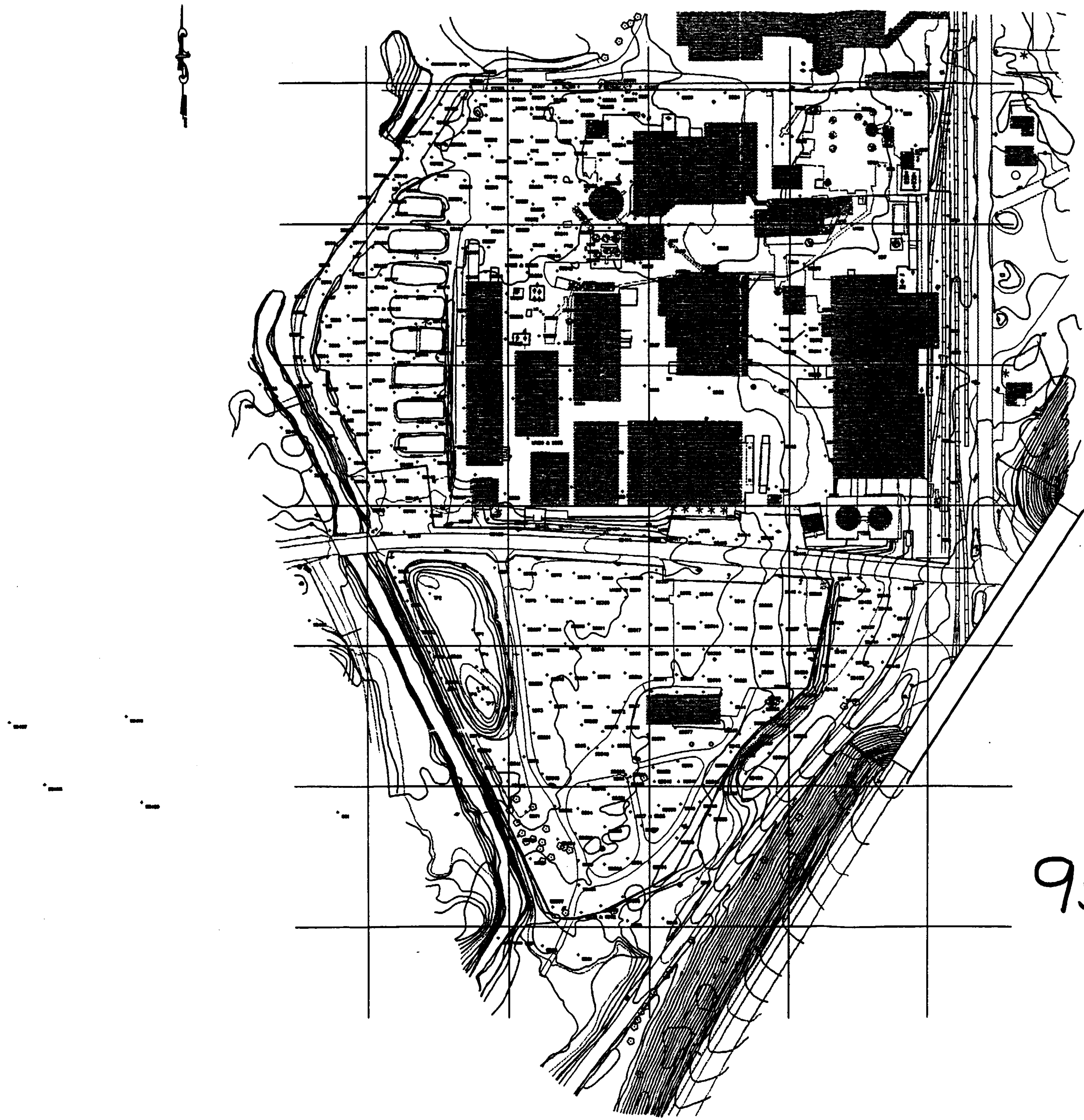
4.5.1 Identification and Characterization of Hydrogeologic Units

The soil boring logs from the site characterization program are presented in Appendix G. As shown in Table E-7 in Appendix E, depths of fill material, while generally on the order of 2 to 12 feet (averaging 7 feet) are highly variable. Figure 4-12 presents the location of geologic cross-sections compiled from monitoring well borings. Figures 4-13, 4-14, 4-15, and 4-16 present cross-sections A-A', B-B', C-C' and D-D', respectively. In addition, isopach maps representing thickness of the fill zone, that include the vadose zone and the water table or fill aquifer, the clay unit, and the sand and gravel unit, are displayed on Figures 4-17, 4-18, and 4-19. The underlying clay unit varies in silt, clay and sand content, plasticity and apparent moisture, as well as in thickness.

4.5.1.1 Field Investigation Program

A soil boring, piezometer, and monitoring well installation program was initiated at the site in April 1994. Three hundred borings were scheduled to be installed, but based upon findings of the borehole gamma logging program, a total of 418 borings were eventually completed.

The purpose of this intensive program was to more accurately define the extent of the fill material and underlying overburden units (i.e., clay unit and sand and gravel unit) and to determine the extent of thorium present in these units. In addition, the placement of piezometers in the fill material aquifer (and in some cases underlying units) is intended to provide sufficient data to accurately map the potentiometric surface at the site in order to adequately assess the potential for contaminant transport off-site. All borings were drilled to bedrock which was determined as auger refusal or split-spoon refusal (50 hammer blows over 6 inches). Approximately 20 percent of the



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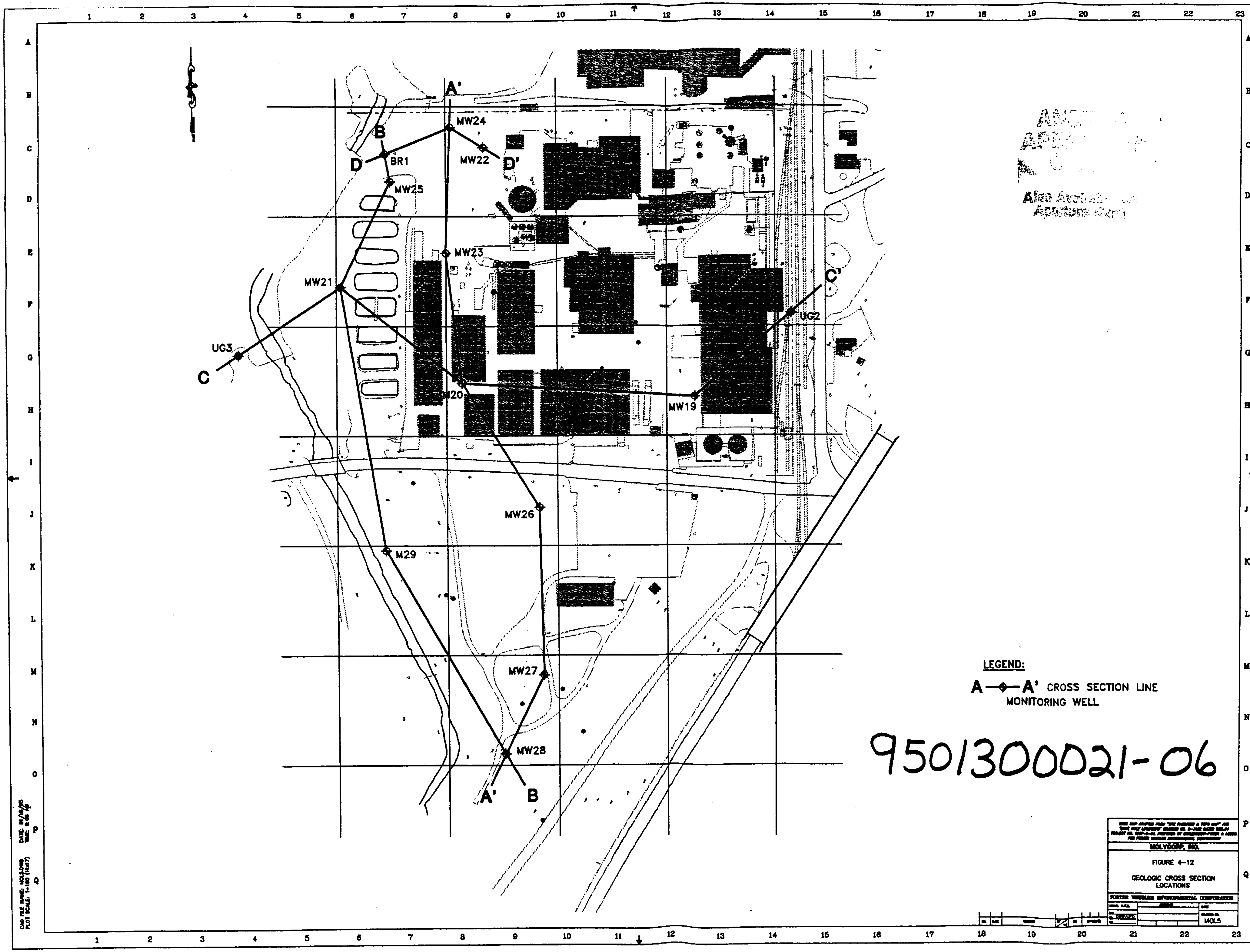
MOLYCORP, INC.

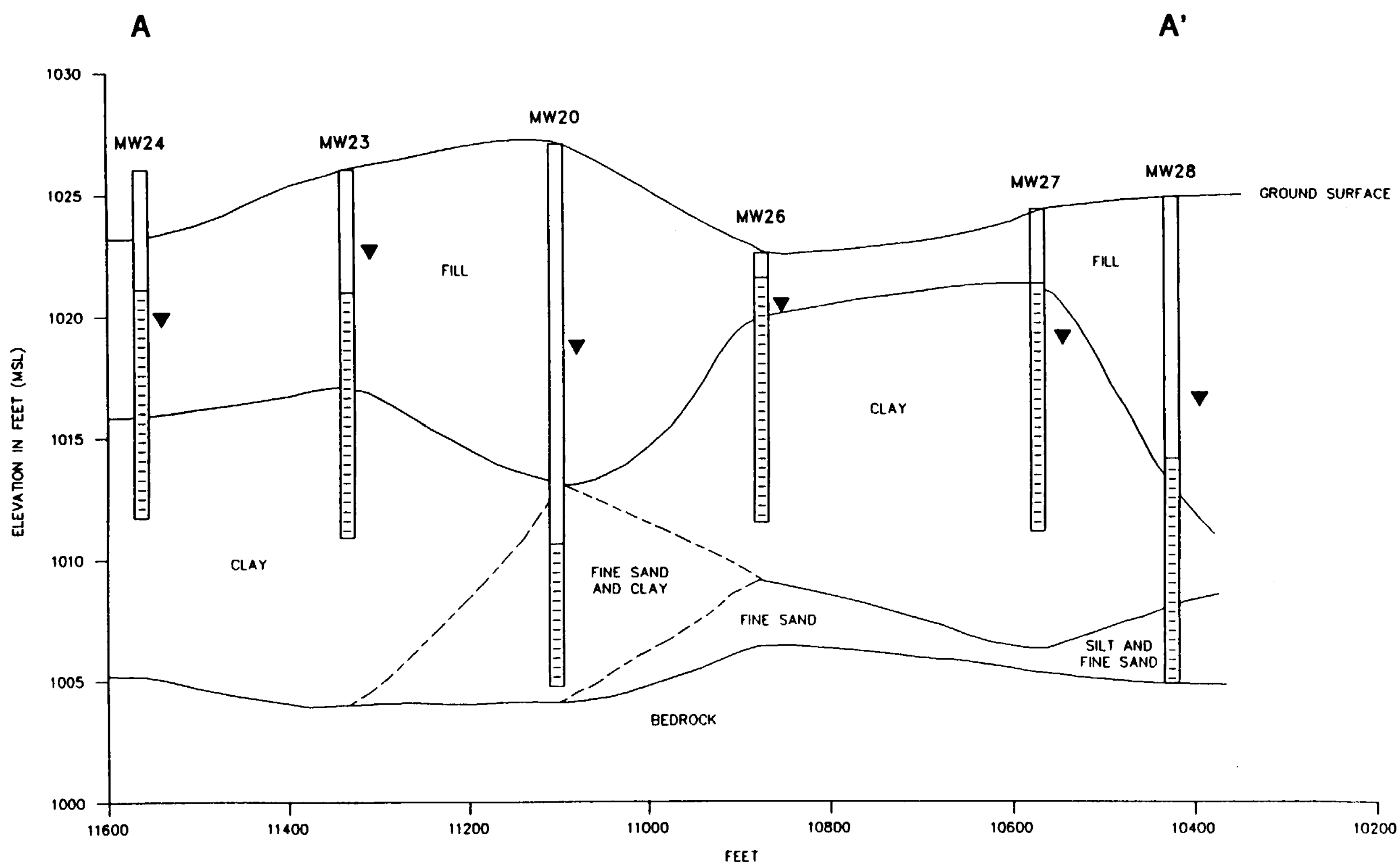
FIGURE 4-11

SOIL BORINGS & MONITORING WELLS LOCATIONS

FOSTER WHEELER ENVIRONMENTAL CORPORATION



A'
MW24
B
BR1
D
MW22
D'
MW25
MW23
MW21
C'
UG2
UG3
C
M20
MW19
MW26
M29
MW27
MW28
A'
B
LEGEND:
A—◆—A' CROSS SECTION LINE
MONITORING WELL
9501300021-06
MOLYCORP, INC.
FIGURE 4–12
GEOLOGIC CROSS SECTION LOCATIONS
FOSTER WHEELER ENVIRONMENTAL CORPORATION
MOL5



DATE: 01/17/95
TIME: 5:35 PM

▼ APPROXIMATE WATER LEVEL 8/16/94

CAD FILE NAME: MOLY-AA.DWG
PLOT SCALE: (FIT)

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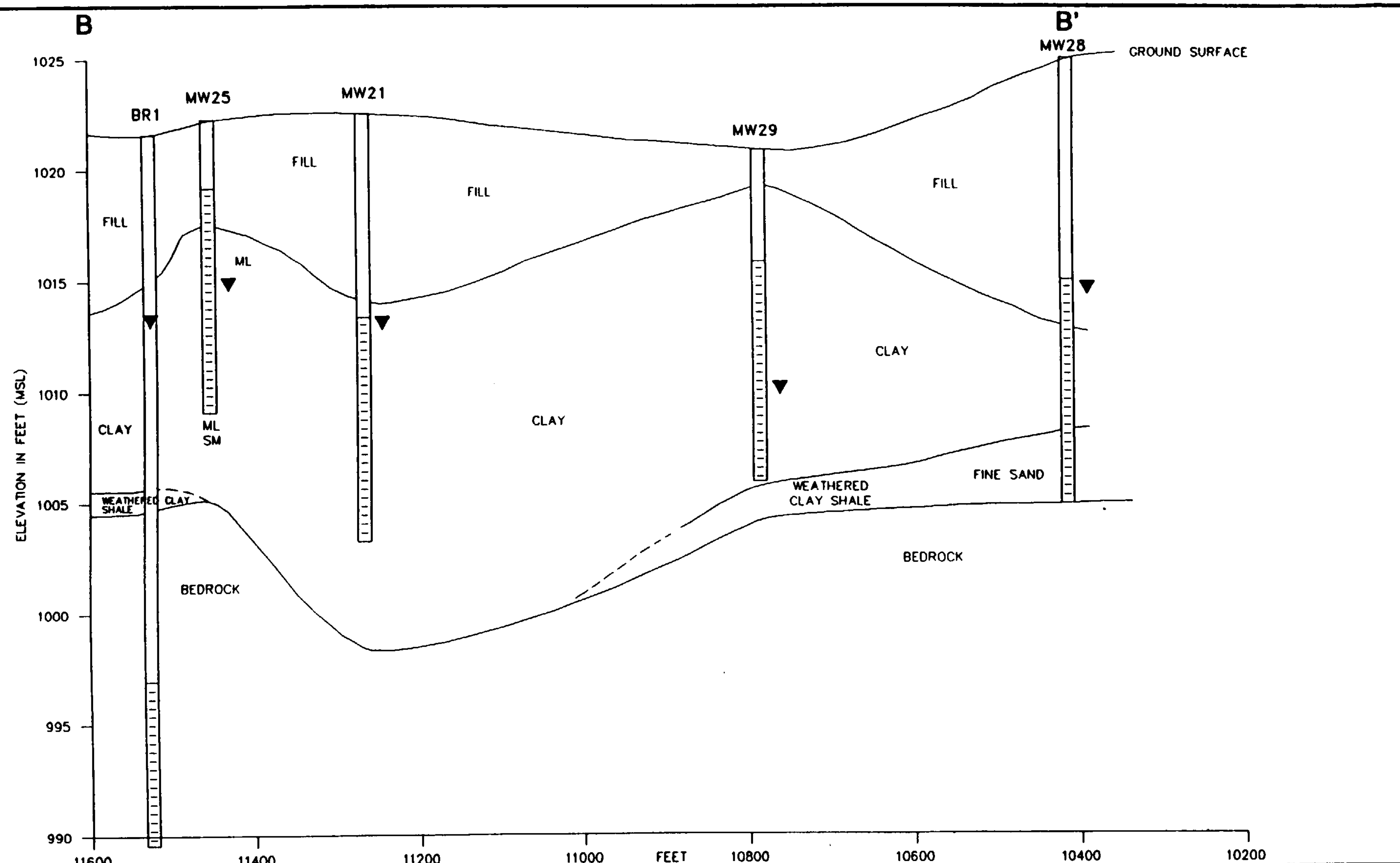
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE 4-13

CROSS-SECTION A-A'

FOSTER WHEELER ENVIRONMENTAL CORPORATION



DATE: 01/17/95
TIME: 5:38 PM

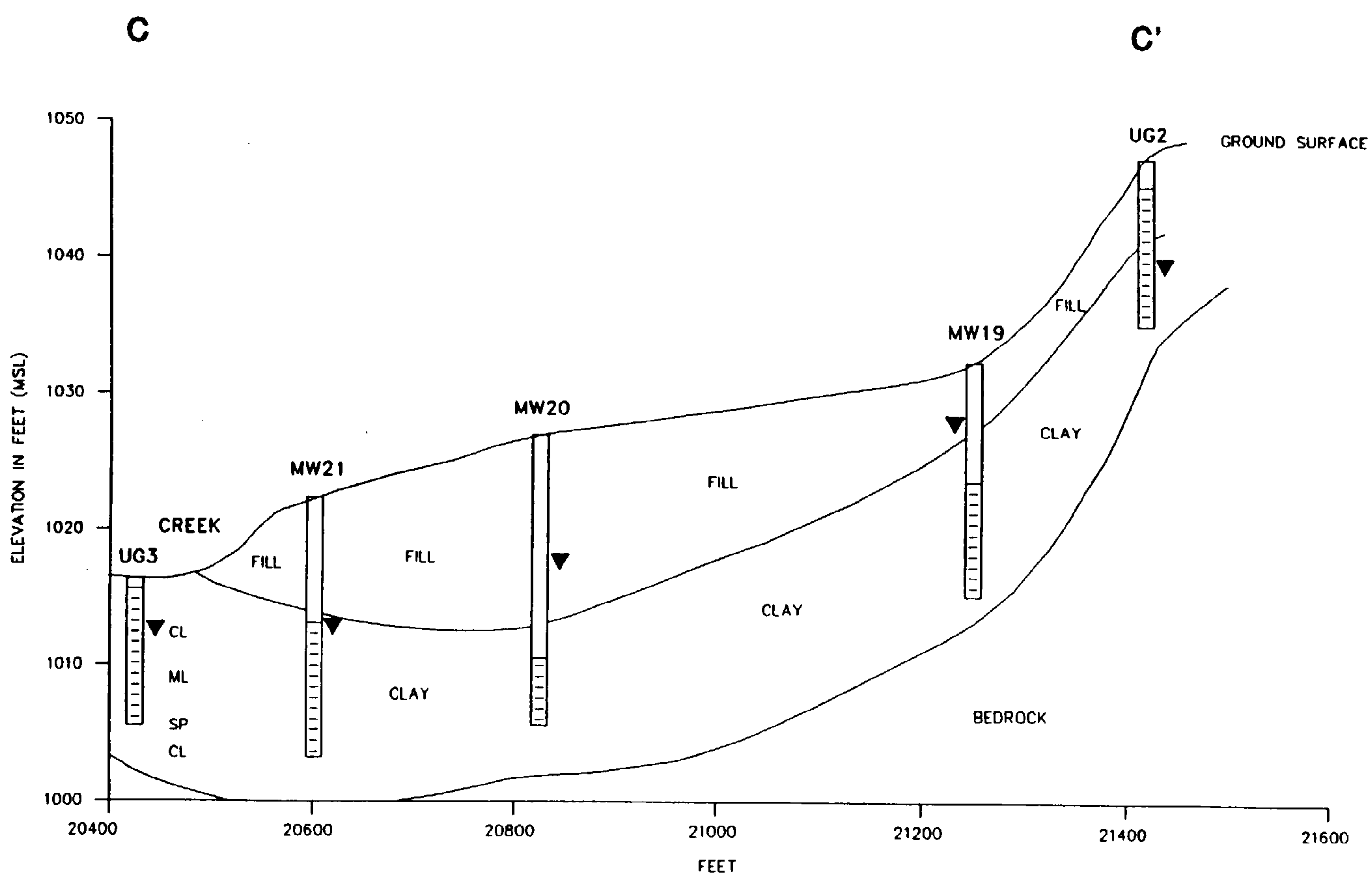
CAD FILE NAME: MOLY-BB.DWG
PLOT SCALE: (FIT)

▼ APPROXIMATE WATER LEVEL 8/16/94

MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE 4-14
CROSS-SECTION B-B'

FOSTER WHEELER ENVIRONMENTAL CORPORATION



▼ APPROXIMATE WATER LEVEL 8/16/94

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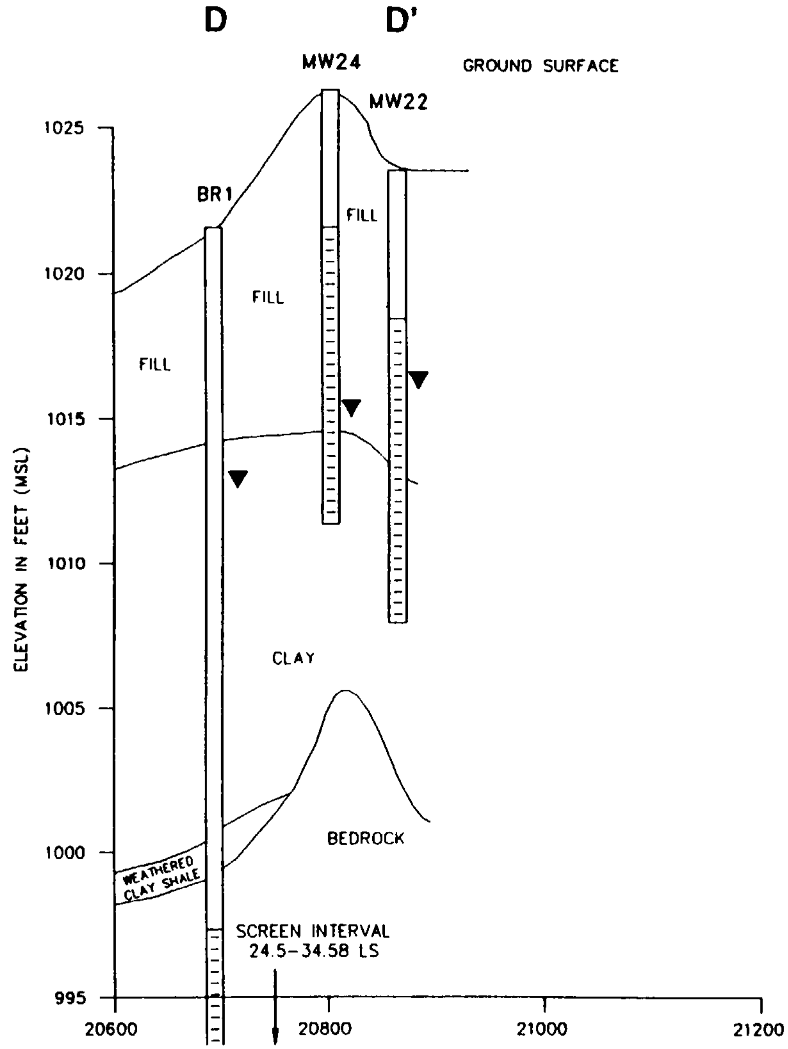
FIGURE 4-15

CROSS-SECTION C-C'

FOSTER WHEELER ENVIRONMENTAL CORPORATION

TIME: 5:40 PM

PLOT SCALE: (FIT)



DATE: 01/17/95
TIME: 5:43 PM

CAD FILE NAME: MOLY-DD.DWG
PLOT SCALE: (FIT)

▼ APPROXIMATE WATER LEVEL 8/16/94

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WASHINGTON, PA

FIGURE 4-16

CROSS-SECTION D-D'

FOSTER WHEELER ENVIRONMENTAL CORPORATION

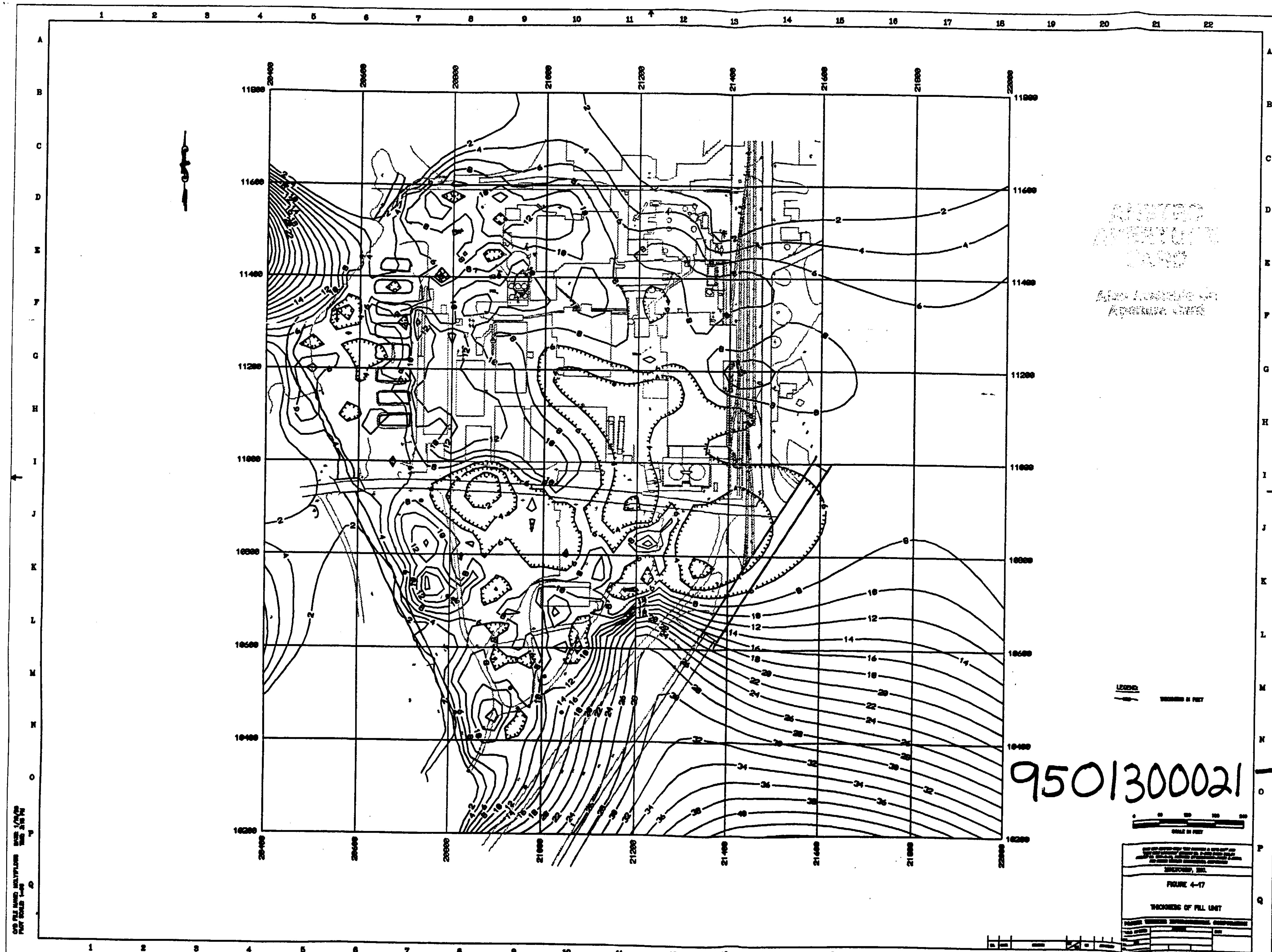


FIGURE 4-17
THICKNESS OF FILL UNIT
LEGEND:
THICKNESS IN FEET
SCALE IN FEET
9501300021-07

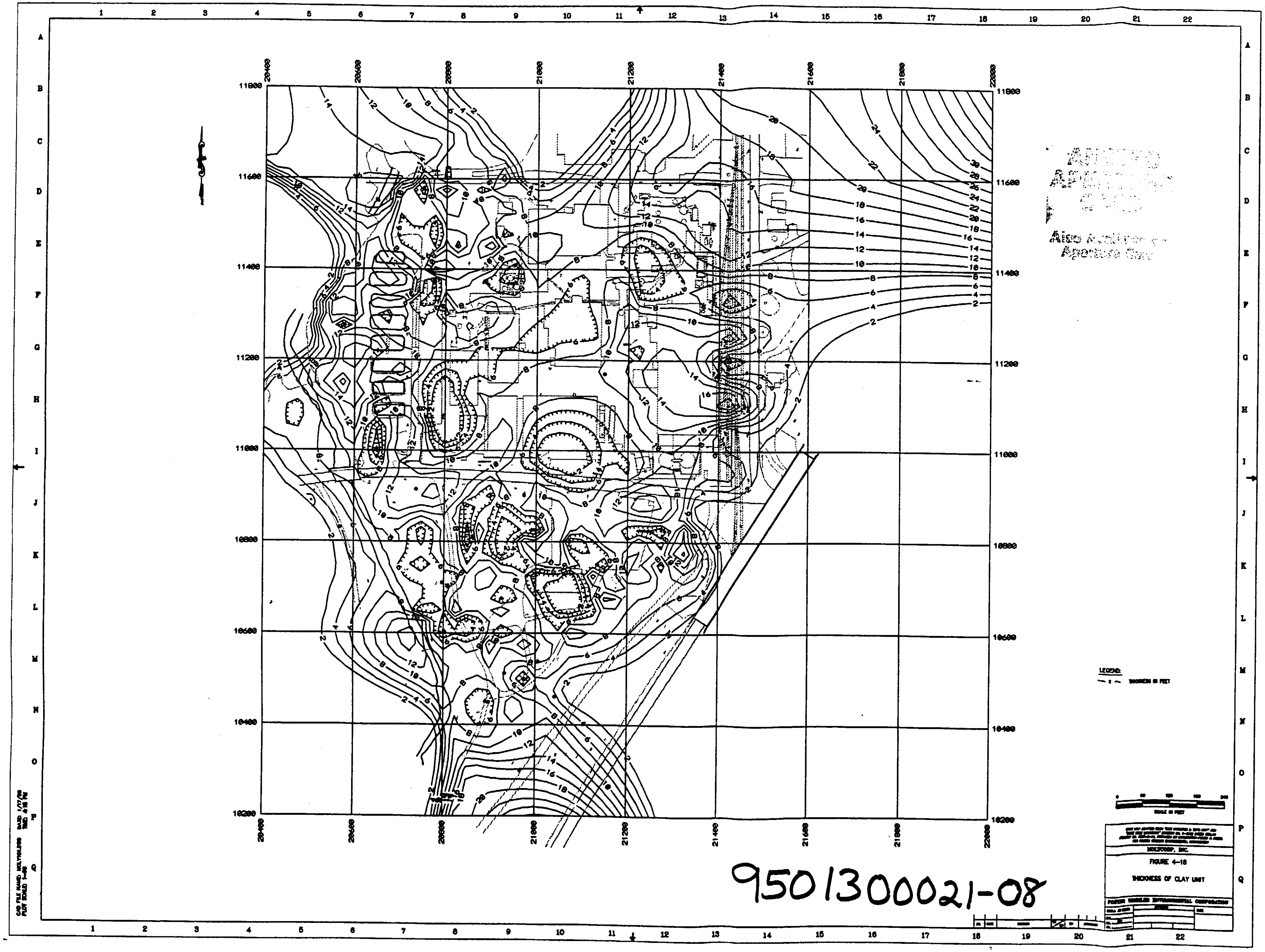
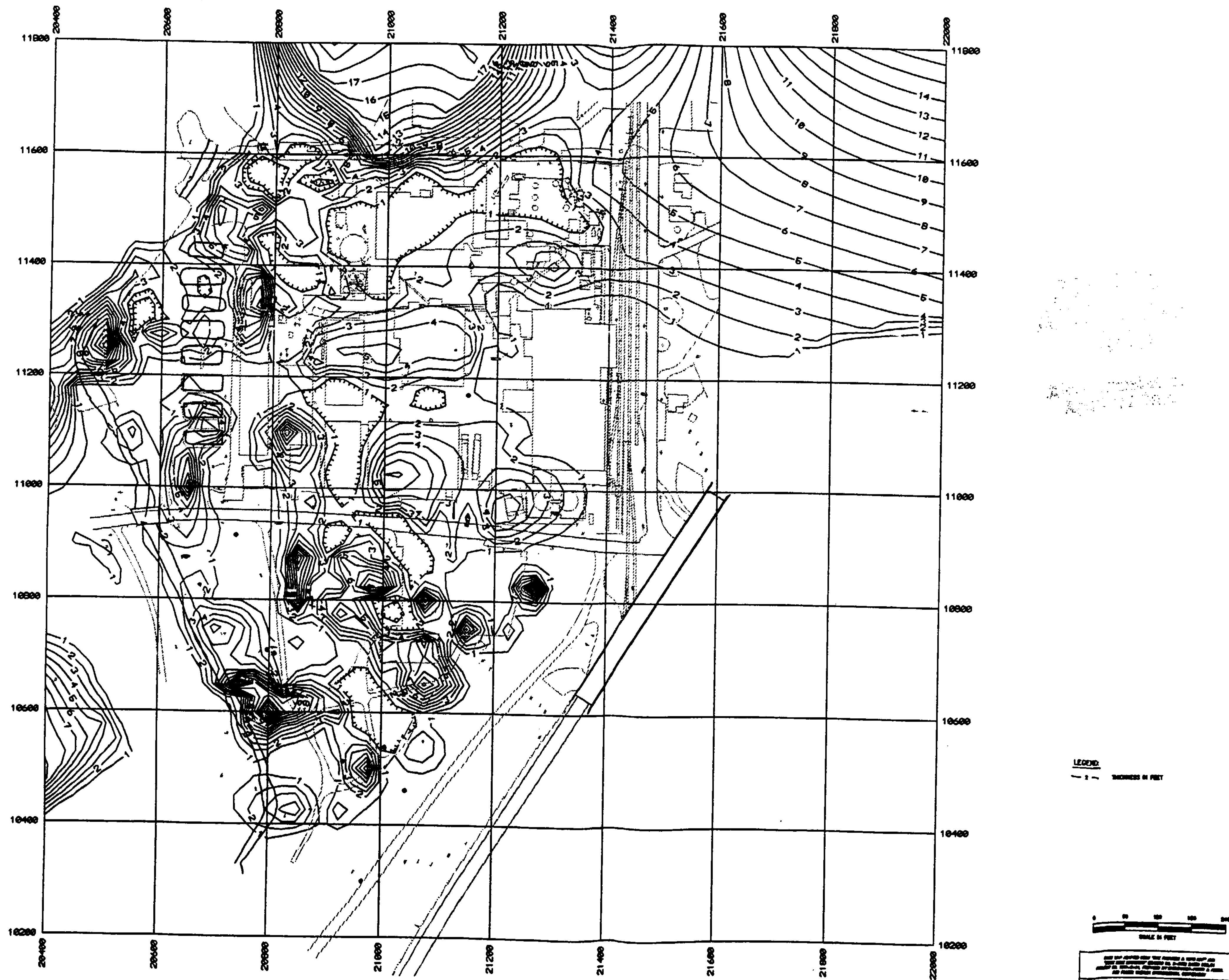


FIGURE 4-16
THICKNESS OF CLAY UNIT
MOLYCORP, INC.
FOSTER WHEELER ENVIRONMENTAL CORPORATION
SCALE IN FEET
LEGEND:
THICKNESS IN FEET
Also Available on Aperture Card
9501300021-08



MOLYCORP, INC.

FIGURE 4-19

THICKNESS OF SAND & GRAVEL UNIT

FOSTER WHEELER ENVIRONMENTAL CORPORATION

9501300021-09

borings were continuously split-spoon sampled using 1.5-feet long, 2-inch ID samplers. Samples were collected every 6 inches and stored for on-site radionuclide analysis.

Drilling was accomplished using CME-45 trailer rigs and hollow-stem (for split-spoon sampled borings) or solid-stem augers. A 2-inch diameter, schedule 40 PVC pipe was placed in the borehole upon reaching maximum depth. Cuttings were stored in 55-gallon steel drums lined with 2 mil plastic bags. A downhole gamma spectroscopy survey was conducted within the PVC pipe in the borehole and the 55-gallon drum of cuttings. The PVC pipes were subsequently removed and all boreholes not to be completed as piezometers or monitoring wells were grouted. Eighty-seven of the boreholes were completed as piezometers. At these locations the water level was measured in the borehole and bentonite chips were placed in the bottom of the borehole and brought to the bottom of the piezometer. The PVC screen (usually 10 feet of a 0.010-inch slot) was placed so that at least 2 feet was above the water. PVC riser (2-inch diameter) was threaded into the screen to bring the wellhead to the surface. The borehole was subsequently covered with plastic sheeting to keep rain and surface runoff from entering the piezometer, pending their removal or site remediation.

Eleven on-site borings were converted to monitoring wells and designated MW-19 through MW-29. The water level was measured in the borehole and the screen interval was determined for each well. At least 2 feet of screen was above the water table. Bentonite pellets were placed in the bottom of the borehole followed by the well assembly of a 2-foot PVC sump, 10 feet of screen (unless otherwise noted) and riser pipe. A screen filter pack of 20/40 Best sand was placed in the annular space around the well screen and brought to one to two feet above the top of the screen. Bentonite pellets were then added to form a seal above the sandpack. The annulus was grouted to the ground surface. The well was protected with a steel surface casing, either flush mount or stickup, depending upon vehicular traffic over the location (see Appendix L for well construction diagrams). In addition, three borings at upgradient locations were converted to monitoring wells (UG-2, UG-3 and UG-4) and on-site monitoring well BR-1 was installed in the underlying bedrock. Two on-site pumping wells were also installed for testing of the fill aquifer: PW-1 (3-foot diameter HDPE plastic) and PW-2 (4-inch diameter PVC). The total number of new wells installed was 17, which, with the 87 piezometers and 21 existing wells (Remcor, 1991), brings the total water level observation points to 125.

4.5.1.2 Vadose Zone Characterization

For the most part, the vadose zone consists of fill and mixed soils. The term mixed soils is used to refer to sandy soils underlying the fill and overlying the clayey zone which may have been placed there during site construction. At some on-site locations, the water table falls below the top of the fill and the clay unit becomes part of the vadose zone. Water table depths average about 4 feet beneath ground surface, whereas the average depth of the fill and mixed soil zone is about 7 feet. Naturally deposited soils are essentially non-existent on the surface of the site. The vadose zone tends to consist of the looser upper portion of the fill material that generally contains a higher portion of slag, spent refractory and glass than the deeper fill material in the saturated zone.

Infiltration testing was conducted at point I-1 in the northwestern portion of the site (Figure D-1 in Appendix D) and at point I-2 in Unit 2 (south of Caldwell Avenue) both representative of the limited unpaved areas of the site. (See Appendix D for details on the use of the double ring infiltrometer.) The infiltration rate stabilized at approximately 3 x 10^{-4} cm/sec at point I-1 and $7x10^{-5}$ cm/sec at point I-2, indicating a moderately low permeability for the fill material. The higher quantity of slag in the top 2 feet at point I-2 may explain the slightly lower value at this location.

4.5.1.3 Saturated Zone Characterization

The saturated zone includes all of the stratigraphic zones described in Section 4.4.2. However, at some locations the fill is unsaturated, so the water table occurs in the upper portion of the clayey zone. Although the deeper clayey zone generally serves as an aquitard, there may be numerous places where there is an interconnection between the water table and a deeper semi-confined aquifer. The semi-confined aquifer is the sand and gravel between the clayey zone and the bedrock, that is highly variable in composition, consisting of gravel, silt, clay, sand and weathered bedrock. The upper portion of the bedrock aquifer underlies the sand and gravel unit. This unit exhibits hydraulic conductivity through fractures which is proven by the slug test value of 0.73 ft clay (Appendix E) comparable to that of the sand and gravel unit.

Two constant rate pumping tests were conducted in the saturated portion of the fill aquifer in the northwest portion of the site at PW-1 and PW-2. In addition, slug tests were conducted in bedrock well BR-1, six fill aquifer wells and ten sand and gravel (lower, semi-confined) aquifer wells (see Appendix E).

The pumping test data from PW2 (near the center of the northwest quadrant) indicate water table aquifer transmissivities ranging from 880 gpd/ft to 1,056 gpd/ft and averaging 1,004 gpd/ft for five observation wells in the fill material. The distance-drawdown plot indicated a transmissivity value of 1,467 gpd/ft and a storage coefficient of 0.062 indicating water table conditions. The calculated radius of influence for 41 hours of pumping was 110 feet. Given the measured saturated thickness of 5 to 10 feet, the hydraulic conductivities range from 100 to 200 gpd/ft^2 or approximately 13 to 27 ft/day. Monitoring well M-18, screened in the deeper sand and gravel unit, indicated a strong response to PW-2 pumping. The sand and gravel aquifer characteristics are difficult to quantify because PW-2 is screened in the fill aquifer, which is presumably separated from the sand and gravel unit by the clay unit; nonetheless, the interconnection between the two aquifers is apparent at this location.

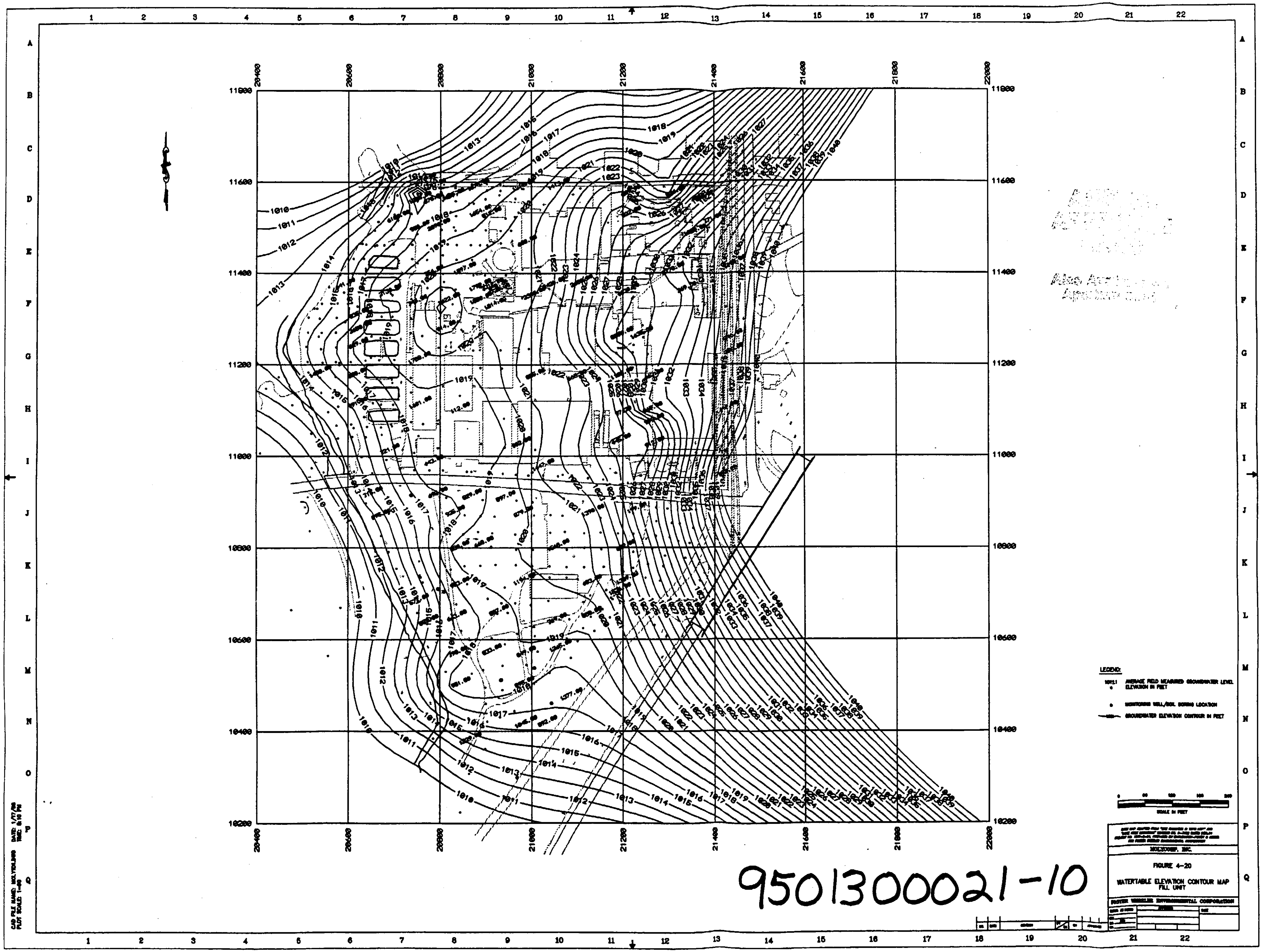
The pumping test data from PW-1 (near the northwest corner of the site) indicate water table transmissivities averaging 1,145 gpd/ft in two observation wells with the storage coefficient averaging 0.064. Although seven hours of pumping did not provide an abundance of data compared to the 41 hours at PW-2, the results are very comparable, confirming the fill aquifer characteristics in this downgradient portion of the site.

In addition, slug tests were conducted in a total of 20 wells in order to extrapolate hydraulic conductivity values from the response of water levels to an instantaneous displacement of a slug of water in each well (see Appendix E). At locations MW-9S, MW-23 and PZ-205, recovery was too rapid to obtain meaningful data. MW-9S was completed in the fill aquifer and PZ-205 was completed in the bottom of the fill aquifer and the entire clayey zone. Of the slug test results obtained, M-18S, completed in fill, had a hydraulic conductivity value of 2.8 ft/day (compared to 18 ft/day at M-18S derived from the pumping test at PW-2 and assuming 7.5 feet of saturated thickness). It is not uncommon for slug test data to yield values more than an order of magnitude lower than from a long-term pumping test. The data from the slug tests indicate an average hydraulic conductivity value for the fill aquifer of 1.25 feet/day (for six wells ranging from 0.45 to 2.8 feet/day) and for the sand and gravel unit of 0.57 feet/day (for 10 wells ranging from 0.059 to 2.15 feet/day). Although these values do not provide exact data, they provide a good indication of relative hydraulic conductivities between these units and areally within the units.

The potentiometric surfaces of the water table (fill) aquifer and of the sand and gravel aquifer are shown in Figures 4-20 and 4-21. Both potentiometric surfaces indicate a westward gradient averaging 0.03 ft/ft. The data presented by Remcor (1991) are essentially confirmed; however, the current investigation provides stronger evidence of interconnection between the water table (fill) unit and the sand and gravel unit, based on the pumping tests and chemical analyses of groundwater samples indicating that the effectiveness of the clay unit as an aquitard is less than previously reported. Similarly, the current limited data from the bedrock aquifer indicate that it has some degree of hydraulic conductivity, based on the boring logs showing fractured bedrock and the chemical data. The chemical analyses are discussed in Section 5. Water level rounds from this investigation confirmed low potentiometric levels at M-11 as previously reported by Remcor. The potentiometric surface is presented for the sand and gravel unit both with and without the measured value for M-11. Additional data would be required to further define this potential anomaly, which could result from man-made activity (e.g., sewers installation) in this area.

The water table in the fill unit averaged 4 feet below ground surface in early autumn 1994, whereas the sand and gravel aquifer averaged 7.5 feet below ground surface. This indicates that there is an average of 3.5 feet of downward vertical hydraulic potential. Differences in the measured potentiometric surfaces between the fill unit and the sand and gravel unit indicate significant downward vertical gradient in the northeastern (upgradient) portion of the active plant site and in the thorium pile south of Caldwell Avenue. The interconnection between aquifers is demonstrated by the response in M-18 during PW-2 pumping (PW-2 is completed in the fill aquifer and M-18 is in the sand and gravel aquifer). Although there is a head difference between the two aquifers, it is less than one foot in the vicinity of PW-2, which is consistent with the interconnection determined during the pumping test. This interconnection may result from either a man-made breach or the natural composition of the clay unit in this area. The zone of downward vertical gradient is also significant in the slurry wall (or clay dike) area, probably as a result of the slurry wall.

The potentiometric surface of the water table (Figure 4-20) in the northwest portion of the site, behind the dike indicates an extended flat area bulging toward the river. This phenomenon appears



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to result from the slurry wall constructed between the surface impoundments and Chartiers Creek, confirming Remcor's statement that the slurry wall regulates the water table in the impoundment area, so the top of the wall acts as a broad spillway. This plateau created by the slurry wall, however, increased the downward potentiometric head from the fill unit to the sand and gravel unit and ultimately to underlying bedrock. The single bedrock monitoring well BR1 shows groundwater elevations (Table E-7) in the range of 2 feet less head than surrounding overburden wells, thereby indicating an increased potential for downward groundwater flow and chemical transport.

4.5.2 Groundwater Flow and Solute Transport Models

Numerical simulation of the shallow aquifer system at the Molycorp plant site, Washington, PA, was performed using hydrologic information acquired to date in order to provide for the testing of the reasonableness of available hydrologic information and to determine a probable range of hydrologic conditions. Presented below is a brief description of methods, parameters and assumptions used in conjunction with the modeling effort, and the results obtained.

The three-dimensional movement of groundwater of constant density through heterogeneous and anisotropic earth material under nonequilibrium conditions may be described by the partial-differential equation

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right)-W=S_s\frac{\partial h}{\partial t} \qquad \textbf{(4-1)}$$

where

x, y, and z are Cartesian coordinates aligned along the major axes of hydraulic conductivity K_{xx}, K_{yy}, K_{zz};

h is the potentiometric head;

W is a volumetric flux per unit volume and represents sources and/or sinks of water (t^{-1});

S_s is the specific storage of the porous material; and

t is time.

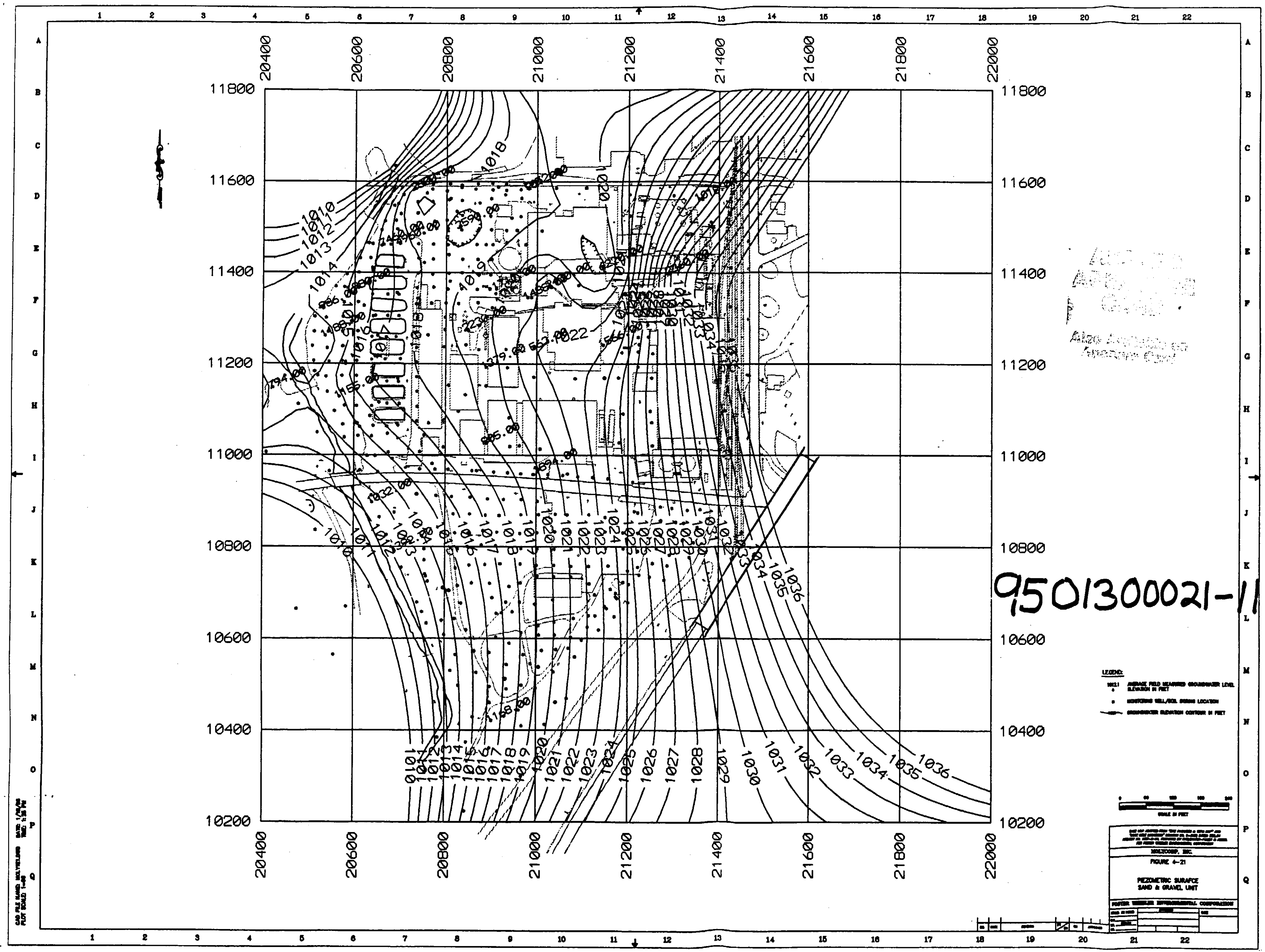
Equation 4-1, together with specification of flow and/or head conditions at the boundaries of an aquifer system and specification of initial-head conditions, constitutes a mathematical model of groundwater flow. A solution of Equation 4-1, in an analytical sense, is an algebraic expression giving h(x,y,z,t) such that, when the derivatives of the potentiometric head with respect to space and time are substituted into Equation 4-1, the equation and its initial and boundary conditions are satisfied. Except for very simple systems, analytical solutions of Equation 4-1 are rarely possible; therefore, various numerical methods must be employed to obtain approximate solutions. One such approach is the finite-difference method of numerical simulation wherein the continuous system described by Equation 4-1 is replaced by a finite set of discrete points in space and time, and the partial derivatives are replaced by differences between functional values at these points.

The process leads to systems of simultaneous linear algebraic difference equations. The solution to these equations yields values of head at specific points and time. These values constitute an approximation to the time-varying head distribution that would be given by an analytical solution of the partial-differential equation of flow.

The groundwater flow model used to provide numerical simulation of the shallow aquifer system at the site was MODFLOW, the U.S. Geological Survey modular three-dimensional finite difference groundwater flow model (MacDonald and Harbaugh, 1988). The MODFLOW model uses a block-centered finite-difference approach to the solution of Equation 4-1. The MODFLOW model assumes that model nodes are located in the center of rectangular cells within which hydraulic properties remain constant. Conductance terms are calculated by the model for each node which are multiplied by the difference in head between adjacent nodes, thereby providing calculations of flow between the node and adjacent nodes. Model layers are defined as either confined, unconfined, or convertible between confined and unconfined. Heads in the top unconfined layer are calculated based upon the Dupuit assumption which assumes that for unconfined conditions, the hydraulic gradient of flow is equal to the slope of the water table. Rates of groundwater flow for each node are calculated by MODFLOW for individual iterations using Darcy's Law and the assumption that the claystone bedrock underlying aquifer system is impermeable.

The MODFLOW General Head Boundary (GHB) Package, is a special type of the specified head boundary condition which allows the water levels at the boundary to change in a transient simulation, provided starting head values are supplied at the beginning of a simulation. The MODFLOW River Package is a specified head boundary condition used to simulate the flow of water between an aquifer and a source reservoir, thereby supplying or removing the water from the model area. The rate of leakage between the river and the aquifer is calculated based upon the length and width of the river, river bottom thickness and the vertical hydraulic conductivity of river bottom material. The MODFLOW Well Package is a specified flow boundary condition used to simulate a recharging or discharging well or spring and the MODFLOW Horizontal Flow Barrier Package is used to simulate a thin vertical slurry wall (i.e., dike) or fault of low hydraulic conductivity.

Areal discretization of the Molycorp, Inc. groundwater flow model, as displayed in Figure 4-22, is composed of a network of 60 by 60 nodes, located 25 feet apart for a total model areal dimension of 1,500 by 1,500 feet (~52 acres) inclusive of the Molycorp, Inc. plant site and the immediate area east of the site and west of U.S. Route I-70. Vertically, the model is divided into two model layers (layers 1 and 2), separated by a confining unit of low hydraulic conductivity. The base of the model was chosen to coincide with the base of the clayey sand and gravel unit. The uppermost leaky unconfined model layer (model layer 1) simulates the fill and mixed soil zone distributed over the site; and the lower confined model layer (model layer 2) simulates the clayey sand and gravel unit directly overlying the claystone bedrock. Horizontal flow in the clay confining unit was assumed to be negligible due to its low relative hydraulic conductivity. Head-dependent vertical leakage conditions between model layers 1 and 2 are simulated at layer boun-



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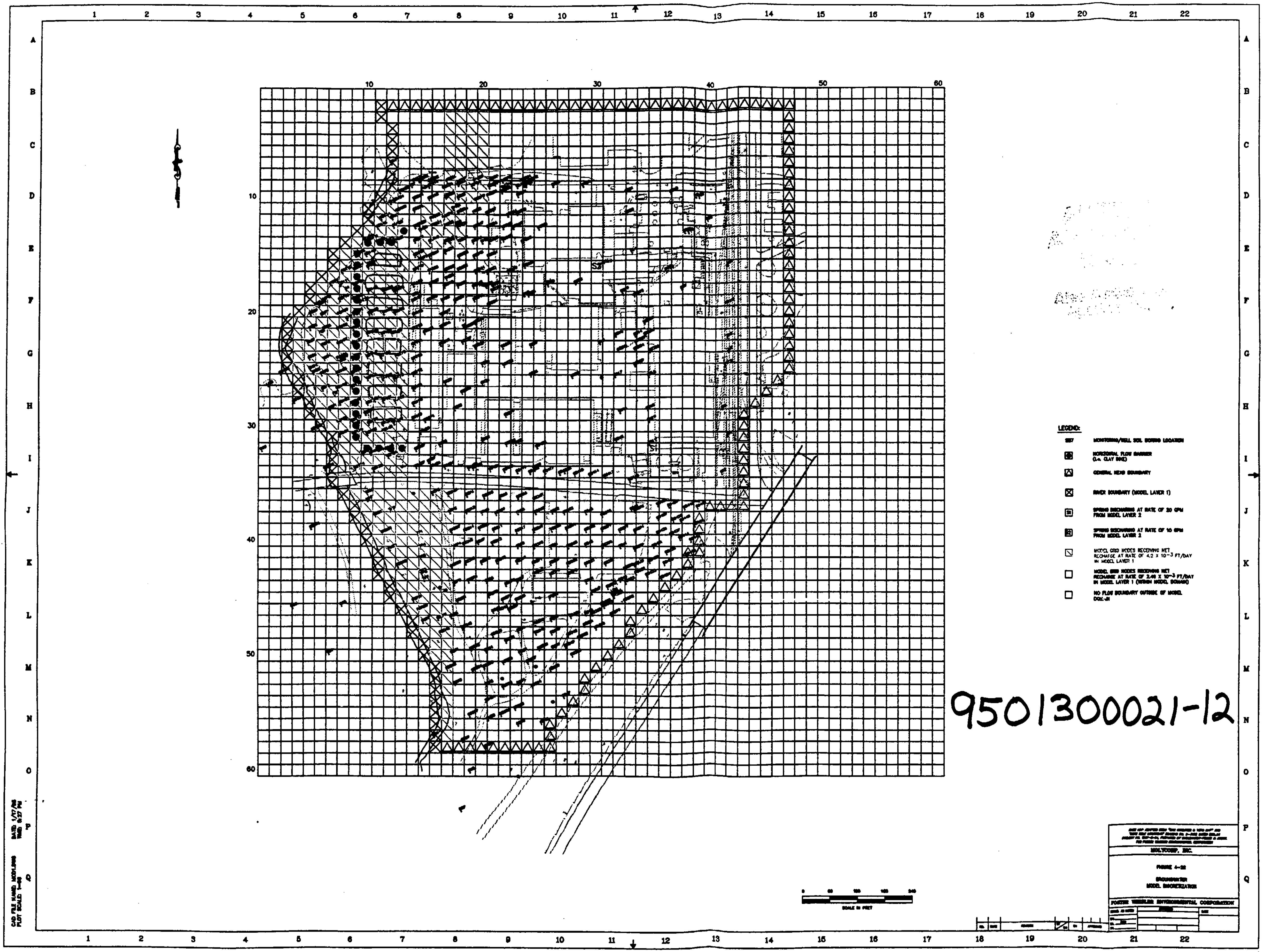

LEGEND:
MONITORING/WELL SOIL BORING LOCATION
HORIZONTAL FLOW BARRIER (i.e. CLAY DIKE)
GENERAL HEAD BOUNDARY
RIVER BOUNDARY (MODEL LAYER 1)
SPRING DISCHARGING AT RATE OF 20 GPM FROM MODEL LAYER 2
SPRING DISCHARGING AT RATE OF 10 GPM FROM MODEL LAYER 2
MODEL GRID NODES RECEIVING NET RECHARGE AT RATE OF 4.2 X 10-3 FT/DAY IN MODEL LAYER 1
MODEL GRID NODES RECEIVING NET RECHARGE AT RATE OF 2.40 X 10-3 FT/DAY IN MODEL LAYER 1 (WITHIN MODEL DOMAIN)
NO FLOW BOUNDARY OUTSIDE OF MODEL DOMAIN
SCALE IN FEET
MOLYCORP, INC.
FIGURE 4-22
GROUNDWATER MODEL DISCRETIZATION
FOSTER WHEELER ENVIRONMENTAL CORPORATION
9501300021-12

daries based upon the distributed thickness of the clay unit and an assumed vertical hydraulic conductivity value of 0.11 ft/day for the clay material. Overall therefore, the model computes values of groundwater flow at 7,200 individual nodal locations. Model boundary condition and property input parameters were based upon information gained during previous subsurface field investigations of the site (Section 4.5.1) and are displayed in Figure 4-22 and presented in Table 4-2.

Limited data on the hydraulic properties of the bedrock unit beneath the site makes it difficult to fully assess the validity of the assumption that the bedrock is impermeable. Examination of bedrock core taken in bedrock well BR-1 (Section 4.4.2) revealed the bedrock to be competent to a depth of about 10 feet below the bedrock surface, despite a high degree of mechanical fracturing due to the rock coring process. In light of the fact, however, that non-radiological contamination of the groundwater has been identified in bedrock well BR-1 and the fact that a downward vertical hydraulic gradient exists between overburden and bedrock units, further study of the bedrock is required to accurately assess the hydrologic relationship between these units. For purposes of this modeling effort, the assumption that the clay stone bedrock is impermeable is used to define the bottom of the sand and gravel unit overlying the bedrock as the lower boundary of the model domain.

A more detailed summary of model boundary conditions, model property input parameters, model iteration statistics, node-specific model-calculated values of hydraulic head and the volumetric water budget for the entire model domain is presented in Appendix M. Model distributed input parameters, such as layer bottom elevation and leakage from model layer 1 and model layer 2 transmissivity were distributed via the minimum curvature method of machine contouring (Briggs, 1974). Model simulations were conducted with the bottom elevation distribution for model layer 1 reduced (i.e., lowered) by a uniform value of 5 feet below that indicated in on-site boring logs and distributed within the active domain of the model. Model layer 1 leakage through the clay confining unit was distributed in the model using a clay confining unit thickness correspondingly reduced by a uniform value of 5 feet and an assumed average vertical hydraulic conductivity of 0.11 ft/day. Based upon pump test results outlined in Section 4.5.1, an average hydraulic conductivity of 22.72 ft/day was uniformly input into the model for model layer 1 hydraulic conductivity. Model layer 2 transmissivity was distributed within the active model domain based upon the distributed thickness of the sand and gravel unit and the distributed hydraulic conductivity for the layer based upon slug test results described in Section 4.5.1. Successive model iteration and hypothesis testing revealed that, in addition to the aforementioned increasing of the thickness of model layer 1, a 50 percent reduction in the hydraulic conductivity of model layer 1 produced model-calculated hydraulic head values consistent with field measured values.

Recharge to the model domain was distributed in accordance with Figure 4-22, whereby model nodal areas not overlain by impervious materials (i.e., asphalt or buildings) were assumed to receive recharge at an approximate rate of 1,370 gallons/acre/day (GPAD) based upon an annual,

Table 4-2 (Sheet 1 of 2)

Molycorp Groundwater Flow Model Input Parameters

Model Input Parameter	Model Layer 1	Model Layer 2
Model Grid Length (ft)	1500	1500
Model Grid Width (ft)	1500	1500
Number of Nodes	3600 (60x60)	3600 (60x60)
Node Length (ft)	25	25
Node Width (ft)	25	25
Layer Type	unconfined w/leakage	confined
Starting Head (ft)[C]	1001.75-1045.11	1003.40-1035.84
Hydraulic Conductivity (ft/day)[C]	22.72	$1x10^{-3}$-1.77
Layer Transmissivity (ft^2/day)[C]	—	$5x10^{-4}$-26.70
Layer Bottom Elevation (ft)[C]	982.83-1042.80	976.42-1048.3
Layer Leakage (ft/day)[A,C]	$5x10^{-4}$-11.36	—
Recharge (ft/day)[C]	$2.46x10^{-8}$ - $4.20x10^{-2}$	—
River Stage (ft)	1009.695-1012.205	—
River Bottom (ft)	1008.042-1010.987	—
River Bottom Conductance (ft/day)	83.3-7100	—
General Head Boundary Conductance (ft/day)[B]	14.958-568.0	0.30-11.308
General Head Boundary Source Head (ft)	999.352-1045.21	1001.61-1041.70
Horizontal Flow Barrier Conductance (ft/day)	$1x10^{-7}$	—
Horizontal Flow Barrier Thickness (ft)	7	—
Discharge to Storm Sewer from Springs	—	20 gpm at M-11, 10 gpm near Acid Holder Tanks
Specific Yield (%)	30	–

Table 4-2 (Sheet 2 of 2) Molycorp Groundwater Flow Model Input Parameters		
Model Input Parameter	Model Layer 1	Model Layer 2
Porosity (%)	25	25
Bulk Density (lbs/ft^3)	131	131
Dispersivity (ft)	5	5
Distribution Coefficient for Cadmium (Baes, 1984)	6.5	6.5
Distribution Coefficient for Selenium (Baes, 1984)	300	300
Distribution Coefficient for Molybendum (Baes, 1984)	20	20

Notes:

A Based upon leakage formula:

$$L = K_v d$$

where: K_v = vertical hydraulic conductivity of clay confining unit = 1.1×10^{-1} ft/day

d = model distributed difference (ft) between bottom of fill and top of clayey sand and gravel unit

B Based upon conductance formula

$$C = Kd$$

where: K = average hydraulic conductivity in model layer

d = distance between model source and boundary heads

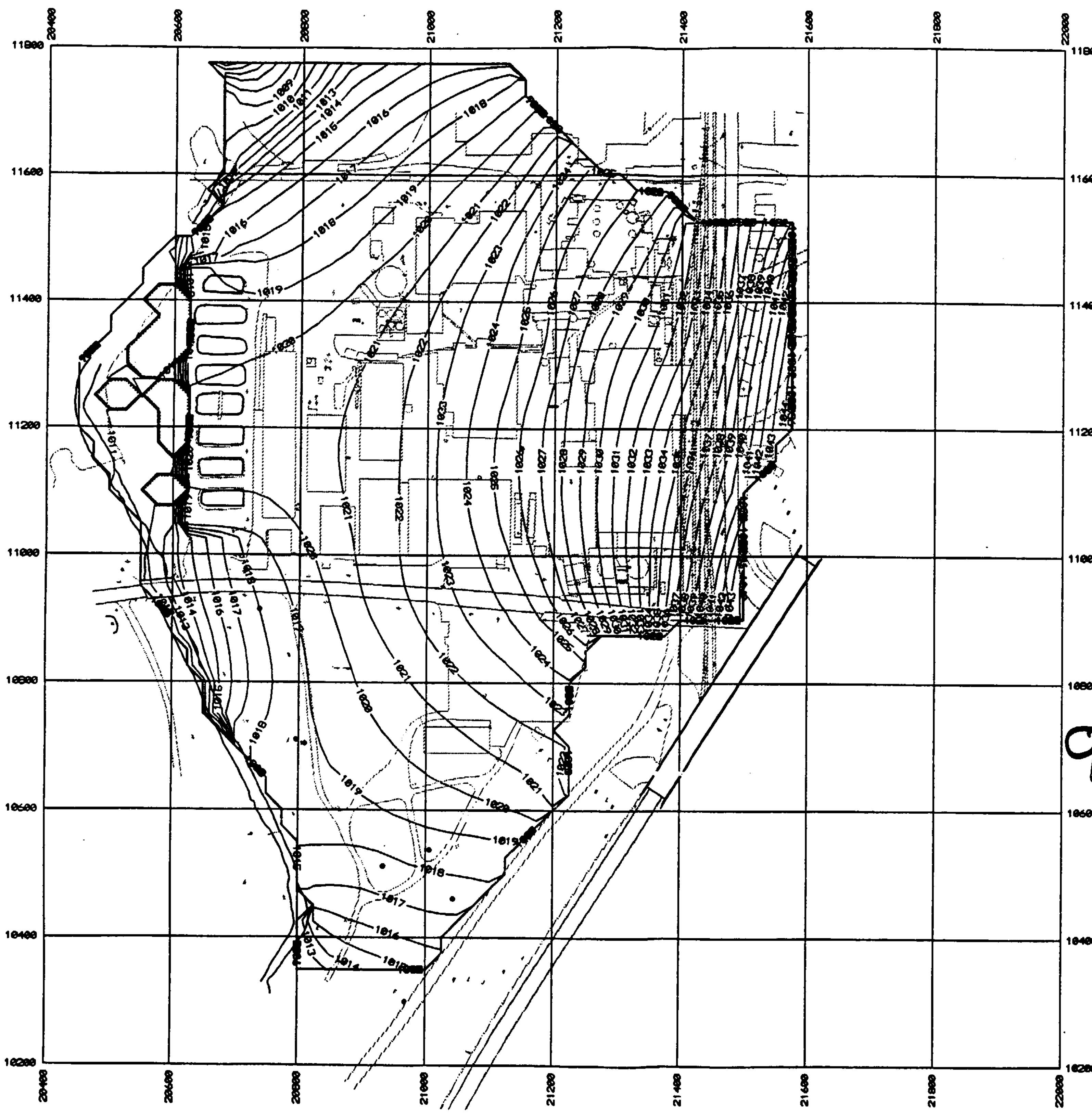
C Model distributed parameter.

D Model nodes in which the distributed layer bottom elevation for model layer 2 exceeded that of model layer 1 (i.e., where the sand and gravel unit pinches out), were arbitrarily assigned a thickness value of 0.5 feet for the transmissivity calculation.

evapotranspiration adjusted precipitation rate of 18 inches distributed over the entire model domain. Model nodal areas overlain by impervious materials were assumed to receive recharge at a conservative rate of $8.2x10^{-4}$ GPAD. Chartiers Creek was simulated in the model using the river boundary condition in model layer 1. River nodes were assigned values of river stage based upon field-measured stage values at both upstream and downstream staff gauge locations and an assumed river stage gradient of 0.2 foot/100 feet. Topographic survey information taken in the channel bottom of Chartiers Creek was used to assign elevations of the channel bottom to each river node. Leakage through the riverbed material was approximated for each river node, using Darcy's Law and riverbed conductance values which were based upon a uniform riverbed thickness of one foot, a channel width estimated from the site topographic map, and a riverbed hydraulic conductivity equivalent to that of the fill and mixed soil materials. A lower value of hydraulic conductivity for the riverbed material was used to calculate riverbed material conductance along Chartiers Creek from the area of Caldwell Avenue to a distance of about 250 feet to the north in order to account for the clayey river bottom materials observed in the vicinity of surface water sampling location CR-3. General head boundaries (GHB) were used to simulate the horizontal flux of groundwater in each layer as indicated in Figure 4-22. Boundary head values for each GHB were input into the model in accordance with synoptic, averaged, field measured hydraulic head elevation contour maps presented in Figures 4-20 and 4-21. GHB conductance values were determined using source head values observed in each model layer at GHB node locations indicated in Figure 4-22 and the average value of hydraulic conductivity observed between each source and boundary head node.

Contour maps displaying steady state, model-simulated hydraulic head elevations based upon Table 4-2 model input parameters are presented in Figures 4-23 and 4-24. Contour maps displaying transient, model-simulated hydraulic head elevations based upon Table 4-2 model input parameters are presented in Figures 4-25 and 4-26. Comparison between these maps and contour maps displaying field-measured hydraulic head elevations (Figure 4-20 and 4-21) provide a qualitative indication of the degree of similarity between field-measured and model-computed heads. In general, field measured and model-computed heads compare favorably and although they do not match exactly, their respective hydraulic gradients compare favorably as well. Model-simulated hydraulic head elevation contour maps for model layer 1 indicate that the model-calculated hydraulic head elevation in the layer falls below the bottom of the layer (i.e., goes "dry") within portions of the northeastern and east central areas of the model domain as well as isolated portions of the impoundment area west of the clay dike and east of Chartiers Creek. Although not apparent in the model-simulated hydraulic head contour maps, model simulations indicate that within the model domain, Chartiers Creek exists as a gaining stream from the upstream staff gauge location to model grid row 54, a losing stream from model grid row 55 to 45 and a gaining stream from model grid row 46 to the downstream staff gauge with the exception of model grid rows 11 and 12 where it loses water to the aquifer for a limited distance.

Contour maps include errors introduced by the contouring algorithm and may or may not be entirely representative of actual field conditions. A more quantitative measure of the reasonableness of model input parameters is afforded via the degree of correlation between field-



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LEGEND:

MODEL-COMPUTED HEAD ELEVATION CONTOUR IN FEET

SCALE IN FEET

MOLYCORP, INC.

FIGURE 4-23

STEADY-STATE MODEL-COMPUTED HEADS FOR MODEL LAYER 1

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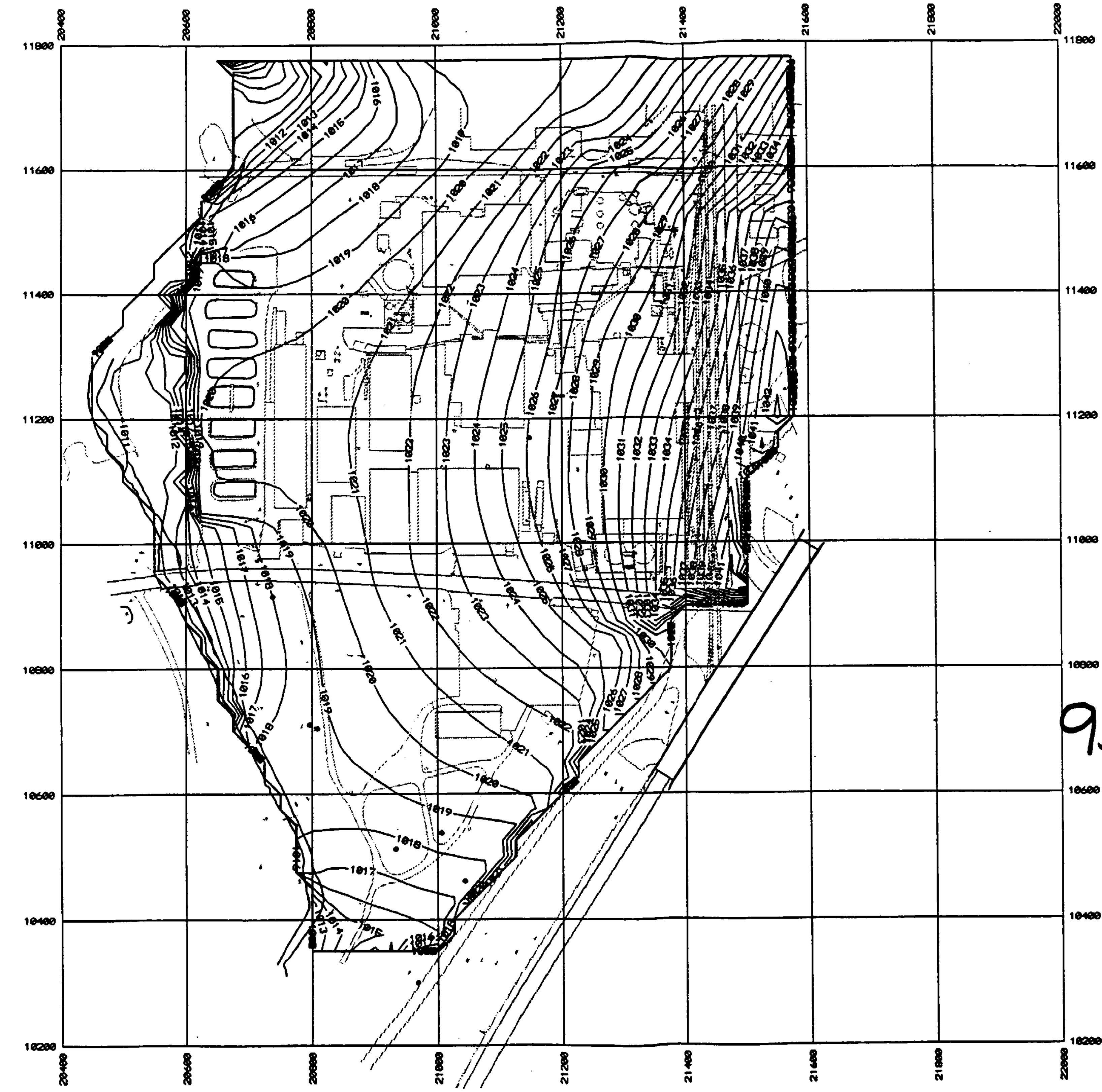

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LEGEND

MODEL-COMPUTED HEAD ELEVATION CONTOUR IN FEET

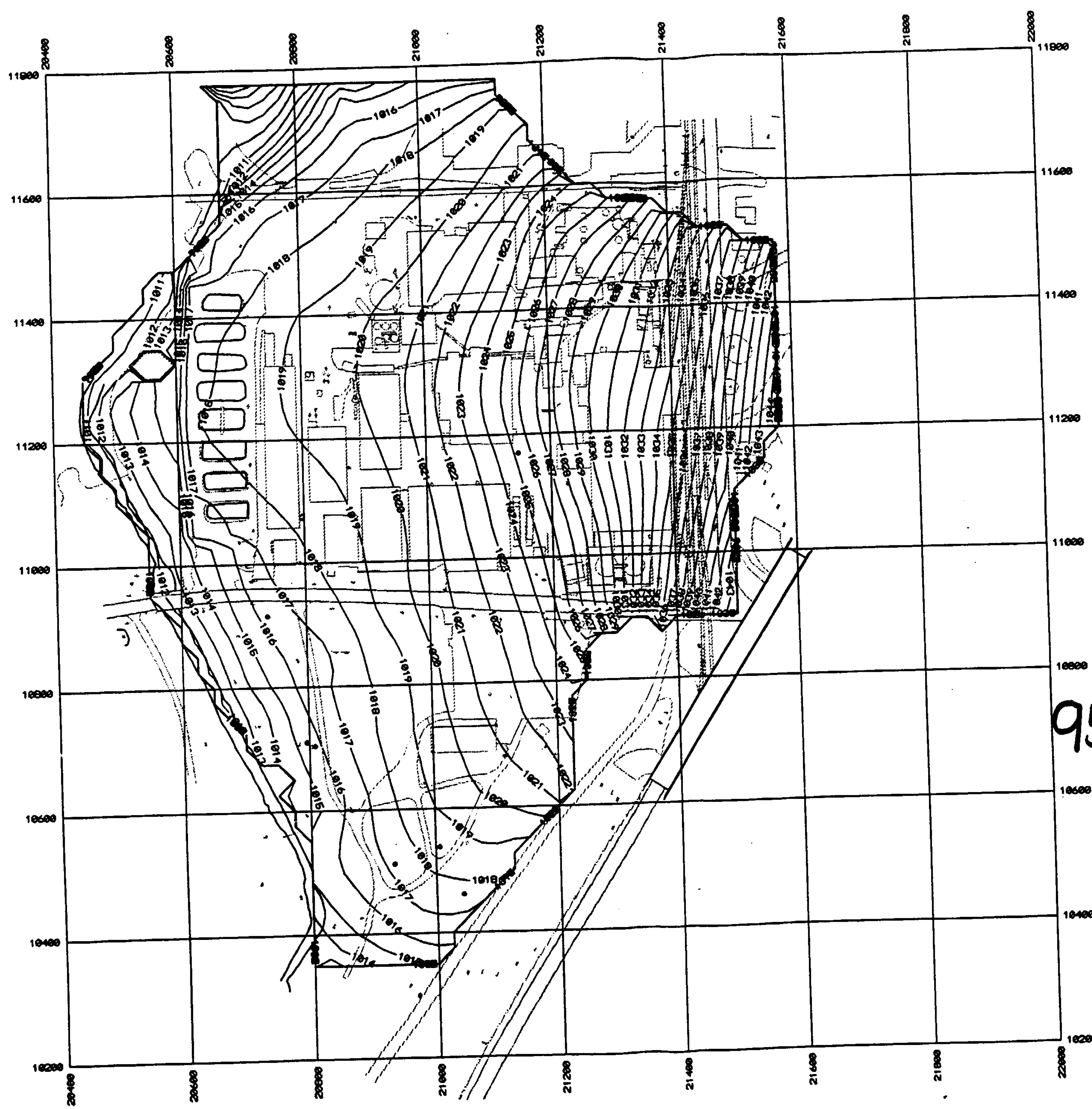
SCALE IN FEET

MOLYCORP, INC.

FIGURE 4-24

STEADY-STATE MODEL-COMPUTED HEADS FOR MODEL LAYER 2

FOSTER WHEELER ENVIRONMENTAL CORPORATION



LEGEND:

MODEL-COMPUTED HEAD ELEVATION CONTOUR IN FEET

SCALE IN FEET

MOLYCORP, INC.

FIGURE 4-25

TRANSIENT MODEL-COMPUTED HEADS FOR MODEL LAYER 1 (SIMULATION DURATION = 30 DAYS)

FOSTER WHEELER ENVIRONMENTAL CORPORATION

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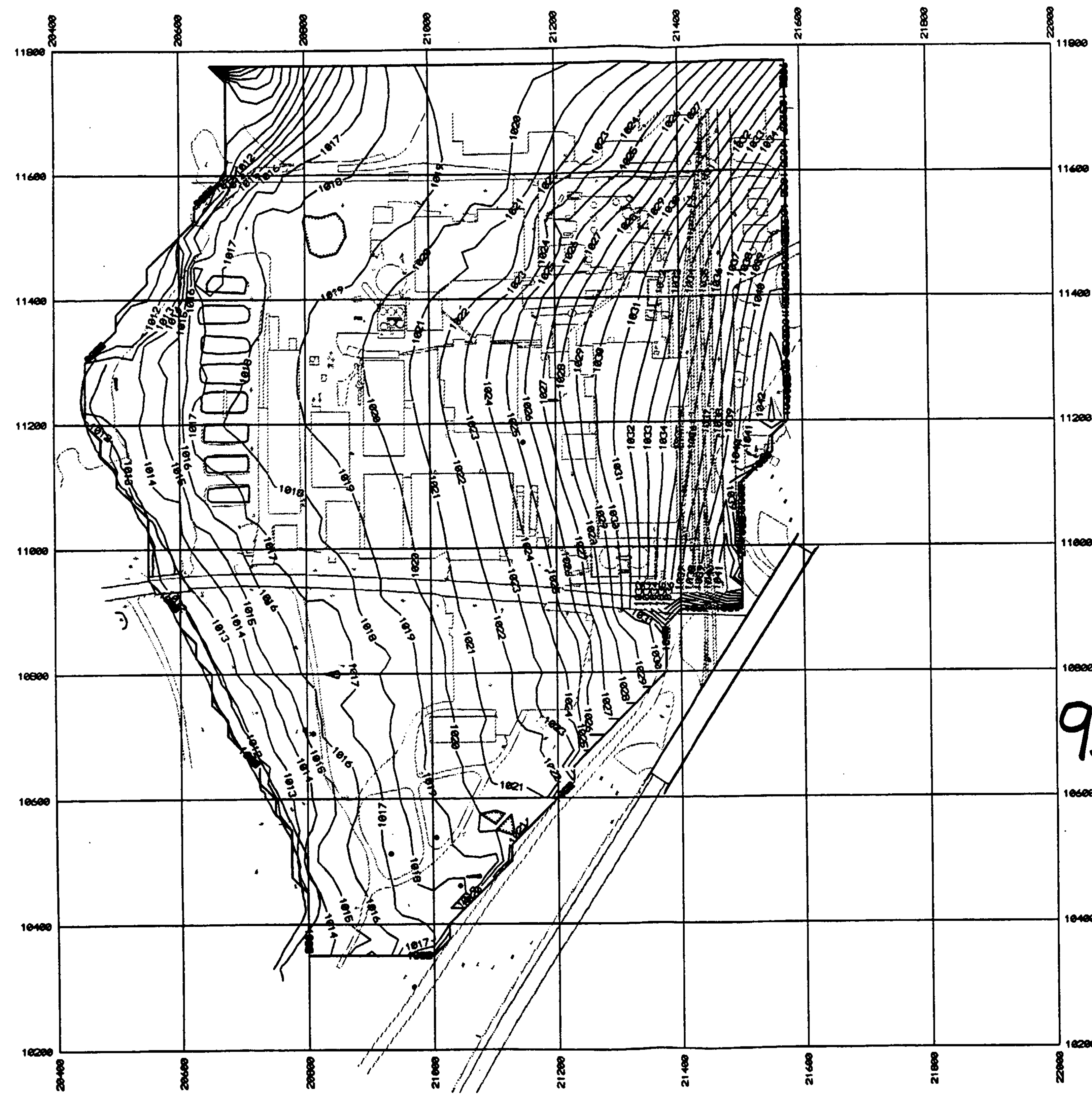

MOLYCORP, INC.

FIGURE 4-26

TRANSIENT MODEL-COMPUTED HEADS FOR MODEL LAYER 2 (SIMULATION DURACTION = 30 DAYS)

FOSTER WHEELER ENVIRONMENTAL CORPORATION

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measured and model-simulated hydraulic head data for each model layer as presented in Table 4-3. Displayed in the table are the residuals at each point of measurement between field-measured and model-simulated head elevations (exclusive of piezometer/monitoring well locations SB5, SB6, SB54, SB70 and MW21 which are influenced by "dry" nodes in model layer 1) as well as root-mean-squared error in head, standard deviation, sum of squares and the simple mean of the range of residuals.

Transient (non steady-state) model verification analysis was also conducted using late-time aquifer pumping test data acquired during the 41-hour pump test of well PW-2. A specific yield of 30 percent was chosen to represent model layer 1 materials and a model simulation was run for a total duration of 2400 minutes with pumping well PW-2 pumping at a continuous rate of 0.5 gpm. Comparison of late-time model-simulated drawdown with field-measured drawdown in monitoring wells/piezometers M-18S, PZ-242 and PZ-243 are presented in Figure 4-27, 4-28 and 4-29, respectively. Overall, agreement between model-simulated and hand-measured drawdown is good. Model-simulated drawdown using a uniformly distributed hydraulic conductivity of 11.36 ft/day in model layer 1 is consistently greater in later time than the hand-measured drawdown. This indicates that hand-measured pumping test results may have been influenced by leakage from the sand and gravel unit during the test. Distribution of the hydraulic conductivity parameters within model layer 1 would provide for higher agreement between model-simulated and field measured drawdown, however additional pump test information of other locations within the fill unit would not be required.

The overall volumetric water budget for the model domain (Appendix M) provides a summary of the cumulative volume of water supplied to and removed from the model domain for transient model simulations. The low overall percent discrepancy between water supplied to and removed from the system for each stress period provides further confirmation of the reasonableness of model input parameters. For transient simulations, the product of the storage coefficient (or specific yield), the area of the model domain and the unit decline in head yields the total volume of water supplied to or removed from the system via storage throughout simulation duration. The volumetric water budget for stress period 1 (30 day duration) indicates that 30 percent of the total volume of water supplied to the system is supplied via release from storage, 6.17 percent via recharge, 8.85 percent via vertical leakage through riverbed materials and 54.97 percent via horizontal flux through head dependent flux boundaries to the active model domain. The volumetric water budget also indicates that 26 percent of the total volume of water removed from the system is removed via storage, 65.72 percent via flow through head dependent boundaries to the active model domain, 7.91 percent via leakage through the riverbed material into Chartiers Creek, and 2.2×10^{-4} percent via spring discharge from model layer 2 into the sewer system near the acid holding tank area, and near well M-11 which also discharges into Chartiers Creek. Somewhat similar mass balance information is observed for the 5-year model simulation (Appendix M), with less water coming into or going out of the system via storage and more water being supplied via head dependent boundaries as steady-state conditions are approached.

Table 4-3A (Sheet 1 of 3) Field-Measured Versus Model-Computed Heads in Model Layer 1							
Well/Boring Designation	Field Measured Head	Steady State Model Computed Head	Residual	Transient Model-Computed Head[1]	Residual	Transient Model-Computed Head[2]	Residual
M9S	1021	1020.535	-0.4652	1020.524	-0.4761	1022.441	1.4406
M15S	1031.12	1030.279	-0.8409	1029.207	-1.9126	1028.008	-3.1121
M18S	1020.26	1020.542	0.2816	1019.962	-0.2985	1020.494	0.2339
MW19	1025.16	1027.321	2.1606	1028.309	3.1493	1029.044	3.8837
MW20	1018.29	1018.411	0.1207	1018.616	0.3262	1020.569	2.279
SB1	1040.05	1037.719	-2.3307	1036.847	-3.2031	1036.791	-3.2589
SB2	1035.77	1035.142	-0.6283	1035.431	-0.3394	1035.52	-0.2498
SB3	1036.02	1035.714	-0.306	1035.363	-0.6575	1034.589	-1.431
SB4	1035.33	1035.077	-0.2526	1034.135	-1.1954	1032.703	-2.6271
SB7	1030.84	1030.879	0.0387	1030.255	-0.5848	1028.993	-1.847
SB8	1031.22	1029.423	-1.7966	1028.783	-2.4368	1027.703	-3.5166
SB10	1022.12	1022.668	0.5475	1025.299	3.1791	1025.972	3.8516
SB11	1025.76	1026.069	0.3087	1027.775	2.0151	1028.886	3.1257
SB12	1030.24	1027.754	-2.4863	1027.621	-2.6191	1028.176	-2.0636
SB13	1030.16	1029.96	-0.2006	1029.276	-0.8843	1028.892	-1.2686
SB14	1029.36	1029.016	-0.3444	1027.71	-1.65	1026.75	-2.6102
SB15	1025.3	1024.697	-0.6031	1025.11	-0.1897	1026.339	1.0389
SB16	1024.83	1024.746	-0.0842	1025.56	0.7302	1026.548	1.7184
SB17	1025.18	1025.578	0.3979	1026.309	1.1284	1026.553	1.3727
SB18	1029.3	1028.379	-0.9215	1026.784	-2.5156	1025.909	-3.391
SB19	1028.13	1027.291	-0.8389	1026.085	-2.0453	1025.342	-2.7881
SB20	1026.58	1026.257	-0.3231	1025.076	-1.5039	1024.999	-1.5806
SB21	1025.42	1024.852	-0.5685	1023.82	-1.5997	1024.177	-1.2434
SB22	1021.88	1022.137	0.257	1023.027	1.147	1024.017	2.137
SB23	1023.77	1022.973	-0.7973	1022.932	-0.838	1023.16	-0.6104
SB26	1021.84	1021.056	-0.7837	1020.744	-1.0958	1022.048	0.2075
SB28	1020.76	1020.677	-0.0831	1020.902	0.1417	1021.51	0.7501
SB29	1021.16	1021.298	0.1381	1021.707	0.5466	1022.197	1.0368
SB30	1020.25	1019.457	-0.7926	1019.135	-1.1147	1019.43	-0.8198
SB32	1019.28	1019.278	-0.002	1019.758	0.4781	1021.787	2.5069
SB36	1019.08	1019.366	0.2861	1019.551	0.4707	1020.995	1.915
SB37	1018.65	1018.024	-0.6256	1017.229	-1.4207	1019.035	0.3848
SB40	1022.62	1022.008	-0.6122	1022.248	-0.3724	1022.184	-0.4359
SB41	1022.67	1022.486	-0.1839	1022.938	0.2684	1023.262	0.5919
SB42	1025.68	1024.887	-0.7933	1024.649	-1.0313	1025.301	-0.379
SB43	1019.19	1019.84	0.6499	1020.585	1.3948	1020.769	1.5788
SB44	1020.45	1020.58	0.1297	1021.077	0.6271	1021.615	1.1647
SB46	1020.88	1021.047	0.1671	1021.762	0.8821	1023.156	2.2761
SB49	1018.37	1019.085	0.7155	1019.228	0.858	1019.738	1.3683
SB50	1019.84	1019.568	-0.2721	1019.591	-0.2494	1020.351	0.5109
SB51	1020.25	1020.14	-0.1102	1020.159	-0.0907	1021.698	1.4482
MW27	1018.93	1018.686	-0.2441	1018.033	-0.8972	1019.071	0.1405
SB57	1019.62	1019.355	-0.2653	1018.69	-0.9305	1020.427	0.8074
MW26	1019.76	1019.461	-0.2994	1019.173	-0.5869	1021.395	1.6351

Table 4-3A (Sheet 2 of 3) Field-Measured Versus Model-Computed Heads in Model Layer 1							
Well/Boring Designation	Field Measured Head	Steady State Model Computed Head	Residual	Transient Model-Computed Head[1]	Residual	Transient Model-Computed Head[2]	Residual
SB60	1019.24	1019.217	-0.0233	1019.213	-0.027	1021.367	2.127
SB64	1018.42	1017.747	-0.6728	1016.422	-1.998	1018.615	0.1953
SB65	1018.17	1018.327	0.1566	1017.592	-0.5777	1019.689	1.5189
SB67	1019.79	1018.961	-0.8286	1017.619	-2.1707	1020.119	0.3287
SB71	1017.16	1015.988	-1.1723	1014.897	-2.2628	1018.425	1.2648
SB72	1016.83	1015.775	-1.0553	1014.964	-1.866	1018.849	2.0189
SB73	1017.69	1017.431	-0.2595	1016.292	-1.3979	1019.27	1.58
SB74	1019.22	1018.428	-0.7922	1016.821	-2.3994	1019.443	0.223
SB75	1017.09	1017.269	0.1786	1016.776	-0.314	1019.226	2.1357
SB76	1018.67	1018.452	-0.2177	1017.867	-0.8033	1020.158	1.4876
SB78	1017.8	1017.704	-0.096	1016.973	-0.8268	1019.011	1.2106
SB79A	1013.27	1013.174	-0.0963	1013.43	0.1597	1018.404	5.1343
SB81	1012.73	1012.881	0.1509	1013.029	0.299	1014.841	2.1106
SB82	1013.63	1013.179	-0.4515	1013.13	-0.5004	1014.216	0.5858
SB85	1014.61	1013.594	-1.0156	1012.161	-2.4489	1011.096	-3.514
SB111	1015.08	1014.746	-0.3343	1012.702	-2.3776	1011.44	-3.6397
SB118	1014.8	1015.209	0.4091	1014.571	-0.2293	1012.686	-2.1137
SB122	1018.37	1017.41	-0.9602	1015.679	-2.6909	DRY	–
SB124	1016	1015.891	-0.1089	1015.196	-0.8043	1013.883	-2.1166
SB148	1016.07	1016.155	0.0849	1015.732	-0.3383	1017.088	1.0183
SB159	1019.25	1017.813	-1.4371	1017.71	-1.5405	1019.775	0.5251
SB190	1018.64	1018.413	-0.2275	1018.053	-0.5873	1020.207	1.5667
SB193	1019.47	1019.479	0.0086	1018.62	-0.8503	1020.271	0.8007
SB197	1019.14	1019.386	0.246	1018.493	-0.6469	1019.873	0.7333
SB202	1017.66	1017.143	-0.5166	1017.395	-0.2651	1017.274	-0.3861
SB204	1016.52	1016.863	0.3434	1016.055	-0.4651	1015.503	-1.017
SB205	1016.16	1015.157	-1.0032	1014.916	-1.2444	1014.462	-1.6976
SB208	1019.77	1019.293	-0.4775	1018.474	-1.296	1019.363	-0.4075
SB213	1017.31	1018.234	0.9244	1016.625	-0.6846	1015.989	-1.3215
SB214	1016.27	1016.082	-0.188	1015.807	-0.463	1015.244	-1.0262
MW23	1022.34	1020.481	-1.8595	1018.981	-3.3594	1019.897	-2.4432
MW24	1017.47	1017.837	0.3668	1017.932	0.4615	1017.875	0.4048
SB232	1020.37	1020.203	-0.1666	1019.218	-1.1523	1019.701	-0.6687
SB242	1020.24	1020.647	0.4069	1019.656	-0.5839	1020.251	0.0109
SB243	1020.09	1020.476	0.3856	1019.563	-0.5269	1020.089	-0.0014
MW22	1018.35	1016.744	-1.6058	1017.161	-1.1888	1016.815	-1.5355
SB250	1017.38	1016.488	-0.8921	1017.277	-0.1027	1017.075	-0.3052
SB252	1020.37	1020.542	0.1716	1019.962	-0.4084	1020.494	0.1239
SB257	1018.92	1018.521	-0.3994	1018.368	-0.5519	1018.507	-0.4129
SB268	1020.51	1020.358	-0.1517	1019.899	-0.6112	1020.278	-0.2318
SB272	1019.01	1018.4	-0.6105	1018.439	-0.5712	1018.419	-0.5908
PW1	1021.3	1018.234	-3.0656	1016.625	-4.6746	1015.989	-5.3115

Table 4-3A (Sheet 3 of 3) Field-Measured Versus Model-Computed Heads in Model Layer 1							
Well/Boring Designation	Field Measured Head	Steady State Model Computed Head	Residual	Transient Model-Computed Head[1]	Residual	Transient Model-Computed Head[2]	Residual
PW2	1021.91	1020.394	-1.5159	1019.743	-2.1674	1020.271	-1.6393
UG4	1021.33	1020.908	-0.4218	1021.526	0.1963	1021.667	0.3367
CR1	1012.17	1012.115	-0.0546	1013.639	1.4692	1015.414	3.244
CR4	1009.96	1009.902	-0.0576	1009.959	-0.0009	1009.96	0.0002
RMS Error in Head		0.814		1.439		1.888	
Standard Deviation		0.740		1.279		1.898	
Sum of Squares		60.2943		-0.668		320.9761	
Simple Mean		-0.347		-0.668		-0.072	

NOTES:

[1] Model-computed heads at end of Stress Period 1 (total simulation duration of 30 days)

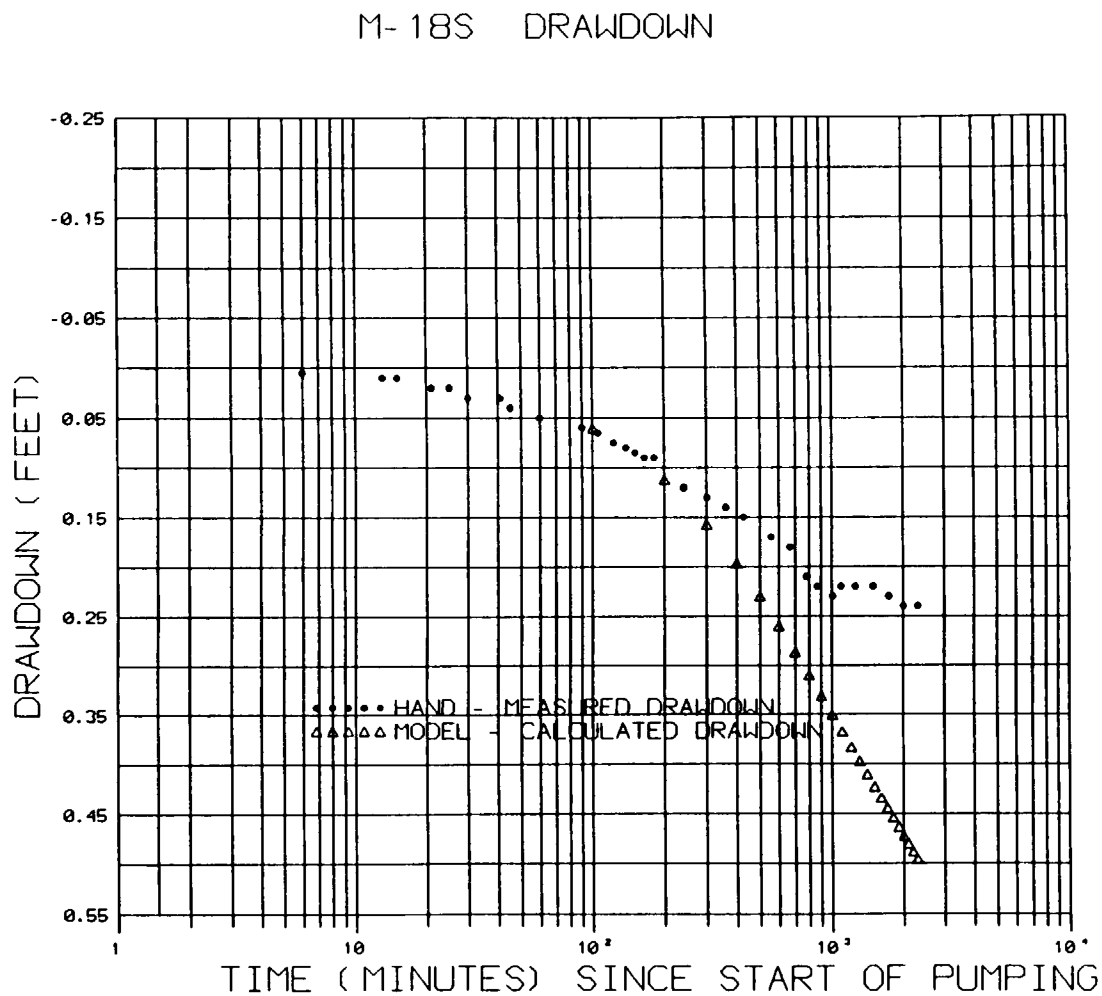
[2] Model-computed heads at end of Stress Period 2 (total simulation duration of 5 years)

Table 4-3B Field-Measured Versus Model Computed Heads in Model Layer 2							
Well/Boring Designation	Field Measured Head	Steady State Model Computed Head	Residual	Transient Model-Computed Head[1]	Residual	Transient Model-Computed Head[2]	Residual
M1	1019.37	1019.387	0.0168	1019.485	0.1147	1020.372	1.0018
M2	1014.78	1014.666	-0.1141	1014.095	-0.685	1011.962	-2.8176
M3	1013.05	1013.475	0.4246	1013.559	0.5089	1012.385	-0.6652
M4	1015.02	1014.75	-0.2697	1012.713	-2.3069	1011.44	-3.5796
M5	1016.32	1015.574	-0.7458	1015.697	-0.6235	1016.157	-0.1633
M6	1018.63	1015.705	-2.9251	1014.949	-3.6809	1014.462	-4.1677
M7	1018.49	1018.76	0.27	1018.76	0.27	1018.76	0.2697
M8	1027.82	1027.274	-0.5464	1027.274	-0.5458	1026.888	-0.9316
M9	1019.93	1020.017	0.0869	1020.393	0.4627	1022.43	2.5001
M11	1018.57	1019.262	0.6924	1022.254	3.6835	1023.846	5.2758
M12	1017.55	1017.941	0.3909	1017.946	0.3962	1017.943	0.3934
M13	1022.77	1025.462	2.6921	1025.061	2.2906	1024.813	2.0433
M15	1029.94	1028.655	-1.2848	1028.761	-1.1792	1027.677	-2.2627
M16	1021.7	1021.571	-0.1287	1021.669	-0.0316	1022.192	0.4922
M17	1020.34	1020.398	0.0577	1020.845	0.505	1021.509	1.1685
M18	1020.04	1019.871	-0.1686	1019.911	-0.129	1020.487	0.4468
SB31	1019.17	1018.76	-0.41	1018.76	-0.41	1018.76	-0.4103
SB33	1018.81	1018.743	-0.067	1018.81	-0.0003	1020.86	2.0495
SB36	1019.37	1019.317	-0.0535	1019.502	0.1319	1020.988	1.6184
MW28	1016.36	1016.147	-0.2129	1015.867	-0.4935	1016.573	0.2132
MW29	1012.14	1011.97	-0.1699	1012.396	0.256	1015.919	3.7791
SB90	1014.53	1014.282	-0.2477	1012.029	-2.5013	1010.755	-3.7755
SB120	1016.54	1016.38	-0.1602	1015.494	-1.0457	1015.494	-1.0457
RMS Error in Head		0.905		1.430		2.260	
Standard Deviation		0.916		1.444		2.307	
Sum of Squares		19.6732		49.0654		122.5388	
Simple Mean		-0.120		-0.209		0.060	

NOTES:

[1] Model-computed heads at end of Model Stress Period 1 (total simulation duration of 30 days)

[2] Model-computed heads at end of Model Stress Period 2 (total simulation duration of 5 years)



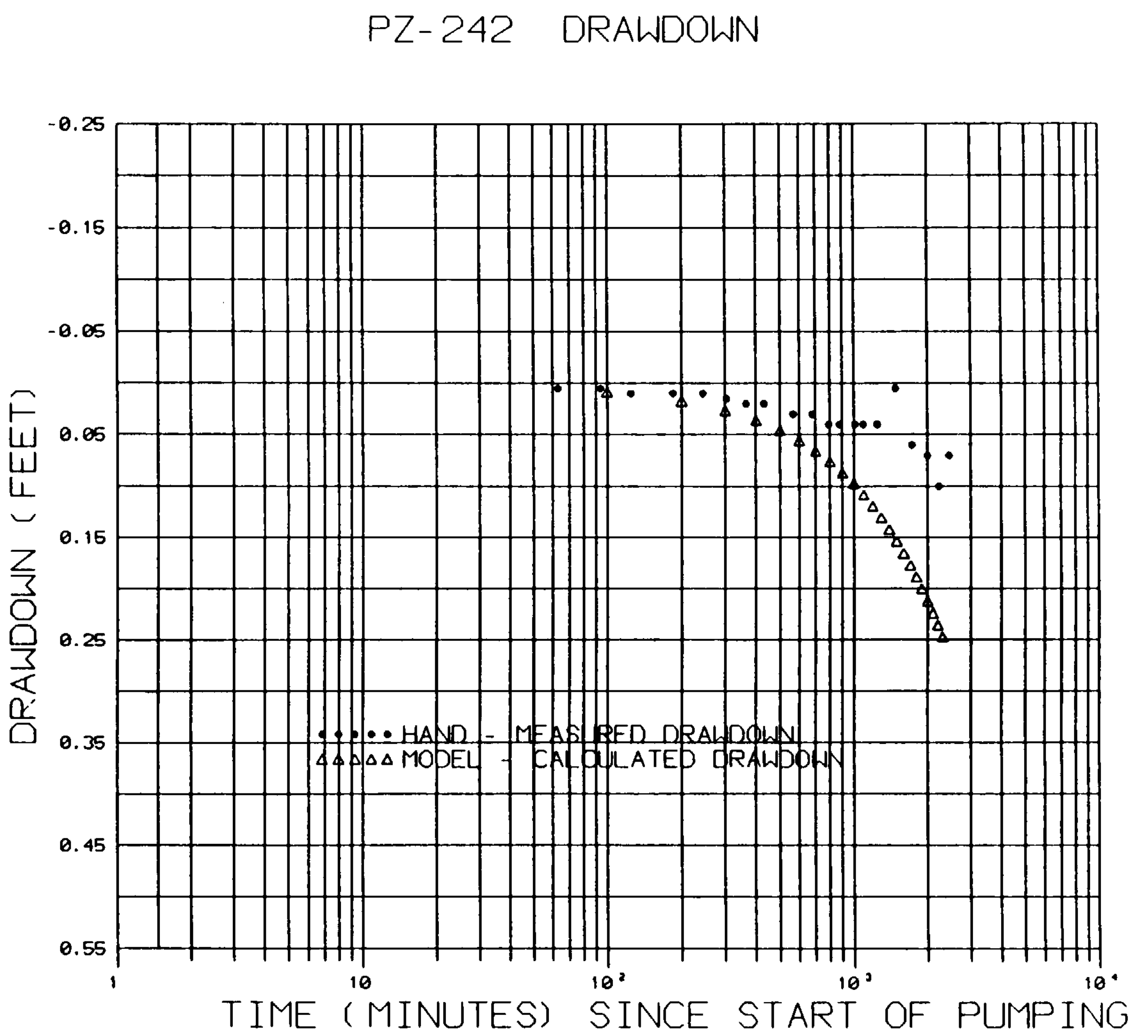
MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE 4-27

DRAWDOWN VERSUS TIME
MONITORING WELL M-18S

FOSTER WHEELER ENVIRONMENTAL CORPORATION

CAD FILE NAME: MOLYDD1.DWG DATE: 1/17/95
PLOT SCALE: TO FIT TIME: 4:00 PM



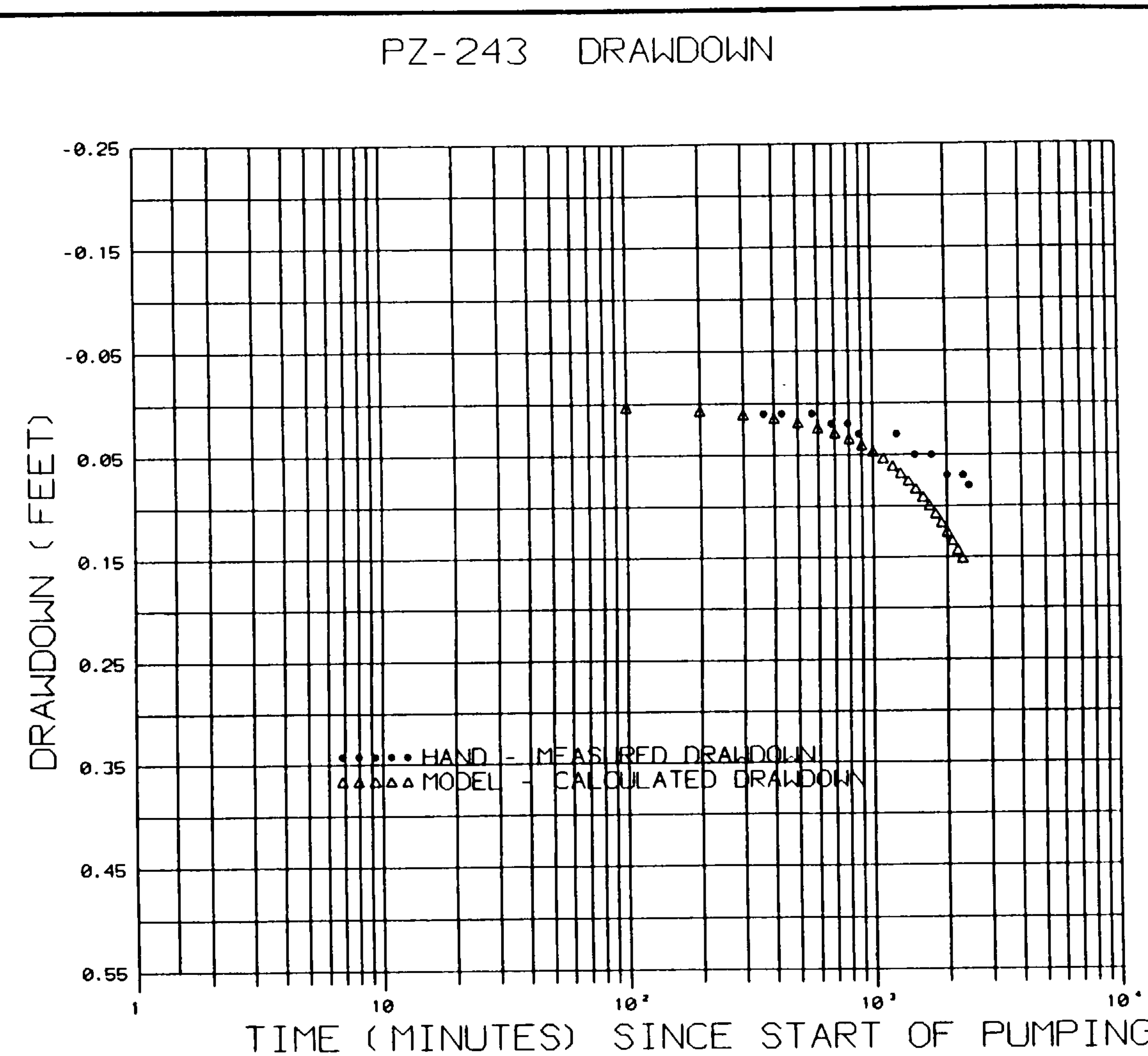
MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE 4-28

DRAWDOWN VERSUS TIME
PIEZOMETER PZ-242

FOSTER WHEELER ENVIRONMENTAL CORPORATION

PLOT SCALE: TO FIT TIME: 4:03 PM



MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE 4-29

DRAWDOWN VERSUS TIME
PIEZOMETER PZ-243

FOSTER WHEELER ENVIRONMENTAL CORPORATION

PLOT SCALE: TO FIT TIME: 4:05 PM

The three-dimensional transport of contaminants or solutes in groundwater may be described by a partial differential equation consisting of terms representing hydrodynamic dispersion, advection, and total mass of solute dissolved in groundwater (Javandel et al., 1984). The model used to provide numerical simulations of solute transport at the site is a modular, three-dimensional transport model (MT3D) for simulation of advection, dispersion, and chemical reactions of dissolved constituents in groundwater (Zheng, 1990). The MT3D model is a particle tracking model with dispersion that retrieves pre-calibrated hydraulic head and flow terms output from MODFLOW, thereby automatically incorporating specified hydraulic head and boundary conditions. MT3D provides solutions to the three-dimensional advective-dispersive-reactive transport equation based upon the assumption that changes in the solute concentration field of the groundwater system will not measurably affect the flow field.

The MT3D program uses a mixed Eulerian-Lagrangian approach to approximate the solution of the advection term of the transport equation whereby the average concentration due to advection in each model node at each new time (i.e., transport step) is solved for via the Lagrangian method on a moving coordinate system; and the average concentration due to dispersion, solute mass, and chemical reactions is solved for via the finite difference approach on a fixed Eulerian grid. The Lagrangian techniques used to approximate the advection term include: the method of characteristics, or MOC (e.g., Gardner et al., 1964; Konikow and Bredehoeft, 1978), which tracks particles forward in time and should be used for advective-dominated systems, and the modified method of characteristics, or MMOC (e.g., Russell and Wheeler, 1983; Cheng et al., 1984), which tracks particles backward in time and should be used for dispersive-dominated systems. The MMOC technique of solution approximation which is computationally more efficient than the MOC technique is, however, more susceptible to numerical dispersion. MT3D, therefore, offers a third technique of approximation to the solution of the transport equation known as the hybrid method of characteristics, or HMOC (e.g., Neuman, 1984; Farmer, 1987) which automatically selects either the MOC or MMOC technique at each model node during the simulation based upon the concentration gradient at the node.

MT3D divides each time step of the implicit hydraulic head solution provided via MODFLOW into smaller increments of time, known as transport steps, during which head and flow terms are considered constant and any particle cannot move more than one node. The size of each transport step is calculated by MT3D based upon an automatic time step size control procedure which seeks to satisfy the Courant condition. The Courant number represents the number of nodes a particle will be allowed to move in any one direction during the transport step. The model calculates transport step size by multiplying the minimum node distance to linear velocity ratio (read from the flow file output from MODFLOW) by the retardation factor and the Courant number specified. Solute mass introduced to the system at specified nodes as particles via the sink/source term is traced through the system and the solute concentration at each node is calculated at the end of each transport step via a volume-weighted averaging algorithm.

Transport simulations using the HMOC solution technique in MT3D are being conducted for the non-radiological solutes cadmium, selenium, molybdenum. Each simulated chemical reaction is equilibrium-controlled linear sorption, which assumes that the sorbed concentration of the solute simulated is directly proportional to the dissolved concentration of the solute and its retardation factor. As the thermal transport does not influence radionuclide transport the results of the modeling will be reported in a separate document.

4.6 LAND USE

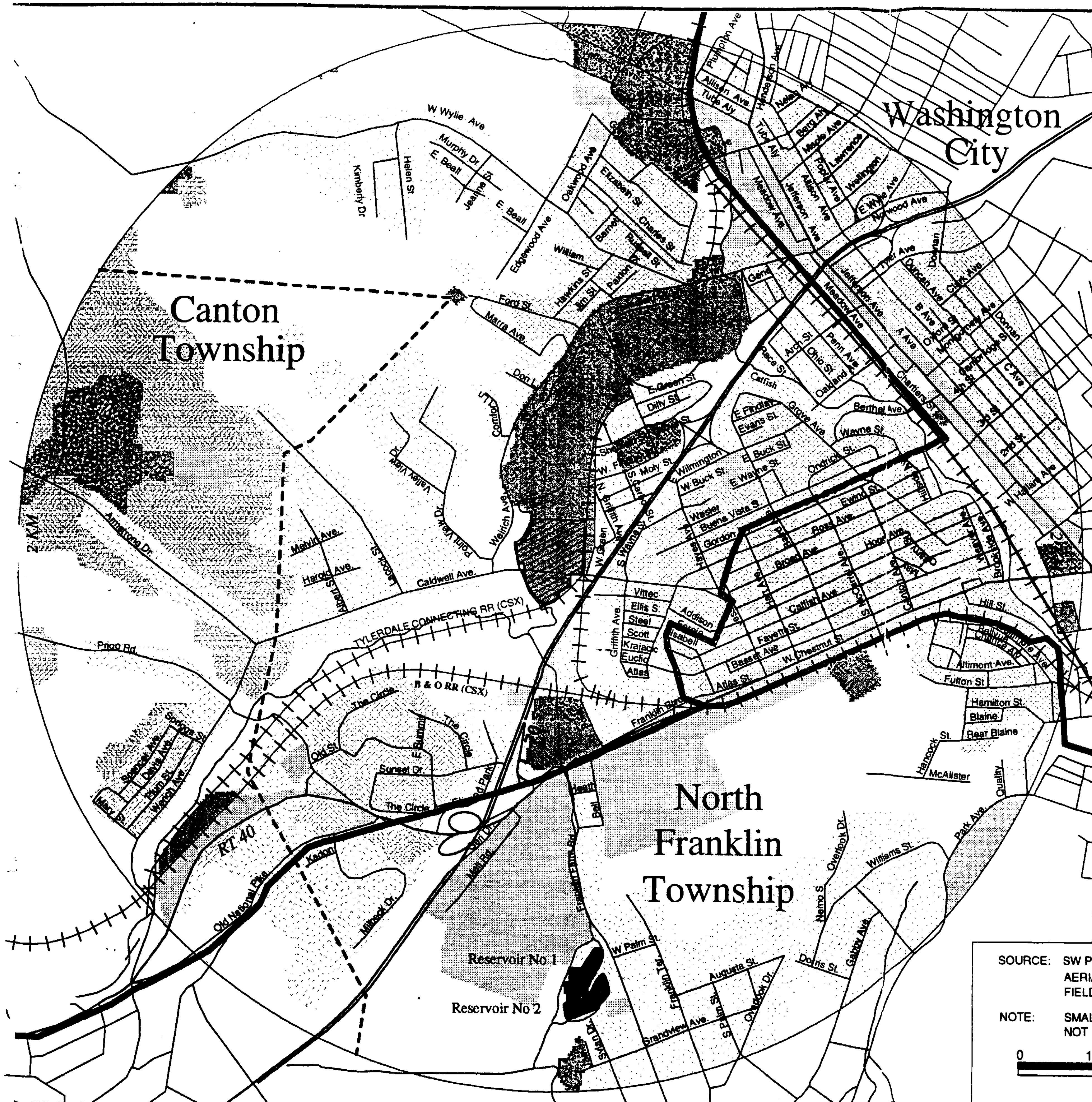
The site is located in a heavy industrial zone in Canton Township (see Figure 4-34 in Subsection 4.7.3.2). Historically, the region was rural and agriculture was predominant. Industries, such as Molycorp, Inc., typically located near transportation arteries including rivers, railroads, and major roadways and the workers for those industries settled in residences nearby. The historical photographs presented earlier in Section 2.0, Photographs #1 through #4, along with the aerial photograph included in this section, indicate the change in land use patterns on and near the site from about 1920 to 1990.

This section describes the current land uses within a 2 km radius from the site and shows the various land uses and acreage for each category in the 2 km radius. This is followed by a section on agricultural land use that provided input into the site-specific dose assessment and analyses in Section 3.0.

4.6.1 Existing Land Uses in the 2 km Radius

The 2 km radius covers 3,106 acres in portions of Canton and North Franklin Townships and the City of Washington. Existing land uses in the 2 km radius from the site center (referred to as the "study area") are shown on Figure 4-30. Unlike the generalized land use map presented earlier (Figure 2-8 in Section 2.0), the land use categories for the 2 km radius are more specific or subdivided, consisting of ten categories (see Table 4-4).

Residential uses, in general, comprise nearly 50 percent of the study area, and are concentrated primarily in the City of Washington and in occasional residential clusters, such as Elwood Park and Log Pile in Canton Township and Franklin Farms in North Franklin Township. The residential land use group is divided into low density (single family), medium density (single/duplex), and high density (urban). The next largest land use in the study area, with approximately 30 percent, is Other. As the notes in Table 4-4 indicate, Other covers non-primary uses (primary are residential, industrial, commercial, etc.) such as vacant land, schools, churches, hospitals and military reservations. There are no hospitals or military reservations in the 2 km radius. Agricultural uses in the study area total approximately seven percent. The Public/Private Open Space category includes historic sites in the region. No historic properties listed on the National Register of Historic Places are found in the 2 km radius. The Pennsylvania Historical and Museum Commission has indicated that while there are no archeological sites of significance in the study area, the facility's historic assessment is presently being reviewed by the Commission.



2 KM RADIUS EXISTING LAND USES

(3105.5 Total Acres)

Use	Percent
Residential	48.81
Industrial	6.42
Commercial	7.87
Cropland	1.44
Pasture, Open, Grasses	5.70
Public/Private Open Space	0.96
Other (vacant, institutional, schools, etc.)	28.80
TOTAL	100.00 %

LEGEND

- Resid-L Density
- Resid-M Density
- Resid-H Density
- Light Industrial
- Heavy Industrial
- Commercial
- Agriculture/Croplands
- Pasture/Open Areas/Grasses
- Public/Private Open Spaces
- Other
- Project Site
- Power Line

9501300021-17

SOURCE: SW PA REGIONAL PLANNING COMMISSION LANDSAT 1990
AERIAL PHOTOGRAPHS, 1990
FIELD VERIFICATION, 1994

NOTE: SMALLER LAND USE AREAS MAY NOT BE ACCURATE

0 1000 2000 3000
SCALE IN FEET

N

MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE 4-30

2 KM EXISTING LAND USE

FOSTER WHEELER ENVIRONMENTAL CORPORATION

Current land uses encircling the site consist of additional industrial land use (Findlay Refractories Co.) to the north, vacant woodland to the west and south, and low and medium density residential land uses (possibly industrial worker housing) to the east that are separated from the site by the Tylerdale Connecting Railroad (CSX) and Green Street. Farther out in the 2 km radius, the land is vacant (without buildings on it but buildable), residential (largely single family with an occasional development or the high density areas in the City of Washington), or agricultural (in this area, mainly pasture for grazing). Commercial land uses are intense along major roadways such as Jefferson Avenue and West Chestnut Street, and other centers include the Franklin Mall and the Ramada Inn complex. Figure 4-31 is a 1990 aerial photograph of the study region and depicts some of these land uses. These uses are basically compatible with Molycorp, Inc.'s heavy industrial land use designation, and also generally conform to local zoning (see Figure 4-34, Section 4.7).

4.6.2 Agricultural Areas

Agricultural land use, as seen on Figure 4-30, is divided into two basic types: cropland acreage (1.4 percent) and pasture, grass and open land acreage (5.7 percent). All of the significant farmland acreage is found near the western edge of the 2 km radius. The site does not contain any soil type that Washington County has designated as prime farmland soils. However, the study area contains four such soil types, covering approximately 14 percent of the 2 km radius. Crops grown on these soils and other soils include snap beans, sweet corn, tomatoes, potatoes, apples and peaches. In 1992 over 80,000 acres in Washington County were harvested for field and forage crops, the largest harvest category in the County (PA Agricultural Statistics Service, 1993).

The predominant agricultural land use in the study area (as well as the County) is Pasture, Grass, Open Land, used for livestock raising (i.e., cattle, sheep, chickens, pigs). There are 1,590 farms in Washington County with 137 acres as the average farm size (Washington County Board of Commissioners, 1993). In 1992, cattle and calves numbered 37,800; sheep and lambs 11,500; hens and pullets 5,400; and hogs and pigs 4,500. The number of milk cows averaged 8,700, and they produced 120,000,000 pounds of milk in 1992. Milk (including ice cream) and dairy products, such as butter and cheeses, are the main agricultural products in the County (PA Agricultural Statistics Service, 1993).

An estimate of milk production in the study area can be calculated by assuming that the total farm acreage in Washington County (1,590 farms x 137 acres per farm) produces 120,000,000 pounds of milk (550 lbs/acre), multiplied by the 177 acres of pasture in the 2 km radius to total 97,500 pounds of milk per year in the study area.

0 1000 2000

SCALE IN FEET

SOURCE: SOUTHWESTERN PENNSYLVANIA REGIONAL PLANNING COMMISSION. WASHINGTON WEST SE QUADRANGLE, 1990

PENNSYLVANIA

QUADRANGLE LOCATION

N

9501300Q21-18

MOLYCORP. INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE 4-31

AERIAL PHOTO OF STUDY REGION

FOSTER WHEELER ENVIRONMENTAL CORPORATION

Table 4-4

Existing Land Uses In The 2 Km Radius

Land Use Category	Acres	% of Total
Low density residential	884	28
Medium density residential	441	14
High density residential	191	6
Commercial	244	8
Light industrial	22	1
Heavy industrial	178	6
Agriculture/cropland	45	1
Pasture, grass, open land	177	6
Public & private open space	30	1
Other	894	29
Total:	3,106	100

Notes: Residential - low density refers to single family homes; medium density refers to two-family homes; high density refers to urban residences and planned unit residential developments.
Commercial - includes office/business, mixed urban, and shopping centers.
Light industrial - includes R&D, non-durable manufacturing, industrial parks, warehousing.
Heavy industrial - includes durable manufacturing.
Transportation - includes highways, railroads and airports.
Agricultural land - is divided into cropland, and pasture/grass/open land.
Public and private open space - includes forest, parks, golf courses, historic sites, cemeteries.
Other - includes vacant, institutional (i.e., government offices, schools, churches, hospitals), military reservations.

Source: Southwestern Pennsylvania Regional Planning Commission LANDSAT Mapping, 1990; Washington West USGS quad 1969; 1990 aerial photographs; site verification visit, July 1994; review of community data and reports.

4.6.3 Current Zoning

The site and the ½ km study area are situated in Canton Township, and are therefore subject to the zoning regulations established by Canton Township's zoning ordinance defined by Ordinance 2 - 1977, effective January 25, 1977. There are seven zoning districts in Canton Township as indicated on the Township's Zoning Map, also enacted in 1977, and five of the seven districts are present within the ½ km study area. A brief description of each of the five districts, including permitted uses, is presented in Table 4-5. The extent of each zoning district in the ½ km study area is shown on Figure 4-34, ½ km Vicinity Map and Zoning found in Subsection 4.7.3.2.

Nearly one-half of the ½ km study area is zoned for residential purposes in both the R-1 low density residential and R-2 medium density residential districts. The bulk of the residential land in the ½ km study area is zoned R-1 low density residential development.

The central portion of the ½ km study area is zoned I-2 heavy industry (i.e., manufacturing plants). The approximately 20-acre site lies entirely within this district although some of the other Molycorp, Inc. property ~~falls within the Township's~~ low-density residential zone. The I-2 district was established for industries like Molycorp, Inc. that are not desirable in residential neighborhoods and require a large area to conduct their business.

The C-1 neighborhood commercial district covers approximately one-eighth of the ½ km study area. This district is located in the northeast quadrant of this study area and is bounded by I-70 on the east and Greene Street on the west. A small piece of the C-2 general commercial district lies immediately adjacent to the old Baltimore and Ohio Railroad right-of-way, now owned and operated by CSX. This C-2 district is located along the southern boundary of the 1/2 km study area.

4.6.4 Anticipated Land Uses on and Adjacent to the Site

After the site has undergone decommissioning, Molycorp, Inc. plans to use the site for some heavy industrial purpose, the specifics of which have not been established at this time.

As Figure 4-30 in Section 4.6.1 showed, the project site is located in a built-up industrial (Canton Township) and residential (City of Washington) area. Future land uses adjacent to Molycorp, Inc. are expected, for the most part, to be useful in the same manner. The Township is in the process of preparing a Comprehensive Plan which may result in some zoning changes throughout the Township.

Table 4-5 Canton Township Zoning Districts Present in the ½ km Radius		
District Name	Permitted Uses	Development Standards
Residential - Low Density (R-1)	Farms & agricultural uses; single-family residences; public schools; recreational facilities; mobile homes on 1+ ac.; essential services	10 ac. for farms; 1 ac. for residences with septic tanks; ½ acre for residences with sewers
Residential - Medium Density (R-2)	Farms & agricultural uses; single-family residences; public recreational facilities; planned unit residential developments; essential services	12,000 s.f. minimum lot size with public water/sewer; R-1 regulations apply with on-site services
Industrial - Heavy (I-2)	Manufacturing plants	½ acre min. lot size; 50% lot cover
Commercial - Neighborhood (C-1)	General retail establishments; professional/business offices; planned unit commercial development	10,000 s.f. minimum lot size; floor area less than 2,000 s.f.
Commercial - General (C-2)	General merchandise stores; offices; public buildings; personal services; motels; gas stations; indoor recreational facilities; planned unit commercial development	½ acre minimum lot size

Source: Canton Township Code of Ordinances, Chapter 27 - Zoning, 1977.

4.7 DEMOGRAPHY

This section presents a description and analysis of the demographics, particularly sensitive populations, in the 2 km radius from a central point on the site. It also provides a more detailed picture of the demographics in the 1/2 km radius surrounding the project site. The municipalities located in the study area are: Canton Township, North Franklin Township, and the City of Washington.

4.7.1 Population Characteristics in the 2 km Radius

Population characteristics can be understood by considering the total number of residents in an area, the population density of that area, presence of transient-type residents, and the business and industries that interact with the population in that area.

4.7.1.1 Total Resident Population in the 2 km Radius

The population in the study area is scattered throughout the 2 km radius, however, the majority of the population (approximately 53 percent) lies within the City of Washington. Other population centers in the study area include: the Franklin Farms and Gabby Heights areas of North Franklin Township and the Elwood Park and Log Pile areas of Canton Township.

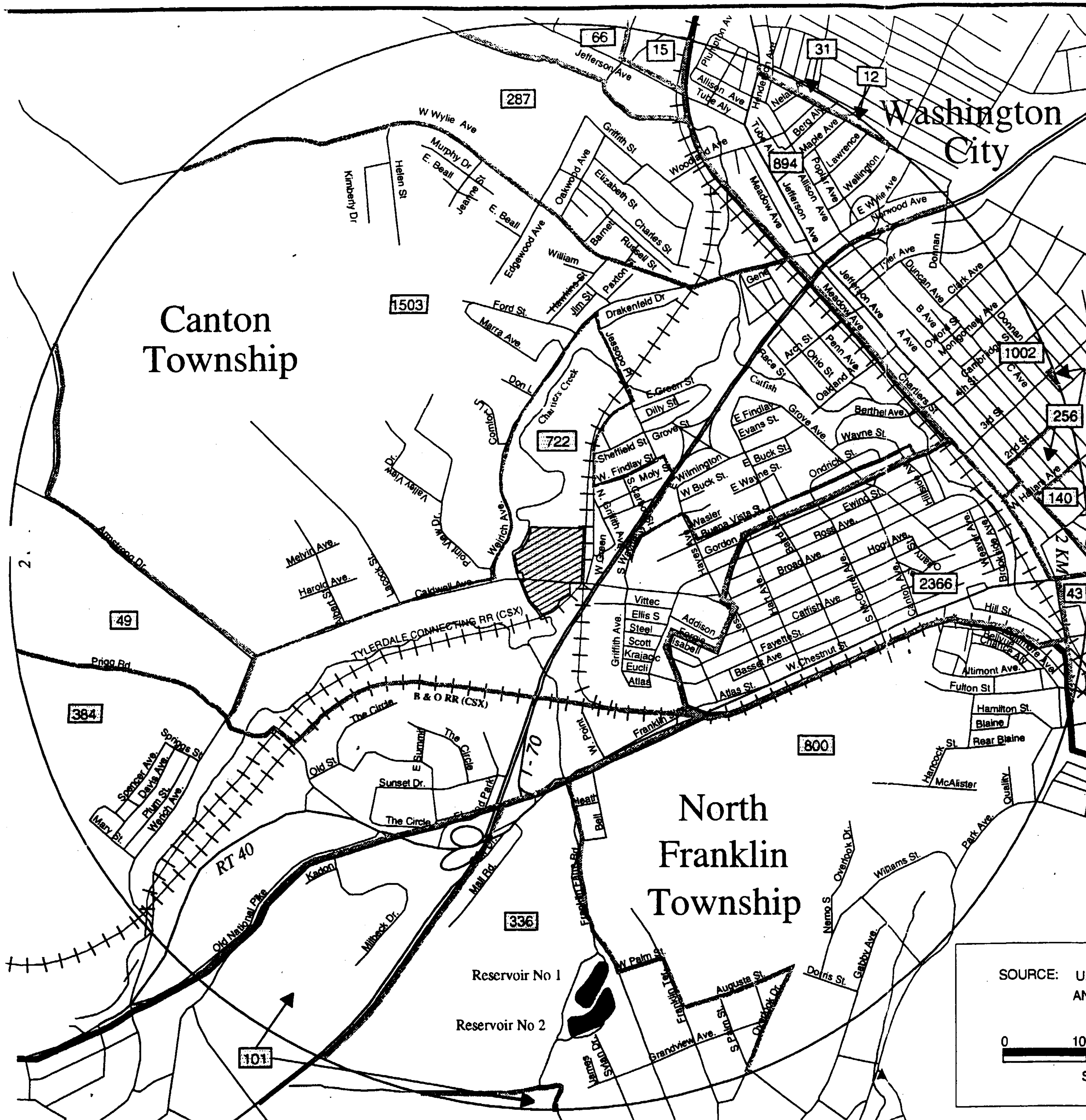
Canton Township comprises the largest physical portion of the 2 km study area, with nearly 59 percent of the land area. North Franklin Township comprises 26 percent of the total land area, and the City of Washington 15 percent. Although the City has the smallest share of the total land area, it is densely developed and contributes a significant population to the study area, estimated to be one and one-half times that of Canton Township also situated in the study area.

The 1990 total resident population in the study area is presented in Table 4-6. The numbers were derived using the U.S. Census digital TIGER/Line files and then linking them to a current USGS-type base map. The 2 km radius population distribution map, Figure 4-32, was created by this method.

Table 4-6

1990 Population Within the 2 Km Radius of the Site
(U.S. Census, 1990)

Municipality	Study Area Population
Canton Township	3,026
North Franklin Township	1,237
City of Washington	4,744
TOTAL:	9,007



LEGEND

Project Site

Census Group

722 # Persons Per Census Group

9501300021-19

SOURCE: U.S. CENSUS TIGER LINE FILES AND STFIA POPULATION DATA, 1990

0 1000 2000 3000

SCALE IN FEET

N

MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE 4-32

2 KM POPULATION AREAS

FOSTER WHEELER ENVIRONMENTAL CORPORATION

As shown above, the City of Washington has the largest population in the study area that could be affected by site decommissioning. The city, as a whole, represents about one-fifth of the County's total population. Approximately 21 percent of the City's population in the study area (1,004 persons) is 16 years of age or younger and 18 percent (862 persons) is over 65 years (U.S. Census, 1990). These two age groups represent most of the sensitive populations, that will be explained further in Section 4.7.2.

By the year 2015, the study area municipalities' population is estimated to grow by approximately 14 percent, except in the City of Washington, assuming the projections for the three municipalities in their entirety shown in Section 2.2 earlier typify the trends for the study area as well (Southwestern PA Regional Planning Commission, Cycle V Forecasts, 1994).

4.7.1.2 Population Density

The 1990 population densities (persons per square mile) for the three municipalities cited above, portions of which are in the study area, are shown in Table 4-7 (U.S. Census, 1990). The table indicates that the City of Washington is the most densely populated municipality of the three in the study area, and Canton Township is the least densely settled.

Table 4-7

1990 Population Densities For Municipalities In The 2 Km Radius

Municipality	Area (Square Miles)	Density
Canton Township	14.9	621
North Franklin Township	7.3	685
City of Washington	2.9	5,470

Source: U.S. Census of Population and Housing, 1990.

In 1990 the number of persons per household was shown as 2.64 for Canton, 2.66 for North Franklin, and 2.23 for the City of Washington (U.S. Census, 1990). Although the City of Washington does not exhibit the highest density in the whole County of Washington, it is very urban and consequently exhibits smaller-sized households residing in densely-spaced living quarters.

Between 1980 and 1990 the municipalities of Canton and Washington experienced a slight decrease in their density patterns, while North Franklin's density increased slightly. By the year 2015 it is projected that the City of Washington will continue to reduce its density, and the other two municipalities will become more dense, especially Canton Township (SPRPC Cycle V Forecasts, 1994). However, a more significant future spurt of growth is expected in northcentral

Washington County, in North Strabane and Peters Townships (Washington County Planning Commission, 1994).

4.7.1.3 Transient vs. Permanent Population

Typical daily variations in the area's baseline permanent population have been studied and are described in this section. However, there appear to be no significant transient (non-permanent) population patterns in the 2 km radius. This can be attributed to numerous factors:

1. The Washington and Jefferson College campus, just outside the 2 km radius, is basically a resident campus, where only 15 percent of the students commute. In May, most students (of the 1,110 enrolled) go home and return at the end of August; others stay for summer courses (W&J College Director, 1994).

2. Agriculture is a major industry in this area; however, it consists largely of raising dairy cattle which, unlike crop farming, is not labor-intensive.

3. There are no large county or state parks, resorts, or recreation facilities that would affect seasonal population movement.

4. Hospitals and clinics are not located in the study area and, therefore, neither are the transient populations that utilize them, except employees traveling to and from these facilities. This activity will be discussed further later in this section.

5. Tourism is growing in this area, but it has not established itself to the point of significant seasonal activity (Washington County Planning Commission, 1994).

Periodic variations in the study area's baseline permanent population consist of daily commutation to and from work, day care centers, health care facilities, government services, and local schools. This area has a typical amount of these facilities that create fluxes in population movement. These have been examined and are presented below.

Daily work trip generators in the area include major manufacturing companies such as Washington Steel Company (Lukens Steel) with 804 employees, Allegheny Ludlum (Jessop Steel Company) with 670 employees, and Cerdec Corporation (Drakenfeld Colors) with 301 employees (Washington County Board of Commissioners, 1993). By far, the largest area employer is Washington Hospital with 1,590 employees (see also Section 4.7.2.5). For these and other daily trips, such as to the Tylerdale CBD (Central Business District), Washington and Franklin Malls, schools and local day care centers (see also Sensitive Populations in the 2 km Radius, Section 4.7.2), the region tends to utilize three main roadways -- Henderson Avenue (Rt. 18), Jefferson Avenue (Rt. 844), and Chestnut Street (Route 40) -- as well as three interchanges on Route 70 (Exits 4, 6, and 7).

The daily morning local rush (cars and trucks) is known to take place from west to east primarily along Jefferson Avenue. The Pennsylvania Department of Transportation identified the actual number of cars (assume one person per car) during the a.m. and p.m. rush hour peaks on Route 70, based on 24-hour traffic counts, to be approximately 21,800 each way through the region (i.e., Canton and North Franklin Townships and the City of Washington) (PennDOT, 1994). This volume of daily travelers, comprising both transient and area permanent population, is considerable when analyzing the weekday flow to and through the study area for purposes described earlier.

4.7.1.4 Industries and Businesses

Industries and businesses in Washington County are diversified and well-established and are experiencing steady growth. Those areas employing the largest number of people in the County today are manufacturing (11,000 persons), services (15,400 persons), and the wholesale/retail trade (16,500 persons) (Washington County Planning Commission, 1992). Major manufacturing employment includes primary and fabricated metals, electrical machinery and repairs, glass, machine shops, plastics, paper, trucking, and advanced technology industries. The mining of coal, oil and gas, and non-metallic minerals has also seen a 1990's resurgence into the local/regional economy. Also, small and large plastics companies (over 20 in the County already) such as Polycom Huntsman are noticeably on the increase. There are approximately 20 industrial parks, such as Henderson, Arden, and Southpointe (mixed use) in Washington County. The most dynamic sector in the County today is services, such as business services, amusement and recreation services, and health and social services. Table 4-8 presents the major employers in Washington County (excluding utilities and institutions).

The County has 95,400 persons in its resident labor force; 66,860 people work in establishments located within the County (U.S. Census, 1990). Table 4-9 lists the light and heavy industrial establishments by municipality found in the 2 km radius. It indicates that for the study area there are 2,597 persons (approximately 36 percent) employed in the industrial sector alone (i.e., industries with 20 or more employees). Some companies in the study area have recently been bought by larger firms and propose ambitious expansion plans. Examples are Drakenfeld Colors (now owned by Cerdec Corporation), Washington Steel (now owned by Lukens Steel) and Jessop Steel purchased by one larger company, Allegheny Ludlum. Other establishments are expanding existing facilities, such as Washington Hospital (heliport, cardiac and cancer centers) just outside the 2 km study area radius.

4.7.2 Sensitive Populations in the 2 km Radius

Several population groups may be sensitive to future decommissioning activities undertaken by Molycorp, Inc. These population groups consist primarily of the young (16 years or younger) and the elderly (65 years and older) who are gathered together for educational, day care, or nursing care purposes. Residents in group quarters and prisons are also addressed in this analysis. These various groups are referred to as sensitive population groups because of the potential health impact they could experience during and after site decommissioning. In the sections which follow, the presence of the sensitive groups within the 2 km radius will be described. Facilities utilized by these sensitive population groups are identified on Figure 4-33, 2 km Sensitive Population Groups. Table 4-10 presents a summary of the sensitive population groups and identifies their locations within the study area.

4.7.2.1 Schools

There are two public school systems with facilities within the 2 km radius -- the Washington School District and the Trinity Area School District. Public education is available to school-aged children from the City by the Washington School District and to the school-aged children from Canton and North Franklin Townships by the Trinity Area School District. A private Diocese of Pittsburgh school is present in the study area, as is the Clark Avenue School, a specialized facility for the severely handicapped. In total, there are four educational institutions within the study area. Several other schools lie just outside the 2 km radius and these schools are described in this narrative, but are not shown on Figure 4-33.

Public Schools

Trinity Area School District. Public school students from North Franklin, South Strabane, Canton and Amwell Townships attend the Trinity Area School District facilities. The district has a High School and Administrative Building in North Franklin Township, a Middle School in North Franklin, and several elementary schools in each of the composite municipalities. The District is in the process of consolidating schools and will have one elementary school in each of the member municipalities of North Franklin, South Strabane, Canton and Amwell Townships by 1995. Only the Trinity West Elementary School in the Gabby Heights area of North Franklin Township lies within the radius study area. There are 511 students in Trinity West Elementary in grades K through 5 (ages 5 through 10) and 39 employees including 34 teachers.

Trinity High School, located on Park Avenue in North Franklin Township, lies 1,000 linear feet (l.f.) outside of the study area. With 1,204 students in grades 9 through 12, 93 teachers, and a 61-person administrative staff in the district's Administrative Offices, the Trinity High School merits attention in this study.

The Trinity Middle School, also located in North Franklin Township with 1,000 students and 109 employees including 67 teachers, is located approximately 2,000 l.f. outside the perimeter of the study area. The remaining Trinity School District elementary schools are located well outside of the study area. (Trinity Area School District, 1994.)

Washington School District. The Washington School District, comprised of the City of Washington and the Borough of East Washington, has one school in the 2 km radius. Washington High School, located on Jefferson Avenue (State Route E844), houses public school students in grades 9 through 12 (ages 14 to 18) at this location. There are a total of 543 students and 80 employees at the school. (Washington School District, 1994.)

Table 4-8

Major Employers In Washington County[1]

COMPANY	MUNICIPAL LOCATION	EMPLOYMENT
Cooper Power Systems	Canonsburg Borough	1,081
Washington Steel Co.[2,7]	Canton Township	804[4]
Corning, Vitro Corp.	Charleroi Borough	700
Jessop Steel Co.[2,3]	Canton Township	670[4]
Black Box Corporation	Cecil Township	515
Wheeling-Pittsburgh Steel Co.	Allenport Borough	500
Beth Energy Mines, Inc.	Somerset Township	500
U.S. Steel Mining Co., Inc.	New Eagle Borough	471
Drakenfeld Colors[5,6]	Canton Township	301
Ross Mould, Inc.[2]	City of Washington	300
MAC Plastics, Inc.[2]	Canton Township	241[4]

Notes:

1 Utilities and institutions were not included in this list. Washington Hospital is the County's largest employer with 1,590 employees (Washington County Industrial Development Agency, 1994).

2 Within the vicinity of the study area.

3 Facility under new ownership of Allegheny Ludlum.

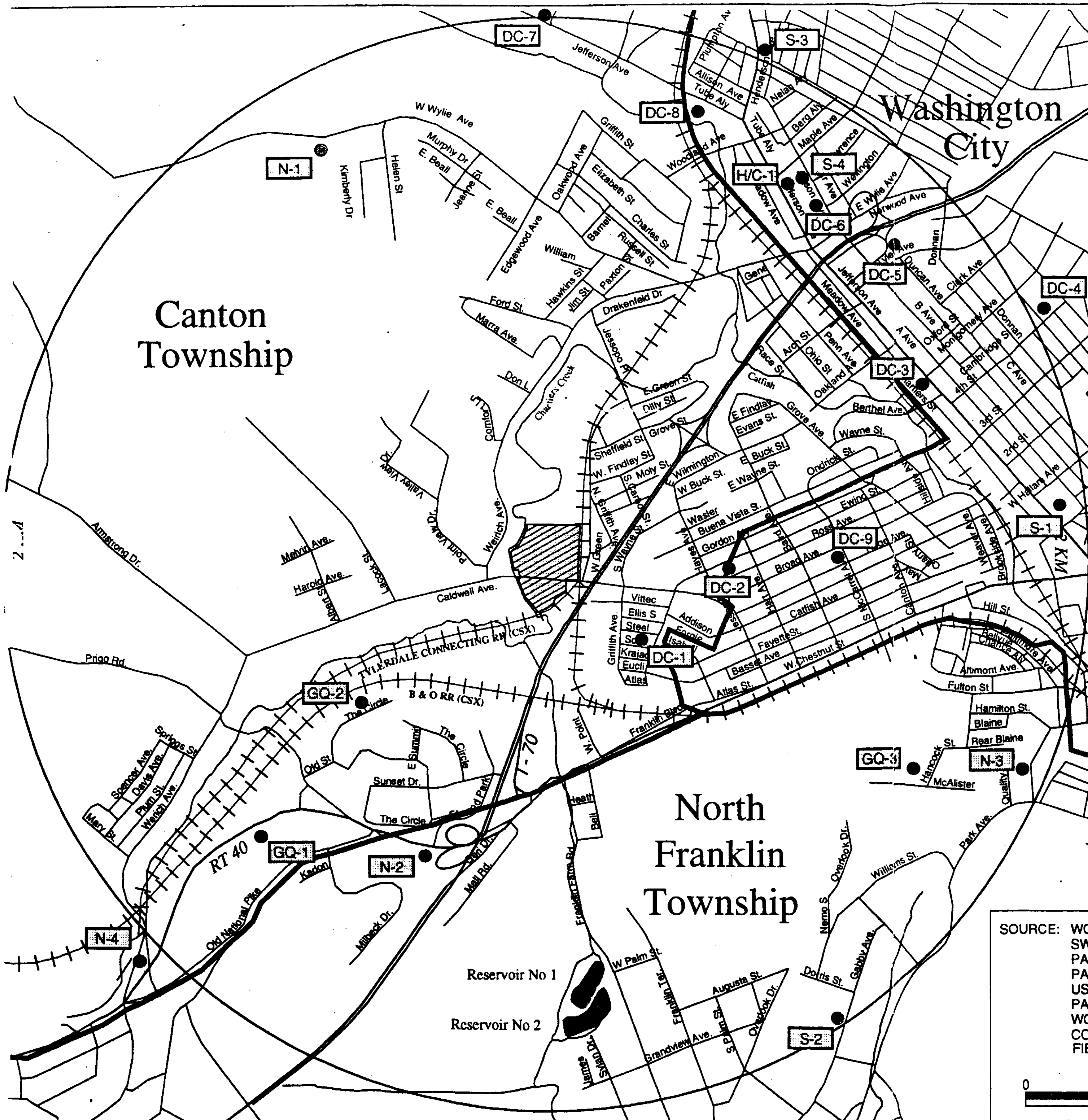
4 Revised number as per more recent data from Southwestern PA Regional Planning Commission, 1994.

5 Facility under new ownership of Cerdec Corporation.

6 Not listed in the W.C. Board of Commissioners Report of 1993.

7 Facility under new ownership of Lukens Steel.

Source: Washington County Board of County Commissioners, 1993.



SENSITIVE POPULATION IDENTIFICATION

DAY CARE CENTERS (Map Key: DC-#)

DC-1	148 Scott Ave. Family Day Care Center (Cynthia Bayus)
DC-2	Scotties Day Care Center (Family Day Care)
DC-3	Rainbow's End Day Care and the United Cerebral Palsy Adult Center
DC-4	Happy Face Learning Center - Washington Center
DC-5	Gwen's Montessori & Day Care Center
DC-6	Cheryl Walsh Family Day Care Center
DC-7	Saturday's Child Day Care Center
DC-8	Neighborhood House Association (Brownson House)
DC-9	Magic Time, Baptist Church

NURSING & PERSONAL CARE HOMES (Map Key: N-#)

N-1	Kade Nursing Home
N-2	Century Plaza (under construction)
N-3	Maiden Pines Personal Care Home
N-4	Lincoln Manor

HOSPITALS & CLINICS* (Map Key: H/C-#)

H/C-1	Stat Care Emergency Clinic
*	There are no hospitals in the 2 km radius; Washington Hospital is approximately 3,000' outside the 2 km radius.

GROUP QUARTERS (Map Key: GQ-#)

GQ-1	Belvedere Acres
GQ-2	Group Quarters Home forRetarded Adults
GQ-3	Woodlands Apartments

SCHOOLS (Map Key: S-#)

S-1	Washington High School
S-2	Trinity West Elementary
S-3	St. Hilary School
S-4	IntermediateUnit I - Clark School

9501300021-20

PRISONS

There are no prisons in the 2 km radius. The closest prison is located at the County Courthouse.

LEGEND

- Day Care Facilities (DC-#)
- Nursing Homes (N-#)
- Hospitals/Clinics (H/C-#)
- Group Quarters (GQ-#)
- Schools (S-#)
- Project Site

SOURCE: WC LOCAL MANAGEMENT AGENCY
SW PA AREA AGENCY ON AGING
PA DEPARTMENT OF PUBLIC WELFARE
PA HOUSING FINANCE AGENCY
US CENSUS OF POPULATION AND HOUSING
PA DEPARTMENT OF HIGHER EDUCATION
WC REDEVELOPMENT AUTHORITY
COMMUNITY ACTION SOUTHWEST
FIELD VERIFICATION 7/94

0 1000 2000 3000
SCALE IN FEET

MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE 4-33

2 KM SENSITIVE POPULATION GROUPS

FOSTER WHEELER ENVIRONMENTAL CORPORATION

Table 4-9
Industrial Employment* in the 2 KM Radius
(Page 1 of 2)

Establishment	Location	Product	Number of Employees
CANTON TOWNSHIP			
Allegheny Ludlum (Jessop Steel Company)	500 Greene Street	Stainless plate and tool steels manufacturing	670
Cerdec Corporation (Drakenfeld Colors)	W. Wylie Avenue	Ceramic pigments, glass, enamel manufacturing	301
Findlay Refractories Co. of PA (Division of Adience, Inc.)	Greene Street	Refractories fireclay, zircone, bonded day tanks and pots	53
MAC Plastics, Inc.	250 W. Wylie Avenue	Miscellaneous plastics manufacturing	241
Master Woodcraft Corp.	61 West Point Road	Architectural woodworking	25
Penn Mould	1660 Jefferson Avenue	Moulds for glass industry	210
Tatano Plastics	1480 Jefferson Avenue	Custom blow molding	40
V-Bat Plastic Processing Corp.	1500 Weirich Avenue	Thermoplastic materials processing	46
Washington Steel Co. (Lukens Steel)	Woodland and Griffith Avenues	Stainless steel production	804
NORTH FRANKLIN TOWNSHIP			
Polymer Grinding & Recycling, Inc.	Baird Avenue	Industrial plastic scrap recycler	22
Washington Tool & Machine Co.	873 Baird Avenue	Precision machine work fabricated steel, carbon, aluminum alloys	57
CITY OF WASHINGTON			
C.B.P. Engineering Corp.	185 Plumpton Avenue	Abrasion resistant pipe & lining systems	25

Table 4-9 Industrial Employment* in the 2 KM Radius (Page 2 of 2)			
Establishment	Location	Product	Number of Employees
Star Dynamics, Inc.	4th and Meadow Streets	Hydraulic cylinders	48
Washington Mould Co.	Greene and Madison Avenues	Grey & ductile iron castings and machining manufacturing.	55
		TOTAL:	2,597

NOTES:

*Industries with 20 or more employees

SOURCE: Washington County Board of County Commissioners, 1993 and Southwestern PA Regional Planning Commission, 1994.

Table 4-10
Sensitive Populations in the 2 km Radius

SCHOOLS

S-1	Washington High School, 201 Allison Drive, Washington, PA 15301
S-2	Trinity West Elementary, 1041 Gabby Avenue, Washington, PA 15301
S-3	St. Hilary School, 340 Henderson Avenue, Washington, PA 15301
S-4	Intermediate Unit I - Clark School, 1099 Allison Avenue, Washington, PA 15301

NURSING & PERSONAL CARE HOMES

N-1	Kade Nursing Home, 1198 West Wylie Avenue Extension, Washington, PA 15301
N-2	Century Plaza (under construction; scheduled for Fall '94 opening)
N-3	Maiden Pines Personal Care Home, 407 West Maiden Street, Washington, PA 15301
N-4	Lincoln Manor, 1633 Weirich Avenue, Washington, PA 15301

DAY CARE CENTERS

DC-1	148 Scott Ave. Family Day Care Center (Cynthia Bayus), Washington, PA 15301
DC-2	Scotties Day Care Center (Family Day Care), 940 Ewing Street, Washington, PA 15301
DC-3	Rainbow's End Day Care and the United Cerebral Palsy Adult Center; United Cerebral Palsy Building, 655 Jefferson Avenue, Washington, PA 15301
DC-4	Happy Face Learning Center - Washington Center, Fairhill Manor Christian Church, 351 Montgomery Avenue, Washington, PA 15301
DC-5	Gwen's Montessori & Day Care Center, 860 Allison Avenue, Washington, PA 15301
DC-6	Cheryl Walsh Family Day Care Center, 1039 Allison Avenue, Washington, PA 15301
DC-7	Saturday's Child Day Care Center, 1758 Jefferson Street, Washington, PA 15301
DC-8	Neighborhood House Association (Brownson House), 1415 Jefferson Avenue, Washington, PA 15301
DC-9	Magic Time, Baptist Church, 682 Broad Avenue, Washington, PA 15301

GROUP QUARTERS

GQ-1	Belvedere Acres, Bel Aire Drive, Washington, PA 15301
GQ-2	Group Quarters Home for Retarded Adults, 2152 The Circle, Washington, PA 15301
GQ-3	Woodlands Apartments, 400 Hancock St., Washington, PA 15301

HOSPITALS & CLINICS*

H/C-1	Stat Care Emergency Clinic, Jefferson Avenue, Washington, PA 15301
*	There are no hospitals in the 2 km radius; Washington Hospital, 155 Wilson Avenue,Washington, PA 15301 approximately 3,000' outside the 2 km radius.

PRISONS

There are no prisons in the 2 km radius. The closest prison is located at the County Courthouse located on South Main Street, Washington, PA 15301.

Source: WC Local Management Agency; Southwest PA Area Agency on Aging; PA Department of Public Welfare; PA Housing Finance Agency; US Census of Population & Housing; PA Department of Higher Education; WC Redevelopment Authority; Community Action Southwest; EEC Field Verification 7/94.

Washington County Intermediate Unit. The Clark Avenue School, located at 1099 Allison Avenue, Washington, PA provides education for the severely handicapped via the Washington County Intermediate Unit I. This facility is located in the study area in the City of Washington.

Private Elementary Schools

There is one Diocese of Pittsburgh private elementary school in the study area. St. Hilary School, located at 340 Henderson Avenue, Washington, PA, had a 1992-1993 enrollment of 103 students in grades K through 6 (ages 5 to 11). The John F. Kennedy School, located at 111 West Spruce Street, is another Diocesan school in close proximity to the study area. John F. Kennedy, however, lies outside the actual study area. With students in grades K through 8, the school's 1993-1994 enrollment was 485 students; an additional 95 students were enrolled in the school's nursery school program.

Colleges and Universities

Washington and Jefferson College (W & J), a four-year co-educational private liberal arts college, is a major educational institution in the Washington area. Although it lies outside the 2 km radius, it is referenced in this text because of its significance to the area. W & J offers Associate and Bachelor of Arts degrees, and several certificates. The college had a 1993-1994 enrollment of 1,110 students. It employs a total of 250 employees of which 237 are full-time. There is a faculty with 89 full-time teachers. The college, with 40 buildings, is located outside the study area at 60 South Lincoln Street, Washington, PA.

4.7.2.2 Nursing Homes

There are three nursing homes and one independent living complex for the elderly (ages 65 and over) in the study area. There are living accommodations for 158 elderly residents in the 2 km radius in nursing homes, personal care homes, and independent living apartments.

The Kade Nursing Home, located at 1198 West Wylie Avenue in Canton Township, provides nursing care for 65 residents. Professional services include 24-hour skilled nursing care, physical, occupational and speech therapies, and social services. Maiden Pines is a personal care home in North Franklin Township providing living accommodations for 16 elderly residents; Lincoln Manor is a personal care home in Canton Township with a capacity for 12 elderly residents.

Century Plaza, an independent living apartment complex, is located on Route 40 in North Franklin Township near the I-70 Interchange #4. Scheduled to open in late 1994, Century Plaza will provide 65 apartments for the elderly.

4.7.2.3 Day Care Centers

There are nine day care centers in the 2 km radius providing care in a variety of settings for infants to school-aged children. These centers have the capacity to provide day care services for

365 children with a variety of needs. There are three family day care centers in the study area; family day care services are licensed by the Department of Public Welfare to serve a maximum of six children at a time. There are four group day care centers in the study area capable of serving between 35 to 110 children. (The Department of Public Welfare's regulations establish standards to determine a center's licensed capacity.) The Brownson House provides nursery school in morning and afternoon sessions for children ages 3 and 4, and the Magic Time program provides after-school care for children in grades K through 5.

The United Cerebral Palsy Adult Center, located at 655 Jefferson Avenue in Washington, is a unique day care center that provides daily care for mentally, physically and developmentally challenged adults between the ages of 18 and 60 years. Although many of the center's clients have cerebral palsy, the programs are designed to help people with developmental delay, Down's syndrome and spina bifida, as well.

4.7.2.4 Group Quarters

All persons not living in households are classified by the U.S. Census Bureau as living in group quarters. The Census further refines the group quarters population into two general categories, those living in institutions and those who are not in institutions. Typical institutional group quarters include prisons, nursing homes, psychiatric hospitals, and schools for the mentally retarded where care is provided by a formally trained staff. Non-institutionalized group quarters include group homes for drug/alcohol abuse; maternity homes; group homes for the mentally ill; group homes for the mentally retarded; and group homes for the physically handicapped. Persons living together are only classified under the group quarters category if 10 or more unrelated individuals share the unit; otherwise, they are classified as housing units.

For the purposes of this study, the Census definition for "group quarters" was not strictly applied and has been modified to meet a particular need. In this study, the term group quarters applies to large-scale government financed housing complexes and group homes occupied by retarded adults. (It should be noted that the latter is typically included in the noninstitutional group quarters category.)

There are three group quarters housing facilities in the study area, two are subsidized housing complexes and one is a group home for retarded adults. These facilities were identified in Table 4-10 and located on Figure 4-33, 2 km Sensitive Population Groups.

The two subsidized housing projects include Belvedere Acres, located on Bel Aire Drive off U.S Route 40 in Canton Township, and the Woodlands Apartments, located at 400 Hancock Street in North Franklin Township. Both apartment complexes were financed by the U.S. Department of Housing and Urban Development (HUD) as subsidized housing under Section 8 of the Housing and Community Development Act of 1974. Belvedere Acres, owned and managed by the NDC Asset Management, Inc., has a total of 96 total dwelling units. Although the majority of the units are designated for general family usage, six apartments are set aside for the elderly and another six are identified as special needs apartments for the handicapped. The Woodlands Apartments complex contains 50 units, 42 for general family use, six for the elderly, and two for special needs families and individuals. The Woodlands is owned by Paul Voinovich and is also managed by NDC Asset Management, Inc.

There is one group home for retarded adults on The Circle in Canton Township, however, information about the number and type of residents in this structure is confidential. (A field inspection conducted by FWENC verified the existence of the home.) The group home is situated in a traditional neighborhood setting comprised of single-family detached dwellings and is not identified for the protection of its residents.

4.7.2.5 Hospitals

Washington Hospital, a 364-bed licensed medical care facility, is located 3,000 feet outside the edge of the 2 km radius. Due to its size and predominance as the major medical facility for most of Washington County, it is included in this report. Washington Hospital is located at 155 Wilson Avenue, Washington, PA 15301. The hospital has 260 members on its medical staff, and is the single largest employer in Washington County, with 1,590 employees. The hospital offers a complete spectrum of medical services including family practice, internal medicine, emergency room, open-heart surgery, and a cancer center. The hospital offers an ongoing series of wellness programs and provides support groups and seminars for the community at large. Washington Hospital also has four satellite facilities, none of which are located in the 2 km radius. The Outpatient Neighbor Health Center is located at 95 Leonard Avenue in the City; the Occupation Rehabilitation Center is located at the Meadowlands; the Professional Building is located at the Waterdam Medical Plaza in Peters Township; and the Family Practice Office is located in Avella (Washington Hospital, September 1994).

4.7.2.6 Clinics

The Stat Care Emergency Clinic, located in the basement of a former school on Jefferson Avenue, is a small osteopathic clinic in the study area.

4.7.2.7 Prisons

There are no prisons in the 2 km radius. The closest prison is located behind the County Courthouse facility on South Main Street in the City of Washington.

4.7.3 Vicinity Analysis in the ½ km Radius

A study of the resident population and sensitive populations in the ½ km study area (194 acres) identifies those people who may be most directly impacted by Molycorp, Inc.'s decommissioning activities. Although the project site is situated in an industrial area and is surrounded by highway and railroad rights-of-way, there are a number of residential neighborhoods on the periphery of the project site. There are 110 people in the ½ km study area 16 years of age and younger; there are 86 people 65 years of age and over. The youthful and elderly populations in the ½ km study area represent approximately one person per acre.

4.7.3.1 Residence Locations

The locations of current residences in the 1/2 km radius from the center of the Molycorp, Inc. site outward are identified on Figure 4-34. The U.S.G.S. Washington West Quadrangle Map (1969) was utilized and information was updated using the 1990 aerial photograph of Washington West, SE and field verification conducted on July 18-30, 1994.

As shown in the figure, the 1/2 km study area, situated entirely in Canton Township, has clusters of residential areas, such as a portion of Elwood Park and neighborhood residences near the City of Washington boundary. The total number of inhabitants of these residences has been calculated and is presented below:

- Number of Residences (1/2 km radius): 178
- Persons Per Household (1990): 2.64
- Total Residential Population (1/2 km radius): 470

(Source: U.S. Census of Population, 1990)

4.7.3.2 Sensitive Populations

The sensitive population sub-groups identified in Section 4.7.2 are primarily located outside of the ½ km study area. There is only one location of a sensitive population sub-group in the ½ km study area. As shown on Figure 4-34, ½ km Vicinity Map, there is a family day care center on Scott Avenue serving 12 children, ages ten months to four years, about 1,200 feet from the edge of the project site. There are no nursing or personal care homes, hospitals, clinics, schools, or prisons in the ½ km study area.

5.0 EXTENT AND CONCENTRATION OF CONTAMINATION

5.1 CHARACTERIZATION OF THE SOURCE

This section characterizes the physical and chemical properties of the ferrocolumbium (FeCb) slag. While the section follows the order presented in the Site Characterization Report (SCR) (RSA, 1993), a better understanding of site conditions minimized the necessity of empirically determining each of the slag, ore, and site parameters as outlined in the SCR. Additionally, where either physical material (e.g., historical raw ore sample) or records were unobtainable, conservative assumptions or literature values were used. As with most sites of this nature, records primarily documented the product material rather than the waste. Also, many records were discarded after a sufficient length of time after the product was sold, as is standard industry practice.

5.1.1 Composition of the Slag

Thoriated slag was a byproduct of the production of ferrocolumbium. This alloy was produced, beginning in 1964, using an aluminothermic reduction with pyrochlore concentrates. The use of pyrochlore as the source of ferrocolumbium became prevalent after 1945. By 1964 production of ferrocolumbium from pyrochlore was equivalent to other raw columbium ores.

5.1.1.1 The Process

The materials used in the aluminothermic reduction mix varied with the grade and constituents of the pyrochlore. The pyrochlore concentrates themselves varied with the origin of the ore. Four examples of the principal components of a pyrochlore concentrate from the USSR are presented below by weight percent:

$(Cb+Ta)_2O_5$	SiO_2	TiO_2	P	S
40.3	12.8	8.4	0.10	0.12
41.2	11.7	4.7	0.11	0.15
44.4	10.4	6.8	0.13	0.09
38.5	12.0	12.5	0.09	0.17

A review of the available records of the Araxa mine (Brazil) concentrates indicates a silicon dioxide weight percent of about 10 percent with a range from 3.1 percent to 17.6 percent, similar to the USSR material. The sulfur and phosphorus content is about an order of magnitude less than that presented, e.g., 0.01 percent for phosphorus and 0.02% for sulfur. Thorium oxide ranged from 1.87 percent to 2.08 percent while uranium "yellow cake" (actually U_3O_8) reflected a low grade ore, i.e., 0.04 percent to 0.06 percent (Personal Communication, Molycorp, Inc., 1994).

Typically a mix consisted of the pyrochlore concentrate, sodium nitrate, aluminum, magnesium, mill scale (scrap iron), punchings (low phosphate iron nodules), and cryolite or spar. Recovery of the FeCb alloy varied from a low of 65 percent to 95 percent with the average between 85 percent and 90 percent.

5.1.1.2 Chemical Reactions

Ferrocolumbium is typically produced exothermically by using the oxidation of aluminum as the primary heat source. If sufficient heat is generated during the reduction of the metal oxide then the reaction can be conducted without the use of a furnace. These systems are commonly referred to as aluminothermic, thermit, exothermic, extrafurnace processes. For a more complete description of these processes refer to Production of Ferroalloys, Electrometallurgy; 2nd ed., V.P. Elyutin et al., translated from Russian, 1961, and Handbook on Material and Energy Balance Calculations in Metallurgical Processes; H. Alan Fine and Gordon H.Geiger, 1979.

The reduction of columbium pentoxide by aluminum proceeds according to the following reaction:

$$\frac{2}{5}Cb_2O_5 + \frac{4}{3}Al_2O_3 \rightarrow \frac{4}{5}Cb + \frac{2}{3}Al_2O_3 \qquad (1)$$

Of particular concern is whether the thorium present in the concentrate becomes a constituent of the slag or the alloy during reduction. To determine if conditions were thermodynamically favorable for the reduction of thorium by aluminum the change in free energy as a function of temperature was plotted for reaction 1 and the following reactions in the temperature range of 1000-2000°K (Figure 5-1). Magnesium as a reductant was included in the comparison because the process used at the site consisted of an aluminum/magnesium mixture of unknown proportions.

$$\frac{2}{5}Cb_2O_5 + 2Mg \rightarrow \frac{4}{5}Cb + 2MgO \qquad (2)$$

$$ThO_2 + \frac{4}{3}Al \rightarrow Th + \frac{2}{3}Al_2O_3 \qquad (3)$$

$$ThO_2 + 2Mg \rightarrow Th + 2MgO \qquad (4)$$

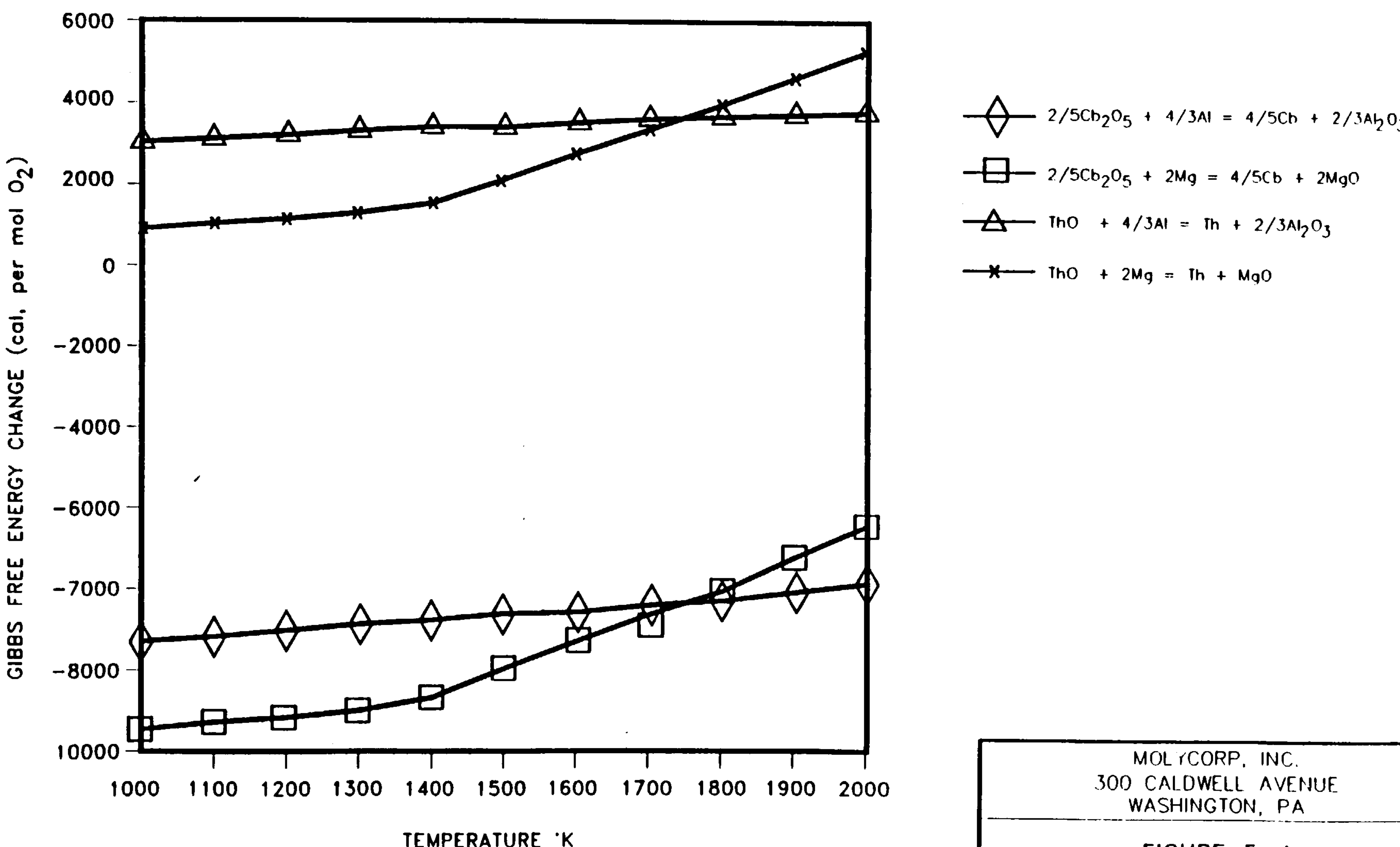
All thermodynamic calculations are presented on a per mole O_2 basis.

Table 5-1 gives the values of the standard free energies of formation as a function of temperature for all species in reactions (1) through (4) above. Figure 5-1 shows the relative ability of both aluminum and magnesium to reduce the oxides of thorium and columbium. As can be seen from the graph, the reduction of columbium pentoxide is thermodynamically favorable, while reduction of thorium dioxide is not favorable to proceed as written in reactions (3) and (4) above.

Table 5-1 Standard Free Energies of Formation as a Function of Temperature								
Species Temp (K)	Cb	Cb_20_5	Th	ThO_2	Al	AL_2O_3	Mg	MgO
1000	-11819	-505728	-16321	-317167	-10199	-424550	-11273	-11518
1100	-13474	-513721	-18514	-320867	-11996	-429014	-13133	-157551
1200	-15191	-522097	-20785	-324738	-13862	-433753	-15083	-159695
1300	-16965	-530829	-23134	-328768	-15792	-438856	-17057	-161943
1400	-18792	-539893	-25557	-332947	-17780	-444497	-19595	-164288
1500	-20670	-549270	-28056	-337284	-19822	-450360	-23901	-166723
1600	-22594	-558943	-30630	-341714	-21915	-456433	-28240	-169242
1700	-24564	-568896	-33303	-346289	-24056	-462707	-32611	-171842
1800	-26577	-579324	-38054	-350982	-26241	-469171	-37011	-174517
1900	-28631	-591219	-38866	-355789	-28489	-475819	-41438	-177265
2000	-30724	-603420	-41737	-360704	-30737	-482642	-45891	-180081
	Cb_2O_5/Al	Cb_2O_5/Mg	ThO_2/Al	ThO_2/Mg				
1000	-76599	-95654	31411	12356				
1100	-75305	-94127	32338	13517				
1200	-74000	-92578	33267	14689				
1300	-72755	-91012	34119	15882				
1400	-71701	-88462	34765	18004				
1500	-70639	-82472	35397	23564				
1600	-69567	-78502	36015	29080				
1700	-68489	-70555	36589	34524				
1800	-67325	-64544	37135	39918				
1900	-65671	-58071	37669	45269				
2000	-63990	-51591	38188	50587				

Free energy values taken from:

Thermochemical Properties of Inorganic Substances Parts I & II, and Barin, I. And Knacke, O., 1973, Thermochemical Properties of Inorganic Substances, Supplement, Parts I & II, Barin, I., Knacke, O., and Kubaschewski, O., 1977.



MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE 5-1

VARIATION OF GIBBS FREE ENERGY OF REACTION WITH TEMPERATURE

FOSTER WHEELER ENVIRONMENTAL CORPORATION

CAD FILE NAME: MOLY5-1.DWG DATE: 1/16/95
PLOT SCALE: TO FIT TIME: 9:20 AM

Because the reduction of columbium is less favorable at the temperatures encountered during the process, equilibrium is attained between elemental aluminum and columbium oxide (CbO). For this reason, excess aluminum is added to the mix to improve the yield of the process, and typically 2 to 4 percent aluminum is contained in the alloy. Yields for this process average 90 percent, while the columbium lost to the slag is assumed to be in the form of CbO. Thorium dioxide does not reduce and also reports to the slag.

The reason magnesium was used in the process is not completely understood at this time. At the temperatures of interest (~2000°K), magnesium should volatilize during the reaction, escaping as a gas. The magnesium may have been used as an extra source of heat for the process.

Table 5-2 presents estimated thorium mass balance calculations based upon early (1964) mix sheets. Detailed mass balance analysis is not possible due to the incomplete nature of the mix sheet information. However, by assuming negligible transfer of thorium to the alloy, the concentration of thorium in the slag generated by the process can be estimated. To simplify the calculations a constant concentration of 1% thorium in the columbium concentrate is used. The analysis shows that the concentration of slag should equal the concentration of thorium in the columbium concentrate. The quantity of slag generated was calculated by subtracting the mass of alloy recovered from the total mass of ingredients present in the mix. The thorium concentration in the slag is based upon the estimated mass of thorium present in the concentrate divided by the mass of slag generated.

5.1.2 Radiochemical Composition of the Slag and Slag/Soil Mix

The concentration of the radioisotopes in the slag varies considerably. According to studies by Applied Health Physics (1975) the concentration of thorium in 20 samples from the slag pile ranged from 3.2 ± 0.1 mg/g to 15.9 ± 0.4 mg/g (Th-232 from 348.8 pCi/g to 1733.1 pCi/g) with an average concentration of 11.4 ± 0.2 mg/g of thorium (Th-232 average 1242.6 pCi/g) These averages correspond to their 1971 core samples in which 21 soil borings were taken with two-inch cores at various depths. The concentrations ranged from background, less than 0.001 percent thorium, to a maximum of 0.73 percent thorium (Th-232 at 795 pCi/g). This is higher than the concentration of samples they obtained from the slag settling basin which contained 0.2 to 0.3 percent thorium (Th-232 from 218 pCi/g to 327 pCi/g).

ORISE (Oak Ridge Institute for Science and Education) in their 1985 report (Martin et al., 1985) reported finding similar results. On the active plant site they report concentrations of Th-232 up to 1,380 ± 20 pCi/g in surface soils with elevated surface radiation levels. On the south property, with the slag pile, the maximum concentration of Th-232 was 1,890 pCi/g.

Table 5-2 Thorium Mass Balance Calculations								
Date of Reaction	Number of Mixes	Mass/Mix (lbs)	Oxide/Mix (lbs)	Th @ 1% (lbs)	Total Th (lbs)	Metal Rec (lbs)	Slag Gen (lbs)	Calc. Slag Th Conc. (%)
2/18/64	15	1470	1000	10	150	11610	10440	1.44
2/21/64	8	1470	1000	10	80	5225	6535	1.22
4/15/64	15	1475	1000	10	150	10860	11265	1.33
5/7/84	7	1515	800	8	56	5394	5211	1.07
6/5/64	14	1345	820	8.2	114.8	7395	11435	1.00
6/22/64	9	1310	800	8	72	4419	7371	0.98
7/27/64	8	1285	800	8	64	4050	6230	1.03
8/21/64	3	1405	800	8	24	1920	2295	1.05
8/24/64	8	1230	750	7.5	60	3712	6128	0.98

The variation in the slag (more appropriately, a slag and soil mix) is in part due to the process it originates in and in part due to ball milling and mixing. The pyrochlore concentrates had measured thorium concentrations of thorium oxide of about one to two percent dry weight (Private Communication Molycorp, Inc., for lots 6547 through 6609, 3/20/63). The concentrate was mixed with aluminum, magnesium, scale, etc. (see 5.1.1.2). After the aluminothermic reaction took place, the slag was separated from the alloy. Due to poor immiscibility, particles of alloy were entrapped in the slag. The slag was ball milled and the $FeCl_3$ separated out. The slag mix was pumped to a settling basin to decant the liquid, which was recirculated. The resulting slag was either stockpiled or mixed with soil and used in other areas of the site. These handling processes have redistributed the original thorium concentrations and in part resulted in the range of thorium sampled.

Radioisotopes in the slag and slag/soil mix were also measured based on their particle size distribution. The samples were sieved and measured by gamma spectroscopy. The size fractions chosen were +4 mesh, 4-50 mesh, 50-100 mesh, and 100-200 mesh. Table 5-3 presents the results of this testing for each sample. Table 5-4 presents the mean thorium activity by particle size. As is obvious, no size dependence vs. thorium concentration is evident in the material on this site. This also confirms the conclusion reached by a separate analysis in Subsection 5.1.2.1.

In addition to the fractionation studies, the degree of secular equilibrium between thorium-232 and its progeny was measured. For this effort both alpha spectroscopy and gamma spectroscopy were employed. The results of these analyses are presented below.

Alpha Spectrometric Analysis

Radioactive equilibrium in six slag samples was determined by dissolution, radiochemical separation followed by alpha spectrometric analysis for the Th-232, Th-230 and Th-228 isotopes by procedures stated in the SCP Appendix C. Results from the alpha spectrometric analysis are presented in Table 5-5.

Gamma Spectrometric Analysis

Gamma spectrometric analysis was performed on 24 other slag samples to provide further confirmation of conclusions regarding radioactive equilibrium of thorium. These are presented in Table 5-6.

The alpha spectroscopy results gave a mean for the Th-228: Th-232 ratio of 1.03 $\pm$ 0.005. The gamma spectroscopy results gave a mean ratio for Tl-208 to Ac-228 of 0.359 $\pm$ 0.030. This ratio is very close to the correct branching ratio of 0.36 found in the Radiological Health Handbook. These results confirm that the radioisotopes are in secular equilibrium.

Table 5-3

Particle Size Fractionation of Slag Study
Concentration Th-232 (pCi/g) Measured By Gamma Spectroscopy

Sample	+4 Mesh	4-50 Mesh	50-100 Mesh	100-200 Mesh
SB-56-02	1.2 ± 0.2	6.2 ± 0.2	1.2 ± 0.2	0.8 ± 0.2
SB-56-03	1.7 ± 0.1	3.0 ± 0.3	0.8 ± 0.1	0.5 ± 0.1
SB-56-15	0.4 ± 0.1	4.5 ± 0..1	6.4 ± 0.6	2.1 ± 0.1
SB-56-18	0.3 ± 0.2	6.6 ± 0.7	39.8 ± 0.4	63.1 ± 0.5
SB-56-21	0.0 ± 0.2	22.8 ± 2.0	7.8 ± 0.3	8.9 ± 0.3
SB-56-24	1.6 ± 0.1	9.7 ± 0.2	4.3 ± 0.1	6.7 ± 0.2
SB-56-27	0.4 ± 0.4	3.6 ± 0.3	4.8 ± 0.5	3.5 ± 0.8
SB-56A-09	1.1 ± 0.3	8.5 ± 0.8	2.6 ± 0.4	0.0 ± 0.0
SB-56A-08	5.9 ± 0.4	20.3 ± 0.5	12.6 ± 0.4	13.9 ± 0.4
SB-56C-08	1.1 ± 0.1	9.2 ± 0.8	2.6 ± 0.1	5.5 ± 0.5
SB-56C-10	0.1 ± 0.4	0.0 ± 0.0	31.1 ± 2.8	3.5 ± 0.4
SB-56C-11	0.6 ± 0.1	14.3 ± 1.2	1.5 ± 0.1	1.2 ± 0.1
SG-01-A	11.9 ± 0.1	16.1 ± 0.8	5.2 ± 0.1	Sample Damaged
SG-01-B	1.4 ± 0.2	6.0 ± 0.3	4.0 ± 0.2	4.5 ± 0.2
SG-01-C	4.4 ± 0.2	6.7 ± 0.1	4.5 ± 0.1	2.5 ± 0.1
SG-01-D	6.3 ± 0.1	4.8 ± 0.1	3.1 ± 0.1	2.0 ± 0.1
SG-04-B	3.5 ± 0.2	9.9 ± 0.5	1.6 ± 0.1	0.9 ± 0.1
SG-31-A	0.0 ± 0.0	12.5 ± 0.7	1.0 ± 0.1	0.7 ± 0.1
SG-31-D	6.0 ± 0.2	65.5 ± 1.5	17.2 ± 0.9	8.0 ± 0.2
SG-34-A	13.2 ± 0.6	26.9 ± 1.0	5.5 ± 0.1	5.8 ± 0.1
SG-35-B	2.6 ± 0.2	13.4 ± 0.7	4.1 ± 0.1	15.2 ± 0.8
SG-39-C	10.6 ± 0.5	28.2 ± 0.6	10.2 ± 0.1	11.3 ± 0.1
SG-39-D	2.3 ± 0.3	15.9 ± 0.7	3.5 ± 0.1	8.4 ± 0.1
SG-46-A	1.9 ± 0.2	15.8 ± 0.2	22.2 ± 0.7	10.9 ± 0.2
TP-1-2	410.9 ± 3.4	328.3 ± 1.2	Sample Damaged	379.8 ± 2.2
TP-1-6	410.9 ± 3.4	295.8 ± 1.8	152.5 ± 0.8	202.6 ± 2.3
TP-3-6	889.4 ± 3.0	583.7 ± 1.8	101.2 ± 0.5	724.6 ± 3.4
TP-5-1	349.6 ± 2.4	361.6 ± 2.0	55.2 ± 0.5	499.4 ± 4.5
TP-6-7	716.4 ± 1.4	901.9 ± 3.4	35.1 ± 0.3	1190.0 ± 7.6
TP-7-3	186.3 ± 1.1	204.7 ± 1.4	16.7 ± 0.2	229.5 ± 3.3

Table 5-4 Summary of the Particle Size Fractionation of Slag Study				
	+4 Mesh	4-50 Mesh	50-100 Mesh	100-200 Mesh
Mean Activity for the Thorium Pile Sample as a Function of Particle Size	493.9 ± 105.7	446.0 ± 104.7	72.2 ± 22.4	537.5 ± 152.1
Mean Activity for the Surface Gamma Sample as a Function of Particle Size	5.4 + 1.3	18.5 ± 4.8	6.8 ± 1.9	6.4 ± 1.4
Mean Activity for the Soil Bore Sample as a Function of Particle Size	1.2 ± 0.5	9.1 ± 2.0	9.6 ± 3.6	9.1 ± 5.0

Table 5-5 Alpha Spectrometry Results		
Sample ID	Th-228:Th-232	Th-230:Th-232
TP3-2	1.09	0.198
TP3-4	1.05	0.095
TP6-3	1.03	0.091
TP6-6	0.97	0.071
TP7-3	1.08	0.302
TP7-7	0.97	0.176
Mean	1.03 + 0.05	0.156 + 0.088

Table 5-6 Gamma Spectrometry Results	
Sample ID	Tl-208: Ac-228
TP1-2A	0.345
TP1-2B	0.341
TP1-2D	0.346
TP1-6A	0.345
TP1-6B	0.369
TP1-6C	0.322
TP1-6D	0.388
TP3-6A	0.341
TP3-6B	0.334
TP3-6D	0.348
TP5-1A	0.371
TP5-1B	0.368
TP5-1C	0.418
TP5-1D	0.346
TP6-7A	0.390
TP6-7B	0.314
TP6-7C	0.426
TP7-3D	0.349
Mean	0.359 + 0.030

5.1.2.1 Physical/Chemical Properties of the Slag

As stated, the FeCb slag was ball milled for the recovery of additional product. A sample of FeCb slag was sent to Dr. Kenneth N. Han, Department of Metallurgical Engineering, South Dakota School of Mines and Technology. The objective of his investigation was to determine if physical separation of the slag was feasible. The results indicated otherwise. Presented below is Dr. Han's report with format modifications to maintain consistency with this report.

Density Measurement and Gravity Separation

The density of the ferrocolumbium slag sample was measured using a water-displacement method. The density was found to be 2.68 g/cm^3.

The sample was crushed and ground to -100 mesh. Attempts were made to separate the heavy components from the light by density separation techniques such as panning with a heavy liquid (tetrabromoethane, p=2.95 g/cm^3). The test results are shown below. As can be noted, although there is a trend of separation, the results are not convincingly positive to implement this separation technique in practice. This rather poor separation may be due to the disseminated nature of heavy components in the matrix of the slag sample.

Results of Density Separation

Element	Tailing (86%)	Conc. (14%)
Th	0.21	0.23
U	0.01	0.09
Fe	1.31	3.08
S	10.65	7.23

X-Ray and Scanning Electron Microscopic (SEM) Studies

X-ray diffraction analyses have indicated that the following species may be incorporated with the sample:

SiO_2; $Ca_3Al_2(OH)_2$; $Al(OH)_3$; $Ca_6Si_3O_{12}H_2O$; $Ca_2Al(Al,Si)_2O_7$

The elemental mapping of SEM on various locations of the sample surface indicated the following metal distribution as a typical composition.

Element	Wt. %
Si	4.72
Al	25.77
Fe	0.45
Mn	0.24
Mg	0.17
Ca	22.91
Cl	2.96
S	2.01
O	40.76
	99.99

Conclusion

Based on the results obtained in this study, it can be concluded that the sample contains small amounts of thorium and uranium. However, these metals are distributed in the sample matrix in a disseminated manner. As a result, physical separation of these elements does not appear to be practical.

5.1.3 Emanating Properties of Slag

The SCP proposed an empirical determination of the emanation coefficient for radon-220. An investigation into the literature regarding emanation coefficients and diffusion of radon indicated that this pathway is of very little concern. The short half life of radon-220 (54.5 seconds) results in negligible quantities of the gas escaping into the atmosphere no matter what the emanation coefficient is. A synopsis of the literature search and the basis for the aforementioned is presented below.

The release of radon-220 into the atmosphere due to the decay of radium-224 (assumed in secular equilibrium with the thorium-232) is a two-step process. Initially, radium decays to the gas radon in those grains of slag containing thorium. A portion of the gas remains "fixed" in the grain of the material, i.e., diffusion out of the grain is extremely low with a diffusion coefficient on the order of 10^{-22} cm^2/sec (Bykhovskii et al., 1969). Some of the gas does however penetrate the capillaries, microfissures and pores of the slag and enters the air or water in the interstitial pore space of the slag/soil material. The emanation coefficient (E) is defined as the fraction of radon which escapes the mineral grain in which it is formed and is free to diffuse through the bulk medium.(Hart and Levins, 1986; Tanner, 1964). The emanation coefficient is therefore the escape to production ratio.

The emanation coefficients vary, depending on the mineral which contains the thorium (equilibrium radium). One author for example (Barretto, 1970) tested a number of samples of

Table 5-7 (Sheet 1 of 2) Radon Emanation Characteristics		
SAMPLE	ROCK TYPE	ESCAPE-TO-PRODUCTION RATE (%)
VKB-437	Gneiss	14.0 ± 0.76
VCS-34	Gneiss	1.0 ± 0.26
I-275A*	Qtz-monz-gneiss	2.4 ± 0.08
E-833*	Qtz-monz. orthogneiss	12.6 ± 1.58
E-829*	Qtz-dior. paragneiss	7.9 ± 0.82
E-830*	Granodiorite	16.9 ± 1.9
E-827*	Granodiorite	40.0 ± 3.1
VCS-25	Granodiorite	3.9 ± 0.16
VFS-276	Granodiorite	12.2 ± 1.28
VFS-279	Qtz. diorite	4.7 ± 0.87
VTR-1571	Qtz. diorite	6.1 ± 0.97
E-832*	Qtz. monzonite	9.2 ± 0.33
VKB-14	Granite	6.8 ± 0.91
VKB-365	Alaskite	15.4 ± 1.2
VKB-640	Granite	32.7 ± 1.3
VCS-26	Pegmatite	4.3 ± 0.15
I-262*	Pegmatite	3.0 ± 0.30
I-271*	Porph. granite	12.5 ± 0.28
E-828*	Granite	40.4 ± 2.7
E-831*	Granite	9.4 ± 0.92
COM-G	Granite	3.8 ± 0.39
MILF-G#	Granite	4.8 ± 0.47
GRAN-G#	Granite	9.1 ± 0.31
CHEL-G#	Granite	7.8 ± 0.63
GR-G	Granite	
FM-100	Granite	7.7 ± 0.39
IBK-G	Granite (W)	16.3 ± 0.56
VM-274	Dacite	6.9 ± 8.1
E-823	Syenite	9.3 ± 0.54
NIM-L*	Lugaurite	15.4 ± 0.74
MBT-57	Basalt	2.8 ± 0.26
MBT-3	Basalt	2.5 ± 0.23
IPS-193	Basalt	7.7 ± 1.0
W-1*	Diabase	9.4 ± 1.6
I-274*	Gabbro	3.6 ± 0.58
AAE-256	Volc. tuff	1.7 ± 0.12
I-268*	Conglomerate	2.3 ± 0.20
I-269*	Conglomerate	10.4 ± 0.48
I-263*	Metacomglomarate	26.0 ± 0.91

Table 5-7 (Sheet 2 of 2) Radon Emanation Characteristics		
SAMPLE	ROCK TYPE	ESCAPE-TO-PRODUCTION RATE (%)
SP-PR	Serpentinite	1.0 ± 0.63
I-272*	Quartzite	10.5 ± 0.84
GC-27	Quartzite	5.3 ± 0.49
GC-22	Quartzite	1.9 ± 0.19
OKL-FR	Sandstone	11.9 ± 0.94
AAC-218	Sandstone	3.2 ± 0.40
AAE-309	Sandstone	5.3 ± 0.22
AAF-374	Sandstone	7.4 ± 0.71
OKL-ST	Red Silt	8.1 ± 1.02
E-825*	Dol. subarkose	5.6 ± 0.53
AUST-L	Limestone	1.6 ± 0.42
EL-AB-A	Asphal. limestone	1.9 ± 0.27
EL-AB-O	orl. Limestone	0.6 ± 0.17
SPL-L	Limestone	1.7 ± 0.56
EL-DOC-L	Limestone	2.2 ± 0.31
GC-5	Silt shale	7.7 ± 0.41
GC-3	Shale	2.67 ± 0.16
EP-7	Laterite (Fe)	2.86 ± 0.19
RM-2	Laterite	2.52 ± 0.15
LIP-60	Volc. glass	0.51 ± 0.04

All samples were crushed and sieved to <60 >115 mesh unless indicated

* = grain sizes < 200 mesh

= MBS rock standard

W = Weathered

different minerals. As indicated in the table, while the emanation coefficients varied considerably, the overwhelming majority of emanation coefficients were less than 0.1 (10%). It should be noted that the variability in E for radon-222 is assumed to be comparable to radon-220, the principal gaseous isotope of concern at this site. This is reasonable, since chemically and physically the isotopes of radon are both inert gases with a difference in mass of 0.0090 and behave the same physically with respect to the laws of thermodynamics (statistical mechanics). The major radiological difference between these nuclides is that their half-lives are T1/2=54.5 seconds for radon-220, and 3.83 days for radon-222. Empirically this conclusion was weakly supported by site data. The measured emanation coefficient for radon-220 was 0.64 $\pm$ 0.03 for bulk material and 0.68 $\pm$ 0.1 for material crushed below 100 mesh. For radon-222 the emanation coefficient was measured to be 0.17 $\pm$ 0.03. The empirical basis for these coefficients is presented in Appendix I.

As previously stated, the second step in the process of releasing radon into the atmosphere begins with the diffusion of the gas from the interstitial pores of the soil/slag matrix to the ground surface. A number of mathematical models have been developed to predict radon transport to the earth's surface. The models are used to predict cover thickness on uranium or thorium waste piles (tailings piles). Studies of radon transport in other areas include exploration for uranium deposits, using radon as a precursor for earthquakes and studying the air/ground/surface interface. These studies assume that radon follows the basic Fick's first law of diffusion. It is:

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial z^2} - \lambda\ C + kP$$

where:

C=the interstitial concentration of radon (pCi/cm^3)
D=diffusion coefficient(cm^2/sec)
λ =the decay constant for radon.(for radon-220 =1.3x10^{-2} sec^{-1}
or radon-222=2.1x10^{-6} sec^{-1})
P=production rate (pCi/gm-sec)=ER (R=radium content)
t=time (sec)
z=distance from surface(cm)
k=constant dependent on bulk density and porosity

The radon flux is then

J=-Dk' ∂ C/ ∂ z surface

where:

J=radon flux (pCi/sq cm-sec)
k'=constant

The most elementary solution of the above assumes an infinite half space with radium homogeneously distributed throughout with a thin slab of material (soil) on the surface. Convection and hydraulic transport are negligible. This condition parallels the site conditions as the higher concentrations of thorium (radium in equilibrium) are below the surface. The solution to the transport equation in this case is

$$C = Co\ \exp\left(-\sqrt{\lambda / D}\ z\right)$$

where Co is the initial concentration and z is the distance through the slab from the surface of the radon producing half space. Substituting a conservative estimate, that of sand, for the diffusion coefficient, $D=5\times10^{-2}$ cm^2/sec and $\lambda=1.3\times10^{-2}$ sec^{-1} gives $\sqrt{D/\lambda} = 1.88$ cm the diffusion length.

Substituting and solving for z gives

$$z = \sqrt{D/\lambda}\ \ln(Co/C) = 1.81\ \ln(Co/C)$$

A hundredfold reduction in the radon concentration occurs when C=Co/100 or z = 8.2 cm. A thousand fold reduction occurs when z=12 cm. Thus, a small increase in the thickness results in a large decrease in the concentration.

The above indicates that whatever radon-220 is generated by the radium, it is in equilibrium with thorium in the slag and escapes and diffuses into the interstitial spaces of the material very quickly. As the radon diffuses towards the surface, the atoms decay. Those surviving reach the surface and escape to the atmosphere. A thin layer of soil (12 cm) is sufficient to provide enough tortuosity (diffusion paths through the soil) to result in negligible radon contribution to the atmosphere (most decays). Thus, the site does not act as a source of radon to the surrounding environment. It should also be noted that the emanation coefficient only influences the initial concentration. Even with a high emanation coefficient the reduction in the radon concentration requires minimal additional soil. In the example quoted, if the emanation coefficient is increased from 0.2 to 0.8, the additional soil required to get an equivalent reduction in concentration in the above examples is 2.5 cm or about an inch.

5.1.4 Slag Leachability

Leachability tests for a 5-day leach and a 90-day leach were conducted on the slag material to determine the diffusion, if any, of radioisotopes out of the slag matrix into the interstitial ground water. The radioisotopes of concern are thorium and radium (Th-232, Th-228, Ra-226). The leach tests were conducted using the EPA's TCLP protocol as the basis. The EPA protocol was chosen as being more representative of the actual conditions, rather then ANSI/ANS-16.1-1986 which is used for solidified low-level radioactive waste. This latter test is part of the Branch Technical Position (BTP) to Meet the Technical Requirements of Part 61 for the Disposal of Low-Level Radioactive Waste. The BTP requires waste form integrity to be maintained for a long time period under a variety of stresses such as high radiation, heat, and immersion in water. The immersion in water is the leachability test which is followed by a compressibility test. This has little relevance to the situation at hand since the slag is not being solidified (in cement, polymer or bitumen), is not 10 CFR 61 waste material, and is not a material which requires structural integrity.

Some initial insight into the leachability of the slag can be gained from a study by S.D. Sheerer and G.F. Lee in their paper "Leachability of Radium-226 from Uranium Mill Solids and River Sediments" (Health Physics, 1964). For uranium tailings it was determined that whatever leaching occurs does so within the first few hours of contact with the water. This holds true whether the material continues to be immersed or repetitive leaching is attempted. To quote their conclusions, "It was shown, for uranium mill waste solids and for river sediments, that an equilibrium was reached rapidly with regard to the amount of radium-226 leached with the solids as a function of time. After about 30 minutes no significant additional radium-226 was leached up to a period of 6 days." As the waste in this case is highly encapsulated in the slag (glass-like from the aluminothermic reaction), little if any diffusion of thorium or radium is expected to take place from the interior of the slag particles after an initial immersion in water. Given that the waste was generated over 20 years ago and was initially ball milled (a wet process), no leaching is expected.

In percolation tests carried out on the site by Applied Health Physics (1970), the measured radioactivity in the leachate was extremely low. Out of 52 leachate samples only 10 had detectable gross alpha concentrations. Of those, the maximum observed was 0.069 pCi/ml gross alpha. This provides additional support to the hypothesis that leaching is a negligible source of radioisotopes. This conclusion is confirmed at least with preliminary results from the 5-day leach test. Final results for the slag and 90 day leach will be provided in a separate document.

5.2 THORIATED SLAG/SOIL SURVEY RESULTS

This section presents the results of an extensive field program designed to delineate those areas of the site expected to require remediation. The database, established through the field program along with data from previous investigations (Applied Health Physics, 1971, 1975, 1982; ORISE, 1985; RSA, 1990), will be used in the formulation of a Decontamination and Decommissioning Plan (D&D Plan). Additionally, while this data is extensive, it by no means negates the need to conduct simultaneous real-time characterization during the execution of the D&D Plan. The material presented below will, however, guide the remediation. Lastly, while the field effort initially followed the basic outline in the SCP, it was considerably augmented; i.e., additional borings were drilled based on field conditions as it became evident that additional coverage would provide a better database.

Two techniques were used to delineate (map) the subsurface distribution of thoriated slag/soil. The first was the down-hole gamma logging technique; the second technique employed gamma-ray spectroscopy. In the former, a NaI scintillator was lowered into each of the boreholes and count rate measurements were taken at 6-inch intervals to the bottom of the boring. Each count rate measurement was converted to a thorium-232 concentration. This technique was fully described in Appendix J of the SCP. NRC concerns regarding this technique along with calibration determinations and responses to the NRC concerns are addressed in Appendix H of this document.

The second technique, gamma spectroscopy of soil samples from the boreholes created a "quality assurance" database. That is, split spoon cores to the bottom of each boring were labeled and archived on site. Gamma spectroscopy measurements of this archived soil were conducted for about 20 percent of the borings. To parallel the down hole logging, the gamma spectroscopy was also conducted in 6-inch increments for every boring selected. Appendix J discusses the gamma ray spectroscopy methodology. Figure B-3 in Appendix B presents the location of each soil boring and monitoring well (labeled "SB" and "MW", respectively).

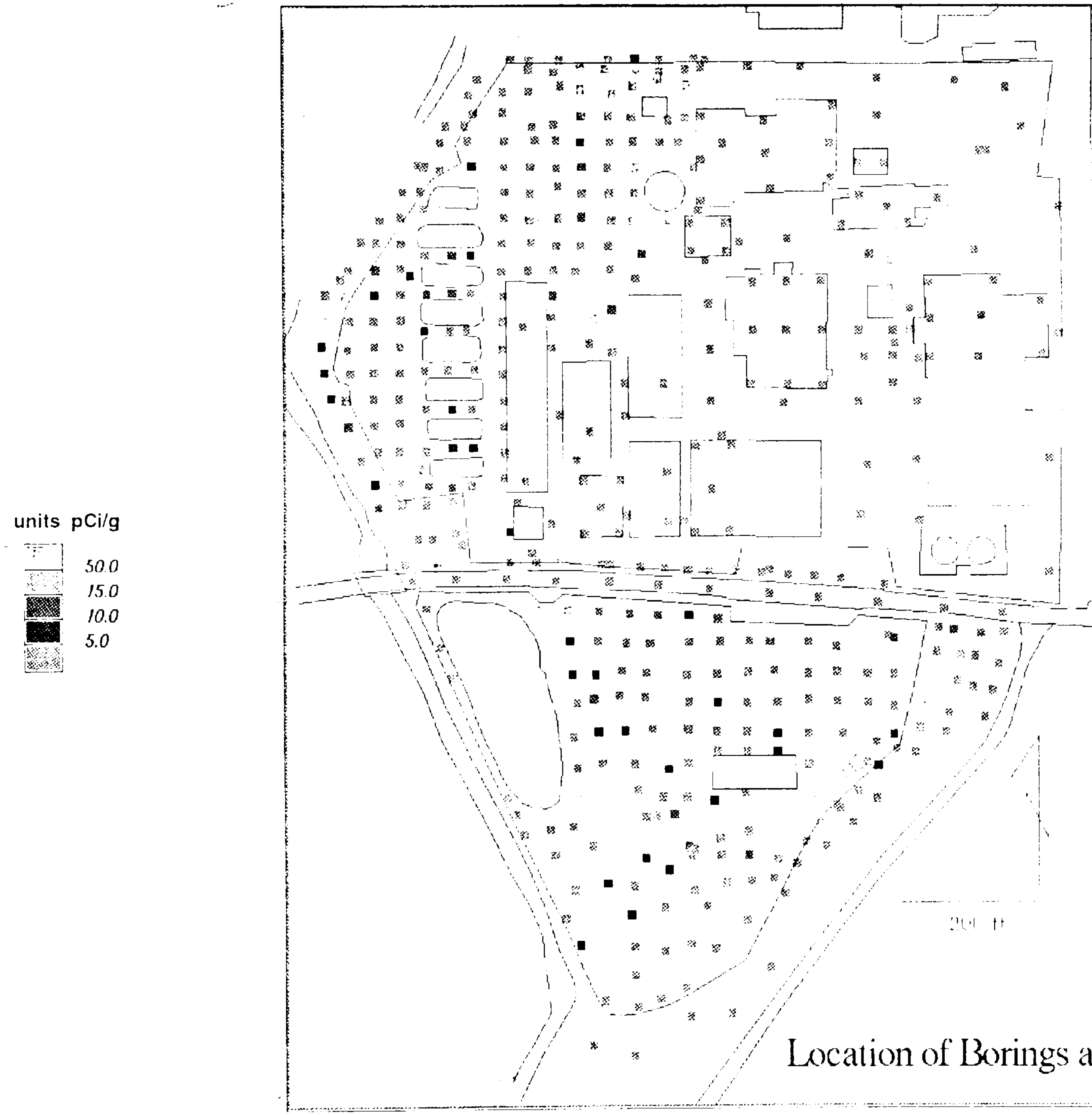
Additionally, a series of borings were taken on the southern thorium pile. (These are labeled "TP" on Figure B-3 in Appendix B). Also located on the figure are the previously installed REMCOR wells (labeled "M") and pumping test wells (labeled PW). In total, 418 borings, monitoring wells and production wells are depicted on the figure. These 418 borings represent a database of 12,499 measurements of surficial and subsurface thorium concentrations.

5.2.1 Subsurface Survey Results

Delineation of the various areas and volumes of elevated thorium concentrations required the use of a commercially available database management, three dimensional graphics system entitled Earth Vision™ by Dynamic Graphics, Alameda, California. This spatial software system provided the ability to map the site in a three-dimensional perspective.

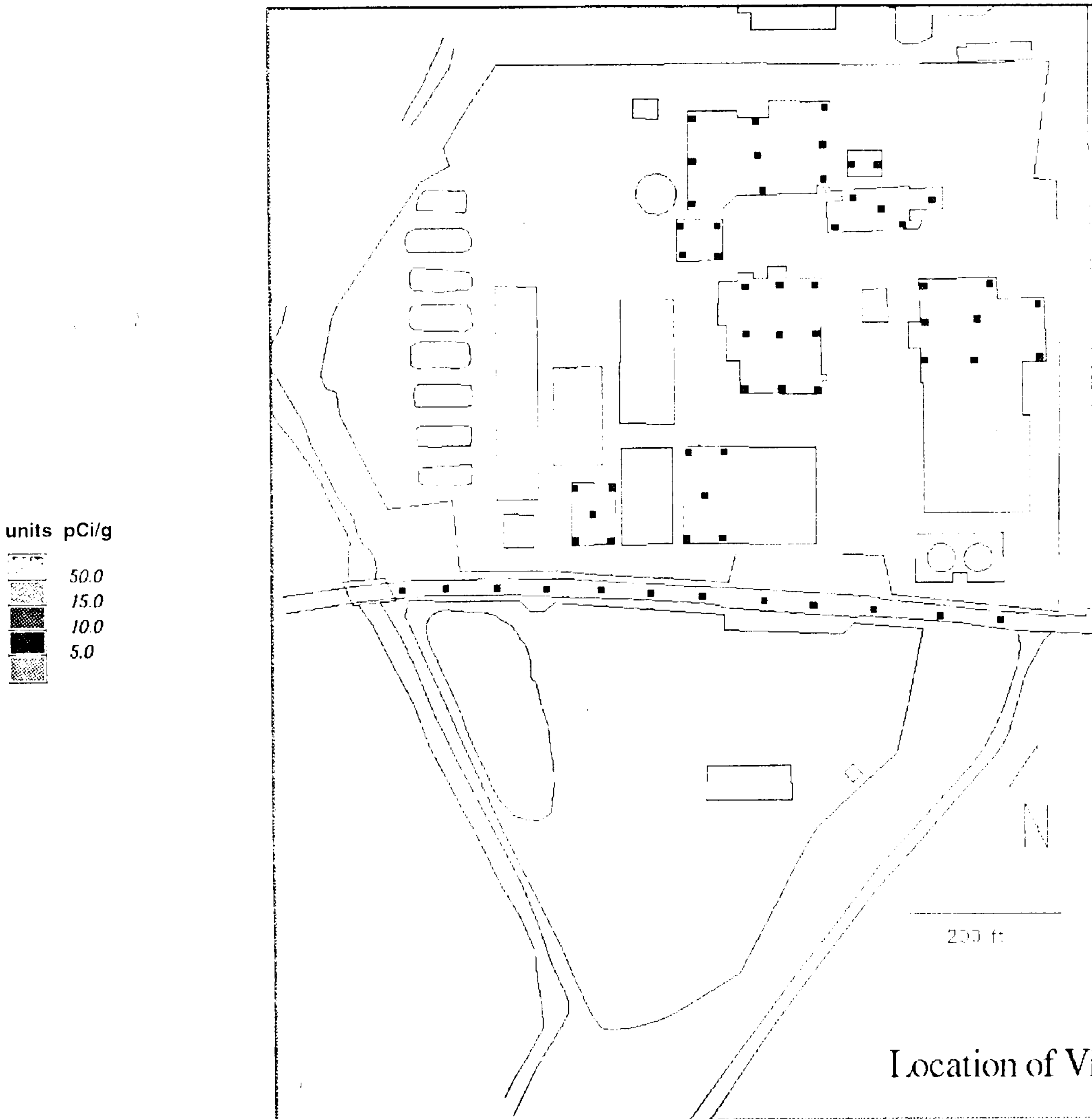
Figure 5-2 presents the location of the borings and the virtual borings. Each boring location was determined by a surveyor and provided with state plane coordinates and a height above sea level. Each boring included the corrected thorium-232 concentrations at 6-inch intervals to the bottom of the boring. The total real data set numbered 12,499 data points and is presented in Appendix N.

The "virtual borings" are not included in this data set. Virtual borings are artificial borings of zero thorium concentrations to the bottom of the virtual boring, see Figure 5-3. Their purpose is to assist in the "true" interpolation of the data. That is, virtual borings were placed in the road and inside the buildings which existed on site in 1964. As these structures were already in existence prior to production of the FeCb, thoriated slag material cannot be in or under these structures (in the road, under the road and buildings). Physically this is equivalent to zero concentrations above background in the road and under these buildings. Mathematically, the virtual borings act as boundary conditions reflecting the actual nature of the site and limiting spurious and misleading interpolation.



Location of Borings and Virtual Borings

FIGURE 5–2



Location of Virtual Borings

FIGURE 5-3

Figure 5-4 presents the borings selected for gamma spectroscopy. For these, soil from each 6-inch interval was analyzed by gamma spectroscopy. The data were input into the "quality assurance" database. These data amount to about 20 percent of the total borings.

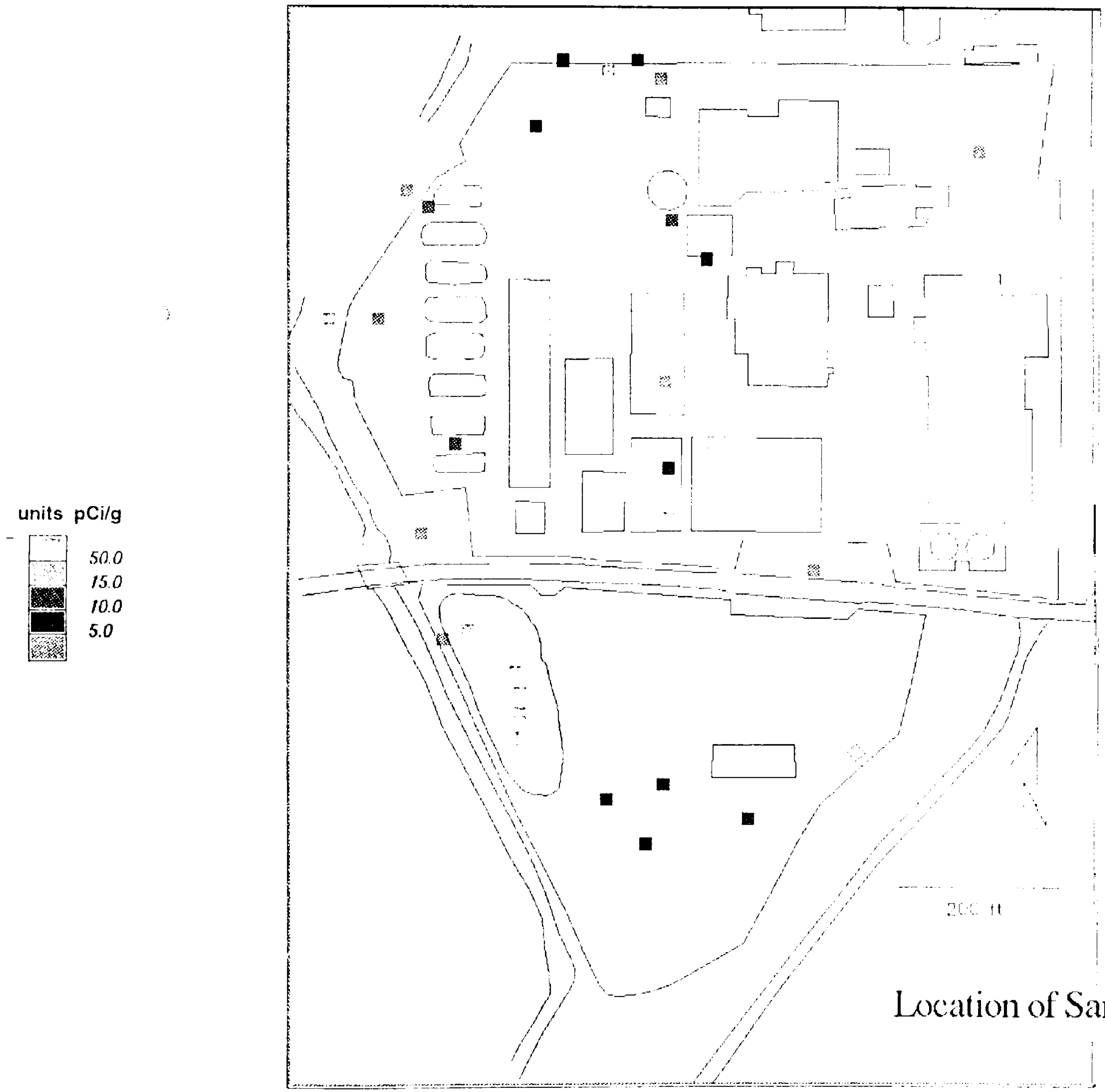
The data are also color-coded as are the other figures in this section. While the thorium concentrations are in tenths of pCi/g, for illustration other intervals were selected. These are: less than 5 pCi/g above background - color dark green; 5 to 10 pCi/g above background - color light green; 10 to 15 pCi/g above backgr ind - color yellow; 15 to 50 pCi/g above background - color orange; and above 50 pCi/g above background - color red.

These intervals were chosen to reflect Options 1 and 2 of the NRC's 1981 Branch Technical Position and the UMTRAP Standards 40 CFR 190. These intervals do not presuppose the concentration required to meet the proposed 15 mrem/year Total Effective Dose Equivalent (TEDE) standard.

Figure 5-5 is a plot of all the borings color coded as discussed. The figure is an oblique three dimensional plot with a Z-axis exaggeration of 20 times actual depth. For reference a planar outline of the site is also presented. Note that this outline, being planar, does not drape the actual topography of the site. This topography is evident by the tops of the borings with the Z exaggeration. What is also evident is that the thoriated material seems to be concentrated in a narrow band from the surface to 6 to 7 feet. This is reinforced by Figure 5-6 which presents just those data points above 15 pCi/gm.

The next step was to determine the horizontal and vertical extent of the thoriated slag/soil. This was attempted using the interpolation (contouring in 3-D) scheme associated with this system. The interpolation scheme is called "minimum tension gridding". The goal of the scheme is to calculate representational surface models from scattered data. That is, to represent (honor) the values of the input data as closely as possible and also to calculate a plausible "natural looking" model for grid nodes that are not on or adjacent to input data points. The two stages of minimum tension gridding are the initial estimate and biharmonic iterations with scattered data feedback. The initial estimate calculates a parameter value for every grid node. The algorithm for this step is described in the Earthvision users manual. The node point values are iteratively re-evaluated using a cubic spline function. The cubic spline function allows the distribution of the "tension" (second derivative or curvature) among the nodes so that the sum of the squares of the tension is minimized. This scheme tends to distribute and smooth out the curvature. Further discussion of these algorithms is presented in the Earthvision user guide.

Figure 5-7 shows the results of this interpolation for the surface of the site. What is immediately obvious is the sharp, polygonal nature of the contamination. This is primarily due to the discrete nature of the thoriated slag and the manner in which the slag was distributed throughout the site. It also implies no migration of the material. Migration of material would have resulted in smooth isopleths. The figure also reflects secondary effects due to the interpolation algorithms. This



Location of Sampled Borings

FIGURE 5-4

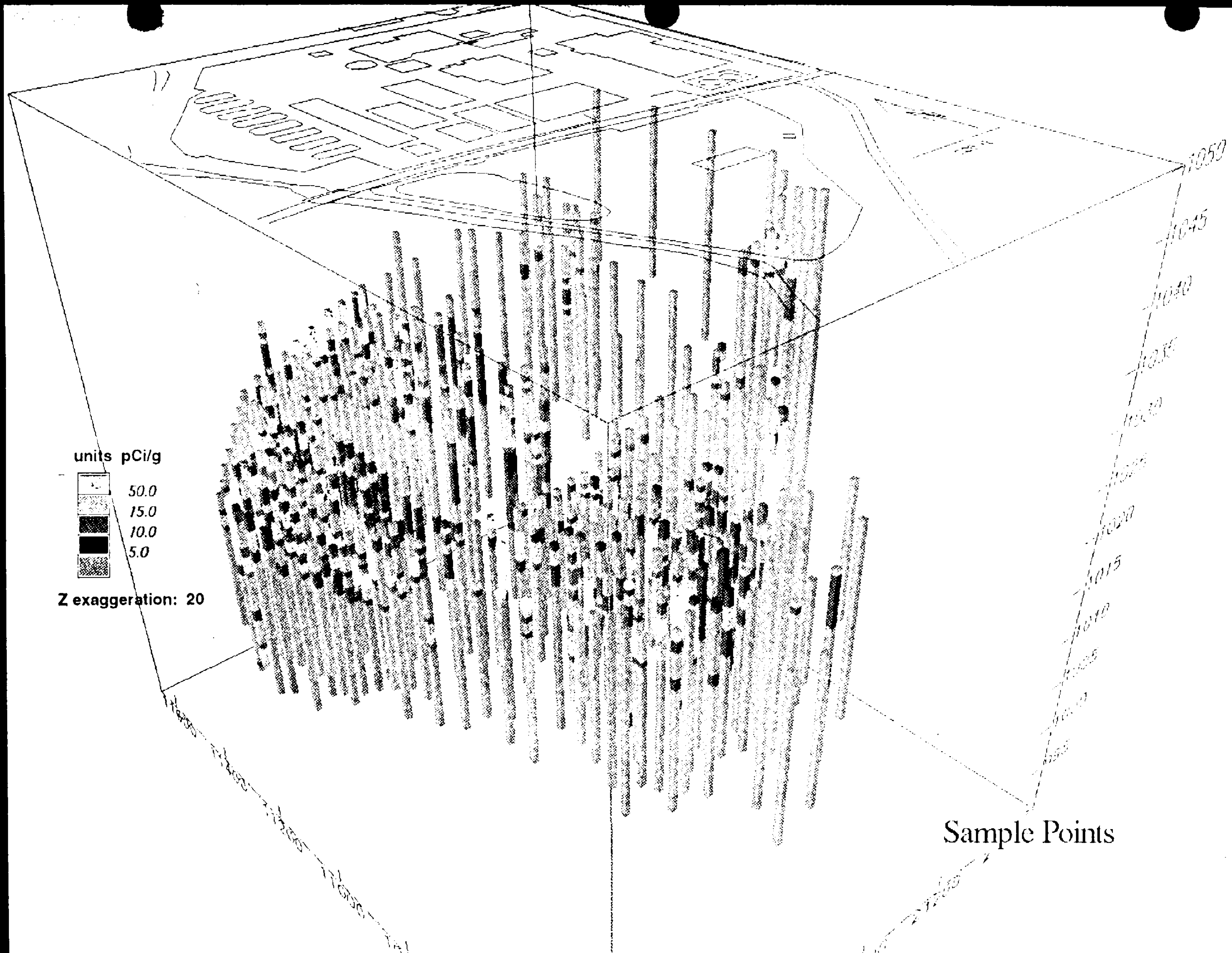

units pCi/g
50.0
15.0
10.0
5.0
Z exaggeration: 20
1050
1045
Sample Points

FIGURE 5-5

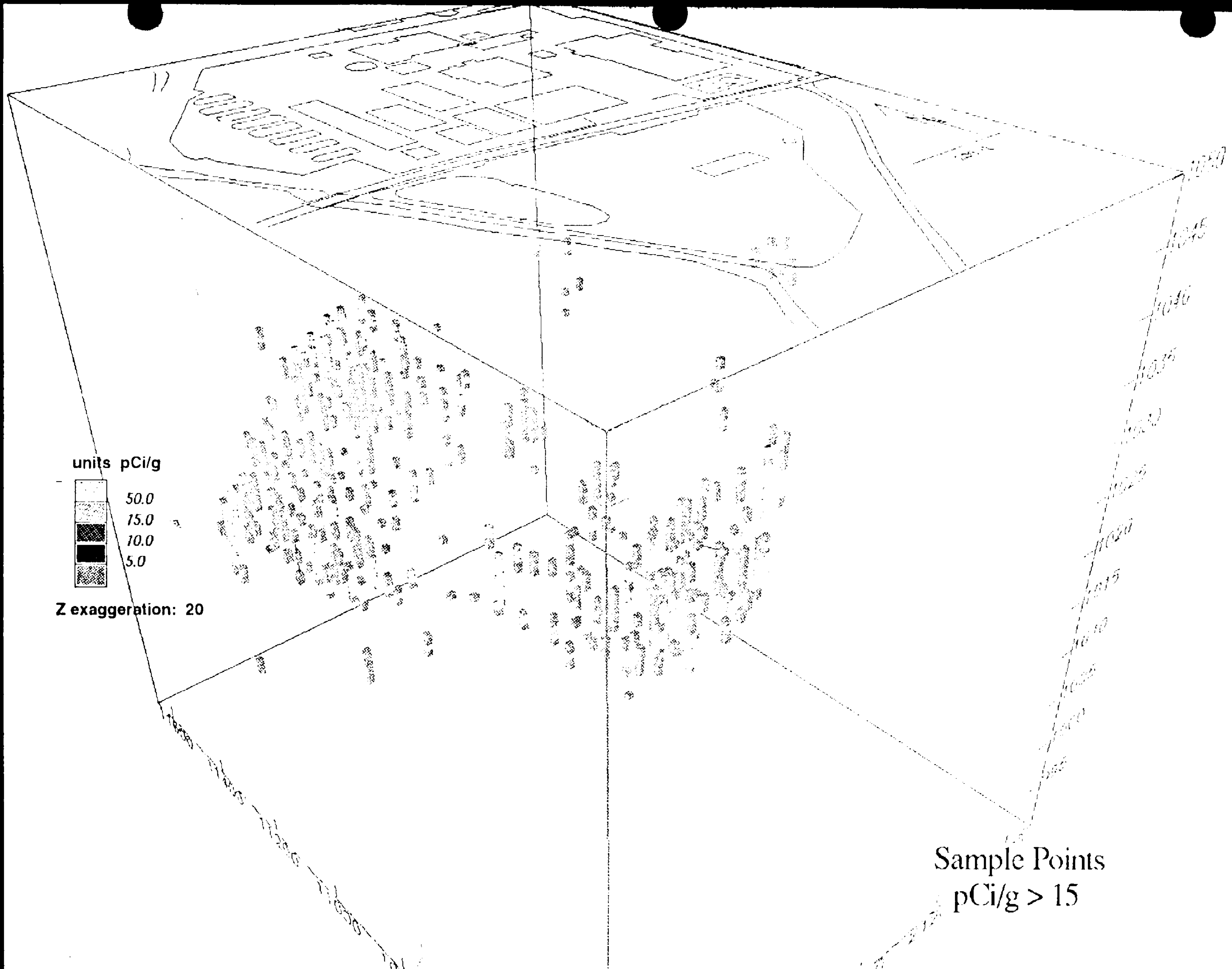
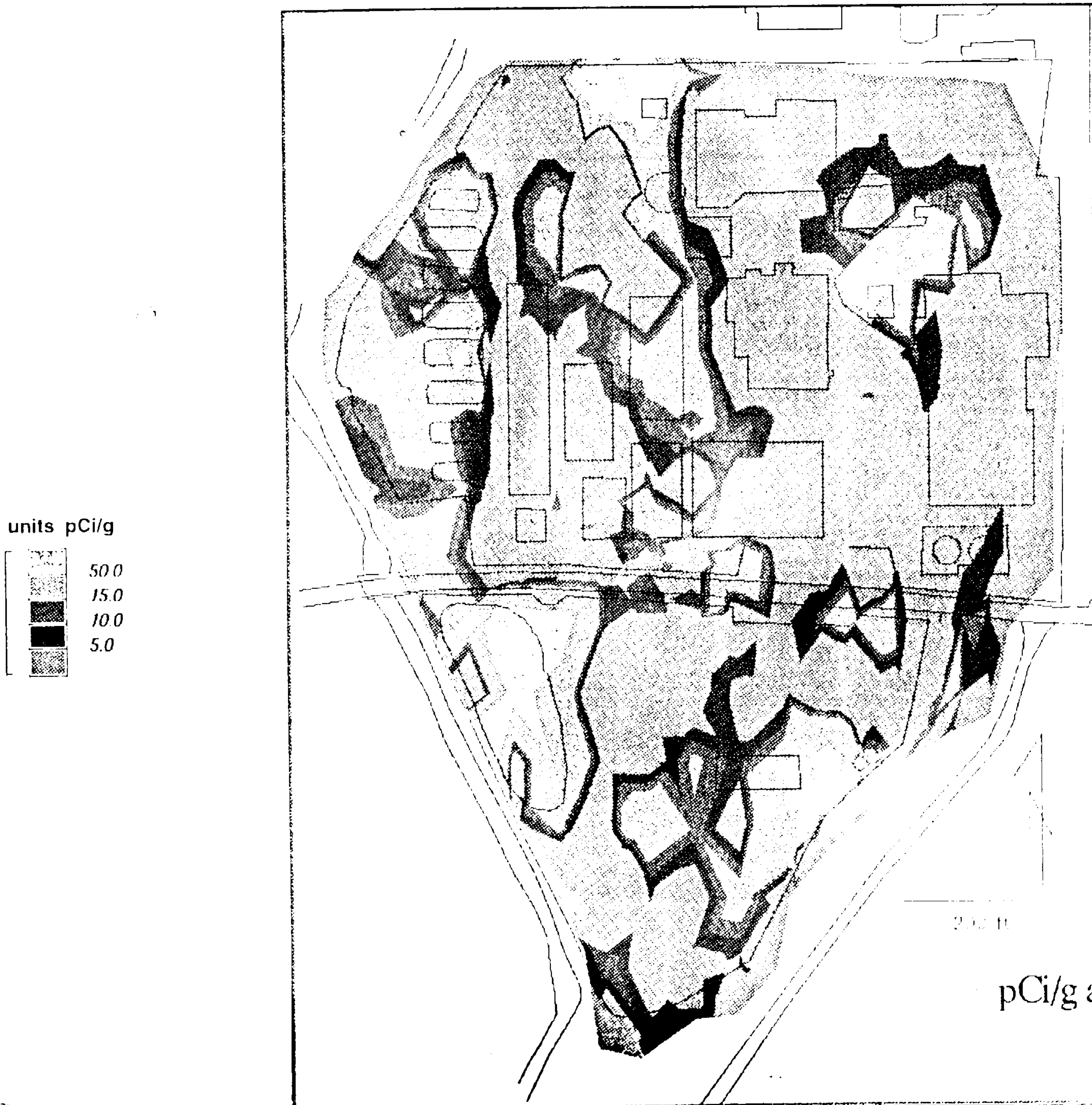

units pCi/g
50.0
15.0
10.0
5.0
Z exaggeration: 20
Sample Points
pCi/g > 15

FIGURE 5-6



pCi/g at Surface

FIGURE 5-7

includes interpolating some radioactive material under the road and buildings with virtual borings and gradations of thorium concentration from high to low (red to green). These effects are also evident in Figure 5-8 through Figure 5-16. These figures present horizontal cross-sections from elevation 1034 feet to elevation 1006 feet. As the topography of the site slopes towards the west, the initial cross-sections do not show the western portion of the site. As the slices get deeper, more of the site is covered.

Figure 5-8 shows some contamination in the northeast quadrant of the site. This contamination is confined to the extreme upper soil layer as reflected in Figures 5-9 and 5-10. As these figures show, the contamination goes quickly back to below 5 pCi/g. Figure 5-10 also begins to intersect surficial (or slightly below the surface) contamination in both the southeast portion of the site and north central portion of the site. Cutting another 4 feet, Figure 5-11 (1022 feet) shows well defined areas of elevated thorium concentrations. Note that the physical depth of this contamination can be retrieved from the topological map.

Figure 5-12, the 1018 foot cross section, encompasses the entire site. As is obvious, no thorium is located at this depth on the eastern portions of the site. The majority of the elevated thorium concentration is evident in the shallow areas both north and south of Caldwell Avenue. Figure 5-13, at the 1016 foot level, indicates that the highest concentrations (greater than 50 pCi/g), rapidly decrease in the northern sector (within 2 feet). This is more dramatic in the next series of two foot elevations (Figures 5-14, 5-15, and 5-16, corresponding to 1014 feet, 1010 feet and 1006 feet above sea level).

The next series of figures present vertical cross-sections in the west east direction at four locations, northings 10640 ft, 10895 ft, 11235 ft, and 11405 ft. These locations are shown as red lines in Figure 5-17.

The first cross-section is in the southern portion of the site at 10640 north. Note that these figures have an expanded vertical axis (Z exaggeration:20). As shown, the overwhelming amount of elevated thoriate material is within a few feet of the surface. Figure 5-19 shows a cross-section on the southern portion of the site close to Caldwell Avenue. Again the major portion of thorium slag seems to be very close to the surface, within the top five feet.

This distribution of material is also reflected in the west to east cross-sections on the northern portion of the site. Figure 5-20 indicates that while a pocket of material extends to about 1015 ft (the red "dumb-bell shape), the majority of material is in the western portion of the site by the impoundments.

The last figure (5-21) again shows the bands of thoriated material extending from the surface to about 10 feet deep. This figure also implies the largest and deepest subsurface volume contribution at the site of the small northern "thorium pile".

FIGURE 5-8

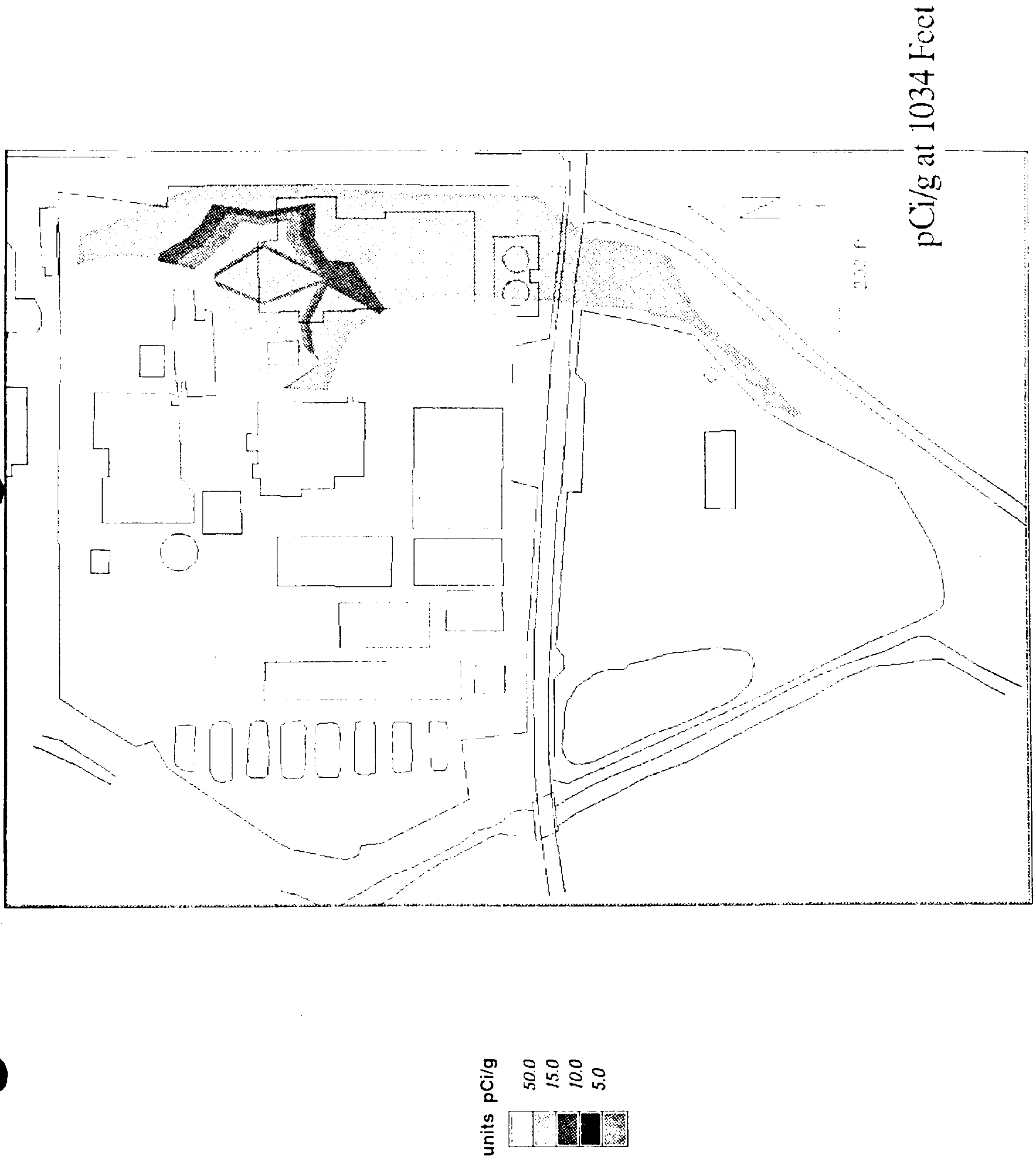
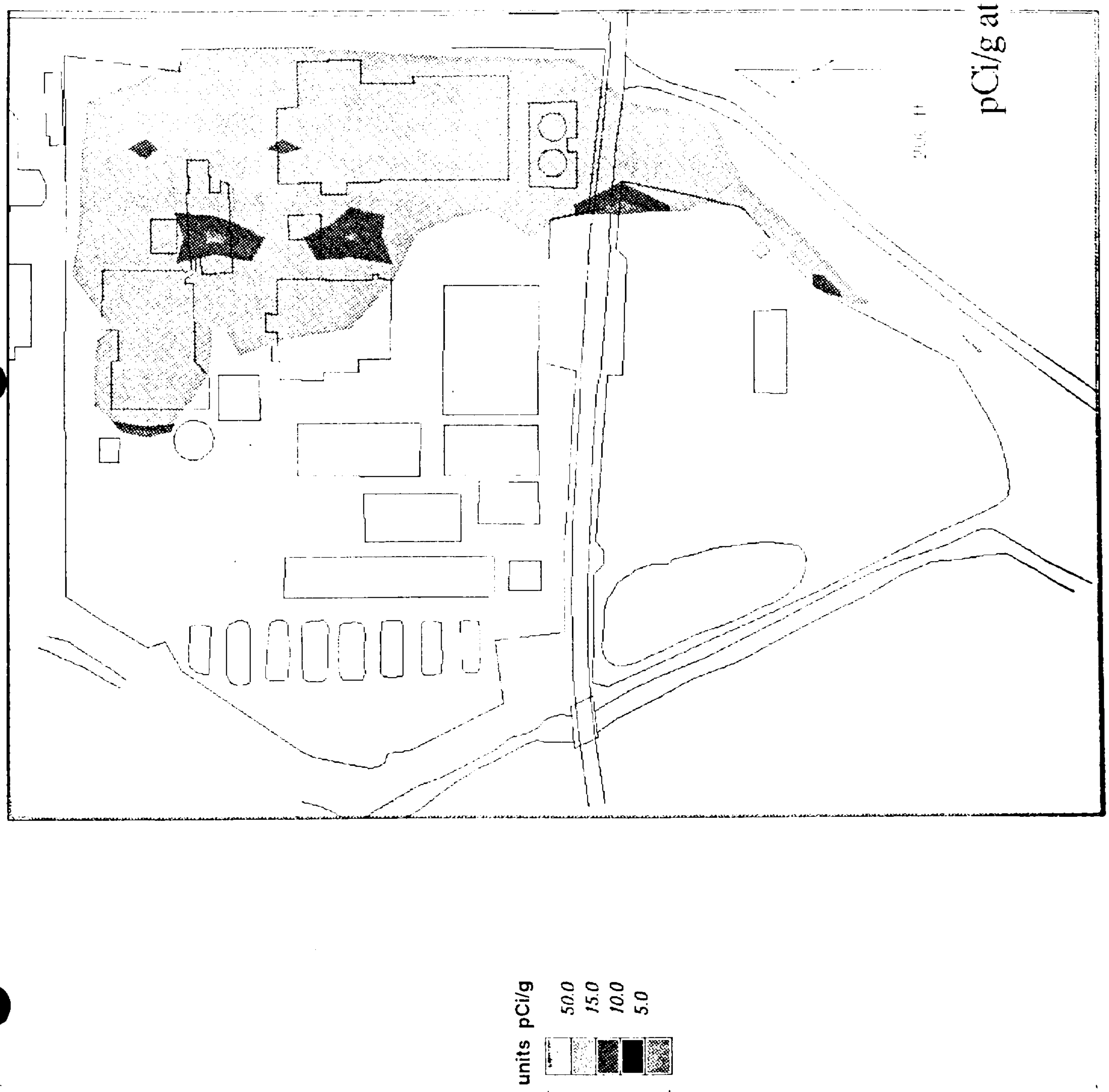
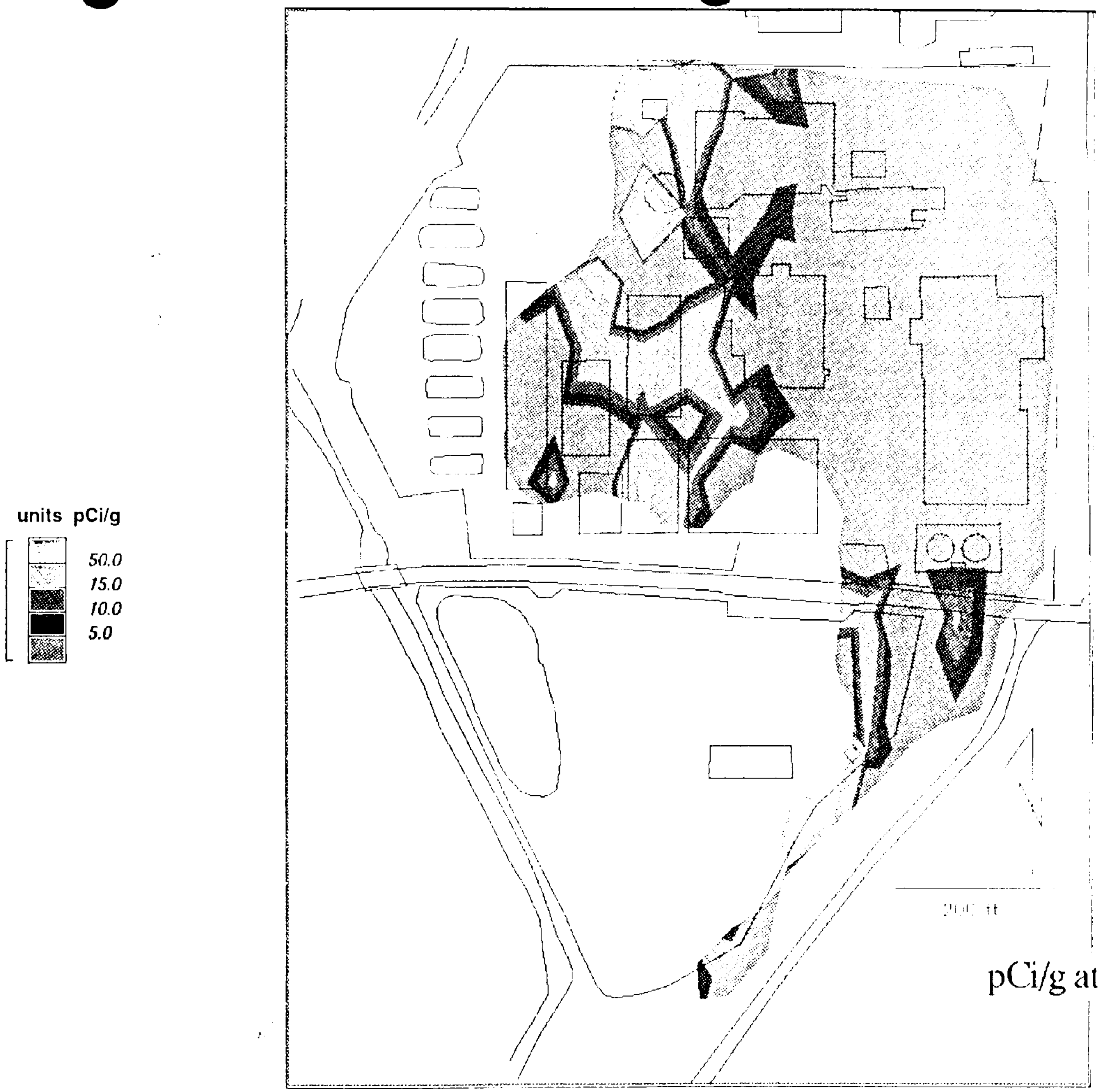


FIGURE 5-9

pCi/g at 1030 Feet





pCi/g at 1026 Feet

FIGURE 5-10

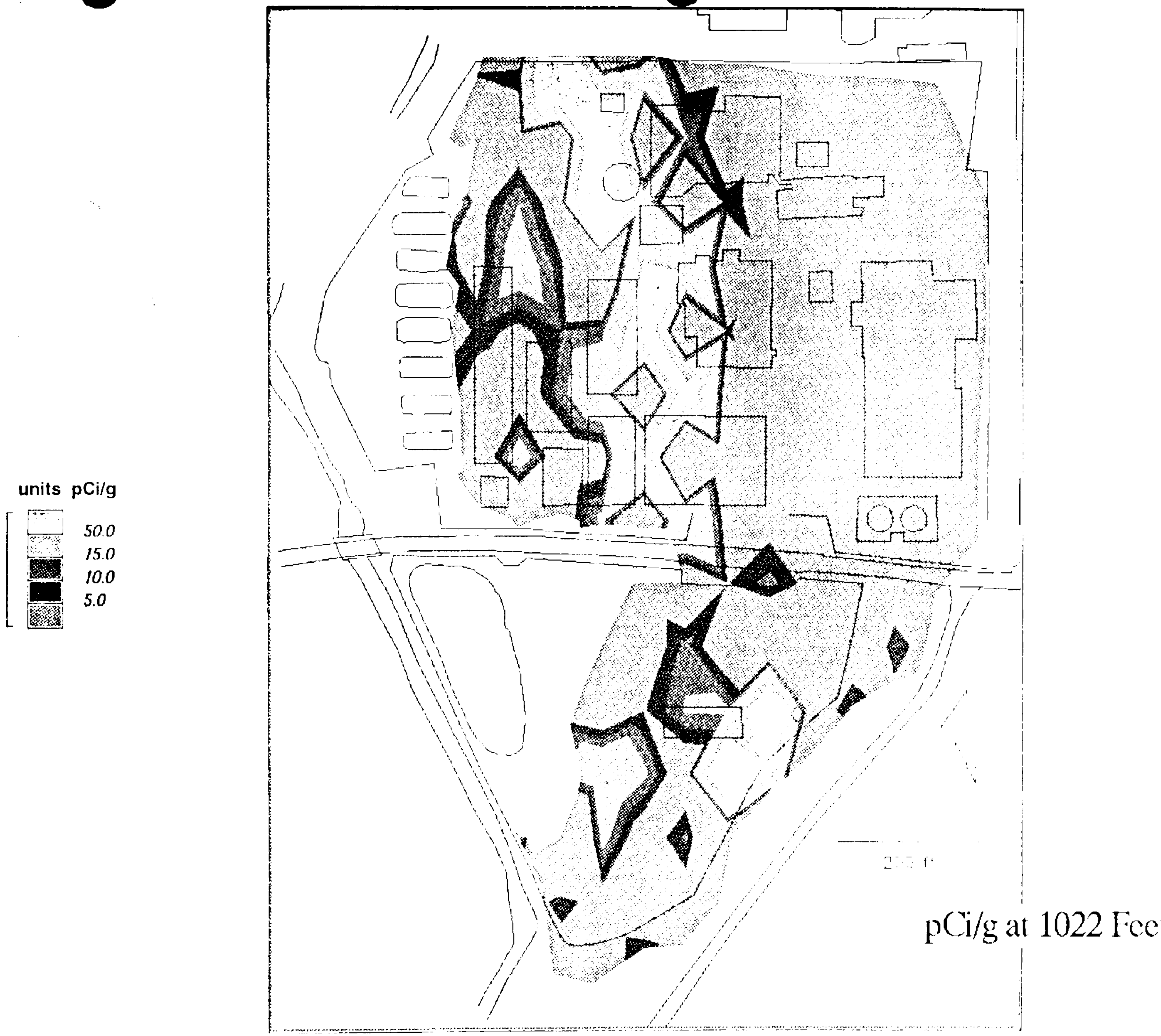
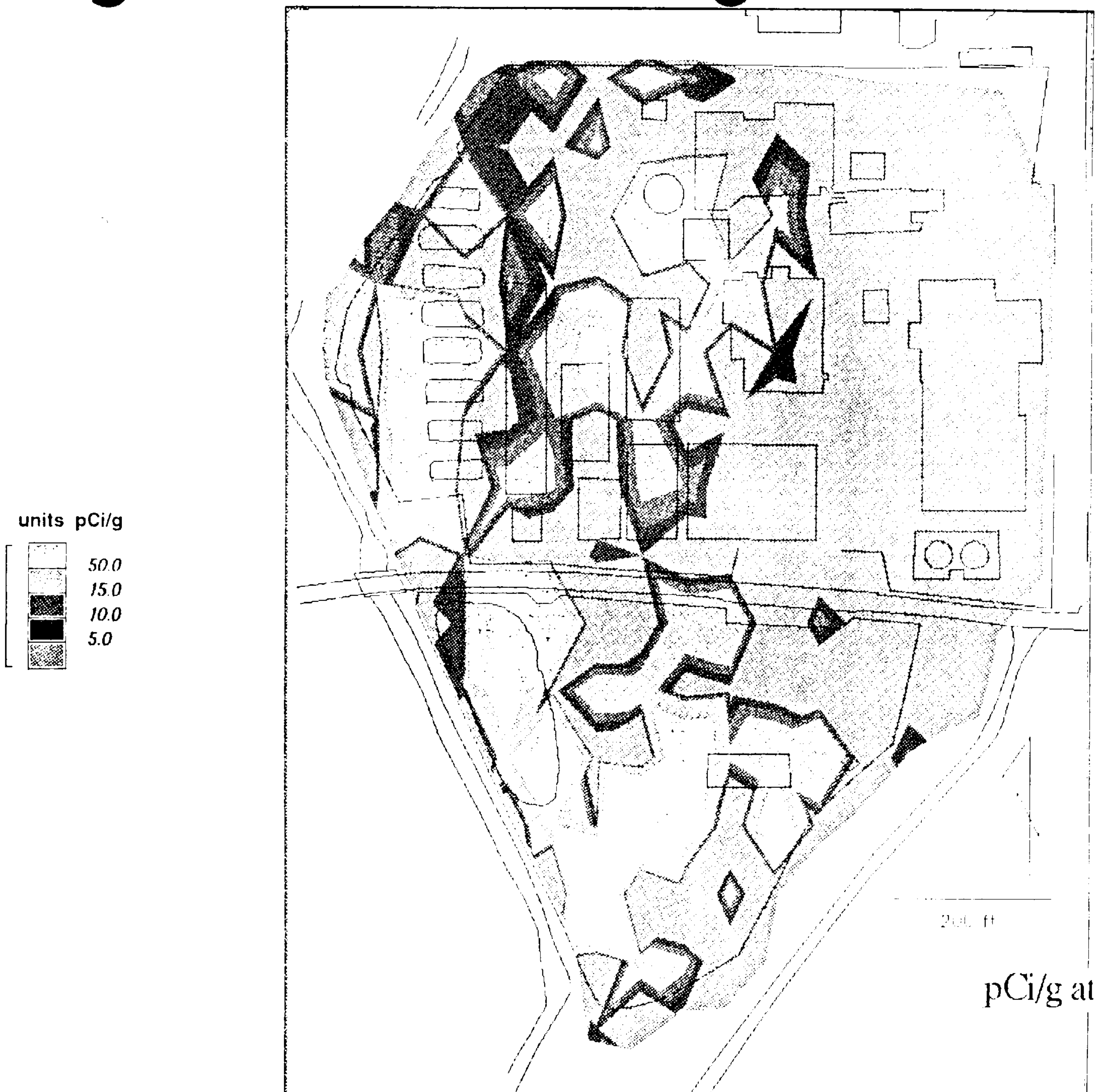
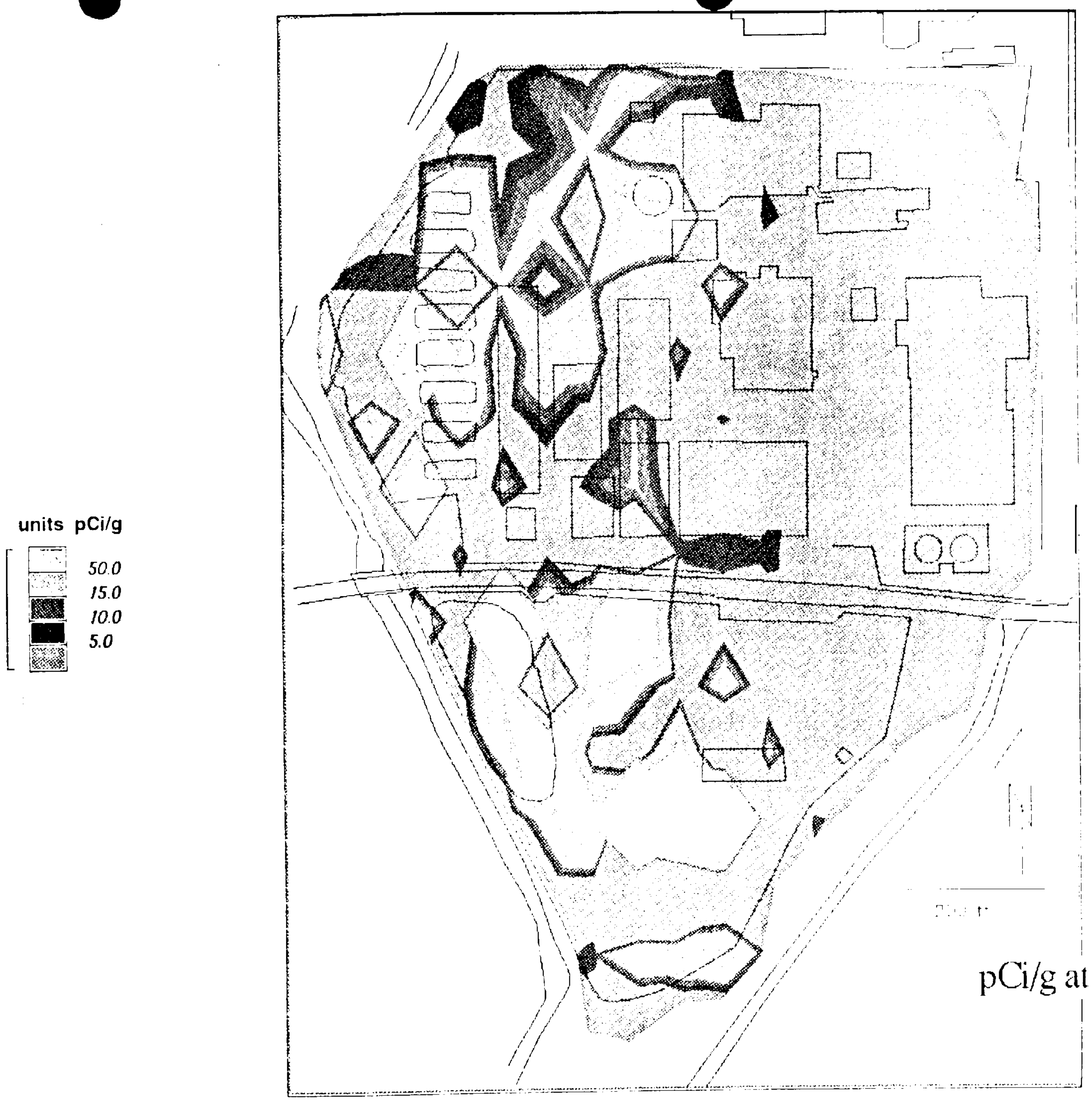


FIGURE 5-11



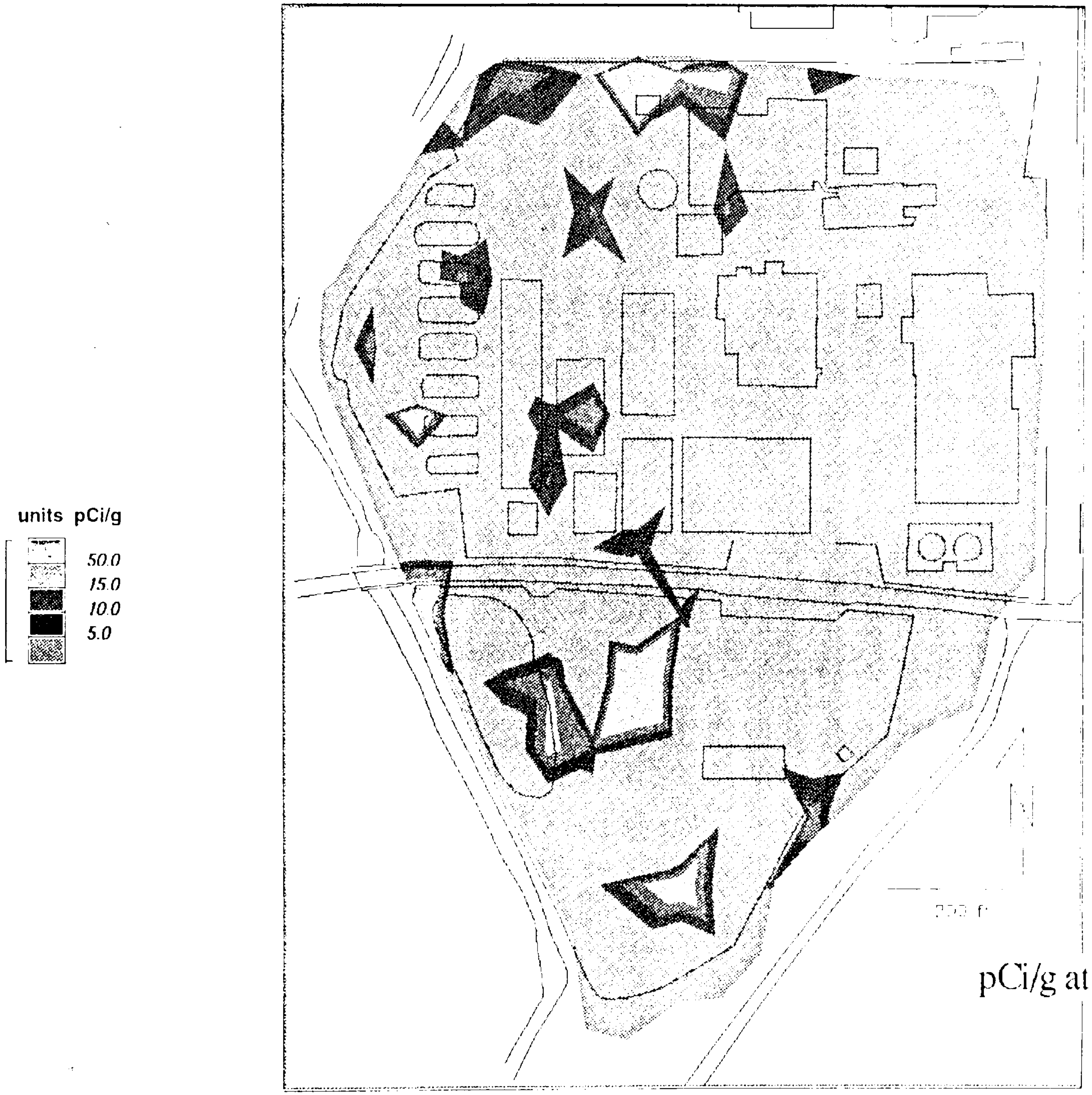
pCi/g at 1018 Feet

FIGURE 5-12



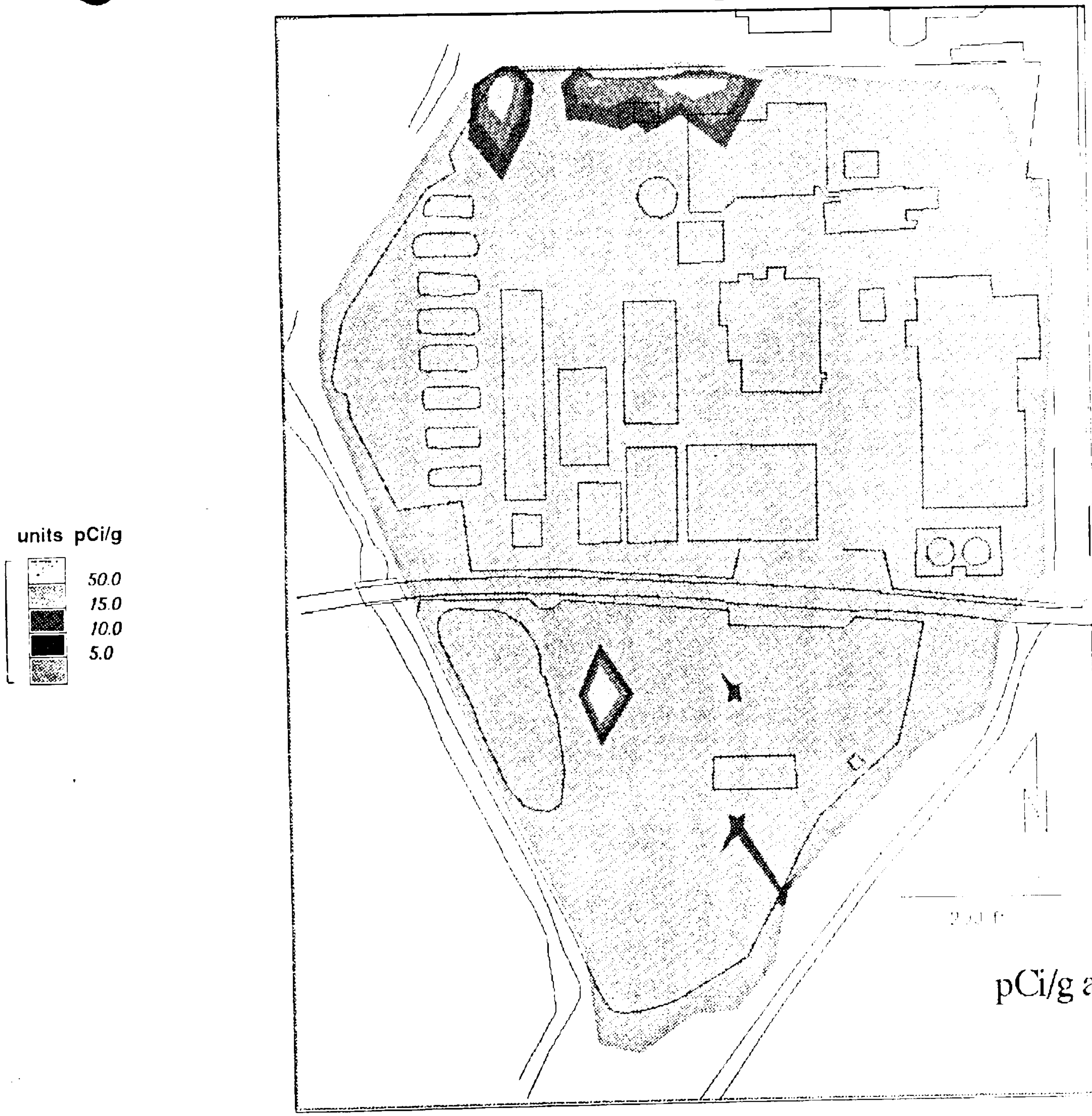
pCi/g at 1016 Feet

FIGURE 5-13



pCi/g at 1014 Feet

FIGURE 5-14



pCi/g at 1010 Feet

FIGURE 5-15

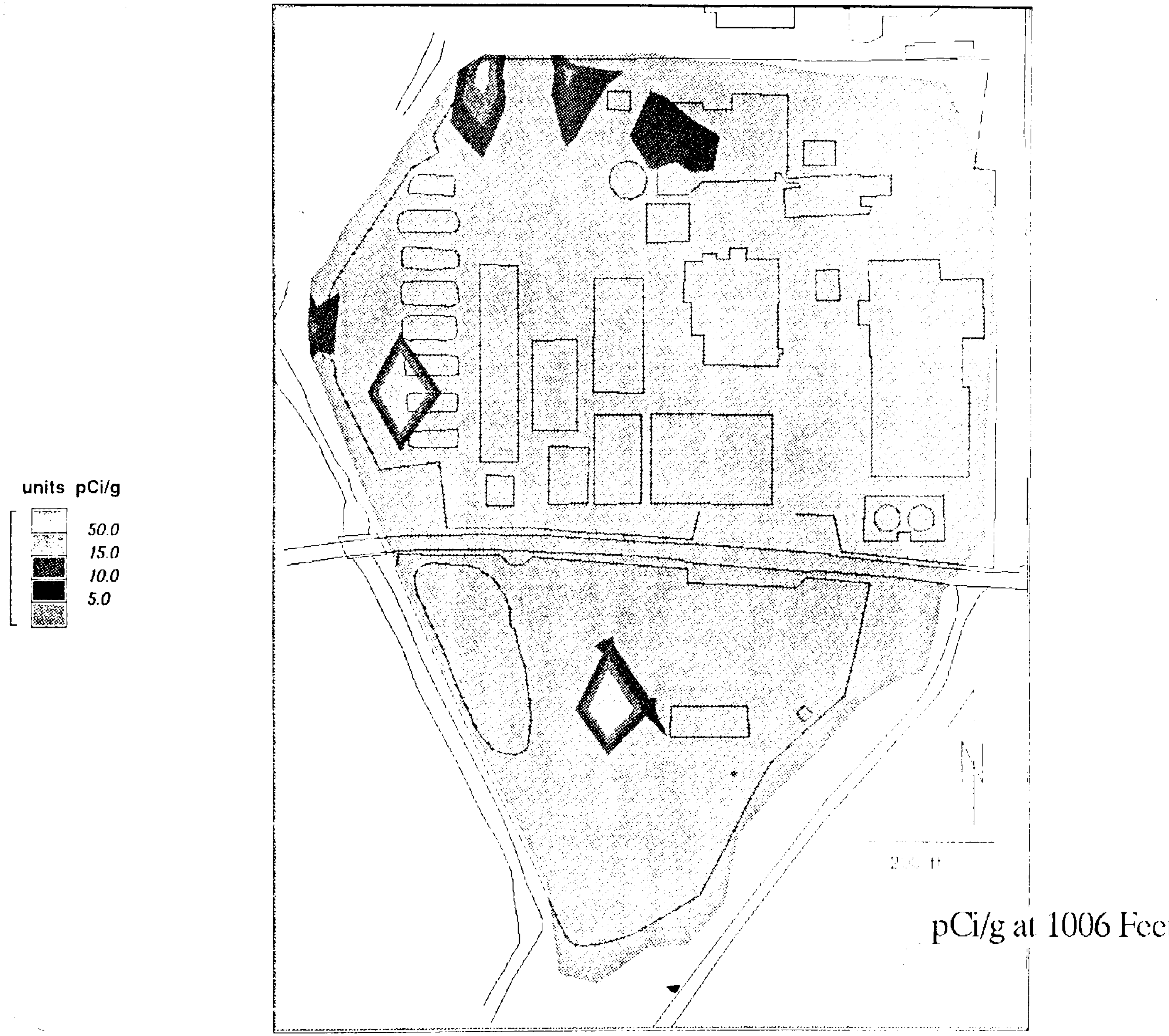
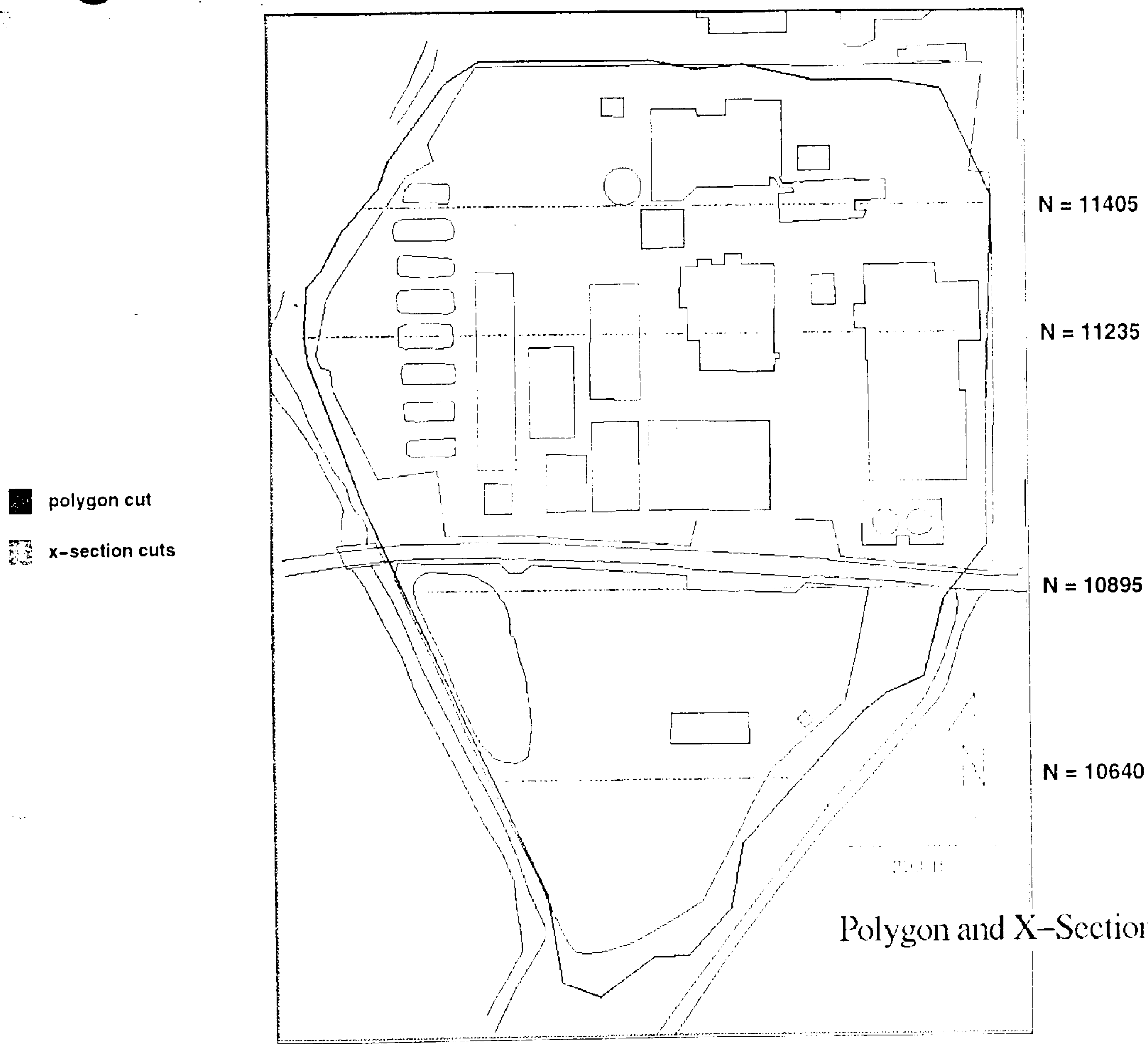


FIGURE 5-16



Polygon and X–Sectional Cuts

FIGURE 5–17

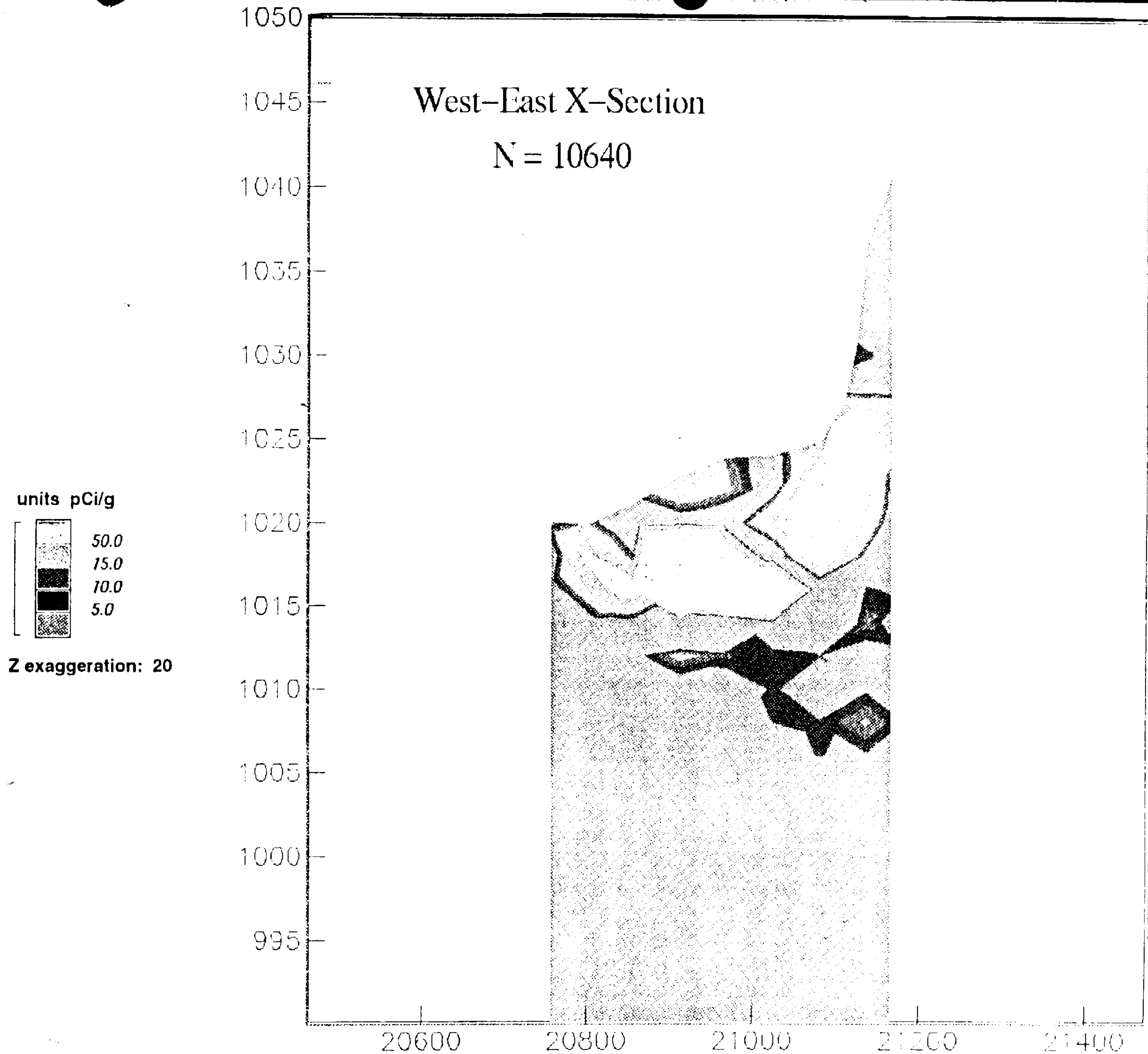

West–East X–Section
N = 10640
units pCi/g
50.0
15.0
10.0
5.0
Z exaggeration: 20
1050
1045
1040
1035
1030
1025
1020
1015
1010
1005
1000
995
20600
20800
21000
21200
21400

FIGURE 5-18

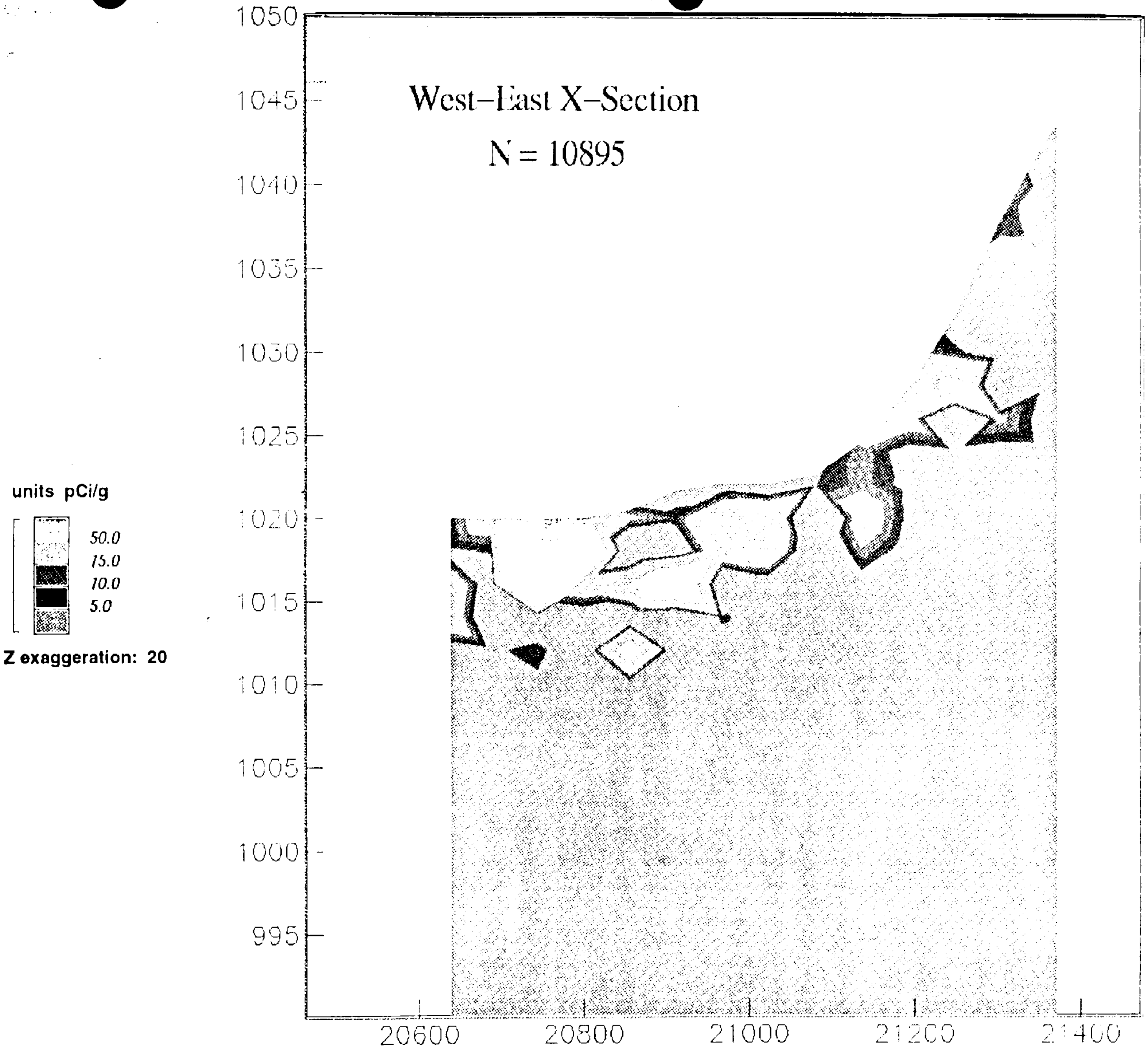

West–East X–Section
N = 10895
units pCi/g
50.0
15.0
10.0
5.0
Z exaggeration: 20
1050
1045
1040
1035
1030
1025
1020
1015
1010
1005
1000
995
20600
20800
21000
21200
21400

FIGURE 5–19

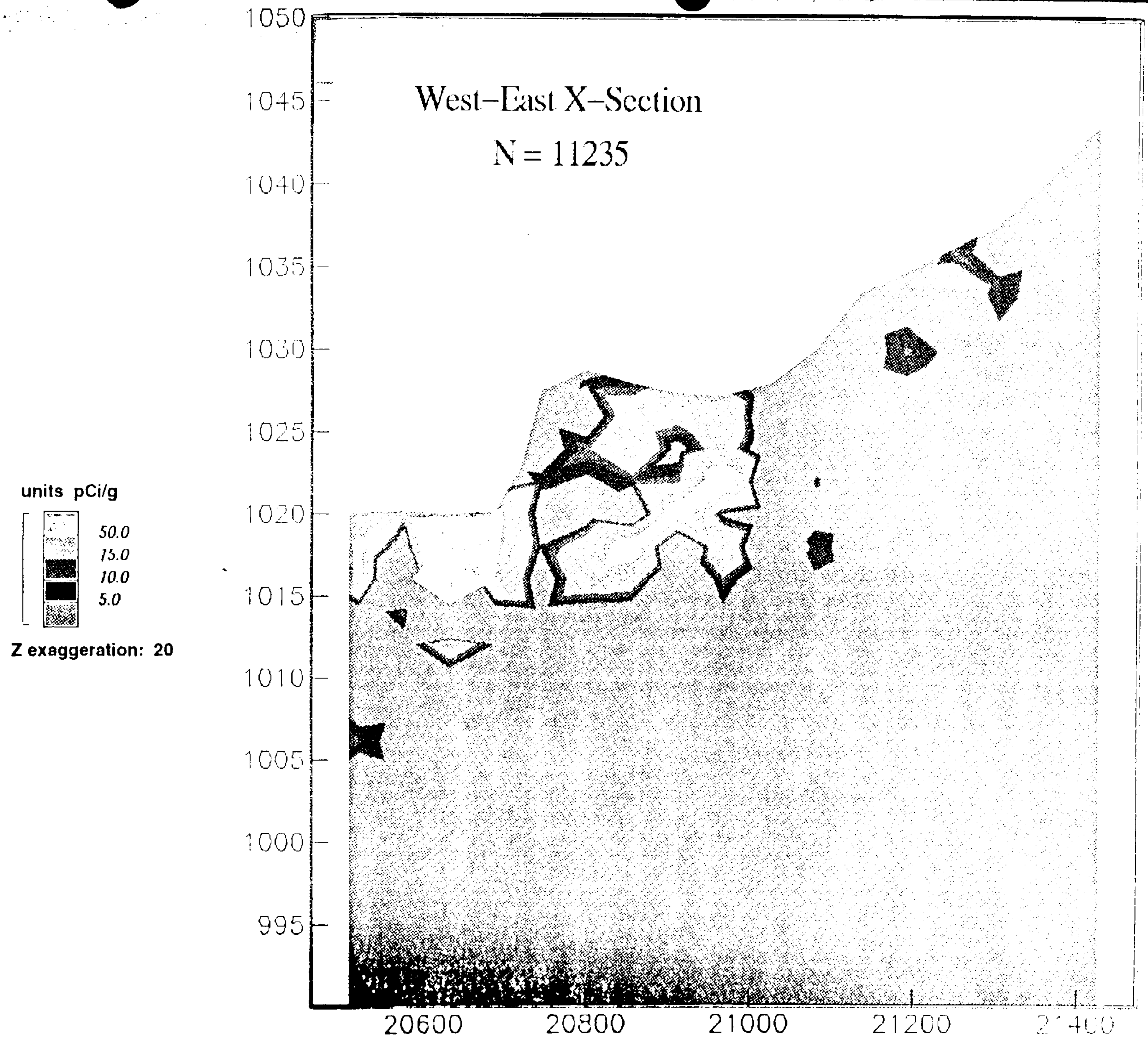

West–East X–Section
N = 11235
units pCi/g
50.0
15.0
10.0
5.0
Z exaggeration: 20
1050
1045
1040
1035
1030
1025
1020
1015
1010
1005
1000
995
20600
20800
21000
21200

FIGURE 5–20

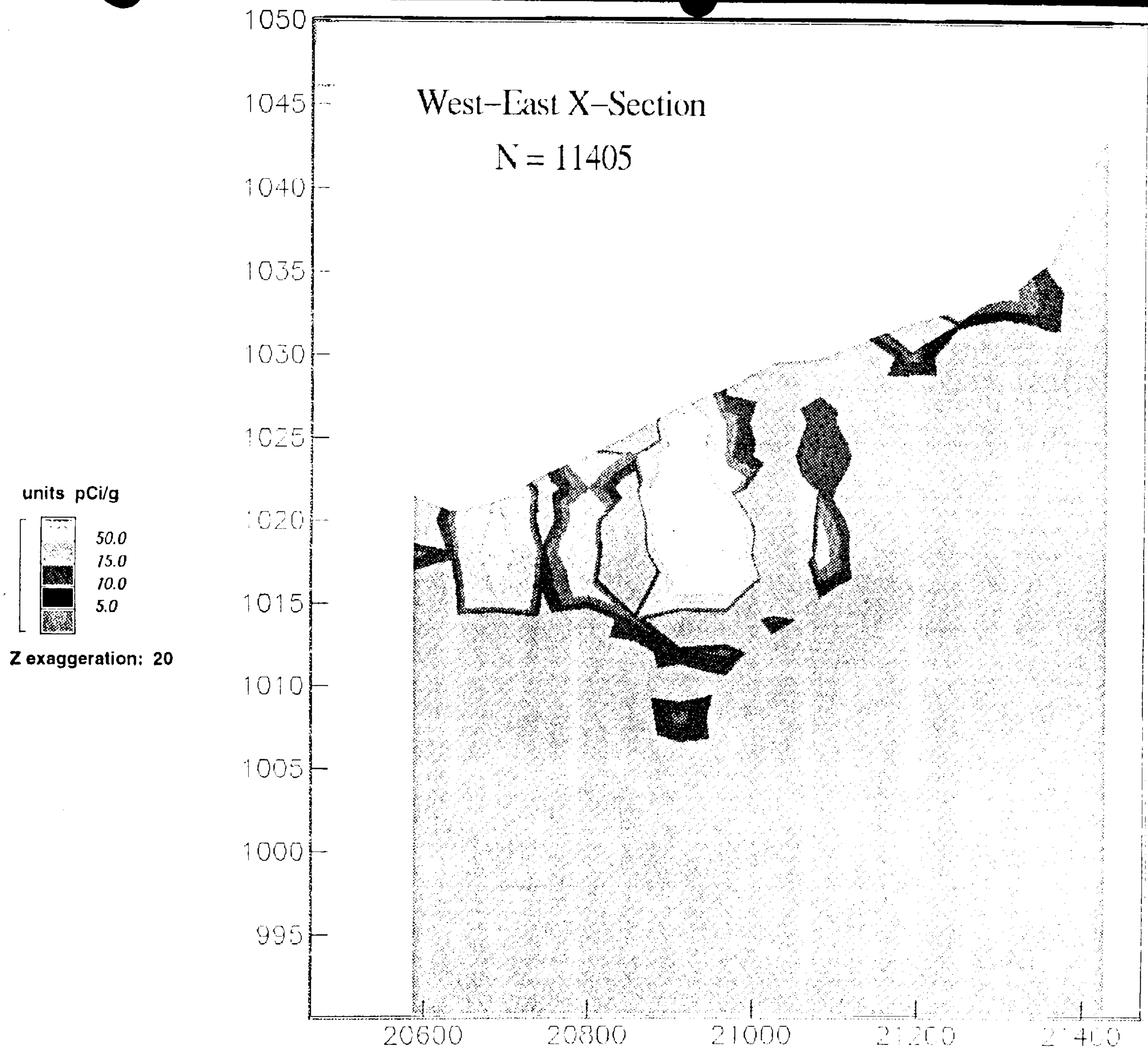

West–East X–Section
N = 11405
units pCi/g
50.0
15.0
10.0
5.0
Z exaggeration: 20
1050
1045
1040
1035
1030
1025
1020
1015
1010
1005
1000
995
20600
20800
21000

FIGURE 5–21

These figures again reiterate the conclusions that:

the thoriated material was distributed randomly

the major portion is close to the surface in irregularly shaped bands

No migration has taken place vertically or horizontally.

Importantly, these figures set the ground work for development of the Decontamination and Decommissioning Plan.

The database and Earthvision system were also used to estimate the volume of material within various ranges of radionuclide concentrations. As these volumes were calculated using the interpolated three-dimensional "solids" (which were used to generate the prior horizontal and vertical cross-sections), they represent an over-estimate of the actual volume. Their utility lies in "bracketing" the amount of material which will have to be dealt with for remediation. The ranges selected were expanded on the high pCi/g interval from 50 pCi/g to 100 pCi/g, 100 pCi/g to 500 pCi/g and greater than 1000 pCi/g. Table 5-8 presents these volumes.

Table 5-8

Estimated Volume of Thoriated Material versus Concentration

Concentration Range		Volume
From pCi/g	To pCi/g	ft3
>1000		0
>500	1000	330
>100	500	223,309
>50	100	341,069
>15	50	1,296,149
>10	15	617,592
>5	10	1,110,737

These volumes will be used as the basis in the selection of the alternatives and their evaluation.

Lastly, it is obvious that the suggestion provided in NRC's February 15 1993 letter regarding simultaneous characterization and remediation is imperative due to the nature of and form of the thoriated soil/slag material. Localized and continuous characterization of the material as the D&D Plan is being executed, for example, will undoubtedly reduce the volumes provided in the table.

5.2.2 Natural Emitters in Off-Site Samples

Soil samples were analyzed (Figure 5-22) for natural background emitters at offsite borings OS-06, OS-09, OS-11, and OS-13 at selected depths from ground surface to 17 feet, 9 feet, 6 feet and 4.5 feet, respectively. Soil borings OS-06 and OS-09 are located west of the site across Chartiers Creek along the north site of Caldwell Avenue. Soil borings OS-11 and OS-13 are located in the railroad area immediately east of the site and north of Caldwell Avenue.

The results are presented in Table 5-9. As is evident in the table, the natural radionuclide series isotopes of uranium and thorium are in background concentration, about 1 to 2 pCi/g. Their ranges in different borings, e.g., Pb-210 in OS-13 from 0.483 pCi/g to 1.11 pCi/g, are reflective of natural variability. This variability is also evident in the values of K-40. K-40 was detected between 8 and 14 pCi/g in both OS-06 and OS-09 whereas all values for OS-11 and OS-13 were between 2 and 9 pCi/g.

5.3 SURFACE WATER, SEDIMENTS AND STORM SEWER SAMPLING

Surface water samples were collected concurrently with groundwater samples from the stream bank and analyzed for TAL metals and radionuclides. Round I stream bank area sampling is coincident with Round II of groundwater samples. Round II of stream bank area sampling is a separate round consisting of the four Chartiers Creek surface water samples and five monitoring wells (M-2, M-3, M-4, M-5 and M-6) were sampled at this time. Both sets of surface water samples were collected during a period without precipitation. Stream sediments were collected between the surface water rounds and analyzed for thorium-232. Storm sewer water samples were collected on November 1, a separate event during another period without precipitation. Sampling events are summarized as follows.

Sampling Event	Dates
Round I Groundwater	6/28 - 7/12/94
Round II Groundwater	7/26 - 8/3/94
Round I Stream Area	8/2 - 3/94
Round II Stream Area	8/9/94
Stream Sediments	8/2 - 3/94
Storm Sewer	11/1/94

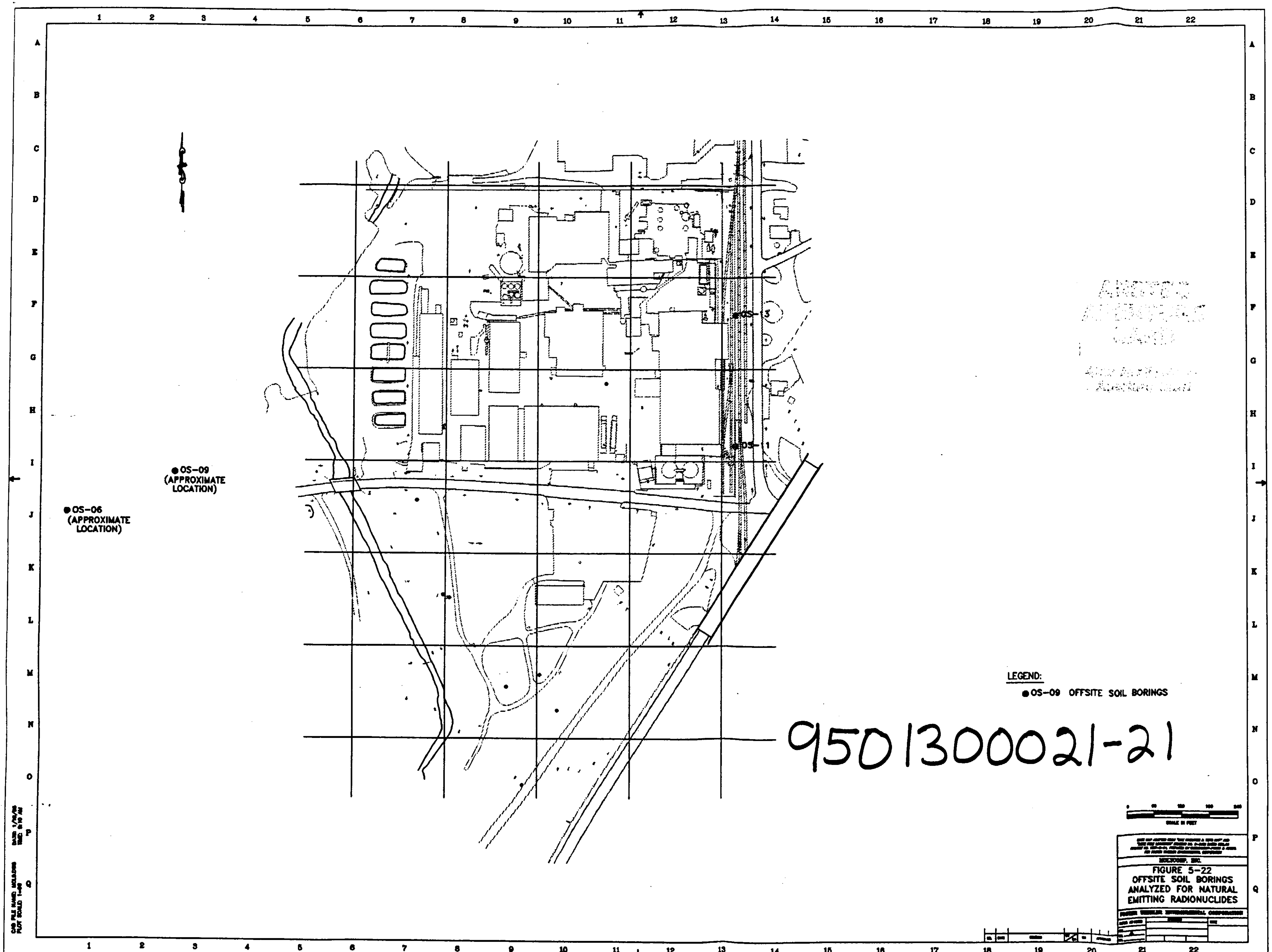
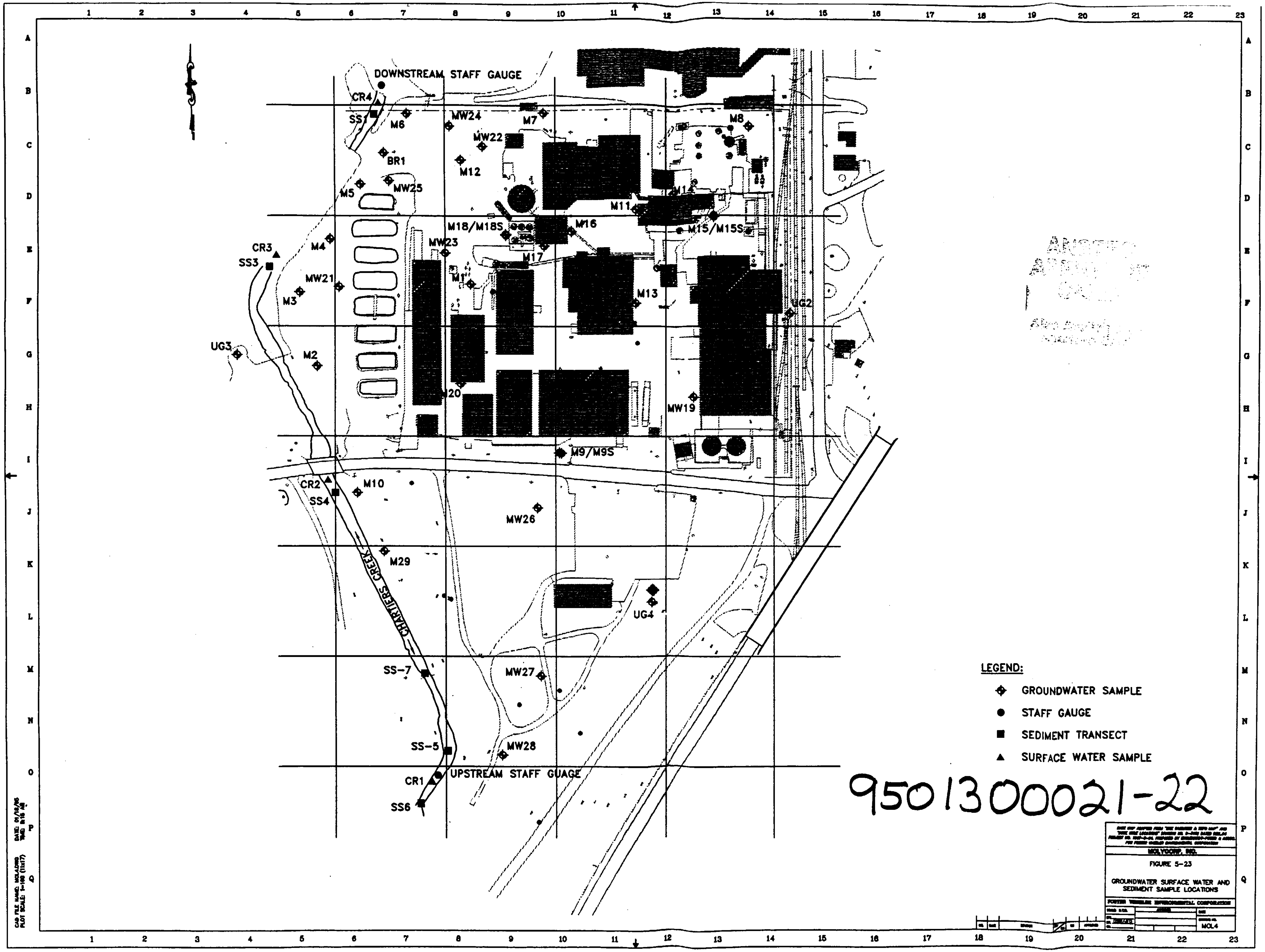


FIGURE 5-22
OFFSITE SOIL BORINGS ANALYZED FOR NATURAL EMITTING RADIONUCLIDES



9501300021-22

Total halogenated hydrocarbons (TOX) was detected above quantification limits in M-4 and M-5 as well as in CR1 and CR4. Available TOX concentration data for surface water indicate 20 ug/l for C1 (filtered, Round II) and 20 ug/l for CR4 (filtered, Round I and dissolved, Round II). All these results are 20 ug/l for M-4 (both rounds) and 20 ug/l and 50 ug/l for M-5 during Round II groundwater and Round II surface water, respectively. In conjunction with the results of M-2, M-3 and M-6 below quantification limit, these data suggest that the site is not a significant contributor to TOX in surface water.

Magnesium concentrations ranged from 12,500 to 14,800 ug/l for all four surface water samples in both rounds, both filtered and unfiltered. Manganese ranged from 313 at CR1 (filtered) during second round and 373 ug/l at CR.4 (filtered second round) to 426 ug/l at CR4 (filtered) during the first round. Other samples, filtered and unfiltered, were within this range. Adjacent well ranged to as high as 84,100 ug/l magnesium and 54,700 ug/l manganese at M-5. These data do not suggest a significant impact to the stream.

Since the site contribution to streamflow is approximately 0.3 percent (Appendix C) of adjacent Chartiers Creek streamflow, dilution of 285,000 ug/l molybdenum at M-5 to 0.3 percent is less than 1,000 ug/l. The implication is that the site is likely to contribute, through groundwater (during periods without surface runoff), an elevated molybdenum concentration compared to what is already present in Chartiers Creek. Note, however, that molybdenum results for surface water are within the variability of the trip (18 ug/l,111 ug/l and 134 ug/l) and field blanks (8 and 134 ug/l).

Selected radioisotopes of radium, thorium and uranium were also analyzed. Only radium-228 was detected in surface water samples CR1 and CR4. Results were in the 5 to 6 pCi/l range during both rounds at CR1 (except nondetected filtered Round I) and the 3 pCi/l range in CR4 for the second round only (filtered only). Adjacent monitoring wells had radium-228 concentrations in the 2 to 4 pCi/l range for M-3 and M-5 for the second round only. In addition, radium-226 was detected in M-3 only at the 0.5 pCi/l range for both rounds. Uranium-234 was detected in M-2, M-4 and M-6 at the 1 pCi/l range. In addition, U-238 was detected at M-2 (both rounds) and M-4 (first round only) at the 1 pCi/l range.

These results do not appear to be statistically significant compared to the metals data nor indicate a significant radiological impact to surface water (see Section 5.2). The lack of thorium-232 concentrations in any of these samples diminishes the significance of these data.

5.3.2 Storm Sewer Baseflow Sampling

Storm sewers on the active plant site were sampled during a period without precipitation contributing to surface runoff, November 1, 1994. Samples were collected at locations 001-01, 001-02, 001-03, 001-04 (North Storm Sewer) and 002-01 (South Storm Sewer). In addition, outfalls were sampled at 001-05 (North Storm Sewer) and 002-02 (South Storm Sewer). These locations are shown on Figure 5-24. See Appendix K for tabulated chemical results and Appendix F for storm sewer flow measurements.

Indicator compounds, molybdenum, selenium and cadmium are presented below for each location in ug/l (or non-detect, ND).

Storm Sewer	North (001-)					South (002-)	
Station No.	01	02	03	04	05	01	02
Molybdenum	990	2700	3200	4700	4900	410	2700
Cadmium	<5	<5	<5	<5	<5	<5	<5
Selenium	<5	<5	7	13	15	<5	9

Cadmium concentrations remain in the undetected range in both the South and North Storm Sewers, however, selenium is detected at 7 to 15 ug/l in both sewers although it is at undetected levels at upgradient stations. Molybdenum concentrations increase from the hundreds (990 ug/l North and 410 ug/l South) to thousands ug/l (4,900 ug/l North and 2,700 ug/l South) range in both sewers. Molybdenum in adjacent monitoring wells (Section 5.3.1) is typically an order of magnitude greater than that found in the storm sewer. The concentrations in the storm sewer water samples appear to have been impacted by groundwater input along the length of the sewers.

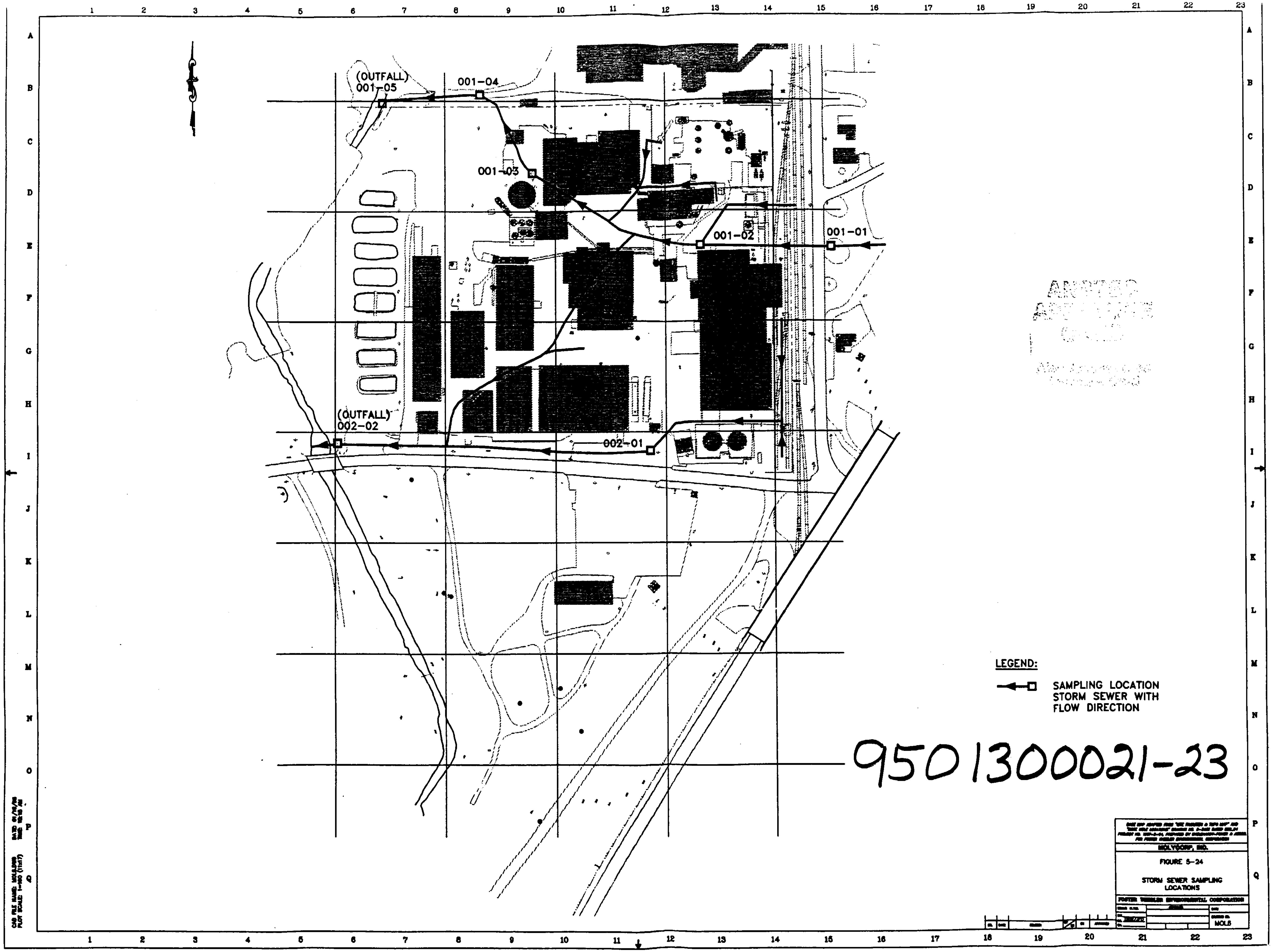
5.3.3 Chartiers Creek Sediment Samples

Stream bottom sediment samples were collected at four points each on transects across the stream width at seven stream locations shown on Figure 5-1. Samples were collected between August 3 to 5, 1994 from the top six inches of sediment. Across the stream width at each given stream location (SS-1 through SS-7) the sample labeled A is from a point on the east (Molycorp) bank, the sample labeled D is from the west bank, B is from below the Creek near the east side and C is from below water in the creek near the west side. Spacing was typically on the order of 10 feet between samples along a transect. The samples consist of varying amounts of sand, gravel, silt, and organic matter.

These samples were analyzed by IEA laboratory for thorium-232. Results are presented in Appendix K. They varied from 0.23 to 0.89 pCi/g with uncertainty from 0.06 to 0.18 pCi/g, thereby indicating no significant site-related impact to the sediment.

5.4 GROUNDWATER

Groundwater was sampled during two rounds from all available monitoring wells (Figure 5-23) over a two-week period between June 28 and July 12, 1994 (Round I) and another between July 26 and August 3, 1994 (Round II).


(OUTFALL)
001-05
001-04
001-03
001-02
001-01
(OUTFALL)
002-02
002-01
LEGEND:
SAMPLING LOCATION
STORM SEWER WITH
FLOW DIRECTION
9501300021-23
MOLYCORP, INC.
FIGURE 5-24
STORM SEWER SAMPLING
LOCATIONS
FOSTER WHEELER ENVIRONMENTAL CORPORATION
MOLS

In addition, the wells M-2, M-3, M-4, M-5 and M-6 near the Chartiers Creek stream bank north of Caldwell Avenue were sampled during mid August to coincide with the second round of Chartiers Creek surface water sampling. The second groundwater sampling round coincided with the first round of surface water samples (see Section 5.3).

Groundwater was analyzed in a certified laboratory for TAL metals, plus molybdenum, TOC, TOX, TDS, sulfate, chloride and phenols. In addition, groundwater samples were analyzed for specific radioisotopes of radium, thorium and uranium. Cadmium, selenium and molybdenum data for Round I and Round II are plotted on a site map on Figures 5-25 through 5-30, respectively.

Concentrations for molybdenum ranged from 46 and 27 ug/l (also in blank) in upgradient wells UG3 and UG4 (Round II only), to greater than 285,000 ug/l (Round II) at M-5 along Chartiers Creek near the northwest corner. Concentrations in the nearby bedrock well BR1 were 98,000 and 126,000 ug/l (Rounds I and II). In general, wells in the northwest corner of the site and/or near Chartiers Creek were in the tens of thousands of ug/l.

In general, heading upgradient to the northeastern portion of the site, wells completed in the upper fill material aquifer tend to be in the thousands of ug/l and wells completed in the lower sand and gravel aquifer tended to be in the hundreds of ug/l. Many minor variations from this general pattern are apparent; however, the consistency between rounds is high for groundwater sampling of inorganic compounds. These data suggest that the clayey zone acts as more of an aquitard in the upgradient portion of the site than near Chartiers Creek.

Selenium tends to be undetected or insignificant except in the northwestern portion of the site where the concentrations were between non-detect (i.e., <2 ug/l) and 83.9 ug/l. However, spotty upgradient occurrences were as high as the 204 ug/l (Round I) in M-15S.

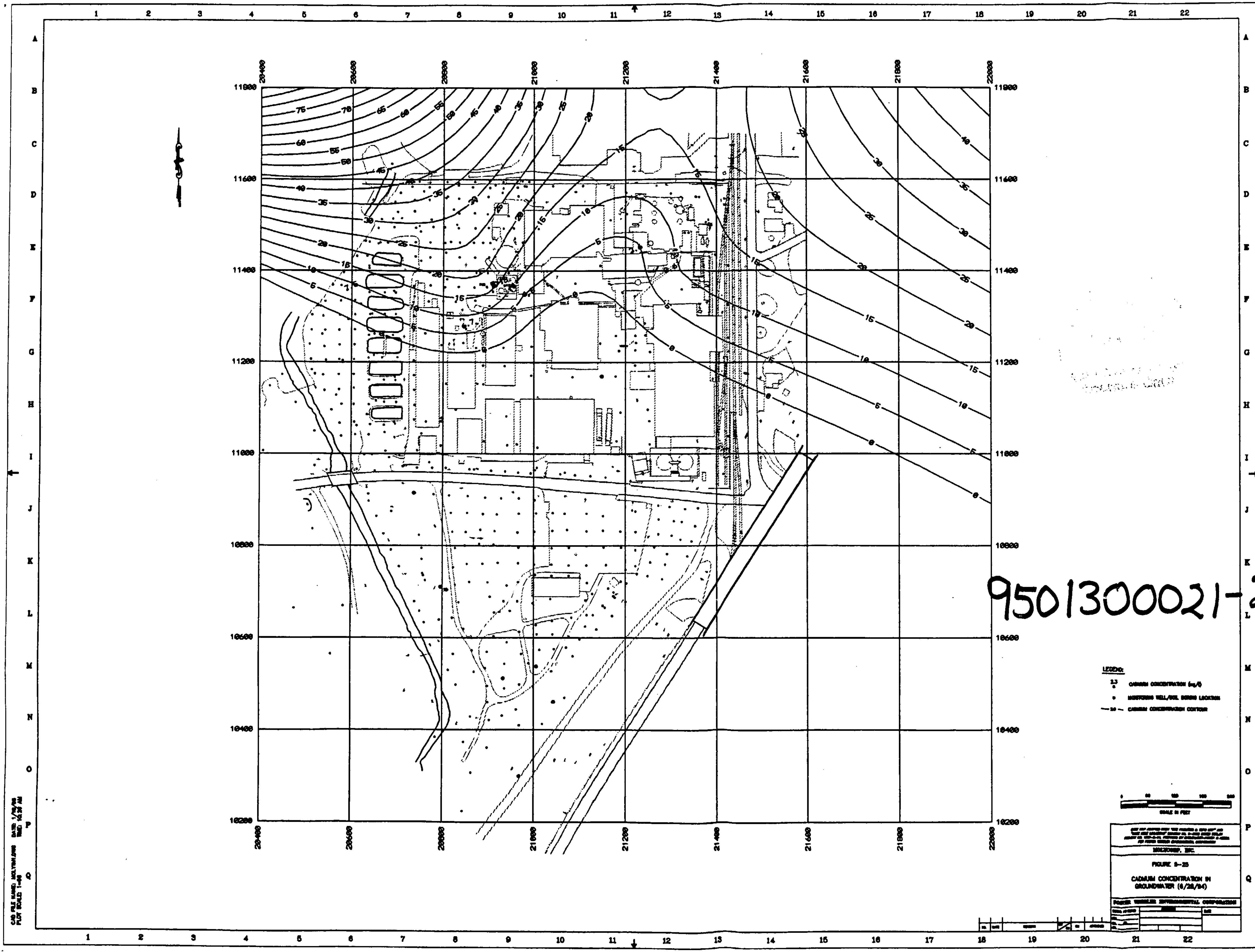
Cadmium is generally below the detection limit (3 ug/l or greater if dilution is performed) except in sporadic locations in the northwestern portion of the site in the low ug/l range, i.e., M-1 at 7 ug/l (both rounds) and M-5 at 32 ug/l (Round II, duplicate was "non-detect," i.e., less than 30 ug/l). However, M-18S had concentrations of 28 and 29 ug/l, and M-15S (considerably upgradient) 9 and 6 ug/l (respective rounds).

These data suggest that the active northern portion of the site is the main source area for these metals, with isolated "elevated areas" such as the M-15S area to the east.

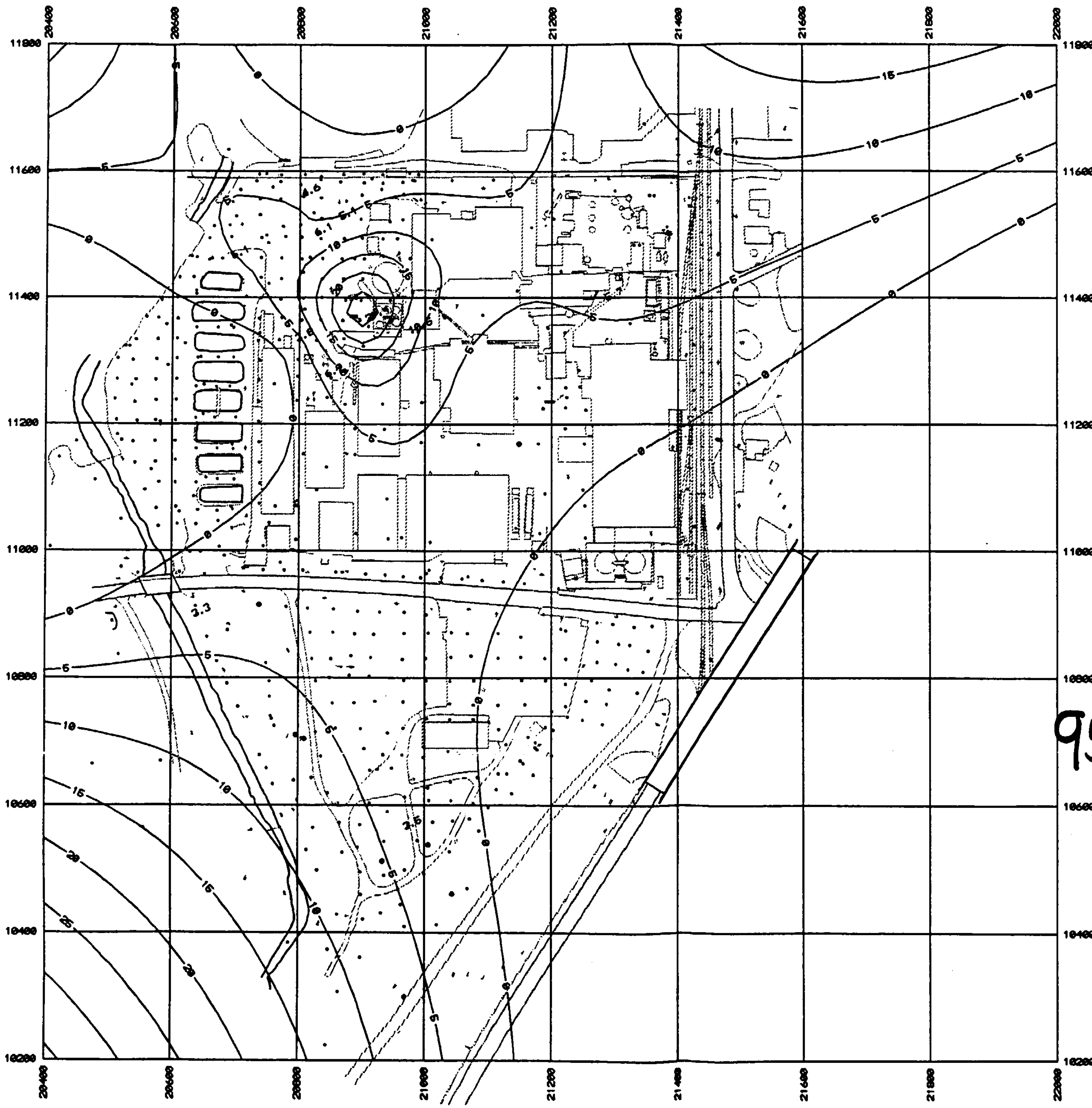
Total halogenated hydrocarbon (TOX) concentrations (Figures 5-31 and 5-32 for Round I and II, respectively) were in the tens of ug/l (a maximum of 40 ug/l at M-4) in the northwest portion of the site and/or along Chartiers Creek. In addition, M-15S showed 10 ug/l (both rounds). This pattern seems to generally apply to site-related chemical constituents.

The general trend for chemical constituents is for the heaviest concentrations to occur in the northwestern portion of the site with other areas of high concentrations under the impoundments.

9501300021-24



9501300021-25



LEGEND:

- 2.3 CADMIUM CONCENTRATION (mg/l)
- • MONITORING WELL/SOIL BORING LOCATION
- —20— CADMIUM CONCENTRATION CONTOUR

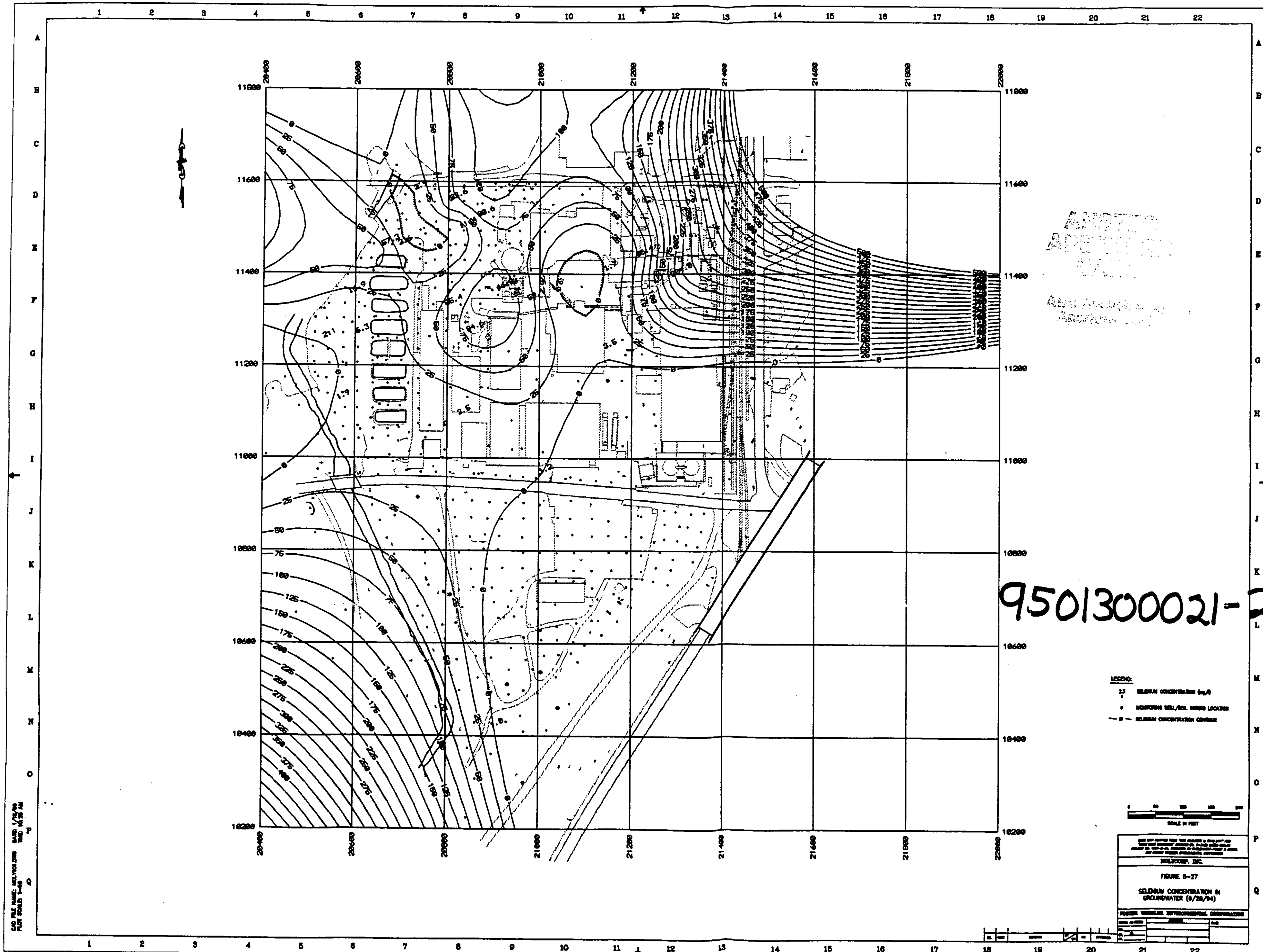
SCALE IN FEET

MOLYCORP, INC.

FIGURE 5-28

CADMIUM CONCENTRATION IN GROUNDWATER (7/27/94)

FOSTER WHEELER ENVIRONMENTAL CORPORATION



9501300021-26

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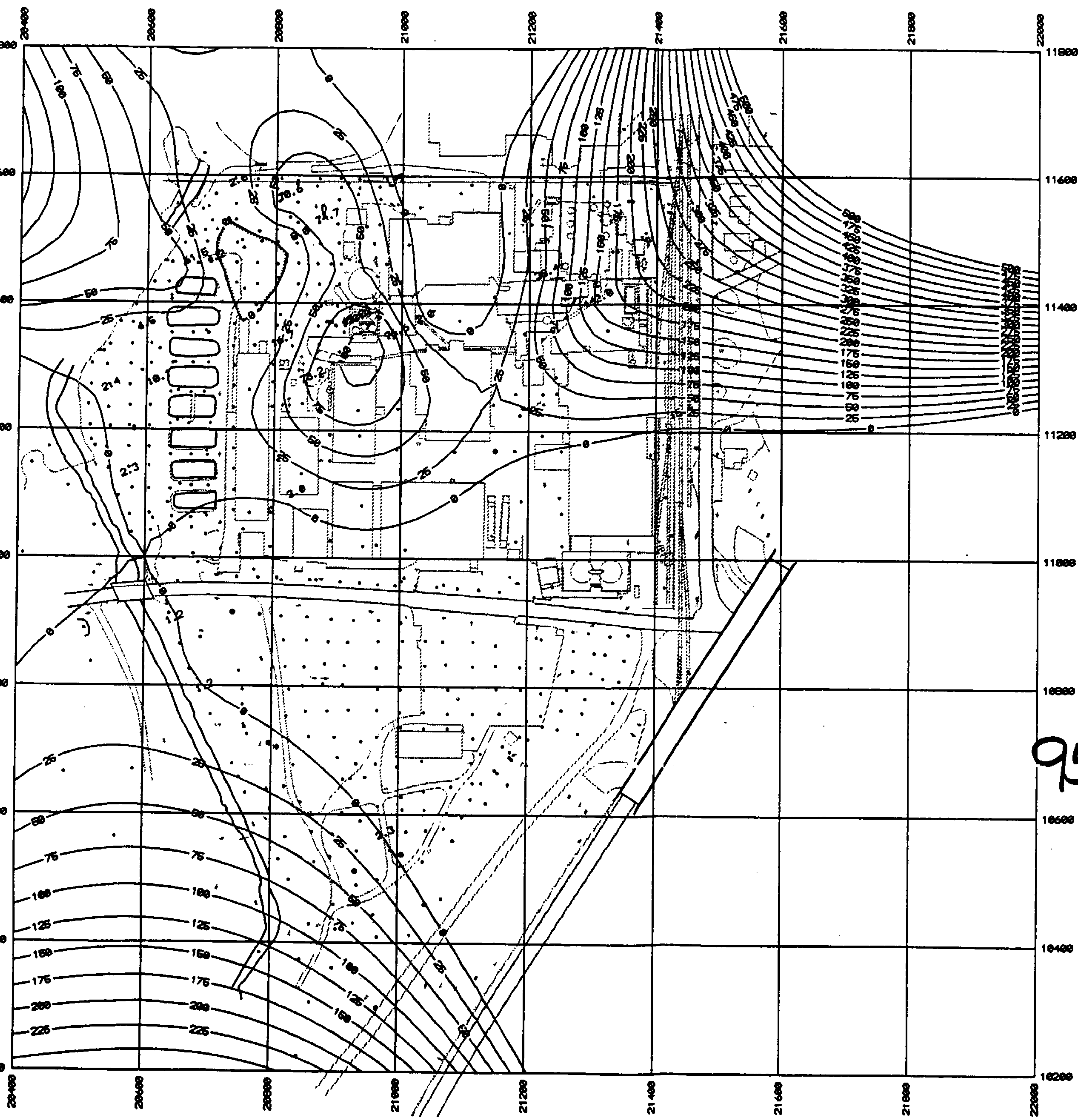


LEGEND:

2.3 SELENIUM CONCENTRATION (mg/l)

• MONITORING WELL/SOIL BORING LOCATION

— 25 — SELENIUM CONCENTRATION CONTOUR

0 50 100 150 200

SCALE IN FEET

MOLYCORP, INC.

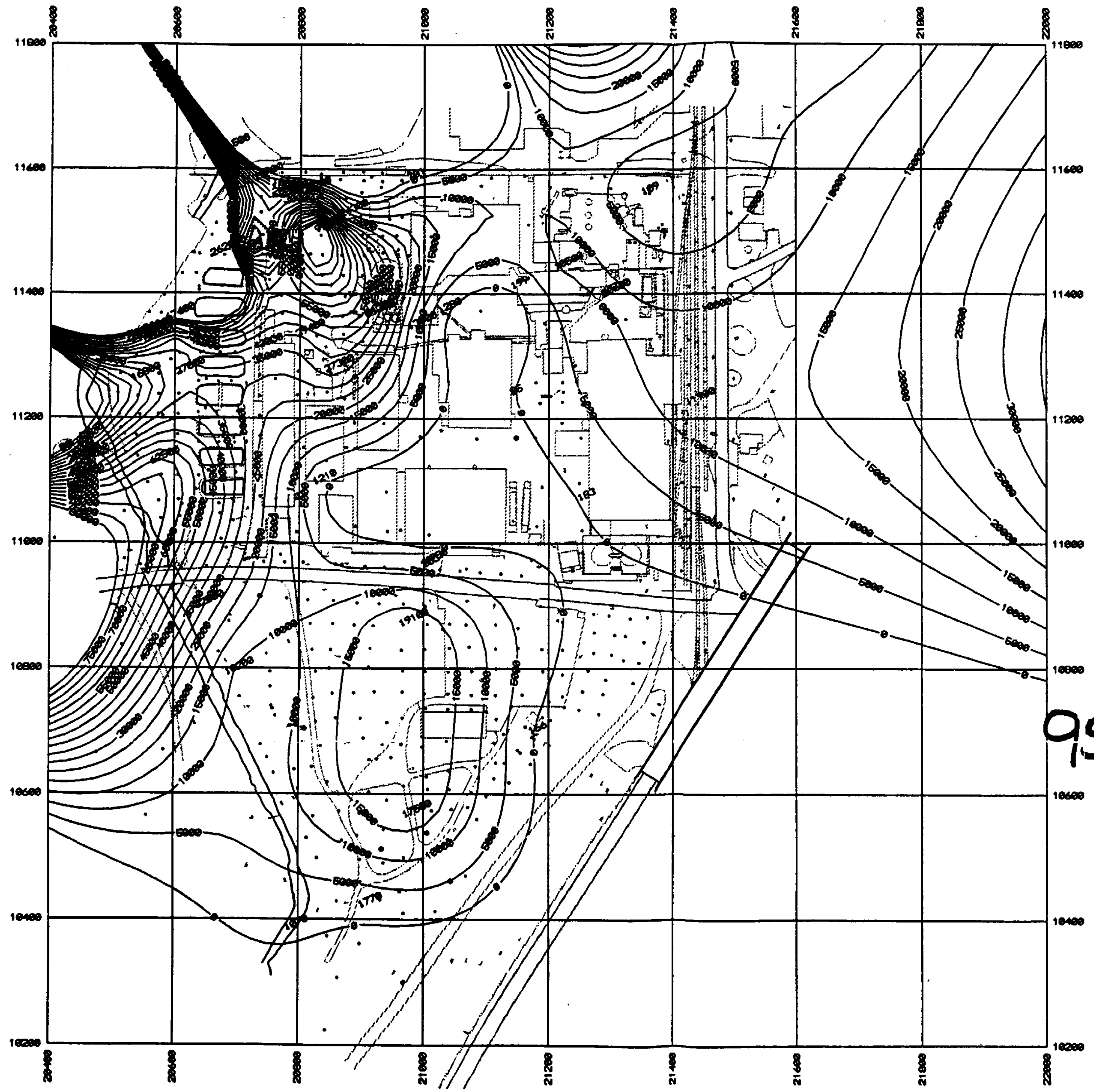
FIGURE 5-25

SELENIUM CONCENTRATION IN GROUNDWATER (7/27/94)

FOSTER WHEELER ENVIRONMENTAL CORPORATION

9501300021-27

950130021-28



LEGEND:

- • MONITORING WELL/SOIL BORING LOCATION
- —— MOLYBDENUM CONCENTRATION CONTOUR (ug/l)

SCALE IN FEET

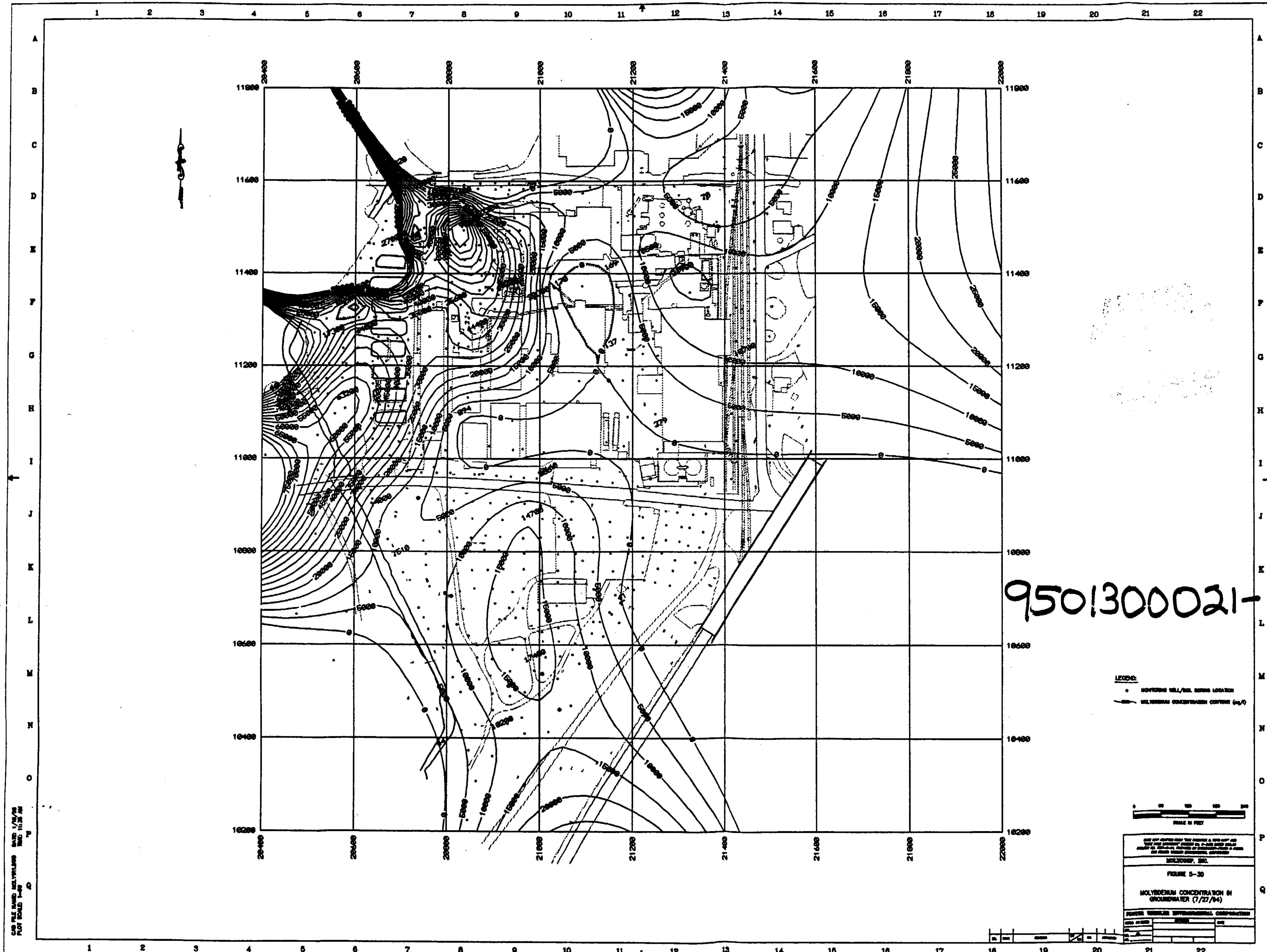
MOLYCORP, INC.

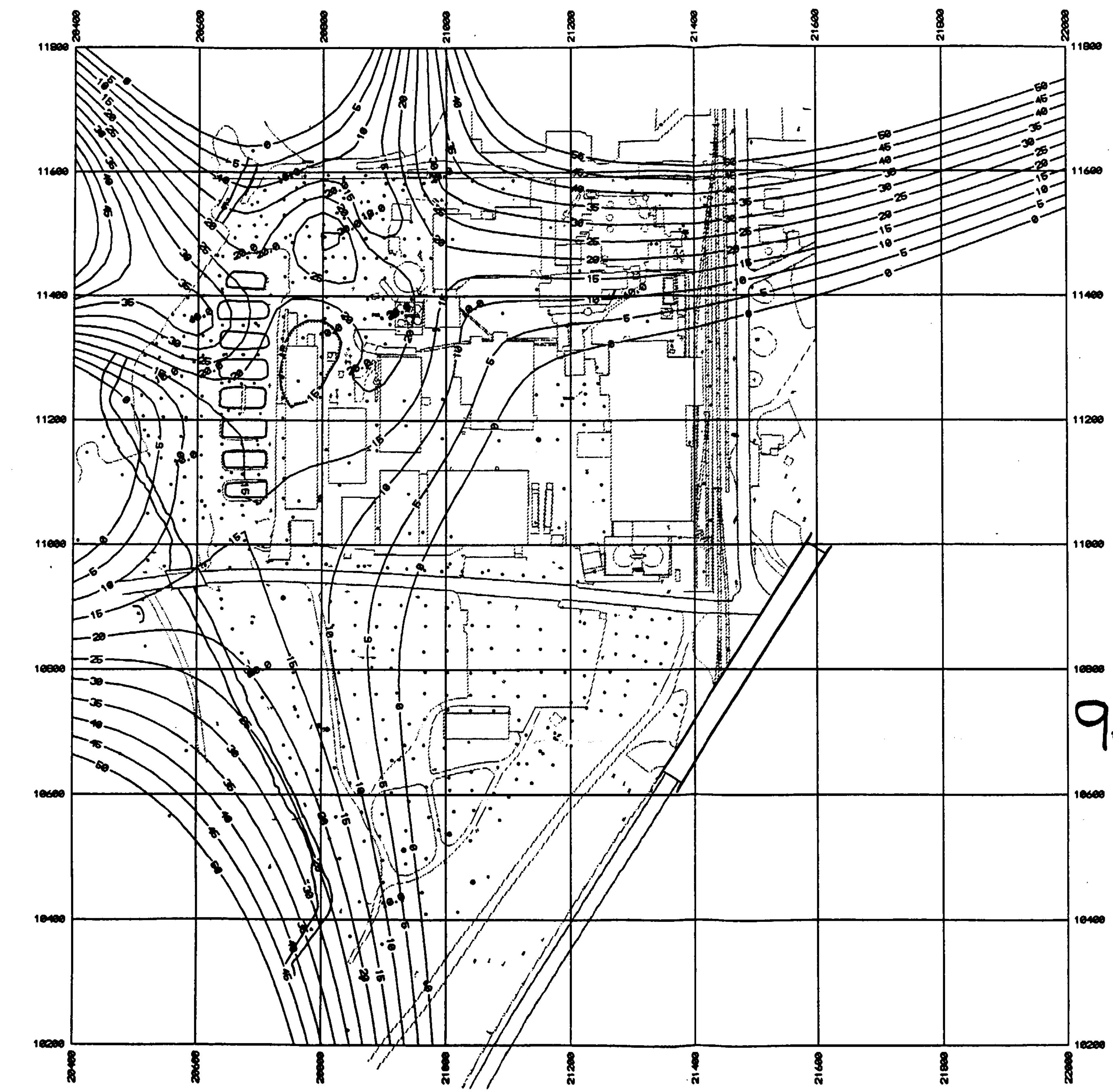
FIGURE 5-29

MOLYBDENUM CONCENTRATION IN GROUNDWATER (5/26/94)

FOSTER WHEELER ENVIRONMENTAL CORPORATION

950130021-29





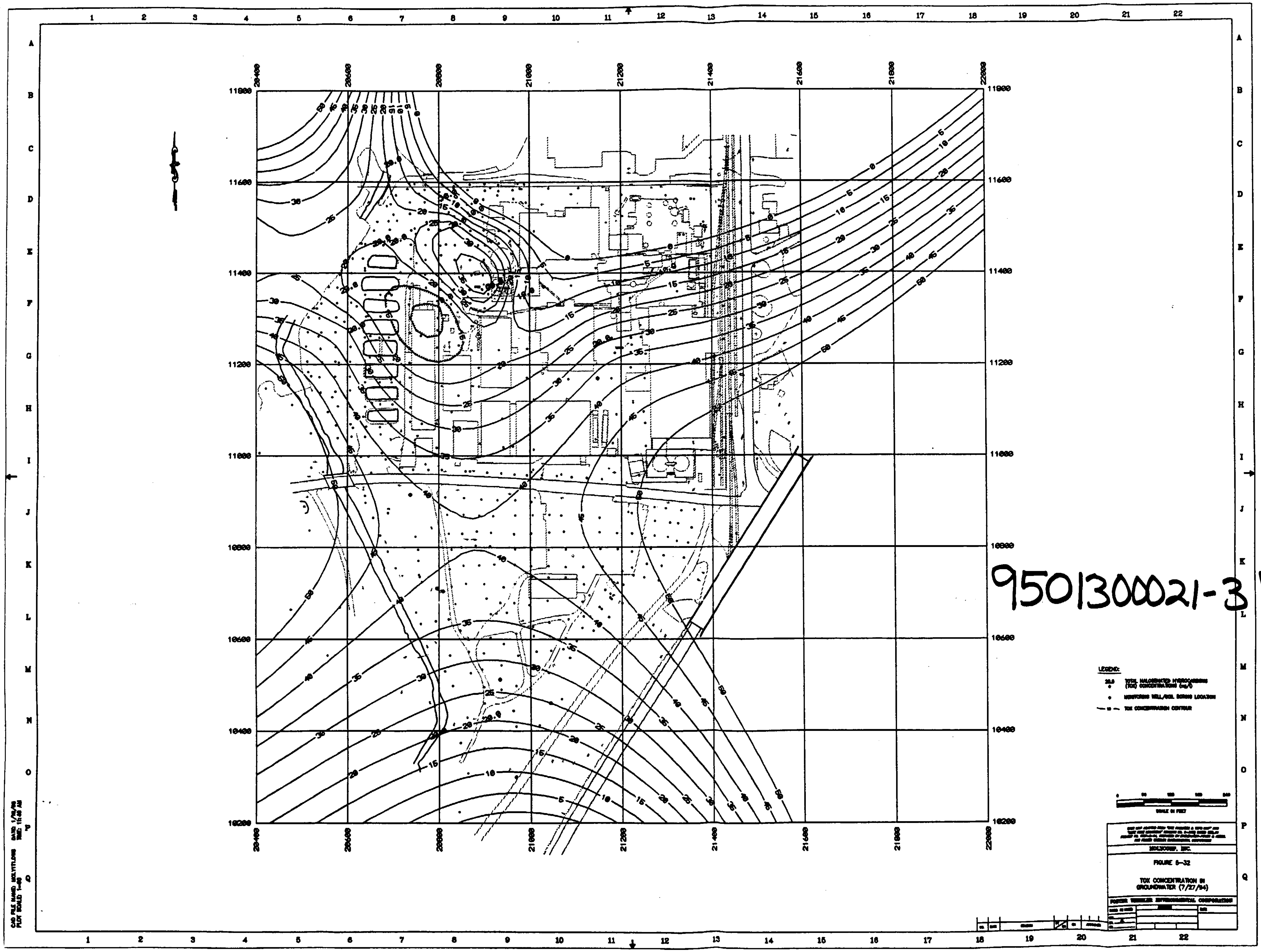
MOLYCORP, INC.

FIGURE 5-31

TOX CONCENTRATION IN GROUNDWATER (6/28/94)

FOSTER WHEELER ENVIRONMENTAL CORPORATION

9501300021-30



950130021-31
LEGEND:
TOTAL HALOGENATED HYDROCARBONS (TOX) CONCENTRATIONS (mg/l)
MONITORING WELL/SOIL BORING LOCATION
TOX CONCENTRATION CONTOUR
SCALE IN FEET
FIGURE 6-32
TOX CONCENTRATION IN GROUNDWATER (7/27/94)
FOSTER WHEELER ENVIRONMENTAL CORPORATION

the small thorium pile, the other slag pile south of Caldwell Avenue and the vicinity of M-15S. The clay unit and the weathered bedrock surface appeared to have offered little water quality protection to the groundwater in BR-1.

In addition, field measurements of specific conductivity and pH were conducted on groundwater collected at all available observation points during August 1994. These data are presented in Table 5-5.

Specific conductivity data are plotted for the fill (water table) aquifer on Figure 5-33 and for the sand and gravel aquifer on Figure 5-34. The pH data are plotted on Figure 5-35 for the fill aquifer and 5-36 for the sand and gravel aquifer.

The specific conductivity data in the fill aquifer indicate values generally above 1,000 umhos/cm in the northern 40 percent of the site, and generally near or below 1,000 umhos/cm in the southern 60 percent of the site. An anomalous high (increase to several points over 6,000 umhos/cm) in the northwest corner along Chartiers Creek, and an area over 2,000 umhos/cm in the northeast portion are consistent with the high levels observed for molybdenum, cadmium and selenium. The sand and gravel sr fic conductivity indicate an analogous but smoother pattern than the fill unit data. These dat: w a consistent exceedance of 2,000 umhos/cm except in the vicinity of Caldwell Avenue and along the upgradient northeastern edge. There is a gradual increase to over 4,000 umhos/cm in some cases and over 6,500 umhos/cm in the southwestern corner along Chartiers Creek. A comparable area inside the northeastern portion exceeds 4,000 umhos/cm with a reading as high as 6,620 umhos/cm.

The pH readings in the fill aquifer range from near neutral (i.e., 7.0) along Chartiers Creek to greater than 10.0 in several areas within the site. These areas include the center of the northern portion of the site, the southern impoundment area, an area south of the thorium pile and an area adjacent to I-70.

The sand and gravel unit indicates pH values generally 7.0 to 8.0 in Unit 2 (south of Caldwell Avenue). In the northwestern portion along Chartiers Creek, values are below 6.0; however, they increase rapidly to over 12 near the center of the processing area. Processing waters apparently may have migrated through breaches in the intermediate clay unit.

Radionuclides were also sampled. Radium-228 was occasionally detected at about 2 or 3 times the detection limit (2 pCi/l) with considerable variance at M-9, M-13, MW-26, MW-28 and MW-29. Most occurrences of other radioisotopes were in the 1 to 2 pCi/l range, mainly for uranium and radium radionuclides. A consistent pattern, however, is far less evident than for the metals. Thorium-230 occurred at 3.0 pCi/l at M-12, where thorium-232 was merely 0.7 pCi/l. At MW-25 thorium-232 occurred at 1.4 pCi/l. Both M-12 and MW-25 are near the northwest corner of the site. There is very little consistency overall in radionuclide data between results for wells inclose proximity to each other and even during different rounds for the same wells. These data indicate that groundwater is not a significant pathway for radionuclides from the site.

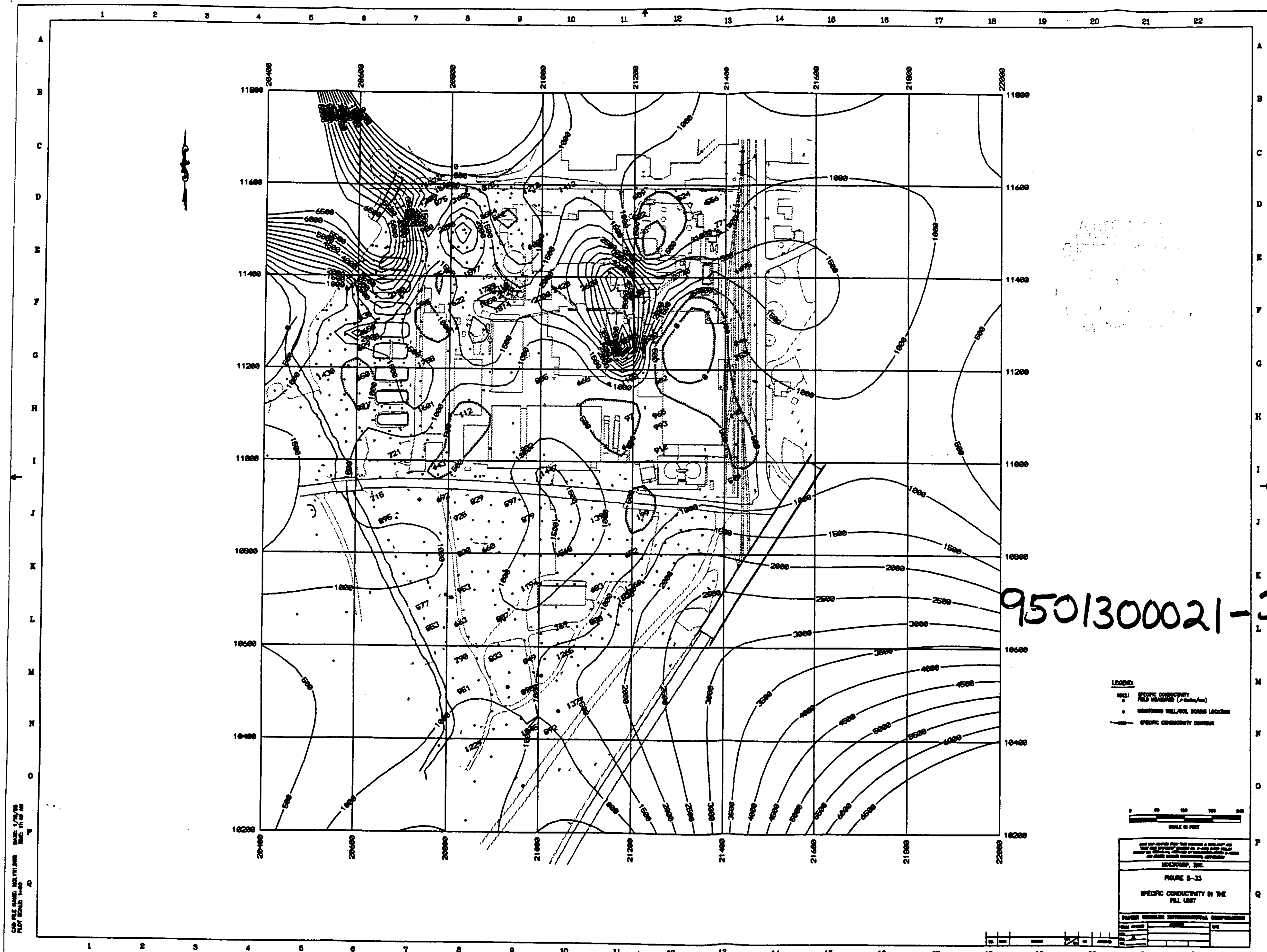
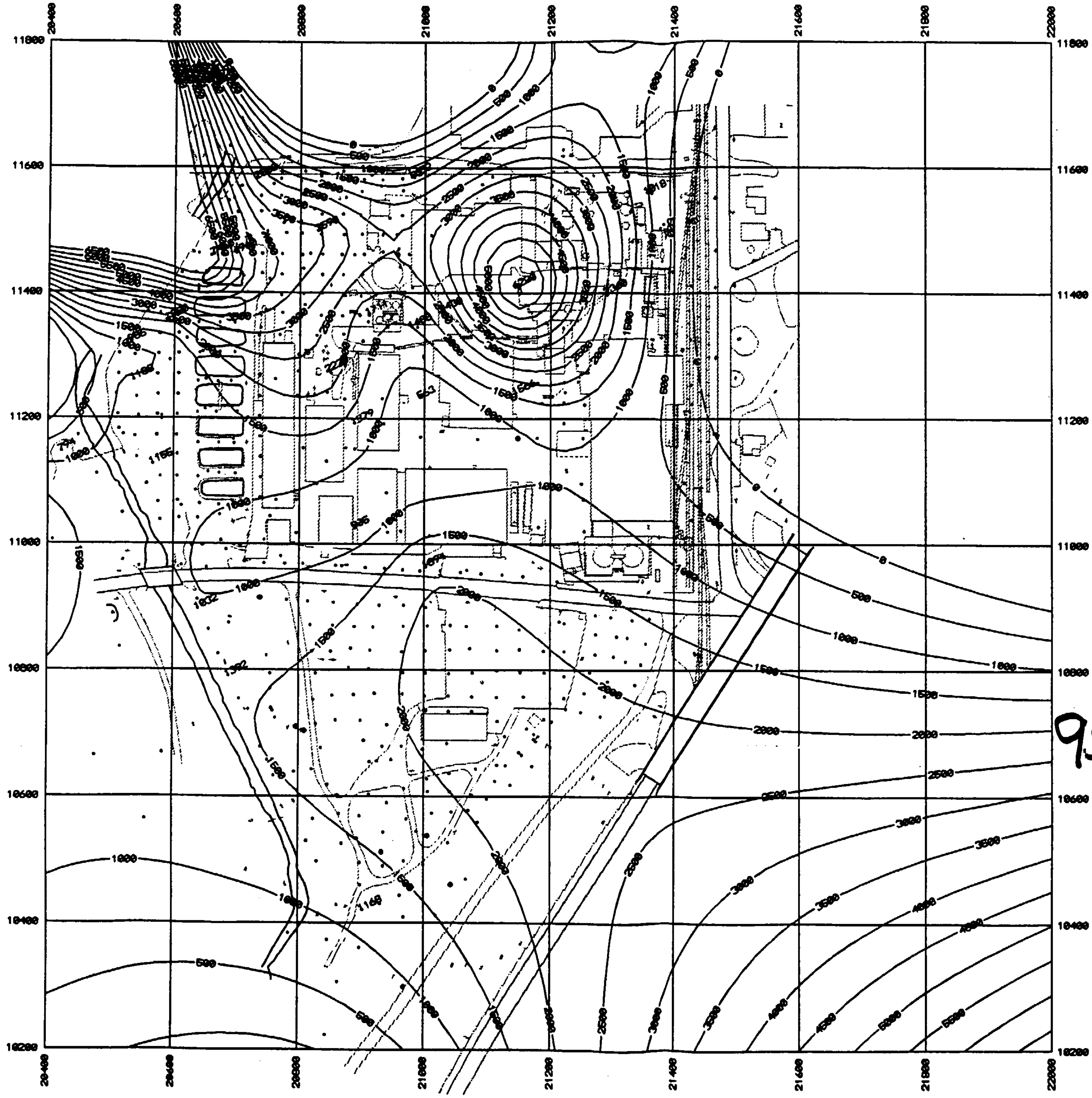


FIGURE 6-33

SPECIFIC CONDUCTIVITY IN THE FILL UNIT

9501300021-32

9501300021-33



Also Available on Aperture Card

LEGEND:

1012.1 FIELD MEASURED (µmhos/cm) SPECIFIC CONDUCTIVITY CONTOUR

● MONITORING WELL/SOIL BORING LOCATION

SPECIFIC CONDUCTIVITY CONTOUR

0 60 120 180 240

SCALE IN FEET

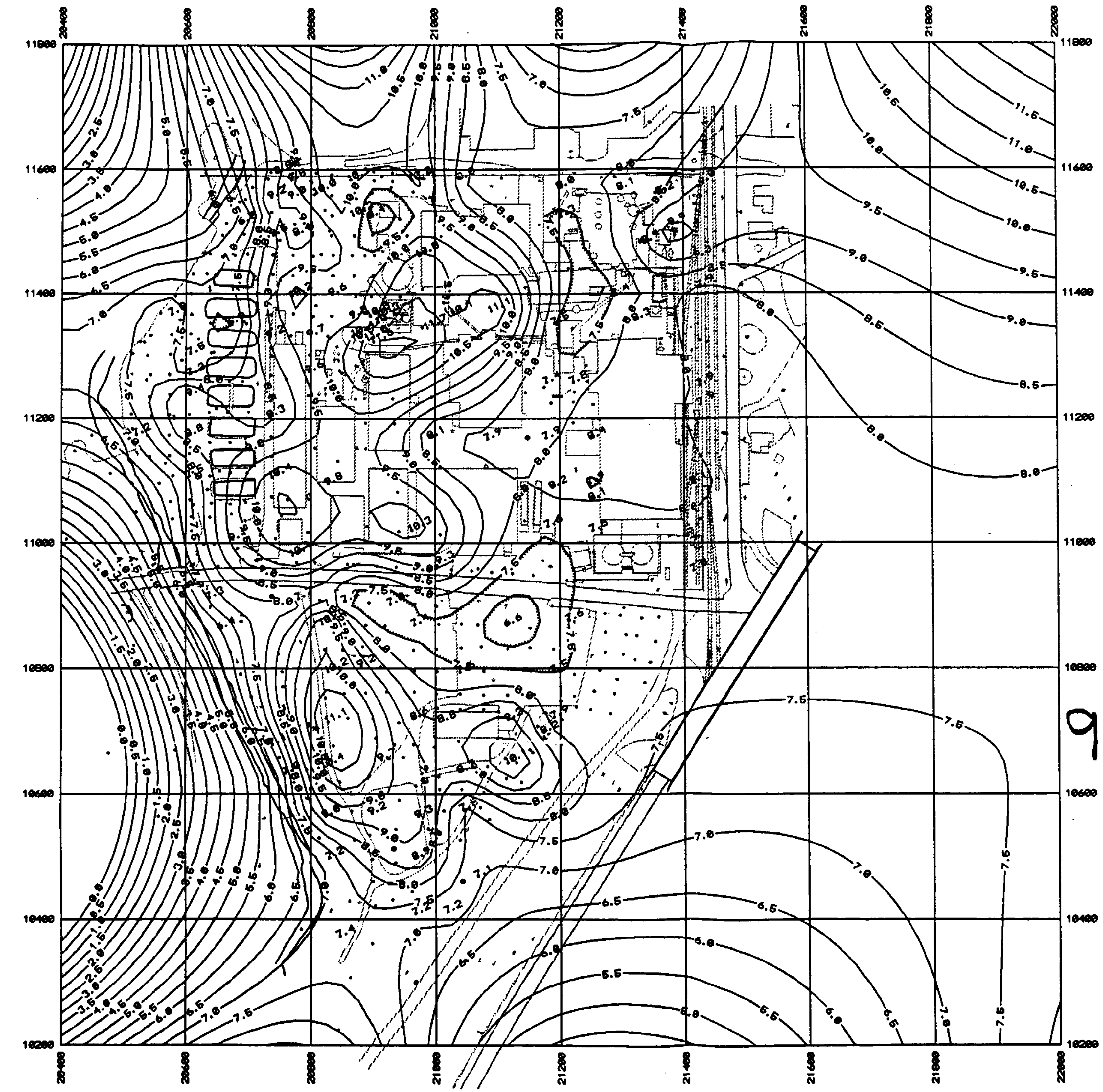
MOLYCORP, INC.

FIGURE 5-34

SPECIFIC CONDUCTIVITY IN SAND AND GRAVEL UNIT

FOSTER WHEELER ENVIRONMENTAL CORPORATION

9501300021-34



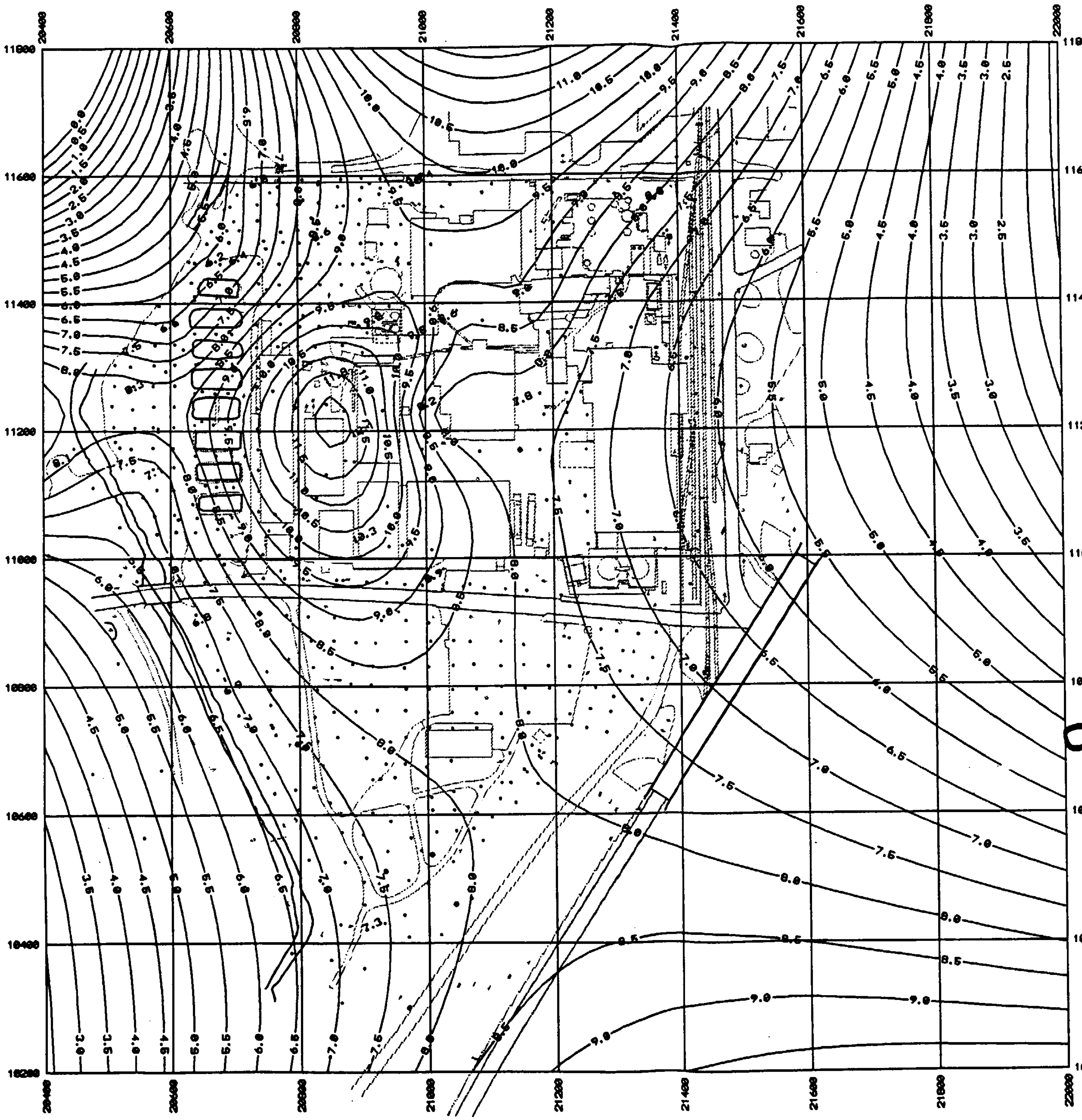
MOLYCORP, INC.

FIGURE 5-35

pH MEASUREMENT
IN FILL UNIT

FOSTER WHEELER ENVIRONMENTAL CORPORATION

950130021-35



LEGEND:

- 7.0 ● pH FIELD MEASUREMENT (STANDARD UNITS)
- ● MONITORING WELL/SOIL BORING LOCATION
- pH CONTOUR

SCALE IN FEET

MOLYCORP, INC.

FIGURE 5-38

pH MEASUREMENT IN SAND AND GRAVEL UNIT

FOSTER WHEELER ENVIRONMENTAL CORPORATION

5.5 BUILDINGS AND EQUIPMENT

5.5.1 Structures and Fixed Equipment

Buildings potentially having surficial contamination i.e., the Samarium Process Building (Bldg. 36), R&D Offices (Bldg. 38), Buildings 31, 33, 34 and 39, were surveyed by ORISE and reported in the 1985 report (Martin et.al, 1985). The results were generally negligible, with the exception of building 34, which had a few areas with elevated beta/gamma above 5000 dpm/100 cm^2, e.g., 7750 dpm/100 cm^2 maximum. As intrusive activity (possibly excavation below the floor) is expected in this and other buildings used in the FeCb process (see Section 5.5.3), internal surveys were placed "on hold" until all internal remediation is completed. At that time all potentially contaminated surfaces will be surveyed for conformance with Regulatory Guide 1.86 standards.

5.5.2 Vehicles and Mobile Equipment

Vehicles and mobile equipment used in the movement of thoriated material have long since been decontaminated and removed from the site. Equipment used in this effort which was intrusive, e.g. drills, was decontaminated as per the field operations plan.

5.5.3 Measurement Under Existing Structures

A total of eight soil borings were drilled under buildings presently located on the site. Of these soil borings, two (SB-279 and SB-280) were drilled under Building 32, two (SB-278 and SB-282) were drilled under Building 34, two (SB-273 and SB-274) were drilled under Buildings 42 and 36, respectively. In addition, one soil boring (SB-281) was drilled under Building 33 and another (SB-283) under Building 35. These building and soil borings are shown on Figure 5-37.

These data indicate that under Building 32 in SB-279, Th-232 concentrations were less than 7 pCi/g to the 20-foot depth except between 1.0 and 2.5 feet where they were 20, 44, and 82 pCi/g with increasing depth, at 0.5-foot intervals. SB-280, also under Building 32 had concentrations under 9 pCi/g to a total depth of 23 feet except at 0.5 to 1.0 feet (57 pCi/g) and 1.0 to 1.5 feet (27 pCi/g) and 6.5 to 7.0 feet (14 pCi/g). SB-278 under Building 34 indicated a Th-232 concentration of 7 pCi/g only at 0.5 to 1.0 feet (19 pCi/g) and 2.5 to 3.0 feet (11 pCi/g).

Corresponding data from downhole gamma logging converted to pCi/g as (in Section 5.2) indicate comparable trends to those represented by the three borings where individual 0.5-foot interval samples were analyzed with gamma spectroscopy. For example, values at SB-279 are above 7 pCi/g from 1.0 to 2.5 feet in the sample analyses. Downhole data indicate these concentrations are from 0.5 to 2.5 feet and also from 4.0 feet to 6.0 feet and from 7.5 feet to 9.5 feet. Concentrations are somewhat lower with the downhole data, i.e. 33.1 pCi/g at 1.5 feet 22.6 pCi/g at 5.0 feet and 14.8 pCi/g at 8.5 feet. Also, data under Building 32 SB-280 indicated a similar trend where sample specific data indicated elevated concentrations from 0.5 to 1.5 feet and a minor increase near the 6.0-foot level. The downhole data reflects the elevated concentration near surface, however, values over 10 pCi/g extended from 0 to 2.5 feet peaking at 38 pCi/g and from 5.5 to 8.5 feet peaking only at 14 pCi/g.

Under Building 34 sample specific data were generally confirmed by the downhole data. The concentration gradient near the surface was smoother in the downhole data. The gradient for the sample from 4.5 to 5.0 feet (23 pCi/g) was absent in downhole data (merely 5.8 pCi/g at 5.0 feet).

SB-282, also under Building 34, was analyzed by downhole survey only and indicated exceedances of 10 pCi/g from 3.0 to 8.5 feet peaking at 5.5 feet (112 pCi/g).

Data from under Building 42 and 36 which are connected into one long rectangle were analyzed by downhole survey only and indicated a high between 0 to 2 feet with a maximum at 1.0 feet (168 pCi/g) in SB 273. SB-274 indicated very low values, a maximum of 5.4 pCi/g at 5.0 feet.

SB-281 under Building 33 indicated very low downhole survey readings with a maximum of 6.6 pCi/g at 9.5 feet and 8.3 pCi/g at 4.0 feet.

SB-283, under Building 35, also indicated low readings, except for a concentration of 6 pCi/g between 12.5 and 14.0 feet with a maximum of 9.8 pCi/g at 13.5 feet.

In summary, these data indicate possible impact from site-related activities under Buildings 32, 34 and 36.

5.6 AIR SAMPLING

5.6.1 Air Samples

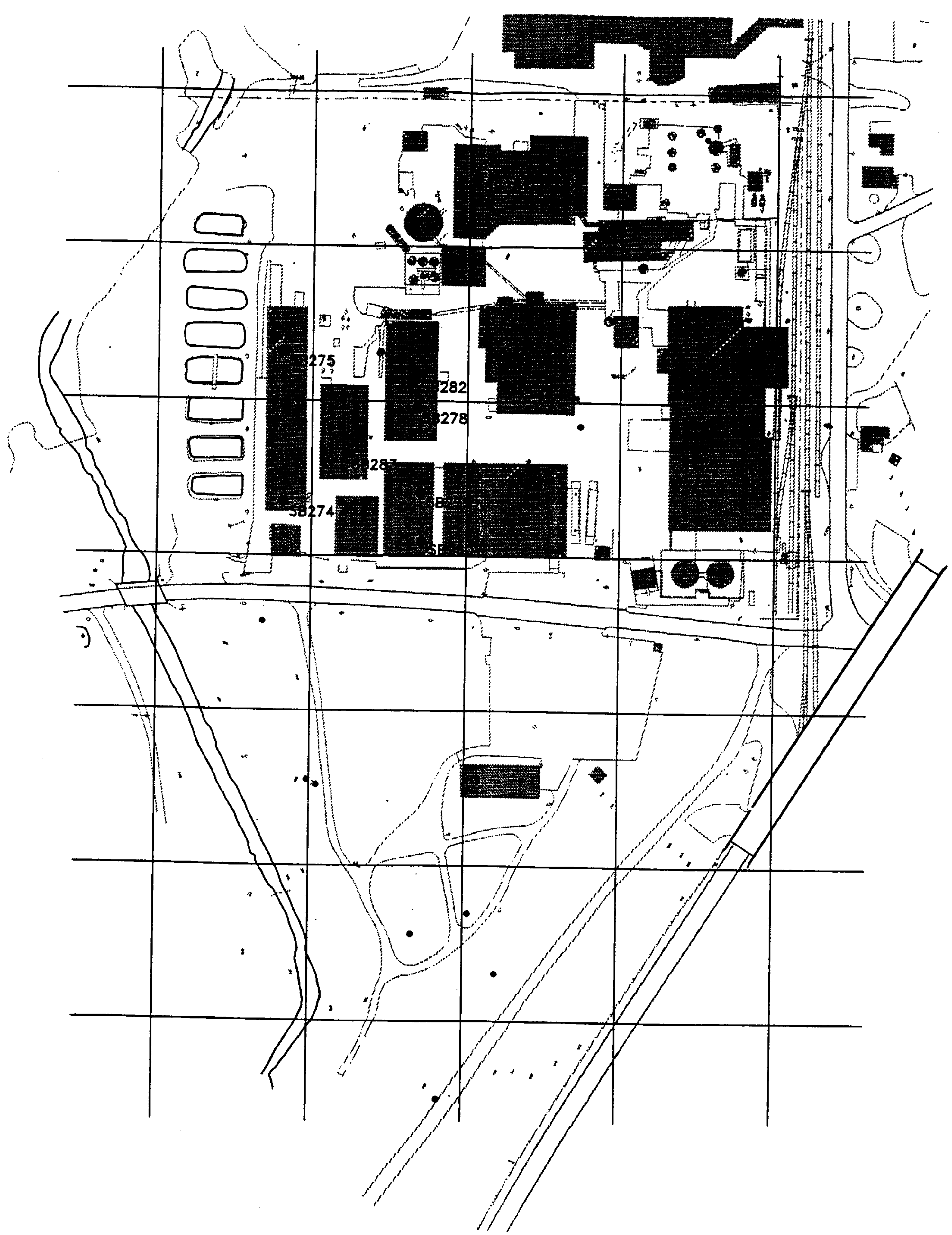
A total of 22 air samples were collected with pumps located in the northeast corner of the site (Pump 1), southwest beyond the slag pile (Pump 2), north of the thickener (Pump 3) and west of the thickener (Pump 4) (Figure 5-38). The sampling was carried out over a period of approximately six months. The total amount of air that circulated through each filter was recorded in cubic feet (ft^3).

5.6.2 Analyses

The filters were analyzed for Th-232 by alpha spectrometry counting. The results were reported in pCi/ ft^3 (Table 5-10).

5.6.3 Concentration of Thorium

The thorium concentration ranged from 8.8E-7 to 9.0E -5 pCi/ft^3, thus 3.1E-5 to 3.2E-3 pCi/m^3 (Table 5-10). These concentrations were less than the effluent concentration allowed in 10 CFR 20 Appendix B (1/1/94) which is 4E-3 pCi/m^3. Thus, Th-232 for the airborne pathway is negligible.



9501300021-36

LEGEND:

● SOIL BORING LOCATION

MOLYCORP, INC.

FIGURE 5-37

SOIL BORINGS UNDER BUILDINGS

FOSTER WHEELER ENVIRONMENTAL CORPORATION

MOL1

CAD FILE NAME: MOLLDWG
PLOT SCALE: 1=160 (11x17)
DATE: 01/18/95
TIME: 11:50 AM

LEGEND:

◇1 AIR MONITORING PUMPS

950130002I-37

MOLYCORP, INC.

FIGURE 5-38

AIR MONITORING PUMPS

FOSTER WHEELER ENVIRONMENTAL CORPORATION

MOL7

CAD FILE NAME: MOL7.DWG
PLOT SCALE: 1=160 (11x17)

TABLE 5-9

RADIOLOGICAL
BACKGROUND EMITTERS
(SOIL SAMPLES)

Sample ID	Pb-210 (pCi/g)	Th-234 (pCi/g)	Pb-212 (pCi/g)	Pb-214 (pCi/g)	Ac-228 (pCi/g)	Tl-208 (pCi/g)	Bi-214 (pCi/g	Bi-212 (pCi/g)	Th-228 (pCi/g)	K-40 (pCi/g)
OS-06-02	1.990 +/-1.610	<1.3	1.140+/-0.101	0.085+/-0.080	1.030+/-0.115	0.356+/-0.047	0.804+/-0.087	0.909+/-0.204	0.989+/-0.131	11.90+/-0.976
OS-06-15	1.350+/-0.586	1.240+/-0.309	1.290+/-0.119	0.972+/-0.101	1.170+/-0.145	0.431+/-0/066	1.010+/-0.113	0.528+/-0.336	1.197+/-0.183	10.50+/-1.140
OS-06-18	<0.5	<1.3	1.280+/-0.135	1.180+/-0.123	1.180+/-0.175	0.466+/-0.075	0.990+/-0.135	1.050+/-0.386	1.294+/-0.208	12.10+/-1.340
OS-06-34	<0.5	<1.3	1.150+/-0.116	0.805+/-0.090	0.953+/-0.131	0.426+/-0.061	0.743+/-0.096	0.739+/-0.291	1.183+/-0.169	8.63+/-0.928
OS-09-01D	<0.5	<1.3	1.430+/-0.150	1.100+/-0.132	1.110+/-0.195	0.454+/-0.086	1.080+/-0.148	0.666+/-0.443	1.261+/-0.239	11.70+/-1.370
OS-09-01	<0.5	<1.3	1.480+/-0.164	1.190+/-0.143	1.180+/-0.209	0.509+/-0.098	1.010+/-0.165	0.875+/-0.557	1.414+/-0.272	10.50+/-1.400
OS-09-02	1.390+/-0.638	1.500+/-0.374	1.480+/-0.146	1.040+/-0.120	1.200+/-0.188	0.442+/-0.076	1.050+/-0.145	0.800+/-0.487	1.228+/-0.211	11.30+/-1.440
OS-09-16	<0.5	<1.3	1.110+/-0.124	0.732+/-0.103	1.040+/-0.179	0.334+/-0.073	0.665+/-0.122	0.555+/-0.419	0.928+/-0.203	12.10+/-1.360
OS-09-17	<0.5	<1.3	1.400+/-0.138	0.742+/-0.098	1.350+/-0.164	0.383+/-0.066	0.751+/-0.108	0.594+/-0.317	1.064+/-0.183	12.80+/-1.290
OS-09-18	<0.5	<1.3	1.350+/-0.136	0.806+/-0.108	1.180+/-0.136	0.404+/-0.084	0.793+/-0.134	1.030+/-0.496	1.122/-0.233	13.30+/-1.390
OS-11-01	<0.5	<1.3	0.737+/-0.096	0.910+/-0.108	0.628+/-0.131	0.198+/-0.056	0.828+/-0.122	0.401+/-0.314	0.550+/-0.156	4.35+/-0.734
OS-11-06	<0.5	<1.3	1.030+/-0.116	1.020+/-0.107	0.814+/-0.415	0.341+/-0.063	0.845+/-0.121	1.010+/-0.452	0.947+/-0.175	8.89+/-0.981
OS-11-08	<0.5	<1.3	1.060+/-0.123	1.100+/-0.128	0.924+/-0.171	<0.1	0.935+/-0.138	0.806+/-0.397	<0.1	6.57+/-1.020
OS-11-11	<0.5	<1.3	1.040+/-0.132	1.320+/-0.138	0.848+/-0.167	0.329+/-0.076	1.240+/-0.150	0.548+/-0.347	0.914+/-0.211	4.05+/-0.866
OS-11-12	<0.5	<1.3	1.150+/-0.110	1.140+/-0.104	1,100+/-0.133	0.414+/-0.057	1.110+/-0.114	0.888+/-0.305	1.150+/-0.158	8.87+/-0.917
OS-13-01	0.483+/-0.541	0.787+/-0.300	0.616+/-0.091	0.756+/-0.101	0.611+/-0.146	<0.1	0.691+/-0.125	0.513+/-0.381	<0.1	4.23+/-0.958
OS-13-06	<0.5	<1.3	0.822+/-0.116	1.420+/-0.146	0.643+/-0.156	0.276+/-0.076	1.310+/-0.161	<1.0	0.767+/-0.211	2.05+/-0.767
OS-13-07	<0.5	<1.3	0.837+/-0.110	1.370+/-0.137	0.708+/-0.164	<0.1	1.210+/-0.156	0.451+/-0.413	<0.1	3.09+/-0.694
OS-13-08	1.110+/-0.635	0.946+/-0.348	0.777+/-0.113	1.220+/-0.136	0.767+/-0.163	0.236+/-0.079	1.220+/-0.156	0.643+/-0.468	0.656+/-0.219	2.26+/-0.834
OS-13-09	<0.5	<1.3	1.040+/-0.137	0.893+/-0.131	0.941+/-0.198	0.350+/-0.088	0.933+/-0.166	0.612+/-0.469	0.972+/-0.244	8.89+/-1.320
OS-13-09D	<0.5	<1.3	0.975+/-0.132	0.896+/-0.1125	0.981+/-0.208	<0.1	0.849+/-0.163	1.260+/-0.551	<0.1	8.25+/-1.460
MEAN	**1.265+/-0.243**	**1.118+/-0.158**	**1.104+/-0.055**	**1.024+/-0.046**	**0.969+/-0.047**	**0.373+/-0.020**	**0.956+/-0.042**	**0.744+/-0.052**	**0.744+/-0.052**	**8.397+/-0.908**

5.3.1 Chartiers Creek Surface Water Samples

Groundwater samples for Round II were taken concurrently with Round I surface water samples from Chartiers Creek. Sampling locations are shown on Figure 5-23. Stream sampling location CR1 is adjacent to the southern upstream end of the site, CR4 is adjacent to the northern downstream end, CR2 and CR3 are intermediate stations. Groundwater sample results are specifically discussed in Section 5.4, however results from the five monitoring wells sampled synoptically with the surface water are discussed here as they relate to surface water.

The monitoring wells installed along the stream bank to the northwest and downgradient of the active plant site (M-2, M-3, M-4, M-5 and M-6) were taken on the same two days (July 27-28, 1994) following a period of at least several days without significant precipitation. This stream area water sampling event also coincided with staff gauge and approximate streamflow measurements.

An additional round of stream area sampling was completed on August 9, 1994; however, it included monitoring wells M-2, M-3, M-4, M-5 and M-6 but did not include other monitoring wells. Staff gauge and streamflow measurements were taken concurrently. Stream area water sampling results are summarized as follows:

The surface water and concurrent groundwater samples were analyzed for TAL metals, molybdenum, chloride, phenols, sulfate, TDS, TOC, and TOX. Molybdenum, selenium, cadmium and TOX are considered indicator compounds of impact from ore refining activities. Molybdenum is also considered because of its elevated levels, the other three because of environmental concerns.

Cadmium was below the detection limit at all surface water sampling locations and stream bank monitoring wells, except in sample M-5 (duplicate) at 32.2 ug/l during groundwater sampling Round I. The original sample however was below the detection limit of 15 ug/l. Cadmium in the groundwater sample obtained from M-5 during the second surface water sampling event was below the detection limit of 30 ug/l (i.e., for this particular sample).

Molybdenum concentrations ranged from 17,300 ug/l at M-3 to 285,000 ug/l at M-5 for the five wells along the stream bank. The surface water sample concentrations however, were generally in the vicinity of 15 ug/l at CR1 to 1,320 ug/l at CR4 for unfiltered samples during Round I. Filtered results are frequently higher than unfiltered, indicating a QA problem with a single increase to the vicinity of 1,000 ug/l at CR4 the downstream location.

Selenium, like cadmium, was not detected at significant concentrations in all surface water and stream bank groundwater samples, except in M-5, where 61.5 ug/l was detected during Round II groundwater (Round I surface water) sampling.

Table 3

AIR ANALYSIS RESULTS

LOCATION	SAMPLE I.D.	PUMP #	FILTER #	SAMPLING DATE	TOTAL VOLUME .ft^3	Th-232(pCi/Filter)	pCi/ ft^3	pCi/ m^3 *
NORTHEAST	9411319-1	1-1	1	4/29/94	45000	<.50	<1.1E-5	<3.8E-4
NORTHEAST	9411319-2	1-2	2-3	5/1/94 - 5/2/94	84294	<.50	<5.9E-6	<2.1E-4
NORTHEAST	9411319-3	1-3	4-10	5/3/94 - 5/11/94	404385	<.50	<1.2E-6	<4.2E-5
NORTHEAST	9411319-4	1-4	11-16	5/13/94 - 5/30/94	171594	<.50	<2.9E-6	<1.0E-4
NORTHEAST	9411319-5	1-5	17-20	6/1/94 - 6/27/94	169450	<.50	<3E-6	<1.1E-4
NORTHEAST	9411319-6	1-6	21-23	6/27/94 - 7/26/94	159650	<.50	<3.1E-6	<1.1E-4
NORTHEAST	9411319-7	1-7	27-29	9/23/94 - 11/10/94	264200	<.50	<1.9E-6	<6.7E-5
SOUTHWEST	9411319-8	2-1	1	5/6/94 - 5/7/94	5580	<.50	<9.0E-5	<3.2E-3
SOUTHWEST	9411319-9	2-2	2-3	5/7/94 - 5/9/94	11941	<.50	<4.2E-5	<1.5E-3
SOUTHWEST	9411319-10	2-3	4-7	5/9/94 - 5/17/94	44083	<.50	<1.1E-6	<3.9E-4
SOUTHWEST	9411319-11	2-4	8-10	5/17/94 - 6/6/94	107800	<.50	<4.6E-6	<1.6E-4
SOUTHWEST	9411319-12	2-5	11-14	6/6/94 - 7/5/94	176000	<.50	<2.8E-6	<9.9E-5
SOUTHWEST	9411319-13	2-6	15-16	7/5/94 - 7/26/94	116000	<.50	<4.3E-6	<1.5E-4
SOUTHWEST	9411319-14	2-7	20-22	9/23/94 - 11/10/94	213900	<.50	<2.3E-6	<8.1E-5
NORTH OF	9411319-15	3-1	1-4	5/19/94 - 6/13/94	156500	<.50	<3.2E-6	<1.1E-4
THICKENER/BLDG.33	9411319-16	3-2	5-8	6/13/94 - 7/11/94	176300	<.50	<2.8E-6	<9.9E-5
	9411319-17	3-3	9-11	7/11/94 - 9/1/94	237200	<.50	<2.1E-6	<7.4E-5
	9411319-18	3-4	13-14	9/23/94 - 10/27/94	181700	<.50	<2.8E-6	<9.9E-5
WEST OF THICKENER	9411319-19	4-1	1-5	5/19/94 - 6/20/94	570800	<.50	<8.8E-7	<3.1E-5
DECON. AREA	9411319-20	4-2	6-9	6/20/94 - 7/26/94	148900	<.50	<3.4E-6	<1.2E-4
	9411319-21	4-3	10-11	7/26/94 - 8/16/94	141000	<.50	<3.5E-6	<1.2E-4
	9411319-22	4-4	13-14	9/23/94 - 10/27/94	166500	<.50	<3.0E-6	<1.1E-4

*Effluent concentration as per Federal Register(10CFR Ch.1.1/1/94), is 4E-15 uCi/ml or 4E-3 pCi/m^3

AIR.XLS

6.0 SUMMARY AND CONCLUSIONS

The sections and appendices presented herewith are the result of the execution of the SCP as augmented in the field and the interpretation of the data gathered from the field program. The collected body of information regarding the site forms the data base which will be used to evaluate remedial alternatives. Evaluation of the alternatives, the estimated costs, and other considerations will be elements of the next objective of the SDMP, the preparation of the Decommissioning and Decontamination Plan. As this next step is largely based on meeting the objectives set out in Section 1.1, presented below is a brief summary of accomplishments keyed to the Section 1.1 objectives.

- The extent and distribution of the thoriated material was extensively characterized both surficially and at depth. The conclusion, however, is that real time confirmatory sampling will have to be part of any alternative to assure waste minimization and adequate remediation. Additionally, as material inside buildings will be excavated, final surficial cleanup and survey will take place after the interior work is complete.

- The rates of migration of thorium and its daughters were determined to be negligible. That is, neither thorium nor any of its daughters migrates off-site to any appreciable degree. This includes the groundwater, surface water and air pathways.

- Non-radiological constituents have no effect on the radiological constituents. They will potentially have an impact on the D&D and will be considered at that time.

- Human exposure for the no-action alternative was evaluated for the resident farmer scenario and industrial scenario. The conclusion was that while the site is currently not a threat to humans or the environment, the no-action alternative is likely unacceptable due to foreseeable future doses under these scenarios.

The final conclusion is that the objectives set out in Section 1.1 have been met, resulting in a solid basis for further evaluation of alternative decommissioning actions and the detailed planning for a preferred approach for decommissioning, decontamination and de-licensing.

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MOLYCORP, Inc.
A UNOCAL 76 COMPANY

Site Characterization Report

for

License Termination

of the

Washington, PA Facility

Volume 2 of 3

January 1995

FOSTER WHEELER ENVIRONMENTAL CORPORATION

APPENDIX A

Legal Land Description

14097

ENGELHARDT-POWER & ASSOCIATES, INC.

CIVIL ENGINEERING SURVEYING ENVIRONMENTAL ENGINEERING

125 SOUTH COLLEGE STREET
WASHINGTON, PENNSYLVANIA 15301

Phone: 412-228-1550
Fax: 412-228-7057

December 2, 1994

Dr. Les Skoski
Foster Wheeler Environmental Group
1290 Wall Street
Lyndhurst, NJ 07071

REFERENCE: Outbound Survey
Molycorp Site, Washington, PA.

Dear Dr. Skoski:

During the performance of the outbound survey of the above referenced site, we field located several existing monuments and iron pins, along with the chain link fence enclosing the area. We have found no significant encroachmonts or deviations from the deed description.

If there is any other information that we can provide for you, please feel free to contact me at your convenience.

Sincerely yours,

ENGELHARDT-POWER & ASSOCIATES, INC.

Michael J. Cannoni, PLS
Chief of Surveys

APPENDIX A

PLEASE NOTE: According to the Washington County Tax Assessor's Office, the Molycorp, Inc. land holdings total 54.9 acres. What follows is the legal land description provided by Molycorp, Inc. In some cases the sale date is actually the recorded date and not the sale date. Discrepancies in acreage or missing acreage can be attributed to the deeds not always showing total acreage, when portions of lots were combined into other tax parcels.

Tax Parcel I.D. No. Not Available

Location: Canton Township, Washington County, Pa.
Tract containing 5.34 acres

Title Reference	Owner	Purchase Date	Sale Date
DBV 244-452 218 Acres 105 Perches	Gordon Land Company	09-28-1900	01-31-1902
DBV 267-546 5.34 Acres	George S. Allmon	06-12-1901	02-01-1902
DBV 273-97	Railway Spring and Manufacturing Company	01-20-1902	04-11-1903
DBV 281-229	Railway Spring Co.	03-10-1903	12-18-1916
DBV 442-52	Electric Reduction Company	12-08-1916	08-25-1920
DBV 483-270	Molybdenum Corp. of America	06-16-1920	Date

NOTE: The Tax Assessor's records indicate that tax parcel I.D. No. 120-011-00-00-0016-00 contains 10.4 acres, but the title search only associates 6.7 acres with this parcel. It is speculated that the remaining 3.7 acres are derived from other tracts.

Tax Parcel I.D. No. 120-011-00-00-0016-00

Present Owner: Molycorp, Inc.

Location: Canton Township, Washington County, Pa.

10.4 acres (Deed Book Volume 637, page 498, Deed Book Volume 707, page 603 and Deed Book Volume 1036, page 462.

Title Reference	Owner	Purchase Date	Sale Date
	James Gordon Estate		09-14-1896
DBV 204, 482 218 Ac. 105 per.	Charles S. Caldwell	09-01-1896	04-18-1899
DBV 224, 93 218 Ac. 105 per.	The Peoples Light and Heat Company	04-18-1899	01-12-1900
DBV 234, 101 218 Ac. 105 per.	John W. Donnan	11-20-1899	10-05-1900
	James Kountz, Jr.	11-20-1899	10-05-1900
	John Slater	11-20-1899	10-05-1900
	David Iseman	11-20-1899	10-05-1900
	L. McCarrell	11-20-1899	10-05-1900
	James S. Stocking	11-20-1899	10-05-1900
	A.G. Happer	11-20-1899	10-05-1900
	Thomas G. Allison	11-20-1899	10-05-1900
DBV 244, 452 281 Ac. 105 per.	The Gordon Land Company	09-28-1900	

<u>As to Tract containing 2.2917 Acres - Deed Book Volume 637, page 496</u>

Title Reference	Owner	Purchase Date	Sale Date
DBV 637, 496 2.2917 Ac	Molybdenum Corporation of America	07-08-1940	Date

<u>As to Tract containing 2.313 acres - Deed Book Volume 707, page 603</u>

Title Reference	Owner	Purchase Date	Sale Date
	Israel Weirich & Estate		6-22-1935

Title Reference	Owner	Purchase Date	Sale Date
WBV 23-287	W. R. Weirich		06-22-1935
	Lillie Mae Weirich Loretta W. Harsh Bessie W. Hoop Bankruptcy	01-29-1918 01-29-1918 01-29-1918	06-22-1935 06-22-1935 06-22-1935
126.1349 Ac.	Luther A. Harr Receiver of Washington Trust Company	04-29-1935	06-22-1935
18.548 Ac. DBV 608-212	Union Fidelity Tit. Insurance Company of Pittsburgh	09-10-1936	09-15-1936
DBV 607-643 18.548 Ac.	Manor Real Estate and Trust Company	09-11-1936	05-15-1946
DBV 707-603 2.0313 Ac	Molybdenum Corp. of America	04-30-1946	Date

As to Tract containing 2.1202 Acres - Deed Book Volume 1036, page 462.

	Israel Weirich & Estate		06-22-1935
WBV 23-287	W. R. Weirich		
	Lillie Mae Weirich Loretta W. Harsh Bessie W. Hoop Bankruptcy	01-29-1918 01-29-1918 01-29-1918	06-22-1935 06-22-1935 06-22-1935
126.1349 Ac.	Arthur A. Harr, Receiver of Washington Trust Company	04-29-1935	06-22-1935
18.548 Ac. DBV 608-212	Union Fidelity Tit. Insurance Company of Pittsburgh	09-10-1936	09-15-1936
18.548 Ac. DBV 600-645 DBV 602-332	A. A. Lacock	09-10-1936	09-03-1943

Title Reference	Owner	Purchase Date	Sale Date
DBV 668-583 5 Ac. +	Manor Real Estate and Trust Company	09-11-1936	01-06-1959
Change of name to	Manor Real Estate Company	12-17-1954	01-06-1959
DBV 1036-462	Molybdenum Corporation of America	12-12-1958	Date

Tax Parcel I.D. No. 120-011-00-00-0018-00

Present Owner: Molycorp, Inc.

Location: Canton Township, Washington County, Pa.
Tract containing 3.5 acres

Title Reference	Owner	Purchase Date	Sale Date
	Israel Weirich & Estate		06-22-1935
WBV 23-287	W. R. Weirich		
	Lillie Mae Weirich	01-29-1918	06-22-1935
	Loretta W. Harsh	01-29-1918	06-22-1935
	Bessie W. Hoop	01-29-1918	06-22-1935
	Bankruptcy		
126.1349 Ac	Arthur A. Harr Receiver of Washington Trust Company	04-29-1935	06-22-1935
18.548 Ac. DBV 608.212	Union Fidelity Title Insurance Company of Pittsburgh	09-10-1936	09-15-1936
18.548 Ac. DBV 600-645 DBV 602-332	A. A. Lacock	09-10-1936	09-03-1943
DBV 668.582 5 Ac. +	Manor Real Estate and Trust Company	09-11-1936	01-06-1959
DBV 607-643 18.548 Ac.	Manor Real Estate and Trust Company	09-11-1936	11-20-1964
Change of name to Manor Real Estate Company		12-17-1954	11-20-1964
DBV 1191-589	Molybdenum Corp. of America	11-03-1964	Date

NOTE: 6.76 acres of the Findlay Clay Products Co. is not accurate, it should be 6.9 acres, although the deed for this portion was not found in the records.

Tax Parcel I.D. No. 120-011-00-00-0017-00

Present Owner: Molycorp, Inc.

Location: Canton Township, Washington County, Pa.
Tract containing 6.9 acres

Title Reference	Owner	Purchase Date	Sale Date
	Israel Weirich & Estate		06-22-1935
WBV 23-287	W. R. Weirich		
	Lillie Mae Weirich	01-29-1918	06-22-1935
	Loretta W. Harsh	01-29-1918	06-22-1935
	Bessie W. Hoop	01-29-1918	06-22-1935
	Bankruptcy		
126.1349 Ac	Luther A. Harr, Receiver of Washington Trust Company	04-29-1935	06-22-1935
18.548 Ac. DBV 608-212	Union Fidelity Title Insurance Company of Pittsburgh	09-10-1936	09-15-1936
DBV 607-643 18.548 Ac.	Manor Real Estate and Trust Company	09-11-1936	05-15-1946
DBV 711-198 6.76 Ac.	Findlay Clay Products Company	04-27-1946	01-12-1971
DBV 1330-1056	Molybdenum Corp. of America	10-29-1970	Date

Tax Parcel I.D. No. 120-011-00-00-0019-03

Present Owner: Molycorp, Inc.

Location: Canton Township, Washington County, Pa.

County tax assessment describes property as 3.4 acres. Description in Deed Book Volume 1615, page 21 lists the property as 6.9515 acres, however, there are exceptions for Interstate Highway to and the Baltimore & Ohio Railroad.

Title Reference	Owner	Purchase Date	Sale Date
	William Anderson		12-23-1872
	Jacob Weirich Estate		08-17-1885
	Laura Wilson		10-21-1899
WBV 12-104	Israel Weirich Estate	08-17-1885	06-20-1918
DBV 4-W-269	Israel Weirich Estate	12-23-1872	06-20-1918
DBV 4-I-235	Israel Weirich Estate	04-08-1871	06-20-1918
DBV 224-628	Israel Weirich Estate	10-21-1899	06-20-1918
WBV 23-287	Lillie Mae Weirich	01-29-1918	06-20-1918
WBV 23-287	Bessie W. Weirich	01-29-1918	06-20-1918
WBV 23-287	Loretta W. Weirich	01-29-1918	06-20-1918
DBV 457-194	Hazel-Atlas Glass Co	05-13-1918	09-14-1956
DBV 973-397	Continental Can Co. Inc.	08-04-1956	10-20-1964
DBV 1189-256	Brockway Glass co. Inc.	10-15-1964	08-05-1975
DBV 1615-21	Molycorp, Inc.	09-08-1975	Date

Tax Parcel I.D. No.	120-011-00-00-0019-01
Present Owner:	Molycorp, Inc.
Location:	Canton Township, Washington County, Pa. Tract containing 16.8 acres

Title Reference	Owner	Purchase Date	Sale Date
	William Anderson		12-23-1872
	Jacob Weirich Estate		08-17-1885
	Laura Wilson		10-21-1899
WBV 12-104	Israel Weirich Est.	08-17-1885	05-20-1918
DBV 4-W-269	Israel Weirich Est.	12-23-1872	05-20-1918
DBV 4-I-235	Israel Weirich Est.	04-08-1871	05-20-1918
DBV 224-628	Israel Weirich Est.	10-21-1899	05-20-1918
WBV 23-287	Lillie Mae Weirich	01-29-1918	05-20-1918
WBV 23-287	Bessie W. Weirich	01-29-1918	05-20-1918
WBV 23-287	Loretta W. Weirich	01-29-1918	05-20-1918
DBV 457-194 23-876 Ac.	Hazel-Atlas Glass Company	05-13-1918	12-01-1943
DBV 674-207 23-876 Ac.	Manor Real Estate and Trust Company	11-30-1943	12-01-1975
Change of name to	Manor Real Estate Company	12-17-1954	01-06-1959
DBV 1635-143 16.8228	Molycorp, Inc.	10-31-1975	Date

Tax Parcel I.D. No. 120-011-00-00-0021-00

Present Owner: Molycorp, Inc.

Location: Canton Township, Washington County, Pa.
Tract containing .6 acre

Title Reference	Owner	Purchase Date	Sale Date
	Jacob Weirich Estate		08-17-1885
	William Anderson		12-23-1872
	Laura Wilson		10-21-1899
MBV 12,104	Israel Weirich & Estate	08-17-1885	10-09-1935
DBV 4-W-269	Israel Weirich & Estate	12-23-1872	10-09-1935
DBV-4-I-235	Israel Weirich & Estate	04-08-1871	10-09-1935
DBV 224-628	Israel Weirich & Estate	10-21-1899	10-09-1935
MBV 23-287	Lillie Mae Weirich	01-29-1918	10-09-1935
MBV 23-287	Loretta W. Harsh	01-29-1918	10-09-1935
MBV-23-287	Bessie W. Hoop	01-20-1918	10-09-1935
	A Lacock	08-26-1935	03-20-1941
DBV 644-485	Thomas J. Brooks	03-20-1941	05-12-1959
	Alice C. Brooks	03-02-1941	05-12-1959
DBV 1045-471	Ralph Morris	05-07-1959	03-03-1980
Died 7-22-1968	Hettie Morris & Estate	05-07-1959	03-03-1980
DBV 1984 1984-134	Molycorp, Inc.	03-01-1980	Date

NOTE: The Tax Assessor's office does not have the acreage for this parcel. It is assumed to be 12.7 acres by calculation.

Tax Parcel I.D. No. 120-011-00-00-0026-08

Location: Canton Township, Washington County, Pa.

Title Reference	Owner	Purchase Date	Sale Date
	Israel Weirich & Estate		06-22-1935
WBV 23-287	W. R. Weirich		
	Lillie Mae Weirich Loretta W. Harsh Bessie W. Hoop Bankruptcy	01-29-1918 01-29-1918 01-29-1918	06-22-1935 06-22-1935 06-22-1935
126.1349 Ac.	Arthur A. Harr, Receiver of Washington Trust Company	04-29-1935	06-22-1935
126.1349 Ac. DBV 600-645 DBV 602-332	A. A. Lacock	06-12-1935	04-22-1958
DBV 1017-229 55.1574 Ac.	Blaine A. Beeghly	04-17-1958	09-09-1980
DBV 1019-653 55.1574 Ac.	Blaine A. Beeghly Wilma Fisher Beeghly C. Wyle Gnagey Edward J. Gnagey	05-27-1958	09-08-1980
DBV 2003-489	Molycorp. Inc.	09-08-1980	Date

Tax Parcel I.D. No. 120-011-04-01-0001-00

Present Owner: Molycorp, Inc.

Location: Canton Township, Washington County, Pa.
Tract containing .628 acre

Title Reference	Owner	Purchase Date	Sale Date
DBV 234, 101	John W. Donna James Kountz, Jr. John Slater	11-26-1889	05-8-1919
218 Acres I	David Iseman L. McCarrell James S. Stocking Thomas G. Allison		
Parcel A	The Gordon Land Company	09-28-1900	06-26-1918
Parcel A Parcel B	The Tylerdale Connecting Railroad Company	05-08-1919	01-12-1981
Parcel C & Parcel D DBV 200, Page 361	William H. Griffith	1-28-1896	09-10-1896
DBV 218, 591	The Peoples Light and Heat Company	09-10-1896	
Merger	The Manufacturers Light and Heat Company	11-01-1899	
DBV 304, 569	Winfield McIlvaine	09-02-1896	08-30-1905
DBV 342, 606	J. A. Milliken Estate	08-30-1905	11-27-1917
DBV 453, 620	Hazel Atlas Glass Company	11-27-1917	04-12-1918
DBV 206, 507	Jonathan Allison John W. Donnan James E. Duncan L. McCarrell	09-04-1986	09-24-1917
DBV 443, 607	Hazel Atlas Glass Company	09-24-1917	04-12-1918

Title Reference	Owner	Purchase Date	Sale Date
DBV 455, 354	Tylerdale Connecting Railroad Company	04-12-1918	01-12-1981
DBV 2018, 86	Molycorp, Inc.	01-12-1981	Date

APPENDIX B

Topographic Survey

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NUMBER OF OVERSIZE PAGES FILMED ON APERTURE CARDS 3

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RECORDS AND REPORTS MANAGEMENT BRANCH

APPENDIX C

Streamflow Data

APPENDIX C

STREAMFLOW DATA

Introduction

Streamflow measurements and calculations were conducted at the site to measure baseflow to Chartiers Creek, which borders the site to the west, and the site's contribution to streamflow from surface runoff and groundwater.

Flow measurements were obtained using a Pygmy meter at four locations (stations) along Chartiers Creek on two different days (August 11 and 16, 1994) during a mid-summer period with little rainfall, and on one day in mid-autumn (November 3, 1994), as shown on Figure 5-23.

In addition, hydrographs were produced from 1993 daily streamflow data for two USGS gauging stations: one on Chartiers Creek approximately 20 miles downstream from the site at Carnegie, and one on Ten Mile Creek in Greene County, which drains similar but slightly steeper terrain than that of Chartiers Creek. Data from these basins were evaluated to help further quantify the flow in Chartiers Creek, at the site, and the contributions to flow derived from the site.

Pygmy Meter Data

The Gurley Precision Pygmy Meter Model 625 was used to estimate streamflow at four stations adjacent to the site along Chartiers Creek. Station CR1 is at the upgradient staff gauge at the southern boundary of the active site area. Station CR4 is at the downgradient staff gauge at the northern boundary of the active site area. Stations CR2 and CR3 are intermediate stations.

Pygmy meter measurements were conducted by placing the rotating cups in the stream at approximately 60 percent depth in cross-sectional areas of apparent uniform flow. With the analog meter the flow rate is measured by counting revolutions (clicks) occurring in 60 seconds, which is converted to feet per minute. The flow rates are multiplied by the cross-sectional areas they represent and are then summed across the stream at a given station to give total flow at the station. The cross section of the stream bed was determined by a surveyor at each location, and the depth of water was measured when the flow measurements were made. The following table summarizes the calculated flows in midsummer and mid-fall.

Station	August 11, 1994 Streamflow in gpm	August 16, 1994 Streamflow in gpm	November 3, 1994 Streamflow in gpm
CR1	618.4	429.0	1177.9
CR2	430.0	486.2	1037.7
CR3	258.1	530.4	880.3
CR4	225.1	733.0	1358.1

These data show an average streamflow of 383 gpm on August 11 and 545 gpm on August 16, suggesting a typical streamflow in the 400 to 500 gpm range during the midsummer low flow period. The higher readings of fall, averaging between 1,000 and 1,100 gpm, reflect the decline in evapotranspiration or increase in rainfall occurring at that time of year.

Due the variability of the flow readings it was not possible to determine whether Chartiers Creek is gaining or losing in streamflow volume adjacent to the site, nor to quantify the groundwater flow to the creek from the site, based on these measurements.

Comparative Basin Calculations

Hydrographs for water year 1993 (October 1992 through September 1993) were compiled from daily records at two stations from USGS 1993 Water Resources Data for the Ohio Basin in Pennsylvania (Figure C-1 and C-2). Each water year begins on October 1 and ends on September 30 (the typical time of lowest streamflow). The Carnegie Station on Chartiers Creek is 20 miles downstream and north of the site and includes a drainage area of 257 mi^2. The Ten Mile Creek South Fork Station in Jefferson encompasses a 180 mi^2 drainage area located approximately 20 miles south of the site. This area may better approximate the upper portion (18 mi^2) of Chartiers Creek south of the site than the total Chartiers Creek basin.

A baseflow curve was hand-drawn to represent the non-spiked portion of the hydrographed streamflow that is likely derived from groundwater recharge (Figures C-1 and C-2). The data are tabulated as follows:

	Chartiers Creek					Ten Mile Creek				
Drainage Area (mi^2)	257					180				
				Baseflow					Baseflow	
Month	Total Flow (cfs)	74 year mean (cfs)	Departure from Mean (%)	(cfs)	(%)	Total Flow (cfs)	62 year mean (cfs)	Departure from Mean (%)	(cfs)	(%)
Oct 92	81.8	118	-30.5	60	73.3	14.2	45.5	-68.8	8	56.3
Nov 92	187	198	-5.6	85	45.5	136	117	+16.2	25	18.4
Dec 92	318	295	+7.8	140	44.0	278	240	+15.8	45	16.2
Jan 93	312	349	-10.6	150	48.1	272	310	-12.2	80	29.4
Feb 93	230	464	-50.4	120	52.1	226	368	-38.6	70	31.0
Mar 93	818	578	+41.5	330	40.3	758	448	+69.2	220	29.0
Apr 93	449	478	-6.1	260	57.9	296	352	-15.9	120	40.5
May 93	206	339	-39.2	140	68.0	63.4	217	-70.8	30	47.3
June 93	188	227	-17.2	80	42.6	26.6	120	77.8	10	37.6
July 93	121	177	-31.6	70	57.9	19.0	77.6	-75.5	5	26.3
Aug 93	69.5	142	-51.1	45	64.7	35.0	55.1	-36.5	5	14.3
Sept 93	98.2	129	23.9	45	45.8	76.1	45.0	+69.1	10	22.2
Water Year '93	**257**	**290**	**-11.4 (annual)**	**127**	**49.4**	**183**	**199**	**08.0 (annual)**	**52.3**	**28.6**

Table C-1 presents proportioned contributions of total streamflow and baseflow using 1993 data for Ten Mile Creek as the basis. The Ten Mile Creek drainage basin appears to be more representative of the site area than the total Chartiers Creek drainage basin.

The drainage area from the upper staff gauge at CRI to the lower staff gauge at CR4 is 0.09 mi^2, 0.03 mi^2 of which is on the west side of the creek across from the active plant site. The drainage area is 0.06 mi^2 through the site from the east side, consisting of surface water that flows over the site and baseflow consisting of groundwater that flows through the site aquifers. Paved areas of the site tend to negate some of the recharge potential of the alluvial deposits underlying the site.

The area of the drainage basin for Chartiers Creek upstream of the site was calculated using a Keuffel and Esser Co. planimeter. A direct reading of square inches was obtained from the planimeter. This figure was converted to square miles using the scale of the topographic maps from which the information was taken.

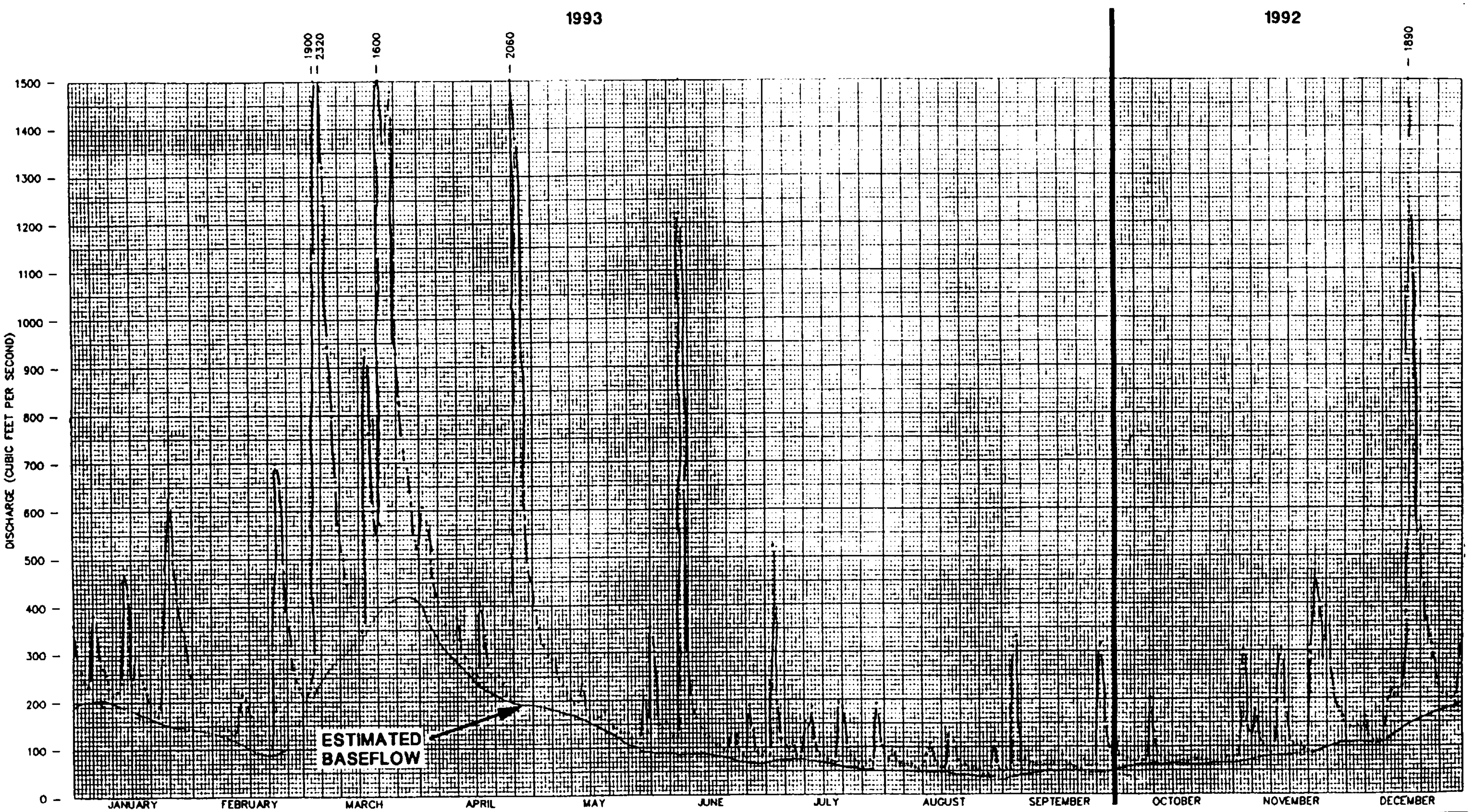
These data correspond to the Pygmy meter measurements in that the low flow to the site from drainage basin calculations was estimated at 224 gpm versus the 383 gpm average from Pygmy readings on August 11, 1994. This correspondence is good for this type of data collection. Based on these calculations, the average contribution through the site during low-flow conditions is estimated at nearly 10 gpm.

TABLE C-1

CALCULATED STREAMFLOW CONTRIBUTION TO CHARTIERS CREEK

Drainage Area	Ten Mile Creek	Total Flow to Site (Chartiers Creek)	Total Flow to Chartiers Creek between CR1 to CR4	Contribution through Site between CR1 and CR4
Area Size	180 mi^2	18.0 mi^2	0.09 mi^2 56.93 ac	0.06 mi^2 41.32 ac
Total Flow 1993	183 cfs (82130 gpm)	18.3 cfs (8213 gpm)	0.0732 cfs (32.8 gpm)	0.058 cfs (26.0 gpm)
Mean Total Flow*	191 cfs (85721 gpm)	19.1 cfs (8572 gpm)	0.0764 cfs (34.3 gpm)	0.060 cfs (27.1 gpm)
Baseflow 1993	52.3 cfs (23472 gpm)	5.23 cfs (2347 gpm)	0.026 cfs (11.7 gpm)	0.017 cfs (7.82 gpm)
Estimated Mean Baseflow*	54.6 cfs (24498 gpm)	5.46 cfs (2450 gpm)	0.027 cfs (12.25 gpm)	0.018 cfs (8.17 gpm)
Estimated Low flow	5 cfs (2244 gpm)	0.5 cfs (224 gpm)	0.0025cfs (1.12 gpm)	0.0017 cfs (0.75 gpm)
Note: mi^2 = square miles, gpm = gallons per minute, cfs = cubic feet per second, ac= acres				

* Long-term mean

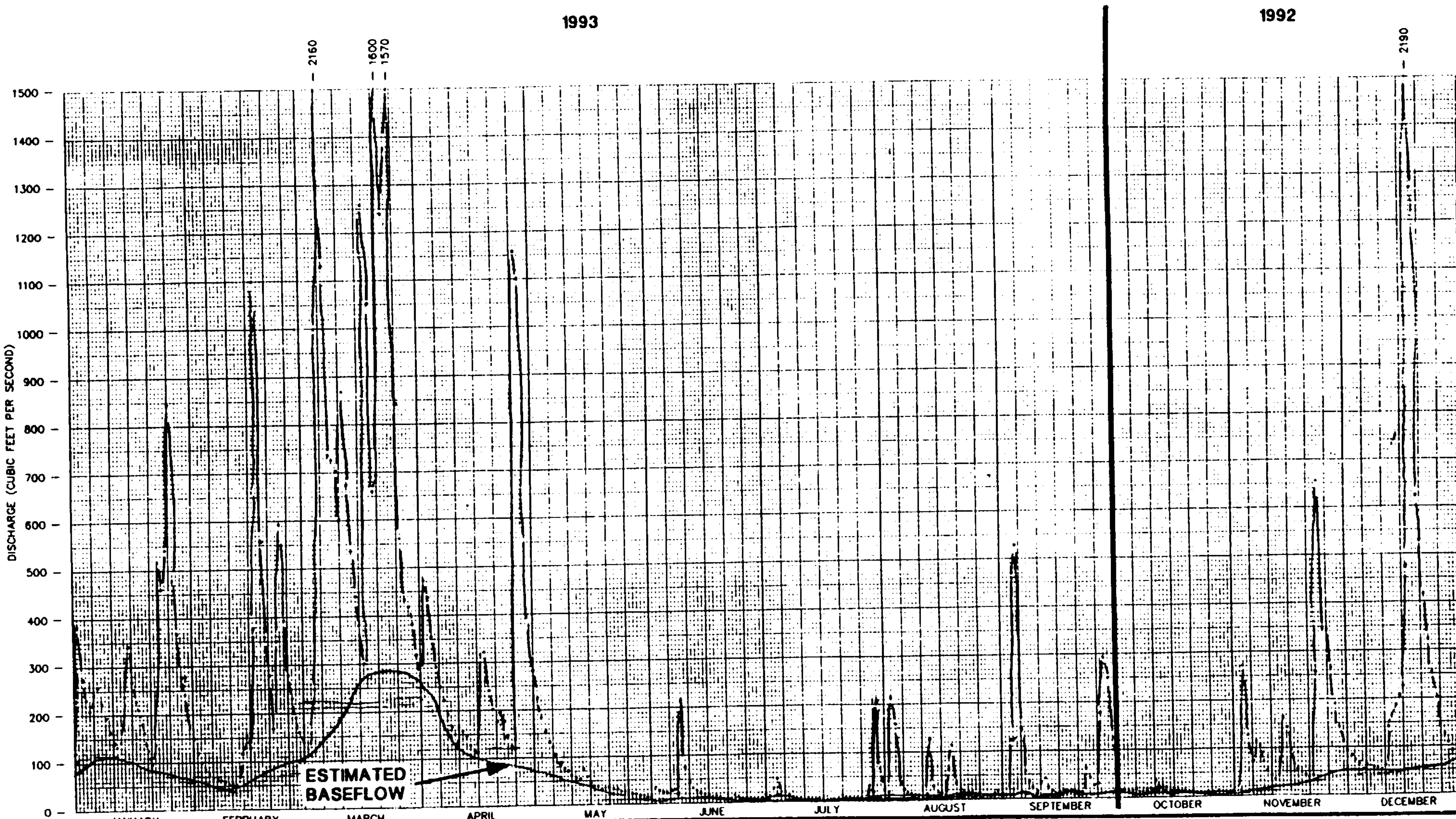


MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE C-1

DAILY STREAMFLOW OF
CHARTIERS CREEK AT CARNEGIE, PA
OCT. 1992 - SEPT. 1993

FOSTER WHEELER ENVIRONMENTAL CORPORATION



MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE C-2

DAILY STREAMFLOW OF
SOUTH FORK TEN MILE CREEK
AT JEFFERSON, PA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

APPENDIX D

Infiltration Testing

APPENDIX D

INFILTRATION TESTING

A sealed double-ring infiltrometer (SDRI) (see Figure D-1) from Rautwein Soil Testing Equipment in Houston, Texas was used to determine the infiltration rates into the fill material vadose zone at two locations on the site. One location (I-1) is in the northwest corner of the site approximately 100 feet southeast of PW-1 and the other (I-2) is located in the center of the fill area south of Caldwell (Figure D-2).

The inner ring, a square tank with an open bottom (5 feet per side) was installed at each location, 6 inches deep with a bentonite seal. An outer square ring (12 feet per side) was installed around the 5-foot inner ring. The outer ring, also a square tank with an open bottom, was installed with sides equidistant from the sides of the inner ring, approximately 18 inches deep and sealed with bentonite.

To conduct the test, the inner ring, a sealed tank with ports, was hooked to IV bags which allowed water to replace what was infiltrated. The outer ring was filled and maintained at a height of one foot to prevent the water that infiltrated through the inner ring from migrating laterally. The elapsed times and spent water volumes were recorded.

Based upon $I = Q/At$, the infiltration rate can be calculated (Rautwein, 1987 ; see table footnote)

where: I = infiltration rate to inner ring, cm/sec

Q = rate of flow between measurements (mls = cm^3)

A = surface area within inner ring (cm^2)

t = time elapsed between measurements (sec)

Vertical hydraulic conductivity $k = Q/iAt$

where: i = hydraulic gradient (dimensionless)

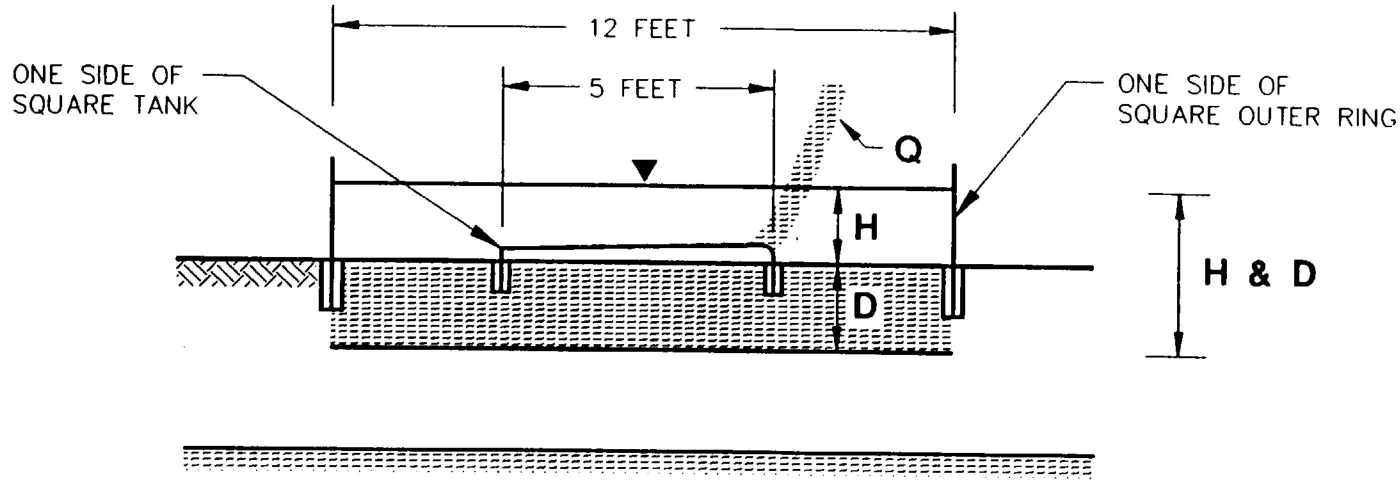
This value approximates the vertical hydraulic conductivity assuming a hydraulic gradient of unity from ground surface to the water table. This assumption can be verified using the Rautwein (1987) assumption that the height of infiltrating water above the water table divided by the depth of water table below the ground surface equals the hydraulic gradient (i). Table D-1 presents the measurement inflow increments, time intervals and estimated hydraulic conductivity from each interval. This operation was conducted for I-1 on August 3 and 4, 1994 and for I-2 on July 26, 1994.

Table D-1 Inflow Data and Estimated Hydraulic Conductivities at Infiltrometers		
Water Mass Discharged ml	Incremental Elapsed Time (sec)	Estimated Hydraulic Conductivity* (cm/sec)
I-1 on August 3, 1994		
2597	480	2.3×10^{-4}
2870	540	2.3×10^{-4}
3394	600	2.4×10^{-4}
3644	900	1.7×10^{-4}
3357	900	1.6×10^{-4}
3530	780	1.9×10^{-4}
3469	600	2.5×10^{-4}
3662	660	2.4×10^{-4}
3001	540	2.4×10^{-4}
3535	780	2.0×10^{-4}
3693	720	2.2×10^{-4}
3403	600	2.4×10^{-4}
I-1 on August 4, 1994		
4299	780	2.4×10^{-4}
3512	660	2.3×10^{-4}
2865	660	1.9×10^{-4}
4429	660	2.9×10^{-4}
3780	600	2.7×10^{-4}
I-2 on July 26, 1994		
1742	960	7.8×10^{-5}
2004	1200	7.2×10^{-5}
2390	1440	7.2×10^{-5}
2288	1500	6.6×10^{-5}

---

*I = Q/At where I = infiltration (cm/sec), Q = quantity of flow (gm = cm^3) between measurements
A = area of ring = 23,226 cm^2
k = Q/iAt, where hydraulic gradient is assumed to approach 1,
therefore, k = I

The average vertical hydraulic conductivity of the vadose zone, estimated at 2.3×10^{-4} cm/sec at I-1's location and 7.2×10^{-5} cm/sec at I-2's location, can be used to approximate vertical hydraulic conductivty in surfaces of the site that are not paved. Although there is no discernible trend in hydraulic conductivity (k) values at I-1 and a slight decrease noted at I-2, it is reasonable to assume that the lower k values represent more stabilized conditions at I-2, i.e., 6.6×10^{-5} cm/sec. However at I-1, the average value (2.3×10^{-4} cm/sec) is a more suitable representation of longer term conditions.



H = HEIGHT OF WATER ABOVE GROUND SURFACE IN OUTER RING

D = DEPTHS FROM GROUND SURFACE TO WETTING FRONT

Q = WATER INFLOW [illegible]

[illegible] FROM RAUTWEIN, 1987

MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

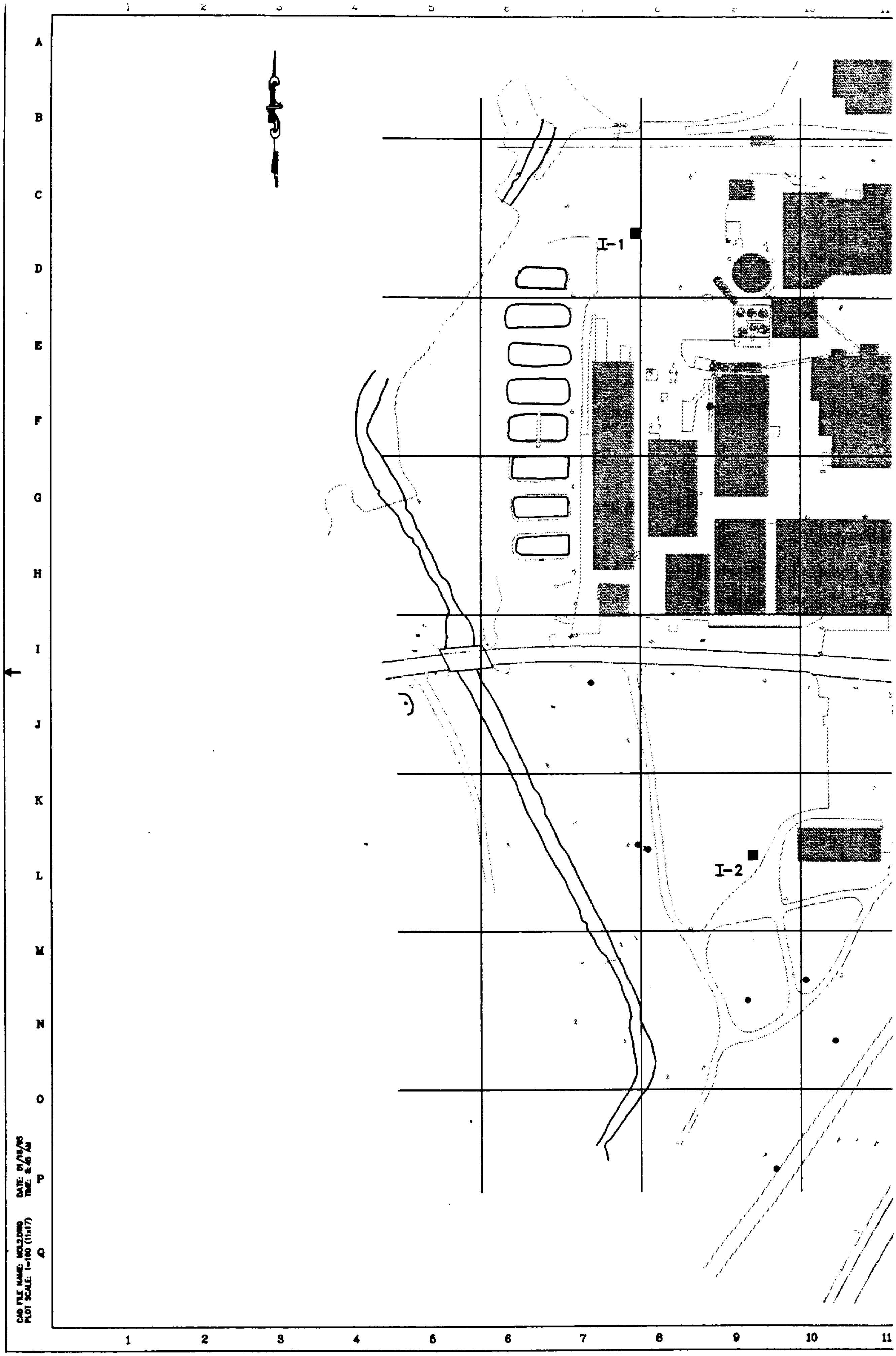
FIGURE D-1

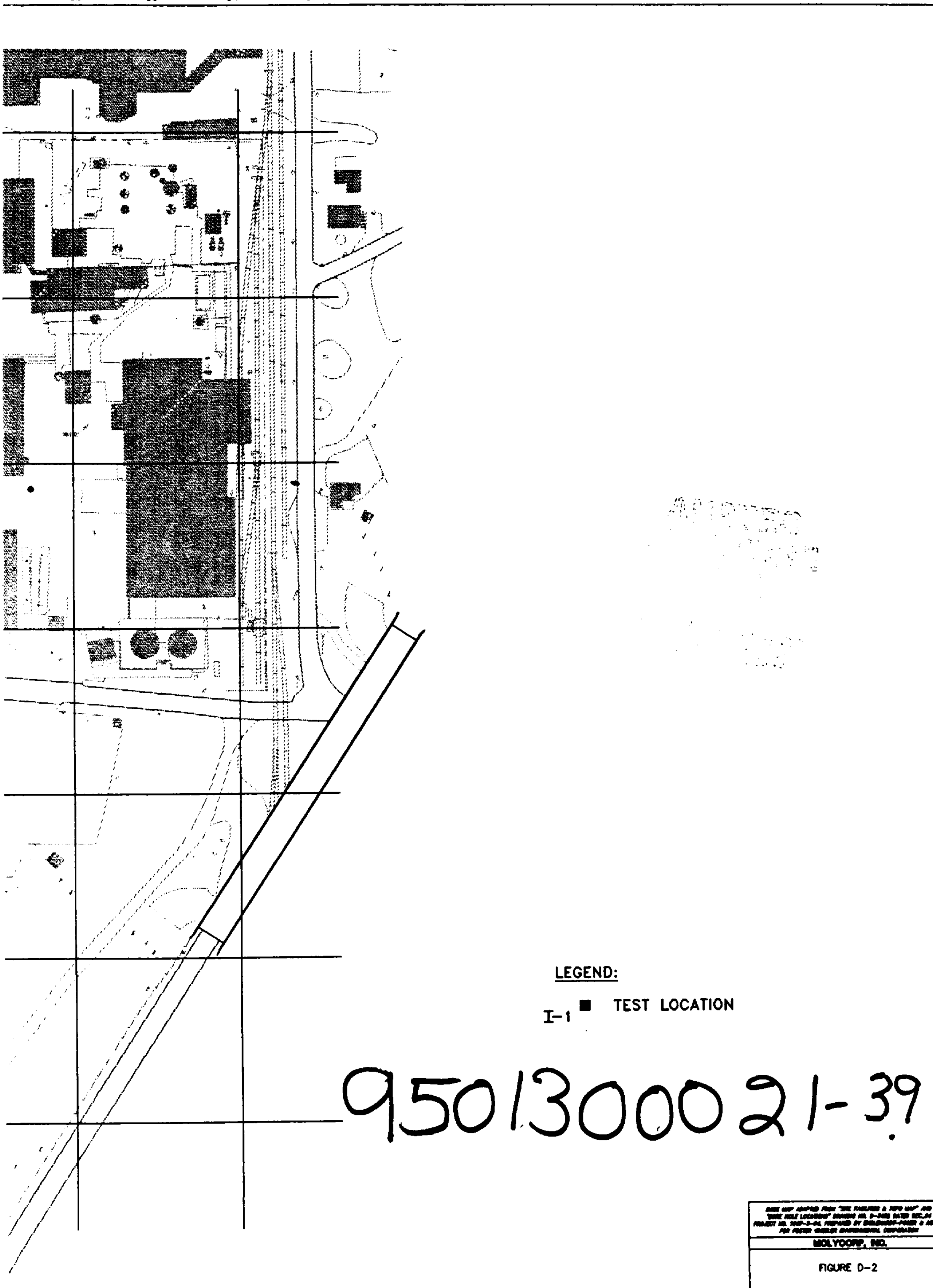
CROSS SECTION OF
DOUBLE-RING INFILTROMETER

FOSTER WHEELER ENVIRONMENTAL CORPORATION

DATE: 01/11/95
TIME: 10:55 AM

CAD FILE NAME: MOLYD-1.DWG
PLOT SCALE: (FIT)


I-1
I-2
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
1 2 3 4 5 6 7 8 9 10 11
CAD FILE NAME: MOL2.DWG
PLOT SCALE: 1=160 (11x17)
DATE: 01/18/95
TIME: 8:45 AM



9501300021-39

MOLYCORP, INC.

FIGURE D-2

INFILTROMETER TEST LOCATIONS

FOSTER WHEELER ENVIRONMENTAL CORPORATION

MOL2

APPENDIX E

Aquifer Testing of Fill Material

APPENDIX E

AQUIFER TESTING OF FILL MATERIAL

A. Introduction

Two pumping tests were conducted during July 1994, as required by the Site Characterization Plan, to establish hydraulic conductivity values for the water table aquifer (i.e., the saturated fill material). The pumping tests were conducted at PW-1 within 100 feet of the northwestern property corner along Chartiers Creek, and at PW-2 approximately 250 feet southeast of PW-1 near storage tanks and Building 34 (see Figure E-1).

In addition, instantaneous injection (slug) tests were conducted in 16 monitoring wells and 1 piezometer in order to supplement the pumping test data.

B. Pumping Test Methodology

Pumping well PW-1 was installed in an excavated pit within the fill material. The well was constructed of 10 feet of hand-slotted 3-foot diameter corrugated HDPE plastic pipe. Pumping well PW-2 was completed next to the tank farm, with 10 feet of 4-inch diameter slotted PVC screen. A 4-inch diameter well was installed because of the high groundwater flow in the area. The open borehole surrounding each well was backfilled with medium to coarse sand. Well development was completed via surging with a Whale Superline 991 electric mini-submersible centrifugal pump. Well completion diagrams and soil boring logs associated with these pumping wells and respective observation wells/piezometers are presented in Appendices L and G, respectively.

A step-drawdown test was conducted in PW-1 on July 7, 1994 with a Whale Superline 991 with 50 minutes of pumping at 0.28 gpm and 30 minutes at 2 gpm. Based on the results of the short term test, a long-term pumping rate of 1 gpm was selected for the pumping test. Water levels within approximately 30 background wells/piezometers were monitored utilizing hand-held instruments at least daily before, during and after the test. Pressure transducers were connected to a Hermit 2000 data logger and installed in pumping well PW-1 and observation wells/piezometers PZ-202, PZ-204, M-6, MW-24, PZ-205, PZ-213 and PZ-214. These wells/piezometers are screened in the water table hydrologic unit which consists of fill material and/or the underlying clayey zone. The well construction diagrams for these wells and piezometers are shown in Appendix L. The long-term pumping test at PW-1 was conducted with a Grundfos Redi Flo 2 submersible pump on July 13, 1994 at a constant rate of 1 gpm for a duration of 7 hours, at which point the drawdown trend steepened and dewatered the well. During the test, measurements of water table drawdown were collected using hand-held electronic water level indicators, along with the data from the transducers. These data were obtained to provide a set of backup data for the test. At the conclusion of the pumping, the recovery of the aquifer was monitored, initially using the hand-held water-level indicators and subsequently with the pressure transducers.

A step-drawdown test was conducted in PW-2 on July 18, 1994 using a Redi Flo 2 pump at 1.5 gpm for 16 minutes and a peristaltic pump at 0.5 gpm for 30 minutes. Based on the results of the short-term test, a long-term pumping rate of 0.5 gpm with a peristaltic pump was selected for the pumping test, to produce maximum drawdown without dewatering the well. Prior to initiating the pumping test, pressure transducers were connected to the Hermit 2000 data logger and installed in pumping well PW-2 and observation wells/piezometers PZ-28, PZ-252, PZ-251, PZ-242, PZ-243, M-18 and M-18S. These wells/piezometers are screened in the water table unit, except for M-18, which is screened in the underlying sand and gravel. Water levels within approximately 40 background wells/piezometers were monitored with water level indicators at least daily before, during and after the test. The long-term pumping test was conducted on July 19, 1994 for a duration of 41 hours at a constant rate of 0.5 gpm. During the test, measurements of water-table drawdown were collected using hand-held electronic water level indicators, along with data from the transducer. These data were obtained to provide a set of backup data for the test. At the conclusion of pumping, the recovery of the aquifer was monitored utilizing pressure transducers over a 4-day period after pumping was stopped.

Some transducer data exhibited erratic patterns which are unexplained but may be related to on-site electromagnetic interference (see letter from manufacturer, Attachment 1 of this Appendix). The Hermit data logger that stored the water level data received by the pressure transducers indicated patterns of noise which made it difficult to discern small trends in water levels. However, transducer data from wells that showed significant drawdown and recovery showed less erratic behavior. Measurable precipitation did not occur during pumping periods and background wells showed little significant variation (e.g., wells in Tables E-2 and E-4 outside of the radius of influence).

Table E-1 presents the elapsed time/drawdown measurements in each pumping well and observation well/piezometer obtained from the transducers and Table E-2 presents the measurements from the hand-held water level indicators.

Tables E-3 and E-4 present the recovery data, including calculation of the ratio of time since pumping started over time since pumping stopped (t/t′).

C. Pumping Test Analytical Methods

For many situations where the aquifer is under nonequilibrium (pumping) conditions, aquifer response to pumping can be described using the classic Theis (1935) equation. The following calculation is adjusted to the English system:

$$s = \frac{114.6QW(u)}{T}$$

$$u = \frac{1.88r^2S}{Tt}$$

where: s = drawdown in feet

Q = pumping rate in gallons per minute

T = coefficient of transmissivity,in gallons per day per foot

$W(u)$ = the "well function of u," an exponential interval generally applied by curve matching for aquifer analyses

r = distance of drawdown measuring point (i.e., observation well) from center of pumped well in feet

S = coefficient of storage, dimensionless

t = time since pumping started in days

These equations assume confined conditions for a homogeneous and isotropic aquifer with unlimited areal extent; and they provide the basis from which the following distance-drawdown and time-drawdown calculations were derived.

Three methods were used to analyze pumping test data for the fill aquifer. Each method utilizes different data sets to determine aquifer characteristics (i.e., transmissivity and storage coefficient).

(1) Distance-Drawdown Method (Driscoll, 1986)
(2) Time-Drawdown, Modified Theis Semilogarithmic Method (Cooper and Jacob, 1946)
(3) Residual Drawdown vs. t/t' Method (Jacob, 1963)

Distance - Drawdown Method

As with the above set of equations, the following equations can be applied to drawdown in observation wells at distance r (Driscoll, 1986). This method was not applied to PW-1 test because 7 hours of pumping had not produced a suitable data set.

$$T = \frac{528Q}{\Delta s(per \log cycle)}$$

and

$$S = \frac{0.3Tt_o}{r_o^{\,2}}$$

where:

528 is a constant conversion factor in minutes/day (includes English units factor conversion);
r_o is distance (r) at zero drawdown (x-intercept);
t_o is time (t) at zero drawdown.

Figure E-1 presents the data used in the distance-drawdown analysis that was applied to the observation wells at the end of the pumping test at PW-2 and the corresponding distance-drawdown plot. Note that drawdown was not observed in the bedrock well, indicating that there is not a direct connection between the fill aquifer at PW-1 and the bedrock fractures at the BR-1 screened interval. In addition, a projected plot for 90 days of pumping (without recharge effects) is shown on each figure. The projected radius of influence is calculated by substituting the values of T and S and solving for r_o.

Resultant T and S values of 1,467 gpd/ft and 0.062 (dimensionless), respectively, were calculated via the distance-drawdown method for this aquifer in the vicinity of PW-2. A projected radius of pumping influence, r_o, of 110 ft was determined for well PW-2.

<u>Time-Drawdown - Modified Theis Semilogarithmic Method</u>

In this method, the classic Theis (1935) nonequlibrium equations (Cooper and Jacob, 1946) are simplified to:

$$T = \frac{264Q}{\Delta s(per \log cycle)}$$

and

$$S = \frac{0.3Tt_o}{\Delta s(per \log cycle)}$$

where: 264 includes a conversion factor (incorporating English factor units conversion) in units of min/day, and

t_o = t at zero drawdown.

These equations assume that "u" is less than 0.05 (dimensionless) and the analytical solution to the equations is provided on semi-logarithmic plots (i.e., Figures E-3 through E-7).

Based upon this requirement, this method is theoretically applicable to pumping well PW-1 and PZ-205 and PZ-214 throughout the PW-1 test and the latter part of observation well M-18, M-18S, PZ-242, PZ-243 and PZ-251 during the PW-2 test when the conditions of "u" (above) are met. The following table includes the input parameters and resultant T and S values calculated (where applicable) for the observation wells/piezometers during these tests.

Observation Well/Piezometer	Q (gpm)	Δs log cycle	r (ft)	t_o (days)	T (gpd/ft)	S (dimensionless)
PZ-205	1.0	0.26	22.3	0.042	1015	0.026
PZ-214	1.0	0.207	14.2	0.054	1275	0.102
PW-1, Test Average	--	--	--	--	1145	0.064
M-18S	0.05	0.13	15	0.022	1015	0.030
PZ-242	0.5	0.15	40.7	0.49	880	0.078
PZ-243	0.5	0.125	27.5	0.44	1056	0.186
PZ-251	0.5	0.13	42.5	0.41	1015	0.069
PW-2 Test Average	--	--	--	--	992	0.09

Residual Drawdown Versus t/t' Method

The modified Theis method can also be applied to recovery data where the recovery data is plotted semi-logarithmically as residual drawdown s' versus the ratio of t/t' and analyzed in a straight line solution to calculate a transmissivity, T (Driscoll, 1986). This ratio t/t' is the time t since pumping started, divided by the time t' since pumping stopped; therefore the value for this quantity will approach "1" following shutdown. The transmissivity is calculated via the following equation:

$$T = \frac{264Q}{\Delta s'}$$

where

$\Delta s'$ = change in residual drawdown per log cycle

Input parameters and resultant T calculations for each pumping test (i.e., PZ-214 from the PW-1 test and M-18S from the PW-2 test) from Figures E-9 and E-10 are tabulated as follows.

Observation Well	Q (gpm)	Δ s' (ft)	T (gpd/ft)
PZ-214	1.0	0.165	1600
M-18S	0.5	0.11	1200
Observation Wells Average	--	--	1400

D. Interpretation and Evaluation of Pumping Test Data

Data yielding interpretive results for aquifer characteristics of the saturated fill material were provided by the pumping tests at PW-1 and PW-2. The observation wells and piezometers for each test depict actual aquifer response. In both tests the pumping wells themselves yielded data that are less reliable and more difficult to interpret because a decline in the saturated thickness becomes more drastic toward the end of each test. In addition, the heterogeneity of the fill material makes it difficult to obtain pumping well development to the point of hydraulic continuity and good well efficiency between the well screen and the fill aquifer.

PW-1

PZ 205 is located 22.3 feet to the northwest of PW-1 and PZ-214 14.2 feet northeast of PW-1 (Figure E-1). Semi-logarithmic plots of drawdown versus pumping time for observation piezometers PZ-205 and PZ-214 for the PW-1 test, which was conducted at a constant pumping rate for 7 hours, are shown on Figures E-3 and E-4. Aquifer transmissivities calculated at locations PZ-205 and PZ 214 by the Cooper and Jacob method were 1,015 gpd/ft and 1,275 gpd/ft, respectively, indicating comparable aquifer conditions. Respective storage coefficients of 0.026 and 0.102 were observed at both locations, indicating water-table (unconfined) conditions.

Semi-logarithmic plots for observation piezometers PZ-213 and PZ-204, located at comparable distances to the south, show no discernible response during the 7 hours of pumping (Tables E-1 and E-2). The reason for lack of response in PZ-213 is not readily discernible from the piezometer boring logs. Observation piezometer PZ-204 is set within a thin zone of saturated fill material, which may account for the lack of response in this piezometer.

The boring log for observation piezometer PZ-205 indicates that the saturated thickness of the fill material in this area is limited; however, the underlying clayey unit appears to contain less clay and more sand than at other locations and may be continuous with the overlying fill aquifer at this location. Note that the semi-log plot of drawdown versus pumping time in observation piezometer PZ-214 indicates an increase of drawdown slope in the later part of the test, suggesting that the expanding cone of depression intersects a thinner saturated zone of permeable material northeast of PZ-214.

Recovery data for PZ-214 indicate a transmissivity of 1,600 gpd/ft, which is slightly higher than that calculated from drawdown data. It is possible that pumping from the more permeable zones around PZ-214 and PZ-205 caused dewatering of this zone against less permeable material which flattened the slope of the recovery plot, thereby causing an apparent increase in the calculated transmissivity (Figures E-9 and E-10).

PW-2

Semi-logarithmic plots of pumping test data from the PW-2 test (Figures E-5 through E-8), which was conducted at a constant pumping rate for a period of 41 hours, indicate transmissivities ranging from 880 gpd/ft to 1,056 gpd/ft averaging 1,004 gpd/ft for 5 observation wells/piezometers set within the fill aquifer. Storage coefficient values were observed to range from 0.030 to 0.186, also indicating water table or unconfined conditions. A stronger response to the pumping of PW-2 was observed in monitoring well M-18 (completed in the underlying sand and gravel aquifer) than that observed in wells and piezometers completed in the fill material (see Tables E-3 and E-4). The reason for this phenomenon is not readily apparent; however, a breach in the confining clay unit which is in vertical and horizontal proximity to the bottom of the PW-2 well screen and borehole may be the mechanism. This mechanism may be a permeable stringer that extends into the sand and gravel aquifer zone screened by M-18.

The combination of limited saturated aquifer thickness and semi-confined conditions may have induced the strong, immediate response to pumping in M-18, which is indicated by the data in Tables E-3 and E-4. However, due to the anomalous nature of the response, reliable quantification of this data is not possible. Recovery data for M-18S indicate a transmissivity of 1,200 gpd/ft, which is fairly consistent with the data from other wells in the area.

The distance-drawdown plot of 6 observation wells and piezometers from the PW-2 pumping test (Figure E-2) indicates a fill material transmissivity of 1,467 gpd/ft (calculated by Cooper and Jacob method) which is slightly higher than the values calculated by other methods. The observed radius of pumping influence for the test as indicated in this plot is 110 feet. A storage coefficient of 0.062 was also calculated from the plot, which is indicative of water table conditions and consistent with values obtained using other methods. This plot, however, is loosely fitted, which suggests a fairly consistent transmissivity overall (time-drawdown plots) with considerable localized heterogeneity (distance-drawdown plot) causing the timing of influence to be irregularly related to distance from PW-2.

Time-drawdown plots for two observation wells/piezometers for the pumping test conducted in well PW-1 and the six observation wells/piezometers for the pumping test conducted in well PW-2 indicate water table conditions (unconfined) in the fill aquifer with transmissivities ranging from 880 gpd/ft to 1,275 gpd/ft, the average being 1042 gpd/ft. The median storage coefficient value is

0.078 as compared to the storage coefficient of 0.062 calculated for the distance-drawdown plot of the PW-2 test.

Summary

The hydraulic conductivity of the fill aquifer appears to range from 100 to 200 gpd/ft^2 (which is 13.5 to 27 ft/day or 5×10^{-3} to 1×10^{-2} cm/sec). The transmissivity is in range of 800 to 1600 gpd/ft. The storage coefficient is in the range of 0.02 to 0.20.

E. Instantaneous Discharge (Slug) Method

A total of 17 instantaneous discharge (slug) tests were conducted: in 15 monitoring wells and one piezometer completed in the overburden units (fill and sand and gravel), and one test in bedrock well BR-1. In M-9S, MW-23, and PZ-205 recovery was too rapid to record data by hand-held instrument. The 16 wells were analyzed as unconfined units and the bedrock well BR-1 as a confined system by the following methods:

(1) Instantaneous Discharge (Slug) Method (Bouwer and Rice, 1976; Bouwer and Rice, 1989) for unconfined aquifers

(2) Instantaneous Discharge (Slug) Method (Hvorslev, 1951) for confined aquifers

The long-term aquifer testing discussed in Sections B, C and D influences a wider area than aquifer hydraulic parameters estimated from instantaneous discharge (slug) tests and results are representative of mean conditions throughout a large region of the aquifer. Slug tests influence aquifer fluids within a small radius of the well or piezometer tested and therefore cannot be substituted for a pumping test. They can, however, provide good backup for pumping test data and information on aquifer variation. Slug tests are conducted by producing an instantaneous change in the water level in an observation well via the introduction (slug injection) or the removal (slug withdrawal) of a measured quantity of water and observing the resultant response of the water table over time. The criterion for the performance of either the slug injection or the slug withdrawal test is dependent on the pre-test water level in the observation well relative to the well screen intake.

Each slug test was conducted by dropping a sealed stainless steel cylinder (i.e., slug) into the well and measuring the resultant water level displacement. First, the static water level was measured with a hand-held instrument from the top of the casing prior to the test. The slug was then dropped into the well and completely submerged within a few seconds. Water levels were measured by hand-held instrument at regular intervals after displacement by the slug. Measurements were continued until approximately 90% recovery had occurred. The data from each well are presented in Table E-5. At some locations, after recovery from the first test was achieved, the slug was removed within a few seconds and recovering water levels were again monitored with a hand-held instrument. Data plots are presented in Figures E-11 thru E-26.

Data recorded from slug tests conducted in the unconfined aquifer consisting of the fill material were analyzed via the Bouwer and Rice (1976) method, a modified version of Hvorslev (1951) and Bouwer (1989) which applies to wells with water-table or unconfined conditions (Bouwer, 1989).

In order to calculate the hydraulic conductivity by the Bouwer and Rice method, the displacement (Y) or elevation of the water column in the riser from the static water level is plotted on a logarithmic scale against time, which is plotted on a linear scale. The other parameters are illustrated as follows:

Effective radius R_e, or radius of influence, is calculated based on an analogy to electrical current.

$$\ln (R_e/r_w) = \left[\frac{1.1}{\ln(H/r_w)} + \frac{A+(B)\ln(D-H/r_w)}{(L/r_w)}\right]^{-1}$$

For H < D cases A and B are derived graphically. (A and B are dimensionless parameters that are functions of L/r_w (Bouwer and Rice, 1976).

$$\text{or } \ln (R_e/r_w) = \left[\frac{1.1}{\ln(H/rw)} + \frac{C}{L/r_w}\right]^{-1}$$

C (a dimensionless parameter that is a function of L/r_w) is derived graphically (Figure E-28)

The hydraulic conductivity, K, is as follows:

$$K = \frac{r_c^2 \ln}{2Lt}\left(\ln\frac{Y_o}{Y_t}\right)$$

where:

r_c = the radius of the riser casing (feet)

r_w = the radius of the well and gravel pack combined (feet)

L = the screen length (feet)

H = saturated thickness above the bottom of the well (feet)

D = saturated thickness above the bottom of the aquifer (feet)

Y_o = maximum displacement (feet)

Y_t = displacement at time t (feet)

t = time since displacement (minutes)

These parameters are illustrated on Figure E-27.

A gravel pack correction is calculated for the r value (casing radius) if the water level rises or falls within the screened interval instead of the casing above the screen (Bouwer, 1989). The corrected radius = $[(1-p)\, r_c^2 + p r_w^2]^{1/2}$, where p is porosity typically estimated at 0.30.

The parameters and resultant hydraulic conductivities are summarized in Table E-6 for the 16 tested wells that had measurable results.

In addition, bedrock monitoring well BR-1 was slug tested using both a pressure transducer and a hand-held electronic instrument. The data in this case were analyzed in accordance with the Hvorslev (1951) method for confined aquifers as a confining clayey zone immediately overlies the screened bedrock interval. The data plots are presented on Figure E-29 and E-30 for hand-measured and transducer-generated data, respectively. The elevations, coordinates, stratigraphic horizons and water levels are presented in Table E-7. Hydraulic conductivity is calculated as follows:

$$K = \frac{r_c^2 \ln\left(\frac{2L}{r_w} + \sqrt{1 + \left(\frac{2L}{r_w}\right)^2}\right)}{2\, L_e t\ @\ 0.37H}$$

where $r_c = 0.083$ ft.

$r_w = 0.20$ ft

$L_e = 10$ ft

t@ 0.37H = time at 37% of displacement

$K = 2.58 \times 10^{-4}$ cm/sec or 0.73 ft/day for hand-measured data and

$K = 2.81 \times 20^{-4}$ cm/sec or 0.79 ft/day for transducer-generated data

These slug test data indicate an average fill unit hydraulic conductivity value of 1.25 feet/day for six wells, with a range of 0.45 to 2.80 ft/day; and an average sand and gravel unit value for 10 wells of 0.57 feet/day; with a range of 0.059 to 2.15 ft/day. The value obtained for the bedrock well BR-1, 0.73 ft/day, is slightly higher than that for the sand and gravel wells. The lower values for wells screened in the sand and gravel unit are consistent with this unit's higher silt and clay composition and irregular extent. Note that the value for M-18S derived from the slug test (2.80 ft/day) is lower than, but within an order of magnitude of, its pumping test derived value (18 ft/day with 7.5 feet of saturated thickness).

Table E-1

[illegible]	W1	[illegible]	[illegible]	MW6	PZ205	PZ214	PZ213	MW24	PW2	[illegible]	W189	PZ252	PZ243	PZ251	PZ242	PZ28
	0.025	-0.007	-0.057	-0.01	-0.026	-0.004	0.009	-0.007	0.152	0.02	-0.029	0.003	-0.007	0.012	0.034	-0.004
1.2	0.031	-0.004	-0.045	-0.01	-0.023	-0.007	0.009	-0.007	0.149	0.031	-0.032	0.003	-0.004	0.012	0.034	0
1.4	0.031	-0.004	-0.038	-0.01	-0.023	-0.007	0.006	-0.007	0.142	0.031	-0.032	0.003	-0.007	0.012	0.031	-0.004
1.6	0.041	0	-0.038	-0.007	-0.02	-0.004	0.009	0	0.139	0.031	-0.032	0.003	-0.007	0.012	0.034	-0.004
1.8	0.041	0	-0.038	-0.007	-0.02	0	0.012	0	0.406	0.031	-0.032	0.006	-0.007	0.012	0.034	-0.004
2	0.044	0	-0.038	-0.007	-0.02	-0.004	0.009	0	0.422	0.031	-0.032	0.006	-0.01	0.012	0.034	-0.007
2.2	0.047	0	-0.038	-0.007	-0.02	0	0.009	0	0.438	0.025	-0.042	0	-0.013	0.006	0.028	-0.016
2.4	0.05	-0.004	-0.038	-0.007	-0.02	0.003	0.009	0	0.45	0.025	-0.045	0	-0.013	0.006	0.028	-0.02
2.6	0.05	-0.007	-0.045	-0.01	-0.023	0	0.009	-0.007	0.476	0.031	-0.035	0.003	-0.01	0.006	0.034	-0.016
2.8	0.05	-0.007	-0.038	-0.01	-0.026	-0.004	0.006	-0.007	0.495	0.031	-0.032	0.006	-0.004	0.012	0.037	-0.01
3	0.05	-0.007	-0.045	-0.01	-0.026	0	0.006	-0.007	0.501	0.031	-0.029	0.006	0	0.012	0.041	-0.004
3.2	0.053	-0.007	-0.045	-0.013	-0.026	-0.004	0.003	-0.007	0.527	0.025	-0.026	0.009	0	0.012	0.041	0.003
3.4	0.05	-0.007	-0.045	-0.013	-0.026	-0.007	0.003	-0.007	0.536	0.031	-0.029	0.009	-0.007	0.018	0.041	0.006
3.6	0.053	-0.004	-0.045	-0.013	-0.026	-0.007	0.003	-0.007	0.543	0.031	-0.032	0.009	-0.01	0.018	0.041	0.003
3.8	0.06	-0.004	-0.045	-0.01	-0.026	-0.004	0.003	0	0.562	0.031	-0.032	0.009	-0.01	0.012	0.037	0.003
4	0.063	0	-0.045	-0.01	-0.023	-0.007	0.003	0	0.565	0.031	-0.032	0.009	-0.007	0.018	0.037	0
4.2	0.066	-0.004	-0.045	-0.01	-0.026	0	0.003	-0.007	0.577	0.031	-0.032	-0.042	-0.007	0.012	0.037	0
4.4	0.066	0	-0.045	-0.01	-0.026	0	0	-0.007	0.581	0.031	-0.032	-0.058	-0.004	0.012	0.041	0
4.6	0.069	0	-0.038	-0.007	-0.023	0.003	-0.004	0	0.574	0.031	-0.032	-0.058	-0.004	0.012	0.041	-0.004
4.8	0.076	0	-0.038	-0.007	-0.02	0.003	0.003	0	0.593	0.031	-0.032	-0.055	-0.004	0.012	0.041	0
5	0.076	-0.004	-0.038	-0.007	-0.02	0.003	-0.045	0	0.6	0.031	-0.032	-0.048	-0.004	0.012	0.041	0
5.2	0.079	0	-0.032	-0.007	-0.02	0.003	-0.089	-0.007	0.606	0.031	-0.032	-0.045	-0.004	0.006	0.041	-0.004
5.4	0.076	0	-0.038	-0.007	-0.02	0.003	-0.083	0	0.619	0.031	-0.032	-0.042	-0.007	0.012	0.041	-0.01
5.6	0.082	0	-0.038	-0.007	-0.02	0.006	-0.093	0	0.616	0.025	-0.038	-0.039	-0.013	0.012	0.037	-0.01
5.8	0.082	0	-0.038	-0.007	-0.023	0.003	-0.093	0	0.619	0.025	-0.045	-0.042	-0.016	0.006	0.034	-0.013
6	0.085	0	-0.045	-0.01	-0.023	0.003	-0.089	0	0.635	0.025	-0.048	-0.042	-0.016	0.012	0.034	-0.016
6.2	0.085	-0.007	-0.045	-0.01	-0.023	0	-0.146	0	0.641	0.025	-0.045	-0.039	-0.013	0.012	0.037	-0.013
6.4	0.082	-0.01	-0.045	-0.01	-0.026	-0.004	-0.194	-0.007	0.654	0.031	-0.032	-0.032	-0.01	0.012	0.041	-0.007
6.6	0.082	-0.01	-0.045	-0.013	-0.029	-0.004	-0.15	-0.007	0.663	0.031	-0.032	-0.029	-0.007	0.012	0.044	-0.007
6.8	0.085	-0.007	-0.045	-0.013	-0.029	-0.004	-0.146	-0.007	0.663	0.031	-0.032	-0.029	-0.004	0.012	0.044	-0.007
7	0.088	-0.007	-0.045	-0.013	-0.026	0	-0.14	-0.007	0.676	0.031	-0.029	-0.026	0	0.018	0.044	0
7.2	0.088	-0.01	-0.045	-0.013	-0.026	-0.004	-0.137	-0.007	0.685	0.031	-0.029	-0.023	0	0.018	0.044	0
7.4	0.095	-0.013	-0.045	-0.013	-0.026	-0.007	-0.137	-0.007	0.685	0.018	-0.032	-0.026	-0.007	0.012	0.041	0
7.6	0.095	-0.01	-0.045	-0.013	-0.026	-0.007	-0.134	-0.007	0.685	0.025	-0.042	-0.026	-0.016	0.006	0.037	0
7.8	0.098	-0.007	-0.045	-0.013	-0.026	-0.007	-0.131	-0.007	0.689	0.025	-0.045	-0.026	-0.016	0.006	0.037	0
8	0.098	-0.01	-0.045	-0.013	-0.026	-0.004	-0.127	-0.007	0.701	0.025	-0.042	-0.023	-0.013	0.006	0.037	0
8.2	0.101	-0.01	-0.045	-0.013	-0.026	-0.007	-0.121	-0.007	0.708	0.031	-0.038	-0.067	-0.01	0.012	0.041	0
8.4	0.098	-0.01	-0.045	-0.013	-0.026	-0.007	-0.118	-0.007	0.711	0.031	-0.038	-0.061	-0.007	0.012	0.044	0.003
8.6	0.104	-0.01	-0.045	-0.013	-0.026	-0.007	-0.115	0	0.714	0.031	-0.032	-0.058	-0.007	0.012	0.044	0.003
8.8	0.104	-0.007	-0.045	-0.01	-0.026	-0.007	-0.112	0	0.73	0.031	-0.029	-0.055	-0.007	0.012	0.047	0.003
9	0.11	-0.004	-0.045	-0.01	-0.023	-0.004	-0.108	-0.007	0.733	0.031	-0.026	-0.051	-0.007	0.018	0.047	0.003
9.2	0.11	-0.004	-0.057	-0.01	-0.023	-0.004	-0.112	-0.007	0.739	0.031	-0.026	-0.045	-0.004	0.018	0.05	0.003
9.4	0.11	0	-0.057	-0.007	-0.02	-0.004	-0.108	0	0.743	0.031	-0.026	-0.042	-0.004	0.018	0.05	0
9.6	0.117	0	-0.057	-0.007	-0.02	-0.004	-0.102	0	0.746	0.031	-0.023	-0.039	-0.004	0.018	0.05	0.003
9.8	0.114	0	-0.057	-0.01	-0.02	-0.004	-0.099	-0.007	0.749	0.031	-0.023	-0.035	-0.004	0.018	0.053	0
10	0.11	-0.007	-0.057	-0.01	-0.023	-0.007	-0.102	-0.007	0.752	0.031	-0.026	-0.032	-0.007	0.018	0.047	0
12	0.136	0	-0.051	-0.01	-0.029	-0.013	-0.083	-0.007	0.717	0.037	-0.029	-0.013	-0.004	-0.013	0.053	0.003
14	0.149	0.006	-0.146	-0.007	-0.026	-0.004	-0.07	0	0.701	0.037	-0.029	-0.004	-0.004	0.012	0.056	0
16	0.168	0.006	-0.127	-0.004	-0.045	0.009	-0.058	0	0.692	0.037	-0.026	-0.01	0	0.018	0.063	0.006
18	0.174	0.003	-0.12	-0.004	-0.052	0.003	-0.054	0	0.727	0.037	-0.032	-0.004	-0.01	0.018	0.06	-0.013
20	0.187	-0.054	-0.108	-0.01	-0.052	-0.004	-0.058	0	0.812	0.037	-0.026	0.003	-0.007	0.025	0.063	0
22	0.199	-0.045	-0.114	-0.007	-0.052	-0.004	-0.054	0	0.851	0.044	-0.029	0.003	-0.01	0.025	0.066	0
24	0.212	-0.029	-0.114	-0.004	-0.052	-0.007	-0.048	-0.007	0.873	0.044	-0.038	-0.029	-0.013	0.018	0.063	-0.01
26	0.215	-0.026	-0.114	-0.007	-0.055	-0.007	-0.067	-0.007	0.901	0.05	-0.029	-0.013	-0.007	0.018	0.066	-0.013
28	0.234	-0.016	-0.101	-0.004	-0.042	0.003	-0.045	0.006	0.939	0.044	-0.048	-0.035	-0.02	0.018	0.063	-0.023
30	0.237	-0.016	-0.095	-0.004	-0.042	0.003	-0.039	-0.013	0.983	0.063	-0.016	-0.004	-0.004	0.031	0.075	0.009
32	0.25	-0.016	-0.095	-0.007	-0.045	0.003	-0.032	0.006	1.012	0.069	-0.01	0.009	0	0.031	0.079	0.015
34	0.25	-0.029	-0.095	-0.007	-0.048	-0.007	-0.042	0	1.028	0.069	-0.01	-0.051	0	0.031	0.082	0.009
36	0.253	-0.026	-0.101	-0.007	-0.052	-0.004	-0.045	-0.007	1.054	0.069	-0.016	-0.032	-0.007	-0.026	0.079	-0.01
38	0.266	-0.029	-0.095	-0.007	-0.058	0	-0.039	-0.007	1.063	0.069	-0.029	-0.026	-0.02	-0.019	0.072	-0.016
40	0.269	-0.026	-0.095	-0.007	-0.061	-0.004	-0.042	-0.007	1.098	0.076	-0.023	-0.02	-0.01	0	0.075	-0.02
42	0.285	-0.013	-0.089	-0.004	-0.055	0.003	-0.045	0	1.13	0.082	-0.01	-0.007	-0.004	0.012	0.085	0.022
44	0.288	-0.026	-0.089	-0.004	-0.055	0.003	-0.058	0.006	1.143	0.082	-0.013	-0.032	-0.01	0.012	0.082	0.012
46	0.298	-0.02	-0.089	-0.004	-0.055	0.006	-0.051	0.006	1.155	0.094	-0.029	-0.01	-0.013	0.012	0.075	0.003
48	0.298	-0.023	-0.202	-0.007	-0.061	0	-0.039	0	1.181	0.094	-0.023	-0.026	-0.01	0.012	0.075	-0.004
50	0.304	-0.02	-0.398	-0.007	-0.055	0	-0.042	0	1.174	0.088	-0.038	-0.013	-0.023	-0.019	0.069	-0.023
52	0.313	-0.02	-0.404	-0.007	-0.052	0.006	-0.042	0	1.197	0.107	-0.023	0	-0.007	0.012	0.079	-0.007
54	0.313	-0.054	-0.372	-0.007	-0.055	0.003	-0.048	-0.007	1.2	0.107	-0.026	0.006	-0.016	0.012	0.075	0.003
56	0.32	-0.054	-0.354	-0.007	-0.052	0	-0.042	0	1.213	0.113	-0.026	0.006	-0.01	0.018	0.079	-0.023
58	0.329	-0.026	-0.347	0	-0.048	0.015	-0.032	0.006	1.216	0.107	-0.045	-0.007	-0.02	0.012	0.063	-0.032
60	0.317	-0.045	-0.354	-0.02	-0.128	-0.01	-0.039	-0.019	1.225	0.119	-0.026	-0.004	-0.013	0.018	0.069	-0.016
62	0.329	-0.051	-0.347	-0.016	-0.122	-0.019	-0.054	-0.019	1.213	0.132	0	-0.055	0	0.031	0.085	0.022

ED F	PW1	PZ202	PZ204	MW8	PZ205	PZ214	PZ213	MW24	PW2	[illegible]18	118S	PZ252	PZ243	PZ251	PZ242	PZ28
64	0.332	-0.058	-0.335	-0.01	-0.115	0	-0.054	0.006	1.213	0.132	0.013	-0.026	-0.004	-0.019	0.082	0.003
66	0.339	-0.048	-0.341	-0.01	-0.119	0.003	-0.045	-0.007	1.213	0.138	-0.004	-0.004	-0.004	0.006	0.088	0.009
68	0.358	-0.01	-0.328	0.009	-0.093	0.028	-0.032	0.012	1.222	0.138	-0.01	0.006	-0.007	0.012	0.088	0.003
70	0.355	-0.013	-0.335	0.003	-0.096	0.022	-0.039	0	1.273	0.145	0	0.015	0	0.018	0.091	0.022
72	0.348	-0.029	-0.322	-0.01	-0.112	-0.004	-0.045	-0.013	1.301	0.151	0	0.019	0.003	0.025	0.091	0.015
74	0.361	-0.013	-0.316	-0.004	-0.099	0.015	-0.051	0	1.295	0.138	-0.029	0.009	-0.026	0.018	0.082	-0.013
76	0.364	-0.02	-0.316	0	-0.106	0.006	-0.051	0	1.33	0.151	-0.013	0.025	-0.004	0.025	0.091	0.009
78	0.37	-0.004	-0.316	0.003	-0.09	0.025	-0.035	0	1.346	0.151	-0.016	0.019	-0.01	0.031	0.091	-0.007
80	0.38	0	-0.297	0.003	-0.083	0.031	-0.029	0.006	1.365	0.151	-0.016	0.022	-0.01	0.025	0.094	0
82	0.386	0.003	-0.291	0.003	-0.074	0.034	-0.023	0.006	1.387	0.164	-0.004	0.034	0	0.037	0.107	0.012
84	0.393	-0.039	-0.291	0.003	-0.074	0.028	-0.016	0.006	1.397	0.164	-0.013	0.025	-0.01	0.031	0.101	-0.007
86	0.393	-0.026	-0.322	0	-0.077	0.028	-0.02	0	1.403	0.164	-0.029	0.019	-0.016	0.031	0.098	-0.029
88	0.393	-0.023	-0.303	-0.004	-0.087	0.009	-0.02	0	1.422	0.164	-0.029	0.019	-0.013	0.031	0.091	-0.01
90	0.386	-0.042	-0.303	-0.013	-0.103	0	-0.029	-0.026	1.425	0.17	-0.019	0.019	-0.013	0.031	0.098	-0.007
92	0.38	-0.058	-0.303	-0.026	-0.125	-0.019	-0.051	-0.026	1.435	0.176	-0.019	-0.258	-0.013	0.031	0.098	-0.004
94	0.393	-0.054	-0.291	-0.02	-0.134	-0.01	-0.054	-0.013	1.451	0.17	-0.032	-0.188	-0.023	0.018	0.091	-0.029
96	0.418	-0.029	-0.278	-0.007	-0.122	0.018	-0.051	0.006	1.476	0.183	-0.01	-0.15	-0.01	0	0.107	0.006
98	0.421	-0.01	-0.272	0.006	-0.103	0.05	-0.032	0.006	1.486	0.189	-0.004	-0.124	-0.004	0.025	0.117	0.009
100	0.427	-0.013	-0.272	0.006	-0.096	0.047	-0.02	0.006	1.511	0.189	0.006	-0.102	0.006	0.031	0.126	0.019
120	0.459	-0.051	-0.259	-0.023	-0.182	0.006	-0.067	-0.013	1.606	0.214	-0.007	-0.035	-0.007	0.037	0.158	0
140	0.516	-0.007	-0.221	-0.007	-0.103	0.044	-0.032	-0.007	1.673	0.239	-0.01	-0.074	-0.01	0.018	0.177	0.003
160	0.567	-0.02	-0.196	-0.02	-0.115	0.044	-0.02	-0.013	1.727	0.271	-0.004	-0.007	-0.004	0.031	0.206	0.015
180	0.63	-0.013	-0.171	-0.007	-0.106	0.069	-0.029	0	1.781	0.284	0.003	0.012	-0.004	0.043	0.237	0.022
200	0.697	-0.013	-0.152	-0.013	-0.103	0.075	-0.042	-0.013	1.847	0.296	0	0.028	-0.004	0.018	0.256	0.015
220	0.76	-0.016	-0.152	-0.01	-0.106	0.085	-0.032	-0.007	2.006	0.309	0.003	0.038	-0.007	0.025	0.269	0.015
240	0.821	-0.067	-0.152	-0.026	-0.16	0.072	-0.058	-0.026	2.171	0.34	0.015	0.05	-0.004	0.043	0.288	0.025
260	0.912	-0.035	-0.127	-0.007	-0.106	0.123	-0.032	-0.007	2.216	0.359	0.015	0.05	-0.007	0.025	0.294	0.025
280	1.004	-0.039	-0.114	-0.01	-0.138	0.113	-0.054	0	2.276	0.391	0.018	0.063	-0.007	0.043	0.307	0.035
300	1.141	-0.061	-0.108	-0.007	-0.099	0.148	-0.039	-0.007	2.266	0.41	0.022	0.069	-0.007	0.05	0.325	0.035
320	1.264	-0.077	-0.127	-0.036	-0.134	0.11	-0.07	-0.045	2.273	0.435	0.028	0.076	-0.004	0.037	0.348	0.038
340	1.451	-0.042	-0.108	-0.013	-0.093	0.155	-0.035	-0.013	2.349	0.454	0.031	0.085	-0.004	0.05	0.354	0.044
360	1.632	-0.048	-0.082	0	-0.074	0.183	-0.032	-0.007	2.362	0.473	0.037	0.098	-0.004	0.056	0.376	0.05
380	1.806	-0.029	-0.076	-0.004	-0.067	0.186	-0.01	-0.007	2.428	0.492	0.044	0.101	0	0.056	0.392	0.044
400	1.965	-0.058	-0.076	-0.02	-0.09	0.158	-0.039	-0.026	2.444	0.505	0.047	0.114	0	0.062	0.408	0.057
420	-	-	-	-	-	-	-	-	2.476	0.517	0.053	0.123	0.003	0.069	0.427	0.063
440	-	-	-	-	-	-	-	-	2.52	0.53	0.056	0.101	0.003	0.05	0.436	0.063
460	-	-	-	-	-	-	-	-	2.542	0.542	0.056	0.123	0.003	0.056	0.443	0.073
480	-	-	-	-	-	-	-	-	2.558	0.555	0.056	0.133	0.003	0.069	0.449	0.076
500	-	-	-	-	-	-	-	-	2.587	0.561	0.06	0.146	0.006	0.075	0.465	0.079
520	-	-	-	-	-	-	-	-	2.596	0.568	0.06	0.149	0.006	0.081	0.474	0.082
540	-	-	-	-	-	-	-	-	2.6	0.574	0.06	0.155	0.006	0.081	0.477	0.086
560	-	-	-	-	-	-	-	-	2.511	0.568	0.056	0.158	0.006	0.087	0.481	0.089
580	-	-	-	-	-	-	-	-	2.625	0.561	0.056	0.158	0.006	0.075	0.487	0.089
600	-	-	-	-	-	-	-	-	2.882	0.574	0.06	0.165	0.009	0.081	0.49	0.092
620	-	-	-	-	-	-	-	-	2.987	0.593	0.066	0.174	0.009	0.087	0.503	0.095
640	-	-	-	-	-	-	-	-	3.041	0.612	0.066	0.174	0.009	0.094	0.503	0.098
660	-	-	-	-	-	-	-	-	3.12	0.624	0.066	0.177	0.009	0.1	0.509	0.098
680	-	-	-	-	-	-	-	-	3.203	0.631	0.063	0.174	0.009	-0.032	0.506	0.089
700	-	-	-	-	-	-	-	-	3.352	0.65	0.069	0.184	0.009	0.018	0.509	0.095
720	-	-	-	-	-	-	-	-	3.437	0.675	0.075	0.19	0.012	0.031	0.515	0.101
740	-	-	-	-	-	-	-	-	3.52	0.694	0.079	0.193	0.012	0.037	0.515	0.101
760	-	-	-	-	-	-	-	-	3.555	0.713	0.085	0.2	0.012	0.05	0.528	0.105
780	-	-	-	-	-	-	-	-	3.628	0.725	0.088	0.206	0.012	0.062	0.531	0.111
800	-	-	-	-	-	-	-	-	3.767	0.744	0.094	0.203	0.015	0.056	0.534	0.111
820	-	-	-	-	-	-	-	-	3.843	0.763	0.101	0.212	0.015	0.056	0.534	0.114
840	-	-	-	-	-	-	-	-	3.84	0.776	0.098	0.216	0.015	0.062	0.534	0.117
860	-	-	-	-	-	-	-	-	3.824	0.782	0.101	0.222	0.019	0.075	0.544	0.117
880	-	-	-	-	-	-	-	-	3.796	0.795	0.101	0.225	0.015	0.056	0.544	0.114
900	-	-	-	-	-	-	-	-	3.77	0.801	0.104	0.228	0.019	0.081	0.544	0.121
920	-	-	-	-	-	-	-	-	3.78	0.814	0.107	0.235	0.019	0.087	0.55	0.124
940	-	-	-	-	-	-	-	-	3.691	0.82	0.11	0.241	0.019	0.094	0.553	0.127
960	-	-	-	-	-	-	-	-	3.678	0.82	0.107	0.241	0.022	0.087	0.547	0.13
980	-	-	-	-	-	-	-	-	3.726	0.826	0.11	0.244	0.022	0.087	0.547	0.111
1000	-	-	-	-	-	-	-	-	3.774	0.826	0.107	0.247	0.022	0.094	0.55	0.137
1100	-	-	-	-	-	-	-	-	4.218	0.871	0.12	0.26	0.031	0.087	0.55	0.127
1200	-	-	-	-	-	-	-	-	4.335	0.915	0.113	0.279	0.031	0.119	0.534	0.14
1300	-	-	-	-	-	-	-	-	4.268	0.921	0.11	0.251	0.031	0.119	0.512	0.111
1400	-	-	-	-	-	-	-	-	4.218	0.915	0.113	0.289	0.038	0.144	0.5	0.13
1500	-	-	-	-	-	-	-	-	4.221	0.883	0.126	0.279	0.05	0.144	0.468	0.028
1600	-	-	-	-	-	-	-	-	4.205	0.864	0.11	0.26	0.044	0.157	0.468	0.082
1700	-	-	-	-	-	-	-	-	4.11	0.845	0.11	0.273	0.041	0.163	0.477	0.101
1800	-	-	-	-	-	-	-	-	3.904	0.845	0.126	0.289	0.047	0.157	0.509	0.015

Table E-1

Table E-1

ELAPSED TIME (MIN)	PW1	PZ202	PZ204	MW6	PZ205	PZ214	PZ213	MW24	PW2	M18	M18S	PZ252	PZ243	PZ251	PZ242	PZ28
1900	-	-	-	-	-	-	-	-	4.04	0.833	0.123	0.295	0.05	0.175	0.512	0.054
2000	-	-	-	-	-	-	-	-	4.097	0.801	0.12	0.301	0.054	0.182	0.522	0.076
2100	-	-	-	-	-	-	-	-	4.513	0.826	0.117	0.298	0.054	0.188	0.525	0.092
2200	-	-	-	-	-	-	-	-	4.538	0.801	0.113	0.305	0.057	0.194	0.544	0.105
2300	-	-	-	-	-	-	-	-	5.09	0.864	0.126	0.317	0.06	0.201	0.569	0.121
2400	-	-	-	-	-	-	-	-	6.413	0.89	0.126	0.327	0.063	0.175	0.572	0.133

Table E-2

ELAPSED TIME (MIN)	PW1	PZ202	PZ204	MW6	PZ205	PZ214	PZ213	MW24	PW2	M18	M18S	PZ252	PZ243	PZ251	PZ242	PZ28
1	-	-	-	-	-	-	-	-	0.35	-	-	-	-	-	-	-
2	0.06	-	-	-	-	-	-	-	0.47	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	0.54	-	-	-	-	-	-	-
4	0.09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	0.1	-	-	-	-	-	-	-	0.65	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	0.005	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	0.71	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	0.76	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	0.12	-	-	-	-	-	-	-	0.78	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	0.73	-	0.01	-	-	-	-	-
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	0.76	-	-	-	-	-	-	-
18	0.16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	0.83	-	-	-	-	-	-	-
20	-	-	-	-	-	-	0.02	-	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-	-	-	-	0.02	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	0.01	-	-	-	-	-	-
23	-	-	-	-	-	0.003	-	-	0.9	-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	-	-	-	0.02	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	0.02	-	-	-	-	-	-
27	-	-	-	-	-	0.003	-	-	0.97	-	-	-	-	-	-	-
28	0.22	-	-	-	-	-	0.02	-	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	1.03	-	0.03	-	-	-	-	-
32	-	-	-	-	-	-	-	-	-	0.02	-	-	-	-	-	-
33	-	-	-	-	-	0.003	-	-	-	-	-	-	-	-	-	-
35	0.24	-	-	-	-	-	-	-	1.1	-	-	-	-	-	-	-
40	-	-	-	-	-	-	0.02	-	1.14	-	-	-	-	-	-	-
41	-	-	-	-	-	-	-	-	-	-	0.03	-	-	-	-	-
42	-	-	-	-	-	-	-	-	-	0.05	-	-	-	-	-	-
45	-	-	-	-	-	0.01	-	-	1.2	-	0.04	-	-	-	-	-
46	-	-	-	-	-	-	-	-	-	0.06	-	-	-	-	-	-
50	-	-	-	-	-	-	-	-	1.24	-	-	-	-	-	-	-
55	-	-	-	-	-	-	-	-	1.27	-	-	-	-	-	-	-
58	-	-	-	-	0.03	-	-	-	-	-	-	-	-	-	-	-
60	-	-	-	-	-	-	-	-	1.28	-	0.05	-	-	-	-	-
61	-	-	-	-	-	-	-	-	-	0.095	-	-	-	-	-	-
63	-	-	-	-	-	-	-	-	-	-	-	-	-	0.005	0.005	-
67	0.33	-	-	-	-	0.01	-	-	-	-	-	-	-	-	-	-
70	-	-	-	-	-	-	-	-	1.35	-	-	-	-	-	-	-
72	-	-	-	-	-	0.03	-	-	-	-	-	-	-	-	-	-
74	0.35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
78	-	-	-	-	0.04	-	-	-	-	-	-	-	-	-	-	-
80	-	-	-	-	-	-	-	-	1.4	-	-	-	-	-	-	-
85	0.37	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
88	-	-	-	-	-	0.03	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	-	-	0.06	-	-	-	-	-
91	-	-	-	-	-	-	-	-	-	0.15	-	-	-	-	-	-
93	-	-	-	-	-	-	-	-	1.49	-	-	-	-	-	-	-
94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.005	-
95	-	-	-	-	-	-	-	-	-	-	-	-	-	0.005	-	-
100	-	-	-	-	-	-	-	-	1.57	-	-	-	-	-	-	-
102	-	-	-	-	-	-	0.02	-	-	-	-	-	-	-	-	-
103	0.41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
105	-	-	-	-	-	0.03	-	-	-	-	0.065	-	-	-	-	-
106	-	-	-	-	-	-	-	-	-	0.17	-	-	-	-	-	-
107	-	-	-	-	-	-	0.02	-	-	-	-	-	-	-	-	-
110	-	-	-	-	-	-	-	-	165	-	-	-	-	-	-	-
113	0.44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
119	-	-	-	-	0.06	-	0.02	-	-	-	-	-	-	-	-	-
120	-	-	-	-	-	0.04	-	-	167	-	-	-	-	-	-	-
122	0.46	-	-	-	-	-	-	-	-	-	0.075	-	-	-	-	-
123	-	-	-	-	-	-	-	-	-	0.19	-	0.005	-	-	-	-
125	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	-
127	-	-	-	-	0.07	-	-	-	-	-	-	-	-	0.01	-	-
133	-	0.005	-	-	-	-	-	-	-	-	-	-	-	-	-	-
135	-	-	-	-	-	-	-	-	1.76	-	-	-	-	-	-	-
138	-	-	-	-	-	-	-	-	-	-	0.08	-	-	-	-	-

TIM	V1	PZ202	PZ204	MW8	PZ205	PZ214	PZ213	MW24	PW2	M18	8S	PZ252	PZ243	PZ251	PZ242	PZ28
139	-	-	-	-	-	-	0.01	-	-	0.21	-	-	-	-	-	-
140	-	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-	-
150	0.52	-	-	-	-	-	-	-	1.77	-	-	-	-	-	-	-
151	-	-	-	-	-	-	-	-	-	-	0.085	-	-	-	-	-
152	-	-	-	-	-	-	-	-	-	0.235	-	-	-	-	-	-
153	-	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-	-
165	-	-	-	-	-	-	-	-	-	-	0.09	-	-	-	-	-
166	-	-	-	-	-	-	-	-	1.81	-	-	-	-	-	-	-
167	-	-	-	-	-	-	-	-	-	0.245	-	-	-	-	-	-
168	-	-	-	-	-	-	-	-	-	-	-	0.005	-	-	-	-
180	-	-	-	-	-	-	-	-	1.85	-	-	-	-	-	-	-
181	-	-	-	-	-	-	-	-	-	-	0.09	-	-	-	-	-
182	-	-	-	-	-	-	-	-	-	0.255	-	0.01	-	-	-	-
185	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	0.01	-
186	-	0.005	-	-	-	-	-	-	-	-	-	-	-	-	-	-
194	0.68	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
195	-	-	-	-	-	-	0.01	-	-	-	-	-	-	-	-	-
198	-	-	-	-	-	0.08	-	-	-	-	-	-	-	-	-	-
204	-	-	-	-	0.13	-	-	-	-	-	-	-	-	-	-	-
225	0.76	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
226	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-
232	-	-	-	-	0.15	-	-	-	-	-	-	-	-	-	-	-
235	0.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
240	-	-	-	-	-	-	-	-	2.23	-	-	-	-	-	-	-
241	-	-	-	-	-	-	-	-	-	-	0.12	-	-	-	-	-
242	-	-	-	-	-	-	-	-	-	0.32	-	0.01	-	-	-	-
244	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	-
245	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	-	-
278	1.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
285	-	-	-	-	-	0.15	-	-	-	-	-	-	-	-	-	-
292	-	-	-	-	0.18	-	-	-	-	-	-	-	-	-	-	-
300	-	-	-	-	-	-	-	-	2.33	-	-	-	-	-	-	-
301	-	-	-	-	-	-	-	-	-	-	0.13	-	-	-	-	-
302	-	-	-	-	-	-	-	-	-	0.39	-	-	-	-	-	-
303	-	-	-	-	-	-	-	-	-	-	-	0.015	-	-	-	-
304	-	0.005	-	-	-	-	-	-	-	-	-	-	-	0.01	0.015	-
313	-	-	-	-	-	-	0.01	-	-	-	-	-	-	-	-	-
331	-	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-
337	-	-	0.005	-	-	-	-	-	-	-	-	-	-	-	-	-
341	-	-	-	0.005	-	-	0.02	-	-	-	-	-	-	-	-	-
344	1.48	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
345	-	-	-	-	-	0.18	-	-	-	-	-	-	-	-	-	-
352	-	-	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-
360	1.62	-	-	-	-	-	-	-	2.43	-	-	-	-	-	-	-
361	-	-	-	-	-	-	-	-	-	-	0.14	-	-	-	-	-
362	-	-	-	-	-	-	-	-	-	0.45	-	0.02	-	-	-	-
363	-	-	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-
364	-	-	-	-	-	-	-	-	-	-	-	-	-	0.015	0.02	-
368	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01
372	1.73	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
405	2.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
406	-	-	-	-	-	0.21	-	-	-	-	-	-	-	-	-	-
412	-	-	-	-	0.22	-	-	-	-	-	-	-	-	-	-	-
418	2.24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
420	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
426	-	-	-	-	-	-	-	-	-	-	0.15	-	-	-	-	-
428	-	-	-	-	-	-	-	-	-	-	-	0.02	-	-	-	-
429	-	-	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-
430	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	-
431	-	0.01	-	-	-	-	-	-	-	-	-	-	-	0.02	-	-
432	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01
436	-	-	0.005	-	-	-	-	-	-	-	-	-	-	-	-	-
440	-	-	-	-	-	-	0.01	-	-	-	-	-	-	-	-	-
441	-	-	-	0.01	-	-	-	-	-	-	-	-	-	-	-	-
531	-	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-
537	-	-	0.005	-	-	-	-	-	-	-	-	-	-	-	-	-
541	-	-	-	-	-	-	0.02	-	-	-	-	-	-	-	-	-
543	-	-	-	0.02	-	-	-	-	-	-	-	-	-	-	-	-
555	-	-	-	-	-	-	-	-	2.55	-	-	-	-	-	-	-
557	-	-	-	-	-	-	-	-	-	-	0.17	-	-	-	-	-
558	-	-	-	-	-	-	-	-	-	0.55	-	-	-	-	-	-
560	-	-	-	-	-	-	-	-	-	-	-	0.02	-	-	-	-

Table E-2

EL / TIME (Mb	PW1	PZ202	PZ204	MW8	PZ205	PZ214	PZ213	MW24	PW2	M18	M188	PZ252	PZ243	PZ251	PZ242	PZ28
563	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	-	-
567	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	-
568	-	-	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-
593	-	-	-	-	-	-	-	-	2.88	-	-	-	-	-	-	-
627	-	-	-	-	-	-	-	0.008	-	-	-	-	-	-	-	-
631	-	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-
638	-	-	0.005	-	-	-	-	-	-	-	-	-	-	-	-	-
641	-	-	-	0.03	-	-	0.02	-	-	-	-	-	-	-	-	-
665	-	-	-	-	-	-	-	-	3.21	-	-	-	-	-	-	-
666	-	-	-	-	-	-	-	-	-	-	0.18	-	-	-	-	-
667	-	-	-	-	-	-	-	-	-	0.8	-	-	-	-	-	-
668	-	-	-	-	-	-	-	-	-	-	-	0.03	-	-	-	-
671	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01
673	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	-	-
677	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	-
678	-	-	-	-	-	-	-	-	-	-	-	-	0.02	-	-	-
688	-	-	-	-	-	-	-	-	3.35	-	-	-	-	-	-	-
692	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
695	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
697	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
702	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
703	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
704	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
709	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
712	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
714	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
723	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
739	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
741	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
754	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
782	-	-	-	-	-	-	-	-	3.7	-	-	-	-	-	-	-
784	-	-	-	-	-	-	-	-	-	-	0.21	-	-	-	-	-
785	-	-	-	-	-	-	-	-	-	0.71	-	-	-	-	-	-
787	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02
789	-	-	-	-	-	-	-	-	-	-	-	0.03	-	-	-	-
790	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	-	-
791	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04	-
792	-	-	-	-	-	-	-	-	-	-	-	-	0.02	-	-	-
800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
817	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
826	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
847	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
850	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
865	-	-	-	-	-	-	-	-	3.81	-	-	-	-	-	-	-
868	-	-	-	-	-	-	-	-	-	-	0.22	-	-	-	-	-
869	-	-	-	-	-	-	-	-	-	0.77	-	-	-	-	-	-
870	-	-	-	-	-	-	-	-	-	-	-	0.03	-	-	-	-
871	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02
873	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	-	-
874	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04	-
875	-	-	-	-	-	-	-	-	-	-	-	-	0.03	-	-	-
995	-	-	-	-	-	-	-	-	3.85	-	-	-	-	-	-	-
1002	-	-	-	-	-	-	-	-	-	-	-	-	0.02	-	-	-
1005	-	-	-	-	-	-	-	-	-	-	0.23	-	-	-	-	-
1006	-	-	-	-	-	-	-	-	-	0.8	-	-	-	-	-	-
1008	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01
1010	-	-	-	-	-	-	-	-	-	-	-	0.04	-	-	-	-
1011	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04	-	-
1013	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04	-
1021	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1026	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1030	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1031	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1058	-	-	-	-	-	-	-	-	3.92	-	-	-	-	-	-	-
1090	-	-	-	-	-	-	-	-	4.18	-	-	-	-	-	-	-
1091	-	-	-	-	-	-	-	-	-	-	0.22	-	-	-	-	-
1092	-	-	-	-	-	-	-	-	-	0.85	-	0.04	-	-	-	-
1094	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02
1095	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04	0.04	-
1233	-	-	-	-	-	-	-	-	4.27	-	-	-	-	-	-	-
1248	-	-	-	-	-	-	-	-	4.19	-	-	-	-	-	-	-
1250	-	-	-	-	-	-	-	-	-	-	0.22	-	-	-	-	-

Table E-2

Table E-2

ELAPSED TIME (MIN)	PW1	PZ202	PZ204	MW6	PZ205	PZ214	PZ215	MW24	PW2	M18	M18S	PZ252	PZ243	PZ251	PZ242	PZ28
1251	-	-	-	-	-	-	-	-	-	0.89	-	0.05	-	-	-	-
1255	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04	-	-
1258	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.015
1253	-	-	-	-	-	-	-	-	-	-	-	-	0.03	-	-	-
1254	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04	-
1375	-	-	-	-	-	-	-	-	4.24	-	-	-	-	-	-	-
1485	-	-	-	-	-	-	-	-	4.32	-	-	-	-	-	-	-
1486	-	-	-	-	-	-	-	-	-	-	0.22	-	-	-	-	-
1487	-	-	-	-	-	-	-	-	-	0.86	-	-	-	-	-	-
1488	-	-	-	-	-	-	-	-	-	-	-	-	0.05	-	-	-
1489	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.005	-
1490	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05	-	-
1491	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01
1722	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1723	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1728	-	-	-	-	-	-	-	-	4.07	-	-	-	-	-	-	-
1730	-	-	-	-	-	-	-	-	-	-	0.23	-	-	-	-	-
1731	-	-	-	-	-	-	-	-	-	0.83	-	-	-	-	-	-
1732	-	-	-	-	-	-	-	-	-	-	-	-	0.05	-	0.06	-
1734	-	-	-	-	-	-	-	-	-	-	-	-	-	0.06	-	0.02
1735	-	-	-	-	-	-	-	-	-	-	-	0.07	-	-	-	-
2000	-	-	-	-	-	-	-	-	4.18	-	-	-	-	0.06	-	-
2002	-	-	-	-	-	-	-	-	-	-	0.24	-	-	-	0.07	-
2003	-	-	-	-	-	-	-	-	-	0.79	-	-	-	-	-	-
2004	-	-	-	-	-	-	-	-	-	-	-	-	0.07	-	-	-
2007	-	-	-	-	-	-	-	-	-	-	-	0.07	-	-	-	-
2009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03
2220	-	-	-	-	-	-	-	-	-	0.87	-	-	-	-	-	-
2221	-	-	-	-	-	-	-	-	-	-	-	0.07	-	-	-	-
2228	-	-	-	-	-	-	-	-	-	-	-	-	-	0.06	-	-
2227	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	-
2317	-	-	-	-	-	-	-	-	4.14	-	-	-	-	-	-	-
2318	-	-	-	-	-	-	-	-	-	-	0.24	-	-	-	-	-
2324	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03
2328	-	-	-	-	-	-	-	-	-	-	-	-	0.07	-	-	-
2334	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03
2393	-	-	-	-	-	-	-	-	-	0.88	-	-	-	-	-	-
2408	-	-	-	-	-	-	-	-	-	0.87	-	-	-	-	-	-
2443	-	-	-	-	-	-	-	-	4.37	-	-	-	-	-	-	-
2450	-	-	-	-	-	-	-	-	4.42	-	-	-	-	-	-	-
2451	-	-	-	-	-	-	-	-	-	-	-	-	0.08	-	-	-
2452	-	-	-	-	-	-	-	-	0.24	-	-	-	-	-	-	-
2454	-	-	-	-	-	-	-	-	-	-	-	0.09	-	-	-	-
2455	-	-	-	-	-	-	-	-	-	-	-	-	-	0.06	-	-
2458	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.07	-

ELAPSED TIME (MIN)	P START/STOP ME RATIO FOR PW1 TEST	PUMP START/STOP TIME RATIO FOR PW2 TEST	PW1	PZ202	PZ204	MW8	PZ205	PZ214	PZ213	MW24	PW2	M18	M188	PZ252	PZ243	PZ251	PZ242	PZ28
1	1401.00	2461.00	2.117	-0.058	-0.108	-0.018	-0.077	0.155	-0.067	-0.026	4.915	0.852	0.12	0.279	0.063	0.157	0.572	0.114
1.2	1167.67	2051.00	2.11	-0.058	-0.101	-0.016	-0.08	0.155	-0.073	-0.026	4.83	0.852	0.12	0.279	0.063	0.157	0.572	0.114
1.4	1001.00	1758.14	2.107	-0.058	-0.101	-0.018	-0.08	0.155	-0.093	-0.026	4.741	0.852	0.12	0.279	0.066	0.157	0.572	0.114
1.6	876.00	1538.50	2.104	-0.058	-0.101	-0.016	-0.077	0.158	-0.099	-0.019	4.662	0.852	0.12	0.282	0.063	0.157	0.572	0.114
1.8	778.78	1367.67	2.104	-0.054	-0.101	-0.013	-0.074	0.161	-0.105	-0.026	4.563	0.852	0.12	0.282	0.066	0.157	0.572	0.117
2	701.00	1231.00	2.101	-0.051	-0.095	-0.01	-0.071	0.161	-0.099	-0.019	4.471	0.852	0.12	0.282	0.063	0.157	0.572	0.114
2.2	637.36	1119.18	2.098	-0.051	-0.095	-0.01	-0.071	0.164	-0.131	-0.019	4.386	0.852	0.12	0.282	0.063	0.157	0.569	0.114
2.4	584.33	1026.00	2.091	-0.048	-0.095	-0.01	-0.071	0.164	-0.127	-0.019	4.3	0.852	0.12	0.282	0.066	0.163	0.569	0.114
2.6	539.46	947.15	2.091	-0.048	-0.095	-0.01	-0.067	0.167	-0.124	-0.019	4.218	0.852	0.12	0.282	0.063	0.157	0.569	0.114
2.8	501.00	879.57	2.088	-0.048	-0.095	-0.007	-0.064	0.17	-0.121	-0.019	4.145	0.852	0.12	0.282	0.063	0.157	0.569	0.117
3	467.67	821.00	2.088	-0.051	-0.095	-0.007	-0.067	0.17	-0.121	-0.019	4.072	0.852	0.12	0.282	0.063	0.163	0.569	0.117
3.2	438.50	769.75	2.088	-0.051	-0.095	-0.01	-0.067	0.17	-0.115	-0.019	3.996	0.852	0.12	0.282	0.066	0.163	0.569	0.117
3.4	412.76	724.53	2.085	-0.051	-0.095	-0.01	-0.067	0.17	-0.108	-0.019	3.923	0.852	0.12	0.282	0.063	0.163	0.569	0.117
3.6	389.89	684.33	2.082	-0.058	-0.19	-0.01	-0.067	0.167	-0.102	-0.019	3.847	0.852	0.12	0.282	0.063	0.163	0.569	0.117
3.8	369.42	648.37	2.079	-0.058	-0.171	-0.013	-0.071	0.167	-0.099	-0.026	3.77	0.852	0.12	0.282	0.063	0.163	0.569	0.117
4	351.00	616.00	2.075	-0.058	-0.183	-0.013	-0.071	0.164	-0.096	-0.026	3.694	0.852	0.12	0.282	0.063	0.163	0.569	0.117
4.2	334.33	586.71	2.075	-0.054	-0.164	-0.013	-0.067	0.164	-0.089	-0.026	3.621	0.845	0.12	0.286	0.063	0.163	0.569	0.117
4.4	319.18	560.09	2.075	-0.051	-0.152	-0.01	-0.067	0.17	-0.083	-0.026	3.548	0.845	0.12	0.286	0.063	0.157	0.569	0.117
4.6	305.35	535.78	2.075	-0.048	-0.146	-0.01	-0.064	0.174	-0.077	-0.019	3.456	0.845	0.12	0.286	0.063	0.163	0.569	0.121
4.8	292.67	513.50	2.079	-0.051	-0.139	-0.01	-0.064	0.17	-0.073	-0.026	3.39	0.845	0.12	0.286	0.063	0.163	0.569	0.121
5	281.00	493.00	2.075	-0.051	-0.133	-0.01	-0.064	0.174	-0.07	-0.026	3.32	0.852	0.12	0.286	0.063	0.163	0.569	0.121
5.2	270.23	474.08	2.072	-0.051	-0.133	-0.01	-0.064	0.17	-0.07	-0.019	3.237	0.845	0.12	0.286	0.063	0.163	0.569	0.121
5.4	260.26	456.56	2.069	-0.054	-0.133	-0.013	-0.071	0.174	-0.067	-0.026	3.19	0.845	0.12	0.286	0.063	0.163	0.569	0.121
5.6	251.00	440.29	2.069	-0.051	-0.127	-0.01	-0.067	0.174	-0.061	-0.026	3.126	0.845	0.12	0.289	0.063	0.163	0.569	0.121
5.8	242.38	425.14	2.069	-0.051	-0.127	-0.007	-0.067	0.177	-0.061	-0.026	3.057	0.845	0.12	0.289	0.063	0.163	0.569	0.121
6	234.33	411.00	2.069	-0.048	-0.127	-0.01	-0.067	0.177	-0.058	-0.026	2.974	0.845	0.12	0.289	0.063	0.163	0.569	0.121
6.2	226.81	397.77	2.066	-0.051	-0.127	-0.01	-0.067	0.177	-0.058	-0.019	2.879	0.845	0.12	0.289	0.063	0.163	0.569	0.121
6.4	219.75	385.38	2.063	-0.058	-0.127	-0.01	-0.067	0.174	-0.058	-0.026	2.8	0.845	0.12	0.289	0.063	0.163	0.569	0.121
6.6	213.12	373.73	2.06	-0.058	-0.127	-0.01	-0.071	0.174	-0.054	-0.019	2.714	0.839	0.12	0.289	0.063	0.163	0.569	0.121
6.8	206.88	362.76	2.063	-0.054	-0.12	-0.013	-0.071	0.174	-0.054	-0.026	2.631	0.845	0.12	0.289	0.063	0.163	0.569	0.121
7	201.00	352.43	2.063	-0.051	-0.12	-0.023	-0.067	0.174	-0.051	-0.026	2.552	0.833	0.12	0.289	0.063	0.163	0.569	0.124
7.2	195.44	342.67	2.066	-0.048	-0.12	0	-0.061	0.18	-0.048	-0.019	2.473	0.845	0.12	0.292	0.063	0.163	0.569	0.124
7.4	190.19	333.43	2.066	-0.042	-0.114	0	-0.058	0.183	-0.045	-0.013	2.39	0.845	0.12	0.289	0.063	0.163	0.569	0.124
7.6	185.21	324.68	2.066	-0.042	-0.114	-0.004	-0.055	0.186	-0.045	-0.013	2.314	0.845	0.12	0.292	0.063	0.163	0.569	0.124
7.8	180.49	316.38	2.063	-0.042	-0.114	-0.004	-0.055	0.189	-0.042	-0.013	2.238	0.845	0.12	0.292	0.063	0.163	0.569	0.124
8	176.00	308.50	2.063	-0.042	-0.114	-0.004	-0.055	0.189	-0.042	-0.013	2.171	0.845	0.12	0.292	0.063	0.163	0.569	0.124
8.2	171.73	301.00	2.063	-0.042	-0.114	-0.004	-0.055	0.193	-0.042	-0.013	2.098	0.845	0.12	0.292	0.063	0.163	0.569	0.124
8.4	167.67	293.86	2.063	-0.039	-0.108	0	-0.052	0.196	-0.039	-0.007	2.032	0.845	0.12	0.292	0.063	0.163	0.569	0.124
8.6	163.79	287.05	2.063	-0.039	-0.108	0	-0.052	0.199	-0.035	-0.013	1.962	0.845	0.12	0.295	0.063	0.163	0.569	0.124
8.8	160.09	280.55	2.06	-0.035	-0.108	0	-0.052	0.199	-0.035	-0.013	1.898	0.845	0.12	0.295	0.063	0.163	0.569	0.124
9	156.56	274.33	2.06	-0.039	-0.108	0	-0.052	0.186	-0.032	-0.013	1.828	0.839	0.117	0.292	0.063	0.163	0.569	0.124
9.2	153.17	268.39	2.06	-0.035	-0.108	0	-0.048	0.186	-0.032	-0.013	1.771	0.839	0.12	0.295	0.063	0.163	0.569	0.124
9.4	149.94	262.70	2.056	-0.035	-0.108	0	-0.048	0.193	-0.032	-0.013	1.724	0.839	0.12	0.295	0.063	0.163	0.569	0.124
9.6	146.83	257.25	2.053	-0.039	-0.108	0	-0.048	0.189	-0.029	-0.013	1.673	0.839	0.12	0.295	0.063	0.163	0.569	0.124
9.8	143.86	252.02	2.053	-0.039	-0.108	0	-0.052	0.189	-0.032	-0.013	1.632	0.839	0.12	0.295	0.066	0.163	0.569	0.127
10	141.00	247.00	2.05	-0.042	-0.101	-0.004	-0.052	0.186	-0.032	-0.019	1.59	0.839	0.12	0.295	0.063	0.163	0.569	0.127
12	117.67	206.00	2.044	-0.029	-0.089	0	-0.048	0.189	-0.039	-0.013	1.349	0.845	0.117	0.298	0.066	0.169	0.569	0.127
14	101.00	176.71	2.037	-0.026	-0.089	0	-0.058	0.196	-0.029	-0.007	1.187	0.826	0.117	0.292	0.066	0.169	0.569	0.13
16	88.50	154.75	2.006	-0.051	-0.089	-0.016	-0.071	0.167	-0.039	-0.026	1.066	0.833	0.113	0.292	0.066	0.163	0.566	0.13
18	78.76	137.67	2.003	-0.042	-0.082	-0.01	-0.058	0.164	-0.035	-0.019	0.968	0.833	0.107	0.295	0.066	0.175	0.563	0.13
20	71.00	124.00	1.999	-0.029	-0.082	-0.004	-0.048	0.17	-0.032	-0.013	0.892	0.82	0.104	0.298	0.066	0.175	0.563	0.13
22	64.64	112.82	1.98	-0.105	-0.089	-0.01	-0.055	0.177	-0.029	-0.013	0.832	0.814	0.098	0.298	0.066	0.175	0.563	0.13
24	59.33	103.50	1.971	-0.077	-0.082	-0.007	-0.052	0.18	-0.026	-0.013	0.784	0.808	0.094	0.301	0.066	0.175	0.563	0.13
26	54.85	95.62	1.968	-0.054	-0.076	-0.013	-0.039	0.189	-0.02	-0.007	0.743	0.801	0.091	0.305	0.066	0.175	0.563	0.133
28	51.00	88.86	1.958	-0.048	-0.07	0	-0.036	0.189	-0.016	-0.007	0.704	0.795	0.088	0.305	0.066	0.175	0.563	0.133
30	47.67	83.00	1.949	-0.042	-0.07	0	-0.032	0.196	-0.016	-0.007	0.67	0.782	0.088	0.308	0.069	0.175	0.563	0.137
32	44.75	77.88	1.933	-0.042	-0.07	0	-0.032	0.193	-0.013	-0.019	0.638	0.776	0.088	0.308	0.069	0.175	0.566	0.137
34	42.18	73.35	1.914	-0.045	-0.07	-0.007	-0.042	0.183	-0.013	-0.013	0.616	0.763	0.085	0.311	0.069	0.175	0.566	0.14
36	39.89	69.33	1.901	-0.045	-0.07	-0.01	-0.045	0.177	-0.02	-0.026	0.6	0.757	0.086	0.311	0.069	0.182	0.566	0.14
38	37.84	65.74	1.892	-0.042	-0.076	-0.007	-0.039	0.186	-0.016	-0.019	0.587	0.757	0.085	0.314	0.073	0.182	0.569	0.146
40	36.00	62.50	1.889	-0.032	-0.07	-0.004	-0.029	0.199	-0.013	-0.019	0.574	0.744	0.082	0.314	0.076	0.182	0.569	0.146
42	34.33	59.57	1.866	-0.042	-0.076	-0.01	-0.042	0.189	-0.013	-0.026	0.562	0.738	0.079	0.317	0.076	0.182	0.572	0.146
44	32.82	56.91	1.857	-0.042	-0.076	-0.01	-0.042	0.18	-0.02	-0.026	0.549	0.732	0.072	0.317	0.076	0.182	0.572	0.133
46	31.43	54.48	1.85	-0.032	-0.064	-0.007	-0.036	0.177	-0.013	-0.013	0.536	0.725	0.072	0.317	0.076	0.182	0.569	0.143
48	30.17	52.25	1.838	-0.035	-0.064	-0.007	-0.039	0.177	-0.054	-0.019	0.523	0.719	0.069	0.32	0.076	0.188	0.572	0.14
50	29.00	50.20	1.831	-0.032	-0.064	-0.007	-0.042	0.183	-0.032	-0.013	0.511	0.713	0.063	0.32	0.073	0.182	0.569	0.14
52	27.92	48.31	1.822	-0.026	-0.057	0	-0.029	0.189	-0.016	-0.013	0.501	0.707	0.063	0.324	0.076	0.188	0.572	0.14
54	26.93	46.56	1.809	-0.032	-0.057	-0.007	-0.036	0.18	-0.01	-0.019	0.489	0.7	0.063	0.324	0.076	0.182	0.572	0.133
56	26.00	44.93	1.8	-0.032	-0.057	-0.007	-0.036	0.183	-0.01	-0.019	0.479	0.694	0.056	0.276	0.073	0.188	0.572	0.13
58	25.14	43.41	1.79	-0.023	-0.057	-0.004	-0.029	0.196	-0.007	-0.013	0.47	0.688	0.053	0.273	0.073	0.182	0.572	0.133
60	24.33	42.00	1.774	-0.029	-0.057	-0.007	-0.032	0.189	-0.007	-0.019	0.46	0.681	0.05	0.273	0.073	0.182	0.569	0.13

Table E-3

ELAPSEL TIME (MIN)	MP START/STOP E RATIO FOR PW1 TEST	PUMP START/STOP TIME RATIO FOR PW2 TEST	PW1	PZ202	PZ204	MW6	PZ205	PZ214	PZ213	MW24	PW2	M18	M18S	PZ252	PZ243	PZ251	PZ242	PZ28
62	23.58	40.68	1.768	-0.026	-0.064	-0.007	-0.029	0.196	-0.004	-0.019	0.454	0.675	0.05	0.276	0.076	0.188	0.572	0.143
64	22.88	39.44	1.755	-0.023	-0.064	-0.007	-0.029	0.196	0	-0.026	0.447	0.669	0.047	0.279	0.073	0.188	0.572	0.14
66	22.21	38.27	1.746	-0.02	-0.057	-0.004	-0.029	0.199	0	-0.019	0.441	0.662	0.047	0.279	0.073	0.182	0.576	0.137
68	21.59	37.18	1.733	-0.023	-0.057	-0.007	-0.029	0.202	0.003	-0.019	0.435	0.656	0.044	0.282	0.073	0.106	0.572	0.14
70	21.00	36.14	1.727	-0.02	-0.051	-0.007	-0.026	0.202	0.006	-0.013	0.428	0.65	0.044	0.282	0.073	0.125	0.576	0.14
72	20.44	35.17	1.717	-0.02	-0.051	-0.007	-0.026	0.199	0.006	-0.013	0.419	0.637	0.037	0.282	0.066	0.125	0.569	0.137
74	19.92	34.24	1.706	-0.016	-0.051	-0.007	-0.026	0.202	0.009	-0.019	0.412	0.631	0.034	0.279	0.066	0.131	0.566	0.137
76	19.42	33.37	1.695	-0.016	-0.051	-0.007	-0.023	0.202	0.009	-0.019	0.406	0.624	0.031	0.282	0.069	0.138	0.566	0.133
78	18.95	32.54	1.686	-0.016	-0.051	-0.007	-0.023	0.202	0.009	-0.013	0.403	0.624	0.037	0.286	0.076	0.15	0.572	0.149
80	18.50	31.75	1.676	-0.016	-0.051	-0.004	-0.023	0.186	0.009	-0.019	0.396	0.612	0.034	0.286	0.073	0.15	0.569	0.149
82	18.07	31.00	1.664	-0.02	-0.045	-0.007	-0.026	0.189	-0.023	-0.013	0.39	0.612	0.034	0.289	0.073	0.157	0.569	0.14
84	17.67	30.29	1.648	-0.02	-0.051	-0.007	-0.029	0.189	-0.013	-0.019	0.384	0.606	0.031	0.289	0.073	0.15	0.569	0.14
86	17.28	29.60	1.638	-0.023	-0.045	-0.01	-0.029	0.189	-0.004	-0.026	0.377	0.599	0.028	0.292	0.073	0.157	0.569	0.14
88	16.91	28.95	1.632	-0.013	-0.045	-0.004	-0.026	0.193	0	-0.019	0.374	0.593	0.031	0.292	0.069	0.157	0.566	0.143
90	16.56	28.33	1.622	-0.016	-0.045	-0.004	-0.023	0.199	0.003	-0.019	0.362	0.593	0.025	0.289	0.066	0.15	0.563	0.13
92	16.22	27.74	1.61	-0.02	[illegible]	-0.007	-0.026	0.199	0	-0.019	0.346	0.568	0.003	0.257	0.05	0.138	0.547	0.095
94	15.89	27.17	1.6	-0.016	[illegible]	-0.007	-0.023	0.202	0.003	-0.019	0.349	0.568	0.012	0.266	0.06	0.119	0.553	0.105
96	15.58	26.63	1.594	-0.013	[illegible]	-0.004	-0.02	0.205	0.003	-0.019	0.346	0.561	0.012	0.266	0.063	0.131	0.553	0.101
98	15.29	26.10	1.581	-0.016	-0.038	-0.007	-0.032	0.202	0	-0.019	0.349	0.568	0.025	0.279	0.076	0.15	0.563	0.124
100	15.00	25.60	1.568	-0.02	-0.045	-0.01	-0.026	0.202	-0.004	-0.019	0.346	0.561	0.031	0.282	0.076	0.157	0.566	0.137
120	12.67	21.50	1.47	-0.016	-0.038	-0.004	-0.016	0.202	0.003	-0.019	0.308	0.511	0.022	0.289	0.073	0.163	0.563	0.156
140	11.00	18.57	1.375	-0.016	-0.026	-0.004	-0.016	0.208	-0.004	-0.019	0.276	0.473	0.018	0.292	0.076	0.163	0.563	-0.004
160	9.75	16.38	1.28	-0.016	-0.013	-0.004	-0.013	0.212	0.009	-0.013	0.254	0.441	0.009	0.292	0.073	0.163	0.56	0.015
180	8.78	14.67	1.191	-0.013	-0.007	-0.004	-0.01	0.215	0.012	-0.013	0.241	0.416	0.009	0.292	0.079	0.175	0.563	0.035
200	8.00	13.30	1.099	-0.01	0	-0.004	0	0.218	0.015	-0.013	0.206	0.378	-0.007	0.273	0.066	0.175	0.547	0.012
220	7.36	12.18	1.011	-0.01	0.006	-0.004	0	0.212	-0.013	-0.013	0.171	0.366	-0.007	0.266	0.069	0.175	0.557	0.015
240	6.83	11.25	0.931	-0.016	-0.013	0	0.006	0.221	0.019	-0.013	0.168	0.347	-0.01	0.27	0.06	0.163	0.55	0.028
260	6.38	10.46	0.868	-0.007	0.006	0	0.009	0.221	0.028	-0.013	0.174	0.34	0	0.273	0.076	0.194	0.566	0.063
280	6.00	9.79	0.814	-0.004	0.018	-0.004	0.019	0.218	0.036	-0.007	0.161	0.315	0.006	0.266	0.076	0.194	0.566	0.066
300	5.67	9.20	0.767	0.003	0.031	0.006	0.031	0.218	0.047	-0.007	0.142	0.29	-0.032	0.247	0.06	0.188	0.541	0.05
320	5.38	8.69	0.719	0.006	0.044	0.006	0.035	0.215	0.05	-0.007	0.142	0.271	-0.013	0.247	0.073	0.201	0.544	0.07
340	5.12	8.24	0.681	0.009	0.05	0.003	0.041	0.212	0.053	-0.007	0.136	0.252	-0.01	0.26	0.076	0.188	0.553	0.057
360	4.89	7.83	0.646	0.009	0.056	0.003	0.035	0.202	0.05	-0.013	0.127	0.239	-0.01	0.251	0.076	0.194	0.567	0.079
380	4.68	7.47	0.614	0.012	0.063	0.003	0.031	0.196	0.05	-0.013	0.117	0.22	-0.023	0.241	0.069	0.194	0.547	0.07
400	4.50	7.15	0.586	0.015	0.069	0.006	0.047	0.199	0.06	-0.007	0.098	0.202	-0.035	0.228	0.06	0.194	0.534	0.063
420	4.33	6.86	0.564	0.019	0.075	0.006	0.057	0.199	0.063	0	0.095	0.183	-0.032	0.212	0.066	0.194	0.525	0.073
440	4.18	6.59	0.542	0.019	0.075	0.006	0.051	0.193	0.06	-0.007	0.098	0.17	-0.029	0.222	0.069	0.207	0.528	0.082
460	4.04	6.35	0.519	0.019	0.081	0.006	0.044	0.183	0.057	-0.013	0.079	0.151	-0.051	0.197	0.06	0.188	0.512	0.057
480	3.92	6.13	0.5	0.022	0.088	0.006	0.054	0.186	0.063	-0.007	0.069	0.126	-0.067	0.187	0.054	0.182	0.5	0.044
500	3.80	5.92	0.481	0.022	0.088	0.003	0.051	0.183	0.063	-0.007	0.076	0.119	-0.042	0.212	0.063	0.201	0.512	0.101
520	3.69	5.73	0.466	0.025	0.094	0.009	0.057	0.183	0.063	-0.007	0.063	0.107	-0.054	0.187	0.057	0.188	0.498	0.06
540	3.59	5.56	0.45	0.025	0.1	0.006	0.051	0.18	0.063	-0.007	0.066	0.107	-0.042	0.206	0.06	0.175	0.512	0.063
560	3.50	5.39	0.437	0.025	0.1	0	0.041	0.174	0.06	-0.013	0.069	0.119	-0.029	0.219	0.066	0.207	0.526	0.108
580	3.41	5.24	0.424	0.022	0.107	0	0.038	0.167	0.057	-0.013	0.06	0.107	-0.057	0.203	0.06	0.194	0.512	0.076
600	3.33	5.10	0.412	0.025	0.113	0	0.035	0.17	0.06	-0.013	0.06	0.113	-0.042	0.2	0.063	0.207	0.526	0.088
620	3.26	4.97	0.402	0.025	0.113	0	0.025	0.167	0.057	-0.019	0.057	c.107	-0.042	0.203	0.06	0.213	0.525	0.101
640	3.19	4.84	0.393	0.028	0.119	0.003	0.028	0.167	0.06	-0.013	0.057	0.107	-0.045	0.206	0.063	0.213	0.525	0.098
660	3.12	4.73	0.383	0.028	0.119	-0.004	0.025	0.167	0.06	-0.013	0.05	0.107	-0.048	0.206	0.057	0.207	0.525	0.098
680	3.06	4.62	0.374	0.031	0.126	0	0.025	0.167	0.06	-0.013	0.05	0.107	-0.042	0.203	0.063	0.207	0.526	0.106
700	3.00	4.51	0.367	0.028	0.132	0	0.025	0.164	0.06	-0.013	0.047	0.107	-0.045	0.2	0.06	0.213	0.534	0.105
720	2.94	4.42	0.361	0.031	0.132	-0.004	0.025	0.164	0.06	-0.013	0.044	0.113	-0.042	0.206	0.038	0.201	0.55	0.101
740	2.89	4.32	0.351	0.031	0.138	0	0.025	0.167	0.063	-0.013	0.044	0.119	-0.035	0.197	0.041	0.213	0.544	0.108
760	2.84	4.24	0.346	0.034	0.146	0.003	0.028	0.167	0.066	-0.007	0.041	0.113	-0.042	0.184	0.041	0.207	0.531	0.092
780	2.79	4.15	0.342	0.034	0.145	0.003	0.031	0.174	0.069	-0.007	0.041	0.107	-0.045	0.19	0.041	0.207	0.541	0.108
800	2.75	4.08	0.336	0.034	0.145	-0.004	0.038	0.174	0.072	-0.007	0.038	0.113	-0.042	0.193	0.041	0.213	0.55	0.114
820	2.71	4.00	0.332	0.038	0.151	0	0.038	0.174	0.072	-0.007	0.038	0.107	-0.042	0.2	0.041	0.213	0.541	0.121
840	2.67	3.93	0.329	0.038	0.157	0	0.038	0.129	0.053	-0.007	0.038	0.113	-0.038	0.203	0.041	0.207	0.544	0.127
860	2.63	3.86	0.326	-0.023	0.157	-0.004	0.038	0.161	0.076	-0.007	0.038	0.107	-0.042	0.2	0.041	0.213	0.544	0.13
880	2.59	3.80	0.323	0.006	0.157	0	0.041	0.158	0.079	-0.007	0.034	0.107	-0.042	0.203	0.041	0.213	0.55	0.133
900	2.56	3.73	0.32	0.019	0.163	0	0.044	0.164	0.082	-0.007	0.034	0.101	-0.045	0.2	0.044	0.213	0.547	0.133
920	2.52	3.67	0.317	0.028	0.17	0	0.047	0.164	0.082	0	0.031	0.101	-0.045	0.203	0.044	0.219	0.55	0.127
940	2.49	3.62	0.31	0.025	0.17	-0.004	0.038	0.155	0.072	-0.007	0.031	0.094	-0.045	0.203	0.044	0.219	0.553	0.133
960	2.46	3.56	0.307	0.025	0.17	-0.007	0.041	0.161	0.076	-0.007	0.031	0.094	-0.045	0.203	0.044	0.219	0.557	0.133
980	2.43	3.51	0.301	0.022	0.157	-0.007	0.041	0.148	0.076	-0.007	0.028	0.094	-0.045	0.206	0.044	0.219	0.557	0.137
1000	2.40	3.46	0.294	0.019	0.145	-0.01	0.038	0.142	0.072	-0.007	0.028	0.094	-0.042	0.203	0.044	0.219	0.55	0.137
1100	2.27	3.24	0.278	-4.358	0.025	-0.051	0.044	0.11	0.034	0	0.022	0.082	-0.048	0.2	0.044	0.219	0.56	0.143
1200	2.17	3.05	0.272	-4.304	0.094	-0.08	0.025	0.139	0.076	-0.013	0.022	0.088	-0.042	0.206	0.044	0.226	0.566	0.146
1300	2.08	2.89	0.272	-3.907	0.17	-0.077	0.009	0.132	0.072	-0.013	0.015	0.082	-0.051	0.2	0.044	0.226	0.563	0.146
1400	2.00	2.76	0.250	-3.762	0.145	-0.071	0.003	0.129	0.06	-0.007	0.015	0.088	-0.048	0.203	0.044	0.194	0.563	0.149
1500		2.64									0.019	0.113	-0.035	0.212	0.05	0.213	0.576	0.149
1600		2.54									0.019	0.113	-0.042	0.209	0.05	0.219	0.569	0.117

Table E-3

Table E-3

ELAPSED TIME (MIN)	PUMP START/STOP TIME RATIO FOR PW1 TEST	PUMP START/STOP TIME RATIO FOR PW2 TEST	PW1	PZ202	PZ204	MW8	PZ205	PZ214	PZ213	MW24	PW2	M18	M18S	PZ252	PZ243	PZ251	PZ242	PZ28
1700	-	2.45	-	-	-	-	-	-	-	-	0.012	0.101	-0.051	0.203	0.047	0.226	0.563	0.149
1800	-	2.37	-	-	-	-	-	-	-	-	-0.007	0.082	-0.092	0.181	0.022	0.207	0.544	0.101
1900	-	2.29	-	-	-	-	-	-	-	-	0.006	0.056	-0.054	0.184	0.05	0.238	0.538	0.082
2000	-	2.23	-	-	-	-	-	-	-	-	0.009	0.075	-0.054	0.187	0.05	0.238	0.538	0.127
2100	-	2.17	-	-	-	-	-	-	-	-	0.009	0.056	-0.057	0.184	0.05	0.238	0.541	0.127
2200	-	2.12	-	-	-	-	-	-	-	-	0.006	0.069	-0.048	0.193	0.047	0.238	0.534	0.121
2300	-	2.07	-	-	-	-	-	-	-	-	0.012	0.094	-0.045	0.2	0.047	0.246	0.534	0.127
2400	-	2.03	-	-	-	-	-	-	-	-	0.012	0.107	-0.042	0.206	0.05	0.245	0.557	0.137
2500	-	1.98	-	-	-	-	-	-	-	-	0.009	0.094	-0.054	0.197	0.05	0.245	0.531	0.137
2600	-	1.95	-	-	-	-	-	-	-	-	0.012	0.088	-0.048	0.203	0.05	0.245	0.55	0.137
2700	-	1.91	-	-	-	-	-	-	-	-	0.012	0.101	-0.045	0.206	0.054	0.245	0.557	0.133
2800	-	1.88	-	-	-	-	-	-	-	-	0.019	0.113	-0.032	0.216	0.054	0.251	0.566	0.149
2900	-	1.85	-	-	-	-	-	-	-	-	0.022	0.132	-0.032	0.222	0.054	0.251	0.572	0.156
3000	-	1.82	-	-	-	-	-	-	-	-	0.022	0.138	-0.038	0.222	0.054	0.245	0.569	0.146
3100	-	1.79	-	-	-	-	-	-	-	-	0.022	0.138	-0.035	0.219	0.057	0.251	0.563	0.143
3200	-	1.77	-	-	-	-	-	-	-	-	0.022	0.119	-0.035	0.212	0.06	0.257	0.566	0.143
3300	-	1.75	-	-	-	-	-	-	-	-	0.025	0.107	-0.042	0.209	0.06	0.251	0.553	0.152
3400	-	1.72	-	-	-	-	-	-	-	-	0.025	0.101	-0.042	0.209	0.066	0.257	0.557	0.143
3500	-	1.70	-	-	-	-	-	-	-	-	0.019	0.094	-0.048	0.203	0.057	0.257	0.557	0.14
3600	-	1.68	-	-	-	-	-	-	-	-	0.019	0.101	-0.042	0.19	0.06	0.257	0.557	0.146
3700	-	1.66	-	-	-	-	-	-	-	-	0.028	0.126	-0.029	0.212	0.06	0.257	0.572	0.162
3800	-	1.65	-	-	-	-	-	-	-	-	0.028	0.126	-0.026	0.219	0.063	0.263	0.588	0.168
3900	-	1.63	-	-	-	-	-	-	-	-	0.031	0.126	-0.029	0.219	0.063	0.263	0.579	0.168
4000	-	1.62	-	-	-	-	-	-	-	-	0.031	0.119	-0.032	0.216	0.063	0.263	0.585	0.165
4100	-	1.60	-	-	-	-	-	-	-	-	0.028	0.101	-0.042	0.209	0.063	0.257	0.582	0.162
4200	-	1.59	-	-	-	-	-	-	-	-	0.031	0.101	-0.032	0.212	0.063	0.263	0.576	0.162
4300	-	1.57	-	-	-	-	-	-	-	-	0.034	0.126	-0.016	0.222	0.066	0.263	0.594	0.175
4400	-	1.56	-	-	-	-	-	-	-	-	0.041	0.132	-0.013	0.231	0.069	0.27	0.598	0.181
4500	-	1.55	-	-	-	-	-	-	-	-	0.047	0.126	-0.01	0.235	0.076	0.263	0.591	0.188
4600	-	1.53	-	-	-	-	-	-	-	-	0.047	0.126	-0.01	0.238	0.082	0.276	0.588	0.194
4700	-	1.52	-	-	-	-	-	-	-	-	0.034	0.107	-0.038	0.203	0.069	0.27	0.563	0.143
4800	-	1.51	-	-	-	-	-	-	-	-	0.034	0.088	-0.023	0.216	0.073	0.276	0.566	0.165
4900	-	1.50	-	-	-	-	-	-	-	-	0.022	0.082	-0.042	0.203	0.06	0.257	0.553	0.152
5000	-	1.49	-	-	-	-	-	-	-	-	0.034	0.107	-0.023	0.209	0.073	0.27	0.576	0.168
5100	-	1.48	-	-	-	-	-	-	-	-	0.038	0.113	-0.016	0.212	0.073	0.27	0.585	0.175
5200	-	1.47	-	-	-	-	-	-	-	-	0.044	0.145	-0.01	0.225	0.073	0.257	0.604	0.184
5300	-	1.46	-	-	-	-	-	-	-	-	0.041	0.138	-0.019	0.225	0.073	0.276	0.604	0.178
5400	-	1.46	-	-	-	-	-	-	-	-	0.041	0.126	-0.026	0.222	0.073	0.27	0.604	0.181
5500	-	1.45	-	-	-	-	-	-	-	-	0.041	0.107	-0.026	0.222	0.076	0.276	0.607	0.178
5600	-	1.44	-	-	-	-	-	-	-	-	0.041	0.113	-0.023	0.222	0.076	0.27	0.607	0.178
5700	-	1.43	-	-	-	-	-	-	-	-	0.041	0.119	-0.023	0.222	0.076	0.245	0.591	0.184
5800	-	1.42	-	-	-	-	-	-	-	-	0.044	0.132	-0.016	0.228	0.079	0.257	0.601	0.162
5900	-	1.42	-	-	-	-	-	-	-	-	0.044	0.126	-0.016	0.235	0.079	0.27	0.598	0.162

Table E-4

ELAPSED TIME(MIN)	PUMP START/STOP TIME RATIO PW1 TEST	PUMP START/STOP TIME RATIO PW2 TEST	PW1	PZ202	PZ204	MW6	PZ205	PZ214	PZ215	MW24	PW2	MW18	MW18B	PZ252	PZ243	PZ251	PZ242	PZ28
1	1401.00	-	2.14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	467.67	-	2.14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	281.00	-	2.1	-	-	-	0.225	-	-	-	-	-	-	-	-	-	-	-
8	176.00	-	2.08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	156.56	-	-	-	-	-	-	0.21	-	-	-	-	-	-	-	-	-	-
12	117.67	-	2.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	108.69	-	-	-	-	-	0.23	-	-	-	-	-	-	-	-	-	-	-
15	94.33	-	2.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	83.35	-	-	-	-	-	-	0.21	-	-	-	-	-	-	-	-	-	-
20	71.00	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24	59.33	-	-	-	-	-	0.234	-	-	-	-	-	-	-	-	-	-	-
25	57.00	-	1.97	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	51.00	-	-	-	-	-	-	0.215	-	-	-	-	-	-	-	-	-	-
30	47.67	-	1.95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45	32.11	-	1.88	-	-	-	-	0.22	-	-	-	-	-	-	-	-	-	-
49	28.57	-	-	-	-	-	0.24	-	-	-	-	-	-	-	-	-	-	-
53	27.42	-	-	-	-	-	-	0.22	-	-	-	-	-	-	-	-	-	-
45	32.11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
77	19.18	-	1.69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
80	18.50	-	-	-	-	-	-	0.22	-	-	-	-	-	-	-	-	-	-
90	16.56	-	1.63	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	15.74	-	-	-	-	-	0.25	-	-	-	-	-	-	-	-	-	-	-
110	13.73	-	1.52	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
114	13.28	-	-	-	-	-	-	0.23	-	-	-	-	-	-	-	-	-	-
120	12.67	-	1.47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
213	7.57	-	1.04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
215	7.51	-	-	-	-	-	-	0.24	-	-	-	-	-	-	-	-	-	-
272	6.15	-	-	-	0.005	-	-	-	-	-	-	-	-	-	-	-	-	-
275	6.09	-	-	-	-	0.68	-	-	-	-	-	-	-	-	-	-	-	-
277	6.05	-	-	-	-	-	-	-	0.02	-	-	-	-	-	-	-	-	-
278	6.04	-	-	-	-	-	-	-	-	-0.005	-	-	-	-	-	-	-	-
282	5.98	-	-	-	-	0.68	-	-	-	-	-	-	-	-	-	-	-	-
283	5.95	-	-	-0.19	-	-	-	-	-	-	-	-	-	-	-	-	-	-
284	5.93	-	-	-	-	-	-	-	0.02	-	-	-	-	-	-	-	-	-
289	5.84	-	-	-	0.005	-	-	-	-	-	-	-	-	-	-	-	-	-
292	5.79	-	-	-	-	-	-	-	0.02	-	-	-	-	-	-	-	-	-
294	5.76	-	-	-	-	0.68	-	-	-	-	-	-	-	-	-	-	-	-
303	5.62	-	-	-	-	-	-	-	0.02	-	-	-	-	-	-	-	-	-
319	5.39	-	-	-	-	0.685	-	-	-	-	-	-	-	-	-	-	-	-
321	5.36	-	-	-	-	-	-	-	0.03	-	-	-	-	-	-	-	-	-
397	4.53	-	-	-	-	-	-	-	0.02	-	-	-	-	-	-	-	-	-
406	4.45	-	-	-	-	0.68	-	-	-	-	-	-	-	-	-	-	-	-
427	4.28	-	-	-	-	0.685	-	-	-	-	-	-	-	-	-	-	-	-
430	4.26	-	-	-	-	-	-	-	0.02	-	-	-	-	-	-	-	-	-
601	3.33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
602	3.33	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-
606	3.31	-	-	-	-	0.695	-	-	-	-	-	-	-	-	-	-	-	-
610	3.30	-	-	-	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-
611	3.29	-	-	-	-	-	-	-	0.05	-	-	-	-	-	-	-	-	-
838	2.67	-	0.34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
839	2.67	-	-	-	-	-	-	0.19	-	-	-	-	-	-	-	-	-	-
906	2.55	-	0.31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1311	2.07	-	-	-	0.03	-	-	-	0.07	-	-	-	-	-	-	-	-	-
1314	2.07	-	-	-	-	0.69	-	-	-	-	-	-	-	-	-	-	-	-
1	-	2461	-	-	-	-	-	-	-	-	4.79	-	-	-	-	-	-	-
2	-	1231	-	-	-	-	-	-	-	-	4.33	-	-	-	-	-	-	-
3	-	821	-	-	-	-	-	-	-	-	4.04	-	-	-	-	-	-	-
5	-	493	-	-	-	-	-	-	-	-	3.35	-	-	-	0.07	-	-	-
6	-	411	-	-	-	-	-	-	-	-	-	0.87	-	-	-	-	-	-
8	-	308.6	-	-	-	-	-	-	-	-	2.19	-	-	-	-	-	-	-
9	-	274.33	-	-	-	-	-	-	-	-	-	-	0.24	-	-	-	-	-
12	-	206	-	-	-	-	-	-	-	-	1.37	-	-	-	-	-	-	-
13	-	190.23	-	-	-	-	-	-	-	-	-	-	-	6.96	-	-	-	-
14	-	176.71	-	-	-	-	-	-	-	-	-	0.84	0.22	-	-	-	-	-
15	-	165	-	-	-	-	-	-	-	-	1.13	-	-	-	-	-	-	-
46	-	54.48	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50	-	50.2	-	-	-	-	-	-	-	-	0.53	-	-	0.07	-	-	-	-
52	-	48.31	-	-	-	-	-	-	-	-	-	-	0.19	-	-	-	-	-
54	-	46.56	-	-	-	-	-	-	-	-	-	0.68	-	-	-	-	-	-
63	-	40.05	-	-	-	-	-	-	-	-	0.47	-	-	-	-	-	-	-
65	-	38.85	-	-	-	-	-	-	-	-	-	-	0.16	-	-	-	-	-

ELAPSED TIME(MIN)	PUMP START/STOP TIME RATIO PW1 TEST	PUMP START/STOP TIME RATIO PW2 TEST	PW1	PZ202	PZ204	MW6	PZ205	PZ214	PZ213	MW24	PW2	MW18	MW18S	PZ252	PZ243	PZ251	PZ242	PZ28
66	-	38.27	-	-	-	-	-	-	-	-	-	0.67	-	-	-	-	-	0.02
67	-	37.72	-	-	-	-	-	-	-	-	-	-	-	-	-	0.07	-	-
69	-	36.65	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
70	-	36.14	-	-	-	-	-	-	-	-	-	-	-	-	0.06	-	-	-
87	-	29.28	-	-	-	-	-	-	-	-	0.38	-	-	-	-	-	-	-
89	-	28.64	-	-	-	-	-	-	-	-	-	-	0.14	-	-	-	-	-
90	-	28.33	-	-	-	-	-	-	-	-	-	0.59	-	0.06	-	-	-	-
93	-	27.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02
94	-	27.17	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	-	-
95	-	26.89	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.06	-
96	-	26.63	-	-	-	-	-	-	-	-	-	-	-	-	0.07	-	-	-
121	-	21.33	-	-	-	-	-	-	-	-	0.32	-	-	-	-	-	-	-
123	-	21	-	-	-	-	-	-	-	-	-	0.51	0.12	-	-	-	-	-
125	-	20.68	-	-	-	-	-	-	-	-	-	-	-	0.08	0.07	-	-	-
127	-	20.37	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	-
128	-	20.22	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	-	-
129	-	20.07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02
153	-	17.08	-	-	-	-	-	-	-	-	0.28	-	-	-	-	-	-	-
154	-	16.97	-	-	-	-	-	-	-	-	-	-	0.12	-	-	-	-	-
155	-	16.87	-	-	-	-	-	-	-	-	-	0.44	-	-	-	-	-	-
156	-	16.77	-	-	-	-	-	-	-	-	-	-	-	0.08	-	-	-	-
157	-	16.67	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
158	-	16.57	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	-	-
159	-	16.47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.07	-
161	-	16.28	-	-	-	-	-	-	-	-	-	-	-	-	0.075	-	-	-
198	-	13.42	-	-	-	-	-	-	-	-	0.31	-	-	-	-	-	-	-
199	-	13.36	-	-	-	-	-	-	-	-	-	-	0.11	-	-	-	-	-
200	-	13.3	-	-	-	-	-	-	-	-	-	0.38	-	-	-	-	-	-
201	-	13.24	-	-	-	-	-	-	-	-	-	-	-	0.08	-	-	-	-
202	-	13.18	-	-	-	-	-	-	-	-	-	-	-	-	0.075	-	-	-
203	-	13.12	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	0.075	-
204	-	13.06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.025
211	-	12.66	-	-	-	-	-	-	-	-	-	-	-	0.07	-	-	-	-
227	-	11.84	-	-	-	-	-	-	-	-	8.79	-	-	-	-	-	-	-
228	-	11.79	-	-	-	-	-	-	-	-	-	-	0.09	-	-	-	-	-
230	-	11.7	-	-	-	-	-	-	-	-	-	-	-	-	0.06	-	-	-
231	-	11.65	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	-
235	-	11.47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03
229	-	11.74	-	-	-	-	-	-	-	-	-	0.36	-	-	-	-	-	-
232	-	11.6	-	-	-	-	-	-	-	-	-	-	-	-	-	0.07	-	-
316	-	8.78	-	-	-	-	-	-	-	-	8.79	-	-	-	-	-	-	-
317	-	8.76	-	-	-	-	-	-	-	-	-	-	0.09	-	-	-	-	-
318	-	8.74	-	-	-	-	-	-	-	-	-	0.28	-	-	-	-	-	-
320	-	8.69	-	-	-	-	-	-	-	-	-	-	-	0.07	-	-	-	-
323	-	8.62	-	-	-	-	-	-	-	-	-	-	-	-	0.07	-	-	-
324	-	8.59	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.07	-
325	-	8.57	-	-	-	-	-	-	-	-	-	-	-	-	-	0.07	-	-
326	-	8.55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02
437	-	6.63	-	-	-	-	-	-	-	-	8.68	-	-	-	-	-	-	-
438	-	6.62	-	-	-	-	-	-	-	-	-	-	0.07	-	-	-	-	-
439	-	6.6	-	-	-	-	-	-	-	-	-	0.17	-	-	-	-	-	-
440	-	6.59	-	-	-	-	-	-	-	-	-	-	-	0.07	-	-	-	-
441	-	6.58	-	-	-	-	-	-	-	-	-	-	-	-	0.07	-	-	-
442	-	6.57	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	-
443	-	6.55	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	-	-
447	-	6.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02
529	-	5.65	-	-	-	-	-	-	-	-	8.67	-	0.07	-	-	-	-	-
530	-	5.64	-	-	-	-	-	-	-	-	-	0.11	-	-	-	-	-	-
531	-	5.63	-	-	-	-	-	-	-	-	-	-	-	0.08	-	-	-	-
532	-	5.62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-1.04	-
533	-	5.62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	-
534	-	5.61	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	-	-
535	-	5.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02
1406	-	2.75	-	-	-	-	-	-	-	-	8.61	-	-	-	-	-	-	-
1408	-	2.75	-	-	-	-	-	-	-	-	-	0.08	0.08	-	-	-	-	-
1409	-	2.75	-	-	-	-	-	-	-	-	-	-	-	0.09	-	-	-	-
1410	-	2.74	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03
1411	-	2.74	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	-	-
1412	-	2.74	-	-	-	-	-	-	-	-	-	-	-	-	0.06	-	0.09	-

TABLE E-5 SLUG TEST DATA

time	mw22	time	y @ mw22	time	mw18s	time	y @mw18	mw18	time	y @mw18	mw13	time
0.5	9.71	0.5	0.42	0.5	7.46	0.5	0.14	6.82	0.5	1.96	10.55	0.5
1	9.76	1	0.37	1	7.5	1	0.1	7.04	1	1.74	10.56	1
1.5	9.8	1.5	0.33	1.5	7.51	1.5	0.09	7.12	1.5	1.66	10.57	1.5
2	8.85	2	1.28	2	7.52	2	0.08	7.17	2	1.61	10.58	2
2.5	9.86	2.5	0.27	2.5	7.52	2.5	0.08	7.22	2.5	1.56	10.6	2.5
3	9.87	3	0.26	3	7.53	3	0.07	7.3	3	1.48	10.6	3
3.5	9.89	3.5	0.24	3.5	7.54	3.5	0.06	7.33	3.5	1.45	10.61	3.5
4	9.91	4	0.22	4	7.54	4	0.06	7.37	4	1.41	10.62	4
4.5	9.92	4.5	0.21	4.5	7.54	4.5	0.06	7.4	4.5	1.38	10.64	4.5
5	9.93	5	0.2	5	7.54	5	0.06	7.47	5	1.31	10.65	5
6	9.95	6	0.18	6	7.54	6	0.06	7.56	6	1.22	10.66	6
7	9.97	7	0.16	7	7.54	7	0.06	7.59	7	1.19	10.68	7
8	9.97	8	0.16	8	7.55	8	0.05	7.65	8	1.13	10.7	8
9	9.99	9	0.14	9	7.55	9	0.05	7.74	9	1.04	10.71	9
10	10	10	0.13	10	7.55	10	0.05	7.76	10	1.02	10.72	10
12	10.02	12	0.11	12	7.55	12	0.05	7.8	12	0.98	10.74	12
14	10.03	14	0.1	14	7.55	14	0.05	7.86	14	0.92	10.76	14
16	10.04	16	0.09	16	7.56	16	0.04	7.91	16	0.87	10.78	16
18	10.05	18	0.08	18	7.56	18	0.04	7.93	18	0.85	10.8	18
20	10.08	20	0.05	20	7.56	20	0.04	8	20	0.78	10.81	20
25	10.08	25	0.05	25	7.57	25	0.03	8.03	25	0.75	10.84	25
30	10.09	30	0.04	30	7.57	30	0.03	8.08	30	0.7	10.87	30
40	10.09	40	0.04	40	7.57	40	0.03	8.14	40	0.64	10.91	40
50	10.09	50	0.04	50	7.57	50	0.03	8.2	50	0.58	10.95	50
60		60		60	7.57	60	0.03	8.23	60	0.55	10.99	60
70		70		70	7.57	70	0.03	8.25	70	0.53	11.01	70
80		80		80	7.57	80	0.03	8.26	80	0.52	11.03	80
90	10.11	90	0.02	90		90		8.29	90	0.49		90
100		100		100	7.58	100	0.02	8.29	100	0.49	11.06	100
110		110		110		110			110			110
120		120		120		120			120		11.08	120
130	10.11	130	0.02	130	7.58	130	0.02	8.3	130	0.48		130
140		140		140		140			140			140
150	10.11	150	0.02	150		150			150			150
160		160		160		160			160			160
170		170		170		170		8.31	170	0.47		170

TABLE E-5 SLUG TEST DATA

y @mw13	mw19	time	y @ mw19	mw2	time	y @mw2	mw21	time	y @ mw21	pz205	time	y @pz205
0.67	5.64	0.5	1.84	9.06	0.5	0.38	9.33	0.5	0.5	7.56	0.5	0.1
0.66	5.93	1	1.55	9.08	1	0.36	9.48	1	0.35	7.56	1	0.1
0.65	6.12	1.5	1.36	9.08	1.5	0.36	9.56	1.5	0.27	7.57	1.5	0.09
0.64	6.23	2	1.25	9.1	2	0.34	9.6	2	0.23	7.56	2	0.1
0.62	6.33	2.5	1.15	9.1	2.5	0.34	9.62	2.5	0.21	7.57	2.5	0.09
0.62	6.43	3	1.05	9.11	3	0.33	9.65	3	0.18	7.57	3	0.09
0.61	6.53	3.5	0.95	9.12	3.5	0.32	9.66	3.5	0.17	7.57	3.5	0.09
0.6	6.61	4	0.87	9.12	4	0.32	9.68	4	0.15	7.58	4	0.08
0.58	6.67	4.5	0.81	9.13	4.5	0.31	9.69	4.5	0.14	7.58	4.5	0.08
0.57	6.72	5	0.76	9.14	5	0.3	9.7	5	0.13	7.58	5	0.08
0.56	6.95	6	0.53	9.15	6	0.29	9.72	6	0.11	7.59	6	0.07
0.54	7.01	7	0.47	9.16	7	0.28	9.74	7	0.09	7.6	7	0.06
0.52	7.01	8	0.47	9.17	8	0.27	9.76	8	0.07	7.6	8	0.06
0.51	7.03	9	0.45	9.18	9	0.26	9.76	9	0.07	7.61	9	0.05
0.5	7.04	10	0.44	9.19	10	0.25	9.76	10	0.07	7.61	10	0.05
0.48	7.09	12	0.39	9.2	12	0.24	9.76	12	0.07	7.62	12	0.04
0.46	7.13	14	0.35	9.21	14	0.23	9.77	14	0.06	7.63	14	0.03
0.44	7.16	16	0.32	9.22	16	0.22	9.77	16	0.06	7.64	16	0.02
0.42	7.16	18	0.32	9.23	18	0.21	9.77	18	0.06	7.64	18	0.02
0.41	7.19	20	0.29	9.24	20	0.2	9.77	20	0.06	7.65	20	0.01
0.38	7.2	25	0.28	9.25	25	0.19	9.79	25	0.04	7.65	25	0.01
0.35	7.21	30	0.27	9.27	30	0.17	9.79	30	0.04		30	
0.31	7.22	40	0.26	9.29	40	0.15	9.79	40	0.04	7.66	40	0
0.27	7.24	50	0.24	9.3	50	0.14		50			50	
0.23	7.25	60	0.23	9.32	60	0.12		60			60	
0.21	7.25	70	0.23	9.33	70	0.11		70			70	
0.19	7.25	80	0.23	9.33	80	0.11		80			80	
		90			90			90			90	
0.16		100			100			100			100	
		110			110			110			110	
0.14		120			120			120			120	
		130			130			130			130	
		140			140			140			140	
		150			150			150			150	
		160			160			160			160	
		170			170			170			170	

TABLE E-5 SLUG TEST DATA

mw5	time	y @ mw5	pz214	time	y @pz214	mw24	time	y @mw24	time	mw26	time	y @ mw26
7.5	0.5	2.45	7.15	0.5	0.43	8.31	0.5	0.25	0.5	1.55	0.5	0.9
7.65	1	2.3	7.19	1	0.39	8.32	1	0.24	1	1.75	1	0.7
7.76	1.5	2.19	7.21	1.5	0.37	8.36	1.5	0.2	1.5	1.75	1.5	0.7
7.88	2	2.07	7.24	2	0.34	8.38	2	0.18	2	1.76	2	0.69
7.98	2.5	1.97	7.26	2.5	0.32	8.41	2.5	0.15	2.5	1.85	2.5	0.6
8.05	3	1.9	7.28	3	0.3	8.43	3	0.13	3	1.9	3	0.55
8.11	3.5	1.84	7.3	3.5	0.28	8.44	3.5	0.12	3.5	1.96	3.5	0.49
8.16	4	1.79	7.32	4	0.26	8.45	4	0.11			4	0.46
8.2	4.5	1.75	7.33	4.5	0.25	8.46	4.5	0.1	4	1.99	4.5	0.42
8.24	5	1.71	7.34	5	0.24	8.46	5	0.1	4.5	2.03	5	0.42
8.31	6	1.64	7.36	6	0.22	8.47	6	0.09	5	2.03	6	0.37
8.37	7	1.58	7.38	7	0.2	8.47	7	0.09	6	2.08	7	0.36
8.41	8	1.54	7.4	8	0.18	8.48	8	0.08	7	2.09	8	0.33
8.45	9	1.5	7.41	9	0.17	8.48	9	0.08	8	2.12	9	0.32
8.49	10	1.46	7.42	10	0.16	8.49	10	0.07	9	2.13	12	0.28
8.53	12	1.42	7.44	12	0.14	8.49	12	0.07	10		14	0.27
8.57	14	1.38	7.46	14	0.12	8.5	14	0.06	12	2.17	16	0.25
8.59	16	1.36	7.48	16	0.1	8.5	16	0.06	14	2.18	18	0.24
8.61	18	1.34	7.49	18	0.09	8.5	18	0.06	16	2.2	20	0.24
8.63	20	1.32	7.5	20	0.08	8.51	20	0.05	18	2.21	25	0.22
8.66	25	1.29	7.55	25	0.03	8.51	25	0.05	20	2.21	30	0.21
8.68	30	1.27	7.55	30	0.03	8.52	30	0.04	25	2.23	40	0.2
8.72	40	1.23	7.56	40	0.02	8.52	40	0.04	30	2.24	50	0.19
8.73	50	1.22		50		8.52	50	0.04	40	2.25	60	0.18
8.75	60	1.2		60			60		50	2.26	70	0.18
8.75	70	1.2		70			70		60	2.27		
	80			80			80		70	2.27		
	90			90			90					
8.76	100	1.19		100			100					
	110			110			110					
	120			120			120					
8.76	130	1.19		130			130					
	140			140			140					
	150			150			150					
	160			160			160					
	170			170			170					

TABLE E-5 SLUG TEST DATA

time	mw27	time	y @ mw27	time	mw28	time	y @ mw28	time	mw10	time	y @ mw10	time
0.5	7.33	0.5	0.14	0.5	10.19	0.5	0.37	0.5	8.71	0.5	1.12	0.5
1	7.37	1	0.1	1	10.31	1	0.25	1	9.08	1	0.75	1
1.5	7.39	1.5	0.08	1.5	10.4	1.5	0.16	1.5	9.33	1.5	0.5	1.5
2	7.4	2	0.07	2	10.42	2	0.14	2	9.45	2	0.38	2
2.5	7.41	2.5	0.06	2.5	10.45	2.5	0.11	2.5	9.55	2.5	0.28	2.5
3	7.41	3	0.06	3	10.47	3	0.09	3	9.62	3	0.21	3
3.5	7.42	3.5	0.05	3.5	10.47	3.5	0.09	3.5	9.65	3.5	0.18	3.5
4	7.43	4	0.04	4	10.48	4	0.08	4	9.7	4	0.13	4
4.5	7.43	4.5	0.04	4.5	10.48	4.5	0.08	4.5	9.71	4.5	0.12	4.5
5	7.44	5	0.03	5	10.48	5	0.08	5	9.71	5	0.12	5
6	7.44	6	0.03	6	10.48	6	0.08	6	9.72	6	0.11	6
7	7.44	7	0.03	7	10.49	7	0.07	7	9.74	7	0.09	7
8	7.44	8	0.03	8	10.49	8	0.07	8	9.75	8	0.08	8
9	7.44	9	0.03	9	10.5	9	0.06	9	9.75	9	0.08	9
10	7.44	10	0.03	10	10.5	10	0.06	10	9.75	10	0.08	10
12	7.44	12	0.03	12	10.5	12	0.06	12	9.75	12	0.08	12
14	7.44	14	0.03	14	10.5	14	0.06	14	9.75	14	0.08	14
16	7.44	16	0.03	16	10.5	16	0.06	16	9.75	16	0.08	16
18	7.44	18	0.03	18	10.5	18	0.06	18	9.76	18	0.07	18
20	7.44	20	0.03	20	10.5	20	0.06	20	9.76	20	0.07	20
25	7.45	25	0.02	25	10.5	25	0.06	25	9.76	25	0.07	25
								30	9.76	30	0.07	30
								35	9.76	35	0.07	
								40	9.76	40	0.07	40
								50	9.76	50	0.07	50
								60	9.77	60	0.06	60
								70	9.77	70	0.06	70
								80	9.77	80	0.06	
								100	9.77	100	0.06	

Table E-5

TABLE E-5 SLUG TEST DATA

mw29	time	y @ mw29	time	mw20	time	y @ mw20
9.06	0.5	1.89	0.5	7.94	0.5	8.49
9.2	1	1.75	1	8.38	1	7.99
9.26	1.5	1.69	1.5	8.58	1.5	7.49
9.34	2	1.61	2	8.69	2	6.99
9.42	2.5	1.53	2.5	8.72	2.5	6.49
9.47	3	1.48	3	8.75	3	5.99
9.52	3.5	1.43	3.5	8.78	3.5	5.49
9.56	4	1.39	4	8.79	4	4.99
9.61	4.5	1.34	4.5	8.8	4.5	4.49
9.64	5	1.31	5	8.81	5	3.99
9.7	6	1.25	6	8.82	6	2.99
9.84	7	1.11	7	8.83	7	1.99
9.87	8	1.08	8	8.84	8	0.99
9.89	9	1.06	9	8.84	9	-0.01
9.94	10	1.01	10	8.84	10	-1.01
10.03	12	0.92	12	8.85	12	-3.01
10.11	14	0.84	14	8.85	14	-5.01
10.18	16	0.77	16	8.85	16	-7.01
10.25	18	0.7	18	8.85	18	-9.01
10.29	20	0.66	20	8.85	20	-11.01
10.4	25	0.55	25	8.85	25	-16.01
10.46	30	0.49	30	8.85	30	-21.01
						#VALUE!
10.57	40	0.38	40	8.86	40	-31.01
10.66	50	0.29	50	8.86	50	-41.01
10.71	60	0.24	60	8.86	60	-51.01
10.76	70	0.19	70	8.86	70	-61.01

Table E-5

TABLE E-6

SLUG TEST RESULTS

BOUWER & RICE PARAMETERS AND RESULTANT HYDRAULIC CONDUCTIVITIES

Well	r_c	Corrected r_c	r_w	L_e	L_w	D	Hydraulic Conductivity (k)		Hydraulic Unit
							in ft/day	in cm/sec	
M-2	0.17	0.27	0.42	10	10	10	0.55	$1.9x10^{-4}$	S&G
M-5	0.083	0.083	0.31	10	11	11	0.46	$1.6x10^{-4}$	S&G
M-10	0.083	0.18	0.31	8.5	8.5	8.5	2.15	$7.62x10^{-4}$	S&G
M-13	0.083	0.18	0.31	8	8	8	0.21	$7.3x10^{-5}$	S&G
M-18	0.083	0.083	0.31	10	11	11	0.059	$2.1x10^{-5}$	S&G
M-18S	0.083	0.083	0.31	3.4	3.4	3.4	2.8	$1.0x10^{-3}$	FILL
MW-19	0.083	0.083	0.29	10	10.5	10.5	0.15	$5.2x10^{-5}$	S&G
MW-20	0.083	0.083	0.29	5	14	14	1.02	$3.6x10^{-4}$	S&G
MW-21	0.083	0.083	0.29	10	10	10	0.36	$1.3x10^{-4}$	S&G
MW-22	0.083	0.17	0.29	7	7	7	0.52	$1.8x10^{-4}$	FILL
MW-24	0.083	0.17	0.29	8.5	8.5	8.5	1.62	$5.7 X10^{-4}$	FILL
MW-26	0.083	0.17	0.29	8.5	8.5	8.5	0.49	$1.7x10^{-4}$	FILL
MW-27	0.083	0.17	0.29	7	7	7	1.11	$3.9x10^{-4}$	FILL
MW-28	0.083	0.083	0.29	10	11	11	0.45	$1.6x10^{-4}$	FILL
MW-29	0.083	0.17	0.29	6	6	6	0.33	$1.2x10^{-4}$	S&G Plus
PZ-214	0.083	0.17	0.29	6.5	6.5	6.5	0.95	$6.7x10^{-4}$	FILL

Table E-7

SOIL BORING/ MONITOR WELL	EASTING	NORTHING	TOP OF CASING ELEV.	GROUND SURFACE ELEV.	BOTTOM OF FILL DEPTH	BOTTOM OF CLAY DEPTH	BOTTOM OF S&G DEPTH	TOP OF BEDROCK DEPTH	SCREEN INTAKE DEPTH (TOP)	SCREEN INTAKE DEPTH (BOTTOM)	8/2/84 WATER ELEV. IN FILL	WATER ELEV. IN S&G	8/6/84 WATER ELEV. IN FILL	WATER ELEV. IN S&G	8/10/84 WATER ELEV. IN FILL	WATER ELEV. IN S&G	8/15/84 WATER ELEV. IN FILL	WATER ELEV. IN S&G	AVE WATER ELEV. IN FILL	AVE WATER ELEV. IN S&G
M1	20646.273	11276.569	1029.2	1027.4						17.4		1019.4		1019.39		1019.32				1019.37
M2	20567.311	11127.603	1022.9	1021.2						17.5		1015.59		1015.23		1014.83		1013.45		1014.78
M3	20536.424	11261.498	1023.7	1022.1						14.5		1013.56		1013.49		1013.31		1011.83		1013.05
M4	20590.57	11357.848	1023.6	1022					6	16		1013.93		1014.69		1017.56		1013.88		1015.02
M5	20661.988	11481.454	1024.817	1021.3584	1.5	14	19	19	9	19.4		1016.367		1016.39		1016.21				1016.32
M6	20730.705	11584.31	1027.4	1022	6.5	13	18.5	18.5	8.5	18.5		1018.69		1018.67		1018.62		1018.54		1018.63
M7	20978.862	11586.021	1027.4	1027.4	8	16.5	22	22	12	22		1018.19		1018.19		1019.1				1018.49
M8	21354.118	11560.765	1034.19	1034.411	2	13			8.2	17.5		1028		1028.01		1027.86		1027.39		1027.82
M9	21002.986	10964.454	1023.867	1023.2584	12	14.3	18.5	18.5	14.6	19.6		1020.017		1020.06		1019.9		1019.75		1019.93
M9S	21006.807	10969.828	1023.887	1023.8					4	11	1021.187		1021.17		1021.03		1020.62		1021	
M10	20639.642	10897.282	1022.1	1020.5	5.5	10.5	16.5	16.5	6.8	16.8		1012.63		1012.58		1012.44				1012.56
M11	21145.077	11410.749	1030.57	1031.3	7.5	15.6	19	19	9.5	19.5		1018.57		1018.63		1018.52				1018.57
M12	20629.526	11500.361	1024.167	1024	6.5	16	20	20	9.5	19.5		1017.477		1017.5		1017.67				1017.55
M13	21144.874	11241.327	1033.65	1032.8584	7.6	13	18.8	18.8	9	19		1022.86		1022.89		1022.84		1022.48		1022.77
M14	21214.327	11441.175	1032.1	1032.36	11.5	14	17	17	7	17										
M15	21290.165	11400.15	1034.157	1032.47	8	13	18.8	18.8	14	18		1030.197		1030.15		1030.02		1029.41		1029.94
M15S	21290.227	11397.77	1034.437	1032.77	8				4	9	1031.517		1031.43		1031.34		1030.22		1031.12	
M16	21028.695	11371.939	1029.587	1029.08	8	17	21.4	21.4	11.5	21.5		1021.617		1021.71		1021.78				1021.7
M17	20979.67	11346.003	1028.26		8	13	20.5	20.5	10	20				1020.51		1020.61		1019.9		1020.34
M18	20910.619	11367.237	1027.5	1027.8	11.5	16	21.4	21.4	14	21		1020		1020.08		1020.03				1020.04
M18S	20910.679	11364.634	1027.53	1027.8					6	11	1020.28		1020.27		1020.23				1020.26	
MW19	21252.657	11071.025	1032.21	1032.5	5	17.8	17.8	17.8	8	17.8	1025.17		1025.19		1026.12				1026.16	
MW20	20828.032	11095.987	1026.9	1027.1	14	14	29	29	15.5	23			1018.36		1018.28		1018.22		1018.29	
MW21	20807.279	11270.956	1023.62	1022.4	5.5	17	24	24	7.5	19.5										
BH1	20693	11069		1020.257	2	17.5	17.5	17.5												
BH3	20612	11081		1020.787	2	18	18	18												
BH4	20654	11115		1020.817	3	18	18	18												
BH5	20695	11167		1021.007	3	18	18	18												
BH6	20581	11199		1021.057	2															
BH7	20649	11215		1021.357	2	18.5	18.5	18.5												
BH8	20650	11262		1020.797	3	17.6	17.6	17.6												
BH9	20593	11293		1021.477	3	17	17	17												
BH10	20645	11306		1021.367	9	18.5	18.5	18.5												
BH11	20692	11356		1021.747	6	18	18	18												
BH12	20638	11405		1020.707	2	17	17	17												
BH13	20678	11461		1020.547	5															
BH14	20737	11344		1024.807	4															
BH15	20896	11364		1025.447	10															
BH16	20914	11588		1026.377	7															
BH17	20735	11595		1020.857	4	18	18	18												
BH18	20816	11463		1022.427	8															
BH19	20751	11422		1022.007	3															
BH20	20808	11381		1023.847	10															
BH21	20887	11461		1024.537	3															
BH22	20822	11534		1023.897	5															
BH23	20747	11498		1020.877	5															
BH24	20514	11183		1020.877	5	18	18	18												
BH25	20526	11323		1021.017	6	16	17.5	17.5												
BH26	20685	11547		1020.597	3	18	18	18												
BH28	20750	11486			7	19	19	19												
BH29	20581	11204			5	15	19	19												
SB1	21415.551	10956.425	1046.3	1043.4	4	12.2	12.2	12.2		7.5	1040.53		1040.1		1039.52				1040.05	
SB2	21415.896	11097.857	1046.6	1043.5	4	25.9	25.9	25.9		20	1036.69		1035.59		1035.03				1035.77	
SB3	21427.276	11254.056	1047.75	1043.7	7	23.6	23.6	23.6		16	1036.23		1035.95		1035.88				1036.02	
SB4	21428.032	11411.601	1043.7	1043.4	9	21	24	24		15	1035.42		1035.34		1035.23				1035.33	
SB5	21361.475	11560.655	1036.9	1034.3	2	15	18.3	18.3		9.5	1028.46		1028.34		1028.25		1029.68		1028.69	
SB6	21381.374	11511.414	1034.7	1034.3				16.5		9.6	1032.56		1031.84		1031.77		1029.82		1031.5	
SB7	21323.264	11358.445	1035.4	1034.3	9	15	16.8	16.8		12	1029.45		1034.28		1029.42		1030.19		1030.84	
SB8A	21329.87	11481.87		1033.6	6	17.9	17.9	17.9												
SB8	21337.979	11481.944	1034.6	1033.3	3	15.6	15.6	15.6		10	1031.19		1031.38		1030.85		1031.44		1031.22	
SB10	21298.84	11568.386	1031.45	1028.8	2.5	18.8	18.8	18.8		12.58	1022.25		1022.24		1022.13		1021.86		1022.12	
SB11	21253.738	11020.512	1034.2	1032.2	5	15	19	19		14	1025.68		1025.99		1025.61				1025.76	
SB12	21249.193	11096.226	1033.7	1032	4	18	17.4	17.4		8.2	1030.19		1030.42		1030.1				1030.24	

SOIL BORING/ MONITOR WELL	EASTING	NORTHING	TOP OF CASING ELEV.	GROUND SURFACE ELEV	BOTTOM OF FILL DEPTH	BOTTOM OF CLAY DEPTH	BOTTOM OF S&G DEPTH	TOP OF BEDROCK DEPTH	SCREEN INTAKE DEPTH (TOP)	SCREEN INTAKE DEPTH (BOTTOM)	[illegible] WATER ELEV. IN FILL	WATER ELEV. IN S&G	[illegible] WATER ELEV. IN FILL	WATER ELEV. IN S&G	[illegible] WATER ELEV. IN FILL	WATER ELEV. IN S&G	[illegible] WATER ELEV. IN FILL	WATER ELEV. IN S&G	AVE WATER ELEV. IN FILL	AVE WATER ELEV. IN S&G
SB13	21251.772	11169.153	1032.32	1032.5	1.5	17.6	17.6	17.6		13	1030.1		1030.33		1030.04				1030.16	
SB14	21221.805	11258.113	1039.5	1036.4	4	21.7	21.7	21.7		11.8	1029.38		1029.43		1029.45		1029.18		1029.36	
SB15	21181.023	11027.197	1028.8	1026.8	3	10	12.7	12.7		6	1025.2		1025.62		1025.08				1025.3	
SB16	21188.94	11090.171	1027.65	1027.9	1.7	10	13.1	13.1		5.3	1024.96				1024.69				1024.83	
SB17	21178.771	11169.311	1030.5	1030.7						9.5	1024.62		1024.96		1024.72		1026.4		1025.18	
SB18	21179.289	11257.645	1037.35	1035.1	8.1	20.4	20.4	20.4		12.5	1029.25		1029.38		1029.41		1029.14		1029.3	
SB19	21192.556	11352.906	1034.25	1033.4	7.5	18.4	18.4	18.4		14.5	1028.26		1030.54		1028.28		1025.43		1028.13	
SB20	21202.903	11524.484	1031.1	1031.1	4.5	17.4	17.4	17.4		10	1026.59		1026.65		1026.52		1026.54		1026.58	
SB21	21201.655	11571.24	1034.15	1030.4	3	17	17	17		11	1026.05		1025.66		1025.57		1024.38		1025.42	
SB22	21084.616	11167.577	1026.95	1027.1	3	13.4	13.4	13.4		8.5	1022.07		1022.43		1021.74		1021.28		1021.88	
SB23	21090.935	11372.59	1030.6	1030.7	12.1	17	18.6	18.6		14	1023.5		1024.03		1023.78				1023.77	
SB24	21107.192	11586.324		1028.5	6	14.5	19.6	19.6												
SB25	21068.305	10959.018		1023	6	6	13	13												
SB26	20993.905	11171.038	1027.25	1027	5	14.5	15.8	15.8		12.8	1021.77				1021.81		1021.95		1021.84	
SB27	20994.369	11234.686	1028.3	1027.2	5.5	10	16	16		13.5		1021.71		1022.87		1021.7		1021.46		1021.94
SB28	20988.203	11345.697	1029.15	1028.7	11	18.9	18.9	18.9	4.2	14.2	1020.74		1020.73		1020.81				1020.76	
SB29	21030.722	11368.428	1030.05	1029.4	9	15.3	15.6	15.6		13.2	1021.07		1021.17		1021.24				1021.16	
SB30	21041.56	11585.976	1028.7	1027.9	11	15	17.1	17.1		13.5	1020.28		1020.24		1020.23				1020.25	
SB31	20982.657	11585.256	1027.6	1027.6	5.5	8	12	12		9.1		1019.2		1019.17		1019.14				1019.17
SB32	20962.456	11020.656	1027.4	1027.6	10.5	17	17	17		15.2	1019.35				1019.2				1019.28	
SB33	20889.752	11026.823	1027.25	1027.4	11		22	22		15.5		1018.88		1018.89		1018.78		1018.67		1018.81
SB34	20888.343	11151.65		1027	12	17.5	17.5	17.5												
SB35	20828.032	11095.997		1027.1	14		23	23		12.5										
SB36	20868.016	11192.864	1028.9	1027.2	10	16.1	16.1	16.1		15.5		1019.39		1019.34	1019.01		1019.14		1019.08	1019.37
SB37	20771.131	10980.996	1025.2	1022.8	4	17	17	17		12.2	1018.26		1019.85		1018.08		1018.42		1018.65	
SB38	20795.33	11017.396		1026.7	13.5	13.5	13.5	13.5												
SB39	20808.188	11152.792		1027.4	12.5	12.5	12.5	12.5												
SB40	21190.218	10721.933	1027.35	1027.3	3	16.1	16.1	16.1		10	1022.56		1022.55		1022.64		1022.71		1022.62	
SB41	21190.577	10795.359	1030	1028	6	13	13	13		13	1022.7		1022.65		1022.62		1022.69		1022.67	
SB42	21214.87	10876.791	1032.2	1029.9	1	17.5	17.5	17.5		10.4	1025.83		1025.35		1025.39		1026.16		1025.68	
SB43	21115.859	10649.396	1029.95	1026.2	7	15	18.5	18.5		13.8	1019.25		1019.23		1019.21		1019.06		1019.19	
SB44	21116.57	10718.849	1027.3	1025	5	19.1	19.1	19.1		12.8	1020.55		1020.48		1020.39		1020.37		1020.45	
SB45	21115.803	10798.905		1024.8	11	15.3	15.3	15.3												
SB46	21115.827	10869.939	1024.45	1024.6	4.5	13	16	16		11	1020.94		1020.86		1020.85				1020.88	
SB47	21067.652	10409.424		1030	17.4	17.4	17.4	17.4	2.4	12.4										
SB48	21018.936	10412.461		1029.1	13.5	24.9	24.9	24.9		21.7										
SB49	21044.36	10575.296	1027.7	1025	10	17.5	17.5	17.5		17.5	1018.42		1018.41		1018.39		1018.26		1018.37	
SB50	21040.597	10636.092	1027.95	1024.9	10	15	20	20			1019.89		1019.85		1019.85		1019.77		1019.84	
SB51	21039.781	10794.474	1023.55	1023.6	3	16.7	16.7	16.6		10	1020.24		1020.18		1020.21		1020.37		1020.25	
SB52	21042.206	10871.132		1022.9	4.5	16.5	16.5	18.8												
SB53	20968.145	10409.274		1026.3	10.5	18.8	18.8	20.7		18.7										
SB54	20966.638	10498.118	1026.6	1024.4	5.8	5.8	16.4			13.5										
MW27	20972.85	10584.279	1026.2	1024.5	3	18	18	19	2.5	13.3	1019.06		1019.03		1018.92		1018.71		1018.93	
SB56	20968.51	10812.21		1023.6	7	16	16.5	18												
SB57	20965.778	10720.592	1025.25	1023.4	8	17.2	17.2	17.2		8.3	1019.75		1019.65		1019.59		1019.5		1019.62	
SB58	20966.774	10795.589		1022.7	4.5	16.8	16.8	16.8												
MW26	20967.04	10869.681	1022.23	1022.6	2.4	13.5	16.1	16.1	0.6	11.67	1019.86		1019.64		1019.78				1019.76	
SB60	20928.438	10903.19	1022.4	1021.5	2	14	14	14.2		11.5	1019.29		1019.24		1019.2				1019.24	
SB61	20897.865	10380.725		1022.4	6.9	15.5	15.5	16.2												
MW28	20902.493	10420.851	1026.8	1024.9	12	18.7	18.7	20	8.5	20.5		1016.45		1016.41		1016.33		1016.25		1016.38
SB63	20898.686	10495.189	1026.35	1023.7	11	19	19	19		12										
SB64	20897.96	10560.138	1025.05	1022.7	3	18.9	18.9	18.9		13	1018.61		1018.59		1018.44		1018.05		1018.42	
SB65	20913.318	10654.55	1024.3	1022.4	1	17.6	17.6	17.6		13	1018.28		1018.23		1018.12		1018.03		1018.17	
SB66	20898.793	10719.791		1022.3	3.5	15	15	18.5												
SB67	20880.372	10803.785	1024.3	1022	4.5	15	15	17.5		11	1019.82		1019.75		1019.79				1019.79	
SB68	20888.889	10868.818		1021.9	4.5	16.5	16.5	16.8												
SB69	20846.709	10373.35		1021.9	7.1	16	16	17.1	5.7	15.7										
SB70	20830.141	10497.492	1024.7	1024.2	6.5	15.5	15.5	20		14	1018.39		1018.4		1018.36		1018.3		1018.36	
SB71	20823.901	10564.515	1022.05	1020.3	6	17	19.5	19.5		13	1017.61		1017.18		1016.9		1016.94		1017.16	
SB72	20821.312	10642.813	1020.75	1020.4	4	17.4	17.4	17.4		10	1017		1016.88		1016.79		1016.64		1016.83	
SB73	20827.72	10714.621	1023.05	1021.1	12	15	15.9	15.9		8	1017.74		1017.7		1017.64				1017.69	
SB74	20827.45	10794.654	1022.5	1021.4	5	15	17	17		9	1019.28		1019.19		1019.2				1019.22	
SB75	20818.321	10871.16	1019.9	1020.6	5	15.1	15.1	15.1		10.5	1016.35		1016.28		1016.63				1017.09	

SOIL BORING/ MONITOR WELL	EASTING	NORTHING	TOP OF CASING ELEV.	GROUND SURFACE ELEV.	BOTTOM OF FILL DEPTH	BOTTOM OF CLAY DEPTH	BOTTOM OF S&G DEPTH	TOP OF BEDROCK DEPTH	SCREEN INTAKE DEPTH (TOP)	SCREEN INTAKE DEPTH (BOTTOM)	[illegible] WATER ELEV. IN FILL	WATER ELEV. IN S&G	[illegible] WATER ELEV IN FILL	WATER ELEV. IN S&G	[illegible] WATER ELEV. IN FILL	WATER ELEV. IN S&G	[illegible] WATER ELEV. IN FILL	WATER ELEV IN S&G	AVE WATER ELEV. IN FILL	AVE WATER ELEV IN S&G
SB76	20855.098	10907.606	1023.95	1021.2	2	12	16.5	16.9		11	1018.74		1018.63		1018.63				1018.67	
SB77	20760.443	10632.81		1021.4	5.5	20	20	20		14										
SB78	20780.478	10911.599	1021.9	1019.9	4	19.5	19.5	19.5		13	1017.91		1017.75		1017.75				1017.8	
SB79A	20739.399	10678.258	1021.3	1021.2	8.5	17.6	17.6	17.6		12	1014.07		1013.4		1012.85		1012.75		1013.27	
MW29	20688.04	10790.768	1023.05	1020.9	5.6	15	15	16.1	5	15.9		1012.24		1012.22		1012.11		1012		1012.14
SB81	20656.511	10864.128	1022.8	1020.5	4.5	15	15	16.7		12.6	1012.88		1012.72		1012.59				1012.73	
SB82	20638.483	10912.25	1021.2	1019.8	1	15	16.5	16.8		13.3	1013.88		1013.65		1013.36				1013.63	
SB83					3	17	17	16.2												
SB84					3.5	17	17	21.7												
SB85	20520.715	11174.145	1022.3	1020.7	3	17	18.2	18.2		12.5	1015.05		1014.74		1014.04				1014.61	
SB86	20511.895	11206.167		1021.4	10	17	21.7	21.7												
SB87	20508.846	11238.930		1021.5	1.5	1.5	18.3	18.3												
SB88	20512.966	11270.504		1021.4	4.5	15	20.3	20.3												
SB89	20513.779	11303.181		1021	7.5	7.5	17	17												
SB90	20532.696	11322.303	1022.4	1021.4	6	13.5	16.5	17.3		14		1014.71		1014.55		1014.32				1014.53
SB91	20657.192	11095.734		1020.7	4.5	14	18.1	18.1												
SB92	20541.497	11138.195		1020.4	5	17.9	17.9	17.9												
SB93	20538.626	11171.705		1020.8	5	18.8	18.8	18.8												
SB94	20544.522	11204.519		1021.5	6	15	19	20.5												
SB95	20541.036	11234.1		1022	7.5	15	20	20												
SB96	20542.826	11269.948		1022.3	5	16.5	16.5	18												
SB97	20538.074	11300.805		1021.49	2	16	18.2	18.2												
*SB98	20542.551	11333.125		1021.5	3	16	17.7	17.7												
SB99	20558.587	11369.153		1021.3	10.5	14	18	18												
SB101	20578.707	11038.197		1020.8	6	15	16	16												
SB102	20575.419	11068.587		1020.4	5	16.4	18.2	18.2												
SB103	20579.02	11107.61		1021.5	2	16	16	20.1												
SB104	20573.714	11140.084		1021.4	5	26.4	26.4	26.4												
SB105	20573.221	11173.237		1021.6	5.5	20	20	20.4												
SB106	20573.902	11205.878		1021.8	8	22	22	22												
SB107	20574.59	11238.024		1022.2	2.5	21	21	21												
SB108	20573.891	11270.158		1022.1	7	12	17.5	17.5												
SB109	20575.185	11302.722		1022.1	2	17	17	21												
SB110	20576.872	11334.094		1022	1.3	15.2	15.2	20.5												
SB111	20577.693	11367.902	1021.5	1021.6	4	17	20	20		11.5	1015.14		1015.05		1015.08				1015.08	
SB112	20582.677	11396.193		1021.7	3	14	17	17.9												
SB113																				
SB114	20612.881	10966.167		1020.5	6.5	13.7	16.6	16.6												
SB115	20629	10997.961		1019.7	4.5	12	16.5	17.7												
SB116	20608.88	11041.603		1020.7	6	16.1	18.8	18.8												
SB117	20606.549	11068.769		1020.9	6	19.1	19.1	19.1												
SB118	20605.57	11107.387	1022	1021.6	3	18	19	20.7		13	1015.23		1015.16		1014.99		1013.8		1014.8	
SB119	20605.703	11143.075		1021.7	7	19	20.7	20.7												
SB120	20604.967	11173.038	1023.8	1021.8	3	18	18	18		12		1016.19		1016.83		1016.8		1016.34		1016.54
SB121	20606.722	11205.932		1022.1	3.5	22	22	29.3												
SB122	20608.507	11238.128	1022.2	1022.2	1.5	16	18.5	18.5		10.1	1018.55		1018.43		1018.12				1018.37	
SB124	20607.432	11303.738	1023.9	1022.2	4.5	20	23.5	23.5		12.5	1016.29		1016.18		1015.91		1015.62		1016	
SB125	20607.43	11335.402		1022.4	3.5	16.5	20.4	20.4												
SB126	20608.721	11366.794		1022.1	5	16	19	19												
SB127	20608.305	11399.785		1021.8	4	14	16.1	16.1												
SB128	20610.969	11431.47		1021.8	8	16	18	18												
SB129	20629.796	11464.615		1021.8	3.5	15	16.5	16.5												
SB130	20652.376	10962.664		1020.041	4.5	10	15.4	15.4												
SB131	20646.09	10998.196		1020.1	5	5	16	16												
SB132	20638.469	11041.266		1020.8	4	4	15	16												
SB133	20641.421	11063.993		1021.2	3.5	14	17.7	17.7												
SB134	20638.659	11107.054		1021.4	10.5	14.5	18.4	18.4												
SB136	20638.545	11161.145		1021.6	6.5	16	20.7	20.7												
SB137	20637.644	11209.331		1022.1	6.5	16.7	18.1	18.1												
SB139	20637.769	11259.045		1022.5	7	16.5	21.5	21.5												
SB140	20640.262	11304.348		1022.6	9	16	17	17												
SB142	20638.267	11352.477		1022.3	4	15	17.5	17.6												
SB143					1															

SOIL BORING MONITOR WELL	EASTING	NORTHING	TOP OF CASING ELEV.	GROUND SURFACE ELEV.	BOTTOM OF FILL DEPTH	BOTTOM OF CLAY DEPTH	BOTTOM OF S&G DEPTH	TOP OF BEDROCK DEPTH	SCREEN INTAKE DEPTH (TOP)	SCREEN INTAKE DEPTH (BOTTOM)	[illegible] WATER ELEV. IN FILL	WATER ELEV. IN S&G	[illegible] WATER ELEV. IN FILL	WATER ELEV. IN S&G	[illegible] WATER ELEV. IN FILL	WATER ELEV. IN S&G	[illegible] WATER ELEV. IN FILL	WATER ELEV. IN S&G	AVG WATER ELEV. IN FILL	AVE WATER ELEV. IN S&G
SB219	20803.312	11384.031		1025.3	10.5	19.3	19.3	19.3												
SB220	20805.882	11398.411		1024.3	8	20.8	20.8	20.8												
SB221	20805.255	11438.058		1023.4	4.5															
SB222	20803.083	11480.53		1023.3	9	17.4	17.4	17.4												
SB223	20802.842	11494.817		1023.3	5					9.9										
SB224	20800.708	11514.578		1023.3	8.5	18.5	18.5	18.5												
SB225	20805.426	11550.138		1023.7	10.5	20.5	20.5	20.5												
MW24	20808.98	11592.29	1025.65	1023.6	10.5	20.5	20.5	20.5	4	15	1017.49		1017.49		1017.44				1017.47	
SB226	20800.529	11578.708		1023.5	5	21	21	21												
SB227	20843.953	11241.884		1026.8	12.1	23.3	23.3	23.3												
SB228	20849.819	11272.743		1026.9	8.5	21	21	21												
SB230	20828.979	11332.089		1026.1	13.5	18	22.5	22.5												
SB231	20833.488	11384.421		1025.7	10	20	20	21.3												
SB232	20834.572	11389.744	1024.2	1024.4	9.5	21.5	21.5	21.5		9.6	1020.4		1020.35		1020.35				1020.37	
SB233	20835.357	11429.135		1023.9	6.6	18	20.5	20.5												
SB234	20835.838	11461.87		1024	16	16	19	19												
SB235	20833.085	11493.211		1024.3	6															
SB236	20833.988	11525.278		1024.3	9	17	20.5	20.5												
SB237	20833.380	11557.889		1024.2	9.5	19	22	22												
SB238	20832.65	11589.627		1024.2	9.5	19	20.4	20.4												
SB239	20872.138	11231.127		1027.3	10.5	19	22	22												
SB240	20872.259	11284.438		1027.2	8	19.5	22.2	22.2												
SB242	20869.881	11334.281	1029.95	1027.2	14	21.8	21.8	21.8	5	15	1020.27		1020.25		1020.2				1020.24	
SB243	20867.988	11363.428	1025.65	1025.3	12.5	18.5	18.5	18.5	0.5	10.5	1020.13		1020.1		1020.05				1020.09	
SB244	20872.226	11395.417		1025	10	19.8	19.8	19.8												
SB245	20869.22	11428.894		1024.7	9	18.5	21.8	21.8												
SB246	20868.083	11461.117		1024.8	5	17	21.1	21.1												
SB247	20869.985	11492.882		1025.1	12	19.9	22.3	22.3												
MW22	20868.59	11525.81	1028	1025.8	10.5	19.5	22.2	22.2	4	15			1018.36		1018.34				1018.35	
SB249	20872.77	11552.52		1025.2	11.6	22	22	22												
SB250	20863.759	11593.153	1026.6	1025.2	10.5	15	22.3	22.3		13.4	1017.45		1017.37		1017.32				1017.38	
SB251	20901.349	11323.128		1027.6	9	20	20	20	5	15										
SB252	20909.111	11354.219	1027.2	1027.2	11	18	21	21	5	15	1020.4		1020.36		1020.35				1020.37	
SB253	20897.577	11394.975		1025.4	7	18	20	20												
SB254	20900.429	11429.453		1025.5	8.5	18.5	18.8	20.1												
SB255	20902.618	11461.372		1026.1	4	21.7	21.7	21.7												
SB256	20909.27	11493.586		1026.1	11	21.7	21.7	21.7												
SB257	20897.098	11523.737	1028.7	1026.1	8.5	20.5	25	25		18	1018.95		1018.9		1018.9				1018.92	
SB258	20898.725	11562.138		1026.3	11	22.5	22.5	22.5												
SB259	20901.83	11581.589		1026.4	13.5	22	23.1	23.1												
SB260	20944.059	11395.172		1026.8	15.3	15.3	15.3	15.3												
SB262	20932.701	11465.379		1026.7	10	15.3	15.3	15.3												
SB263	20932.312	11492.477		1026.7	14.7	22.1	22.1	22.1												
SB264	20943.192	11519.882		1026.7	10	21.5	22.5	22.5												
SB265	20929.447	11571.017		1026.5	13	18	23.5	23.5												
SB266	20931.907	11580.725		1026.8	6															
SB267	20980.272	11408.125		1026.4	8.3															
SB268	20975.138	11461.654	1027	1026.8	8	20.1	20.1	20.1		15	1020.53		1020.51		1020.48				1020.51	
SB269	20966.28	11482.819		1026.7	13.5	21.4	21.4	21.4												
SB270	20963.472	11523.393		1026.9	13	19.5	21.8	21.8												
SB271	20964.918	11563.557		1027	8.5	22.6	22.6	22.6												
SB272	20963.39	11582.648	1028.2	1027.2	15	15	23	23		13.3	1019.05		1018.99		1019				1019.01	
SB273	21220.373	11344.558		1034	4	8	8	19												
SB274	20762.81	11070.055		1027.7	6	6	9.2	9.2												
SB275	20760.61	11262.954		1027.2	9.5	18	23	23												
SB276	20834.384	11085.482		1021	10	19.5	24.5	24.5												
SB278	20836.405	11101.935		1027.5	11	17.5	17.5	17.5												
SB279	20839.653	11081.958		1027.5	11	21	21	21												
SB280	20941.535	11018.737		1027.4	11	24	24	24												
SB281	21010.448	11401.757		1033.9	14	23.5	24	24												
SB282	20832.29	11231.85		1026.93	9	15	20.8	20.8												
SB283	20843.29	11131.86		1027.5	12	20.5	22.7	22.7												
SB284	21221.588	11226.407		1035.104	9	20	20	20												

Table E-7

SOIL BORING/ MONITOR WELL	EASTING	NORTHING	TOP OF CASING ELEV.	GROUND SURFACE ELEV.	BOTTOM OF FILL DEPTH	BOTTOM OF CLAY DEPTH	BOTTOM OF S&G DEPTH	TOP OF BEDROCK DEPTH	SCREEN INTAKE DEPTH (TOP)	SCREEN INTAKE DEPTH (BOTTOM)	[illegible] WATER ELEV. IN FILL	WATER ELEV. IN S&G	[illegible] WATER ELEV. IN FILL	WATER ELEV. IN S&G	[illegible] WATER ELEV. IN FILL	WATER ELEV. IN S&G	[illegible] WATER ELEV. IN FILL	WATER ELEV. IN S&G	AVE WATER ELEV. IN FILL	AVE WATER ELEV. IN S&G
SB285	21243.779	11298.037		1036.194	6.5	20.3	20.3	20.3												
SB286	21242.383	11285.301		1036.490	7.5	20.4	20.4	20.4												
SB287	20821.643	10829.845		1020.876	8	17.7	17.7	17.7												
SB288	20883.418	10834.471		1021.953	2	17.2	17.2	17.2												
SB289	20823.309	10752.677		1021.186	5.5	15.8	15.8	15.8												
SB290	20887.903	10780.531		1022.031	6.5	17.6	17.5	17.5												
SB291	20835.554	10878.587		1020.871	7	16.2	16.2	16.2												
SB292	20903.931	10888.316		1022.089	7	16.3	16.3	16.3												
SB293	21222.485	10874.121		1030.39	3	18	18	18												
SB294	21222.669	10829.541		1030.228	15	20.1	20.1	20.1												
SB295	21222.484	10780.063		1029.917	2.5	17.5	17.5	17.5												
SB296	21200.476	10747.047		1028.234	5.5	19.5	19.5	19.5												
SB297	21189.412	10830.265		1028.177	10	17.3	17.3	17.3												
SB298	21151.085	10884.079		1028.075	3	15	15	15												
SB299	21151.348	10832.58		1028.184	4	14.6	14.6	14.6												
SB300	21152.71	10798.082		1028.228	6	16.2	16.2	16.2												
SB301	21156.028	10757.549		1028.182	6	8	18	18												
SB302	21115.583	10831.044		1028.481	7	16.3	16.3	16.3												
SB303	21088.042	10889.528		1022.978	7	15.9	15.9	15.9												
SB304	21073.384	10834.191		1023.332	5.5	15.5	17	17												
SB305	21077.16	10795.412		1023.894	6	6	16.5	16.5												
SB306	21076.724	10757.289		1024.416	8	17	17.8	17.8												
SB307	21039.084	10759.07		1024.294	6	19.6	19.6	19.6												
SB308	21041.148	10832.323		1023.34	4.5	18.5	18.5	18.5												
SB309	20919.158	10886.107		1021.784	6	6	14.7	14.7												
SB310	20983.2	10804.486		1021.602	2.5	2.6	2.5	14.3												
SB311	20914.109	10831.849		1021.941	6	6	6	16												
SB312	20884.187	10871.077		1021.246	2.5	2.5	15.8	15.8												
SB313	20911.845	10802.3		1022.11	9	9	16.2	16.2												
SB314	20861.081	10829.445		1021.852	8.5	8.5	17.8	17.8												
SB315	20821.163	10782.687		1022.417	6	8	16.7	16.7												
SB316	20848.951	10800.182		1021.891	7.5	7.5	16	16												
SB317	20864.457	10828.793		1021.807	4.5	4.5	17.5	17.5												
SB318	20853.484	10750.724		1021.89	15	18.5	18.5	18.5												
SB319	20865.693	10781.95		1023.331	7	7	17.8	17.8												
SB320	21222.426	10755.152		1029.538	2	19.2	19.2	19.2												
SB321	21115.315	10758.87		1025.057	14	16.8	16.8	16.8												
SB322	21225.431	10738.089		1029.83		5	11.5	11.5												
SB323	21202.504	10717.787		1028.03		13	17	17												
SB324	21173.888	10880.167		1027.18	4	17.9	17.9	17.9												
SB325	21150.571	10889.537		1028.495	5	21	21	21												
SB326	21177.244	10886.826		1027.68	6	18.5	18.5	18.5												
SB327	21155.02	10865.234		1028.133	10	22.8	22.8	22.8												
SB328	21129.847	10848.887		1027.787	16	16	23.5	23.5												
SB329	21221.488	11180.027		1032.861	6	18	18	18												
SB330	21253.880	11222.487		1036.366	7	20.4	20.4	20.4												
SB331	21185.86	11224.86		1034.16	6.5	19.5	19.5	19.5												
SB332	21223.34	11242.34		1036.4	7.5	17	21	21												
SB333	21163.116	10708.761		1026.34	9															
SB334					6	18.4	18.3	18.3												
SB335	20984.4	10878.738		1023.366	9	18.6	18.5	18.5												
SB336	21082.86	10843.43		1024.9	8	9	20.1	20.1												
SB337	21128.428	10884.906		1025.89	12	18.9	18.9	18.9												
SB338	21005.271	10827.384		1024.292	9	17.9	17.9	17.9												
SB339	20848.012	10857.902		1023.049	9	18	18	18												
SB340	20825.278	10856.717		1022.675	7.5	17.7	17.7	17.7												
SB341	20793.179	10838.819		1019.014	6	5	16.5	16.5												
SB342	20798.79	10807.989		1019.328	1.5	1.5	19.2	19.2												
SB343	20846.916	10818.659		1021.119	7	7	19.4	19.4												
SB345	20812.680	10803.138		1022.78	7.5	12	19.9	19.9												
SB346	21008.75	10807.34		1024.2	13.5	18.4	18.4	18.4												
SB347	21041.487	10807.328		1024.98	18	20.8	20.8	20.8												
SB348	21070.854	10802.231		1025.564	5.7	18.8	20.9	20.9												

SOIL BORING/ MONITOR WELL	EASTING	NORTHING	TOP OF CASING ELEV.	GROUND SURFACE ELEV.	BOTTOM OF FILL DEPTH	BOTTOM OF CLAY DEPTH	BOTTOM OF S&G DEPTH	TOP OF BEDROCK DEPTH	SCREEN INTAKE DEPTH (TOP)	SCREEN INTAKE DEPTH (BOTTOM)	[illegible] WATER ELEV. IN FILL	WATER ELEV. IN S&G	[illegible] WATER ELEV IN FILL	WATER ELEV. IN S&G	[illegible] WATER ELEV. IN FILL	WATER ELEV. IN S&G	[illegible] WATER ELEV. IN FILL	WATER ELEV. IN S&G	AVE WATER ELEV. IN FILL	AVE WATER ELEV IN S&G
SB349	21071.358	10578.304		1025.408	9.2	17.1	18.6	18.6												
SB350	21013.193	10573.401		1024.78	10	19.3	19.3	19.3												
SB351	20941.71	10580.78		1023.87	10	17	17	18.6												
SB352	20895.128	10572.594		1021.784	11	16	19	19												
SB353	20813.23	10529.88		1023.12	8.1	18.1	18.1	18.1												
SB354	20889.741	10525.884		1022.78	10	18.6	18.6	18.6												
SB355	20894.295	10533.888		1022.871	6.5	17.4	17.4	17.4												
SB356	20938.228	10543.171		1023.7	8	15	18.1	18.1												
SB357	20988.06	10544.68		1024.44	10	19.5	19.5	19.5												
SB358	21039.075	10527.181		1024.948	10	17.5	19.8	19.8												
SB360	20750.2	10857.895		1021.098	1	1	17.4	17.4												
SB362	20705.028	10754.291		1020.884			18.7	18.7												
SB363	20871.896	10825.68		1020.854	5.5	13.6	18.8	18.8												
SB365	20814.323	10909.083		1018.86	3	15.4	15.4	15.4												
SB366	20867.192	10803.042		1022.053	8.5	11.5	18.1	18.1												
SB367	21002.772	10899.354		1022.21	4		15.8	15.8												
SB368	21006.717	10870.321		1022.11	5	14	16	16												
SB369	21002.431	10830.57		1022.383	5	6	15.5	15.5												
SB370	21002.872	10786.266		1023.005	6	16.5	15.5	15.5												
SB371	21001.188	10758.983		1023.575	6	17.1	17.1	17.1												
SB372	20941.261	10713.098		1023.098	6	17.3	17.3	17.3												
SB373	20934.005	10878.854		1023.268	13.5	16	19.5	19.5												
SB374	20858.97	10720.54		1021.76	4	15	17.5	17.5												
SB375	10888	20888		1022	6	17	19.5	19.5												
SB346	21008.751	10807.338		1024.189	6	17	19.5	19.5												
SB376	20897.816	10874.221		1023.988	9	16	19.4	19.4												
SB377	21038.909	10883.65		1024.888	18	18	19.5	19.5												
SB378	21076.782	10734.413		1024.612	8	8	17	18.3												
SB379	21039.306	10734.419		1024.328	9	15	18.8	18.8												
SB380	21003.215	10735.489		1024.17	11	11	18.6	18.6												
SB381	21113.049	10824.357		1027.881	12	19	20.5	20.5												
SB382	21100.954	10580.218		1028.73	10	20.9	20.9	20.9												
SB383	21085.858	10550.482		1028.258	11.6	18.2	21.8	21.8												
SB385	20789.795	11583.705		1027.028	8	19.9	19.9	19.9												
SB386	20807.357	11584.444		1023.309	12	17	21	21												
SB387	20833.243	11581.433		1024.133	10	21	21	21												
SB388	20868.69	11594.988		1023.744	8.5	20.3	20.3	20.3												
SB389	20901.178	11586.818		1024.007	10.5	18	20.5	20.5												
SB390	20931.249	11594.569		1024.383	8.7	19.8	20.7	20.7												
SB391	20974.41	11589.849		1025.989	8.5	8.5	21.4	21.4												
SB392	20988.495	11585.188		1028.842	8.1	8.1	20.8	20.8												
SB393	20836.898	10489.802		1024.407	12	21.5	21.5	21.6												
SB394	20899.505	10481.888		1024.703	12.5	18.6	19.1	19.1												
SB395	20861.758	10443.849		1024.802	6.5	20.1	20.1	20.1												
SB396	20830.838	10430.378		1024.002	6	18.8	20.7	20.7												
SB397	20861.856	10428.824		1024.453	10	15.5	20.9	20.9												
SB398	21200.734	10877.598		1041.085	18	28.2	28.2	28.2												
SB399	21171.339	10847.378		1040.592	19.5	28.8	28.8	28.8												
SB400	21137.408	10818.145		1039.24	22	31	33.7	33.7												
SB401	20899.278	10459.918		1024.298	18.5	19.7	19.7	19.7												
SB402	20548.899	10984.864		1015.837		11.6	11.6	11.6												
SB403	20519.889	11049.097		1014.248	3	11	12	12												
SB404	20478.252	11111.001		1018.841	8	13.4	13.4	13.4												
SB405	20448.184	11172.598		1018.428	4.5	9.7	9.7	9.7												
SB406	20618.937	10838.308		1019.803	3	3	4.4	4.4												
SB407	20092.144	10992.988		1028.718	10	13	19.2	19.2												
SB408	20141.235	10804.108		1029.2	13	15.5	20.9	20.9												
SB409	20278.712	10578.383		1029.281	7	10	11.5	11.5												
SB410	20257.713	10700.613		1030.124	11.3	11.3	11.3	11.3												
SB412	21211.007	10940.745		1029.072	2.5	8	15.1	15.1												
SB413	21158.818	10948.564		1025.108	3	11.8	11.8	11.8												
SB414	21123.731	10951.428		1023.892	6	7.5	10.9	10.9												
SB415	21080.788	10853.254		1023.151	8	11	11	11												

Table E-7

SOIL BORING/ MONITOR WELL	EASTING	NORTHING	TOP OF CASING ELEV.	GROUND SURFACE ELEV.	BOTTOM OF FILL DEPTH	BOTTOM OF CLAY DEPTH	BOTTOM OF S&G DEPTH	TOP OF BEDROCK DEPTH	SCREEN INTAKE DEPTH (TOP)	SCREEN INTAKE DEPTH (BOTTOM)	[illegible] WATER ELEV. IN FILL	WATER ELEV. IN S&G	[illegible] WATER ELEV. IN FILL	WATER ELEV. IN S&G	[illegible] WATER ELEV. IN FILL	WATER ELEV. IN S&G	[illegible] WATER ELEV. IN FILL	WATER ELEV. IN S&G	AVE WATER ELEV. IN FILL	AVE WATER ELEV. IN S&G
SB416	21058.228	10958.637		1022.583	7			12.7												
SB417	21025.667	10957.926		1021.907	12	13.3	13.3	13.3												
SB418	20993.104	10957.56		1020.841	5	13	13	13												
SB419	20995.768	10959.17		1020.7			13	13												
SB420	20937.03	10961.504		1020.241	6	11	13	13												
SB421	20906.124	10963.062		1020.121	1	12.7	12.7	12.7												
SB422	20868.675	10965.778		1020.208	1	13	19	19												
SB423	20858.492	10968.025		1020.076	1	13	17	17												
SB424	20808.444	10968.767		1020.438	5	18.7	18.7	18.7												
SB425	21008.268	11013.479		1031.11	11	12	20.5	20.5												
SB426	20777.331	10908.873		1020.48	10	15	18.5	18.5												
SB427	20744.06	10909.427		1020.04	7	18.5	18.5	18.5												
SB428	21272.289	10887.23		1037.82	10	24.2	24.2	24.2												
SB429	21272.75	10857.08		1038.78	6	21	21	21												
SB430	21272.152	10824.739		1039.44	5	8	21.6	21.6												
SB431	21263.209	10798.214		1039.18	5.75	13	13	13												
SB432	21254.691	10763.304		1039.57	8	18.6	18.6	18.8												
SB433	21246.936	10733.62		1039.99	9	20.2	20.2	20.2												
SB434	21280.32	10728.868		1042.13	5	11.5	11.5	11.5												
SB435	21286.864	10758.776		1041.89	5	7	7	7												
SB436	21291.422	10782.018		1041.02	5	18.8	18.8	18.8												
SB437	21300.857	10821.743		1039.89	2.3	11.5	11.5	11.5												
SB438	21305.902	10853.307		1039.28	2.75	10.5	11.6	11.5												
SB439	21298.584	10884.282		1037.74	5	18.1	18.1	18.1												
SB440	21358.554	10881.489		1043.33	4.3	4.3	4.3	4.3												
SB441	21352.504	10842.102		1043.09	2.5	5.2	5.2	5.2												
SB442	21344.383	10809.236		1042.98	3	10	10	10												
SB443	21336.238	10776.775		1043.47		17.1	17.1	17.1												
SB444	21330.318	10813.318		1042.17	4	22.9	22.9	22.9												
SB445	21323.12	10851.512		1039.86	2	9.2	9.2	9.2												
SB446	21330.81	10879.614		1039.48	2	9.1	9.1	9.1												
TP1	20748.87	10823.083		1028.4	14.5	17	17	24												
TP2	20698.758	10874.787		1028.7	10															
TP3	20756.158	10739.822		1033.8	19.5	19.5	24													
TP4	20754.583	10794.48		1028.5	13.5															
TP5	20754.857	10770.624		1028.5	11															
TP6	20757.833	10735.448		1034.3	18															
TP7	20762.349	10724.168		1035.2	18															
OS1	20558.865	10584.185		1024.07			3	3												
OS2	20475.757	10864.588		1027.77			5.7	5.7												
OS3	20583.98	10989.12		1027.78			2	2												
OS4	20228.588	10710.209		1030.47			3.5	3.5												
OS5	20388.87	10804.49		1027.78	3	13.5	13.5	13.5												
OS6	20248.29	10805.13		1027.78	8	18	18	18												
OS7	20843.93	10223.62		1022.4	4.5															
OS8	20883.01	10307.18		1022.4	1.5															
OS9	20407.57	11006.11		1015.84	6	12	13.5	13.5												
OS10	20388.09	10978.31		1015.84			6	6												
OS11	21428	11038.34		1043.38	7.5	7.5	7.5	7.5												
OS12	21423.17	11192.69		1043.38	9	9	9	9												
OS13	21428.46	11325.95		1043.59	7.5	7.5	7.5	7.5												
PW1	20758.289	11574.182	1032.7	1027.6	7.5	9.5	9.5	9.5	3.5	9.5	1021.3								1021.3	
PW2	20895.294	11386.17	1029.68	1027.88	12	16	16	16	3	16	1021.98		1021.91		1021.85				1021.91	
UG2	21428.781	11223.582		1043.54	6	13.5	13.5	13.5	1	13.5										
UG3	20421.036	11147.31	1018.02	1016.369		7	12.8	12.8	0.8	12.8		1014.89		1014.87		1014.48				1014.75
UG4	21174.294	10896.158	1028.84	1026.688	6	16.7	16.7	16.7	4.5	16	1021.33		1021.32		1021.35				1021.33	
CR1	20784.559	10383.866		1009.22							1012.22	1012.22			1012.12	1012.12			1012.17	1012.17
CR4	20686.111	11634.447		1008.36							1009.96	1009.96			1009.94	1009.94	1009.99	1009.99	1009.96	1009.96

CAD FILE NAME: MOL3.DWG
PLOT SCALE: 1=160 (11x17)
DATE: 01/18/96
TIME: 8:50 AM
PZ205
PZ214
PW1
PW2
M18/M18S
PZ243
PZ253
PZ242
PZ251

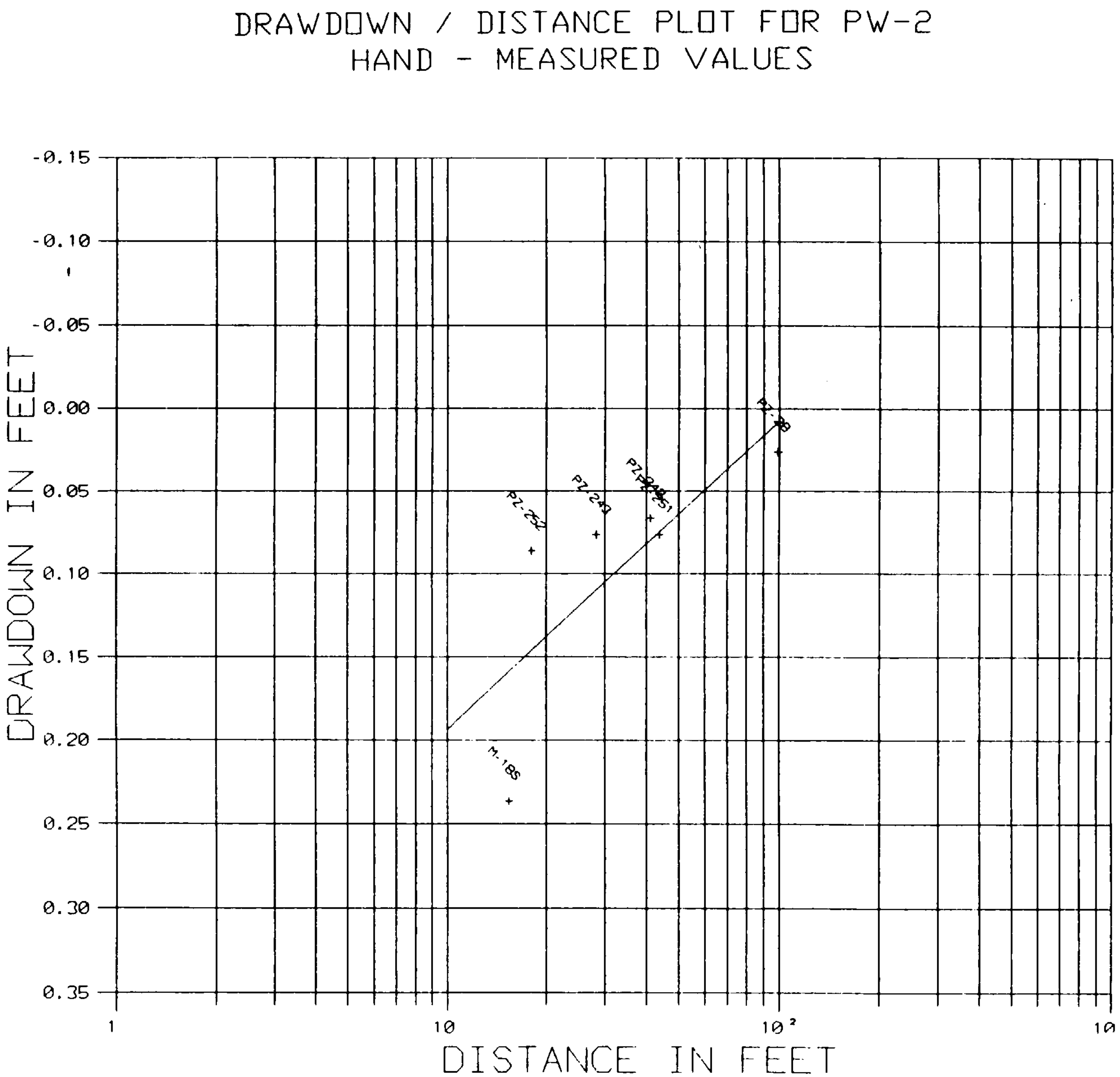

DRAWDOWN / DISTANCE PLOT FOR PW-2
HAND - MEASURED VALUES
DRAWDOWN IN FEET
DISTANCE IN FEET
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
1
10
10²
10³
PZ-252
PZ-243
M-18S

FIGURE E-2

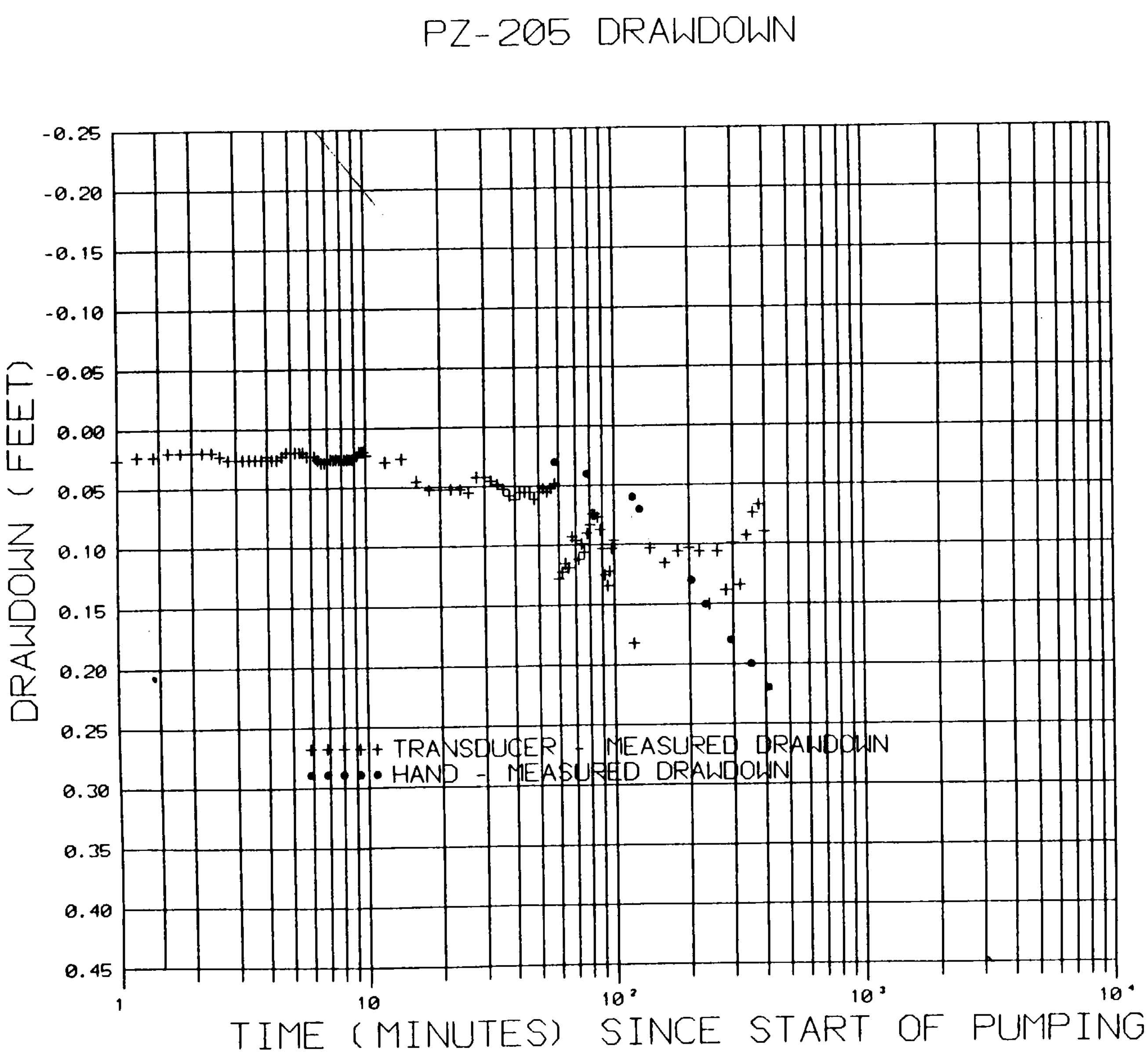

PZ-205 DRAWDOWN
DRAWDOWN (FEET)
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
1
10
10^2
10^3
10^4
TIME (MINUTES) SINCE START OF PUMPING
+ TRANSDUCER - MEASURED DRAWDOWN
• HAND - MEASURED DRAWDOWN

FIGURE E-3

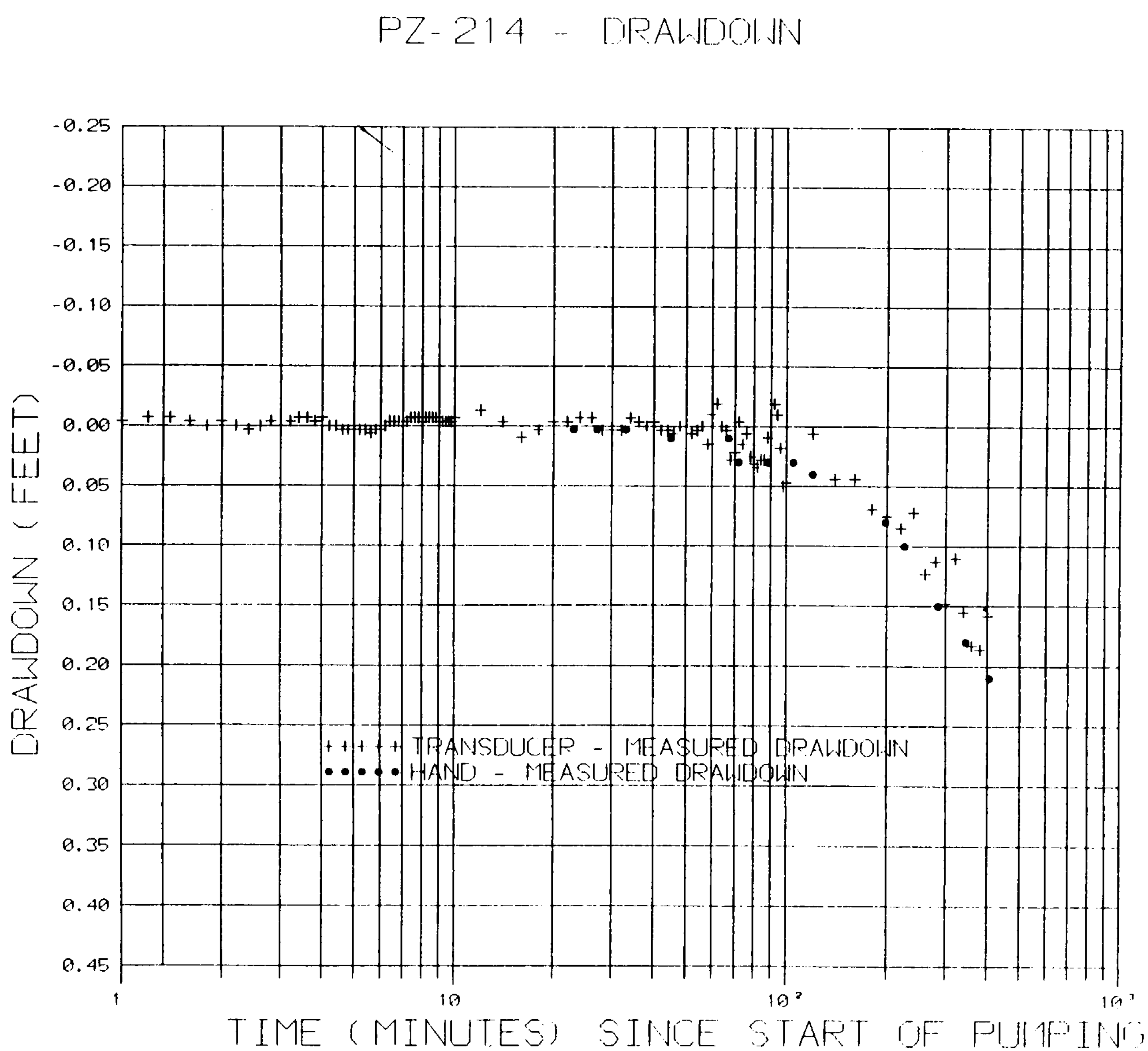

PZ-214 - DRAWDOWN
DRAWDOWN (FEET)
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
1
10
10²
10³
TIME (MINUTES) SINCE START OF PUMPING
TRANSDUCER - MEASURED DRAWDOWN
HAND - MEASURED DRAWDOWN

FIGURE E-4

M-18S - DRAWDOWN

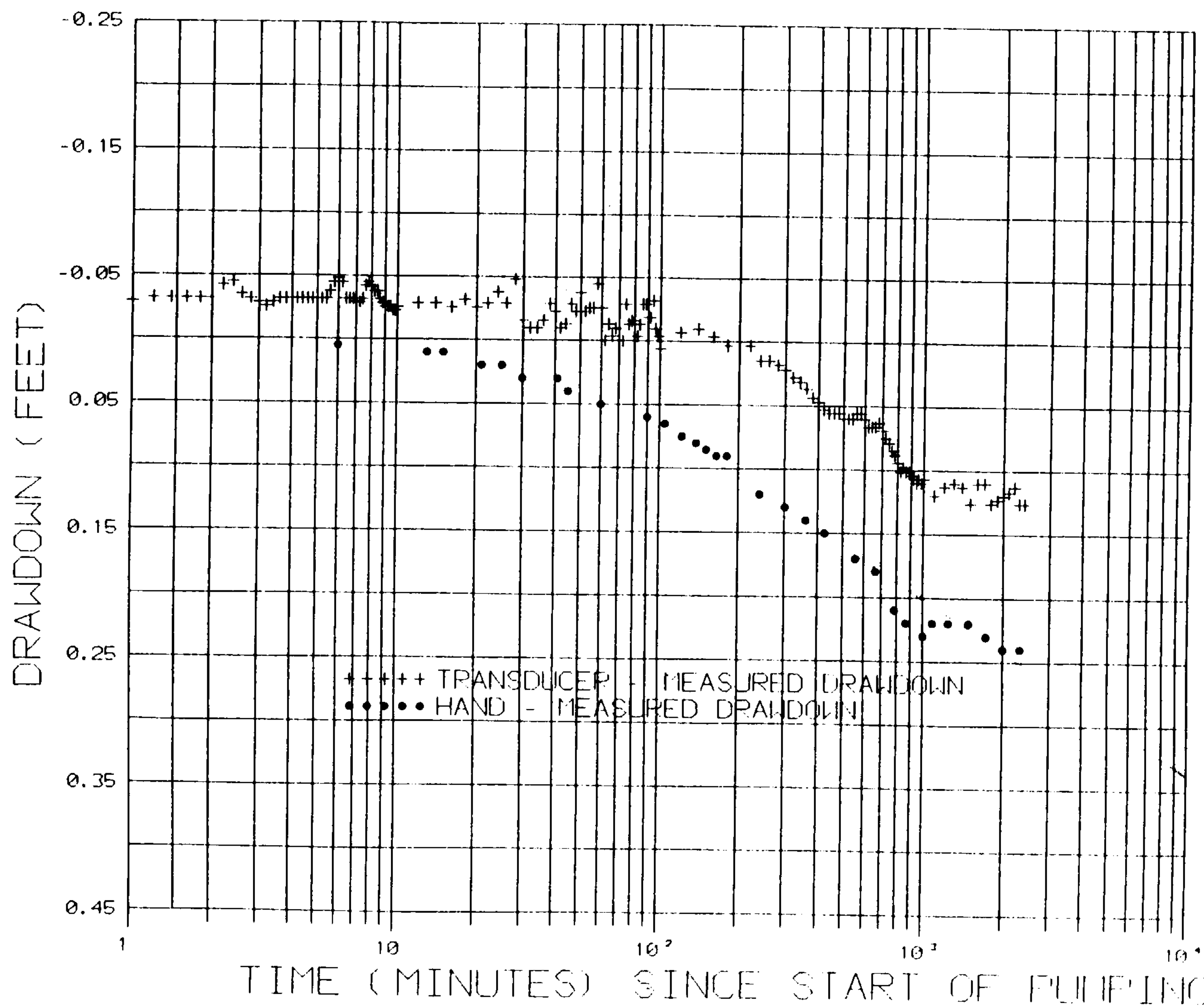


FIGURE E-5

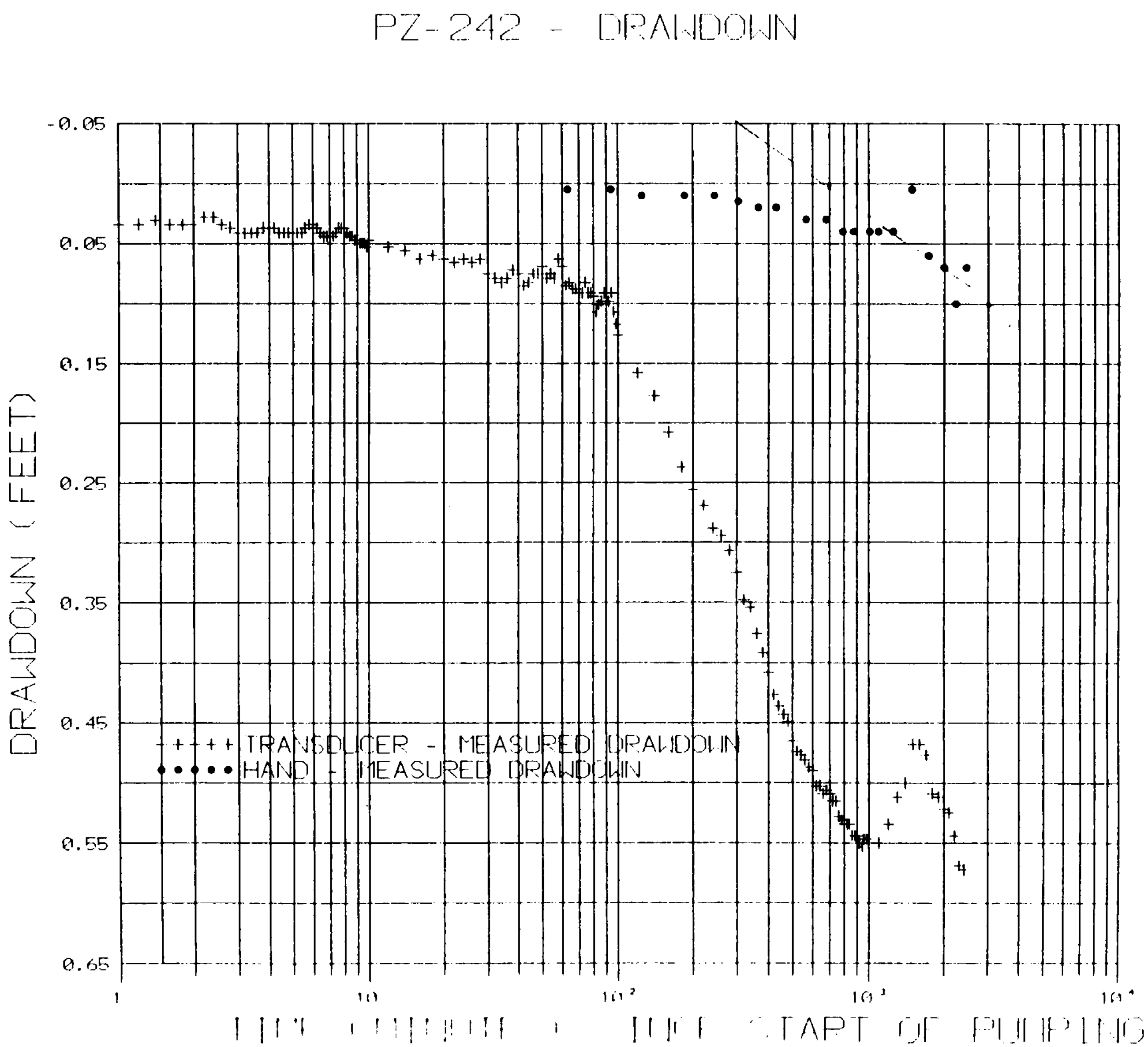
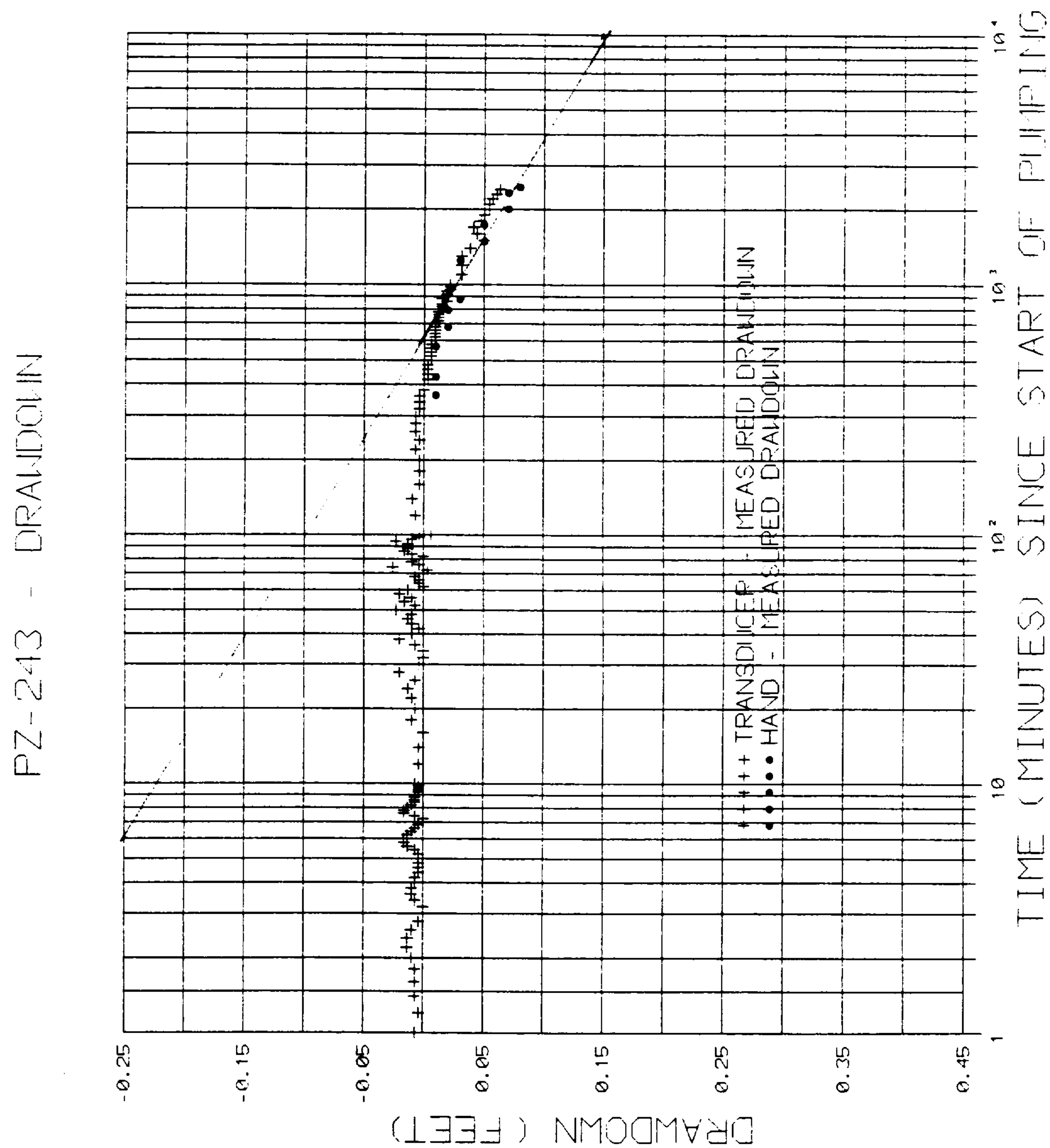

PZ-242 - DRAWDOWN
DRAWDOWN (FEET)
-0.05
0.05
0.15
0.25
0.35
0.45
0.55
0.65
1
10
10²
10³
10⁴
START OF PUMPING
TRANSDUCER - MEASURED DRAWDOWN
HAND - MEASURED DRAWDOWN

FIGURE E-6

FIGURE E-7


PZ-243 - DRAWDOWN
+ + + + TRANSDUCER - MEASURED DRAWDOWN
• • • • HAND - MEASURED DRAWDOWN
TIME (MINUTES) SINCE START OF PUMPING
DRAWDOWN (FEET)
-0.25
-0.15
-0.05
0.05
0.15
0.25
0.35
0.45
1
10
10²
10³
10⁴

PZ-251 - DRAWDOWN

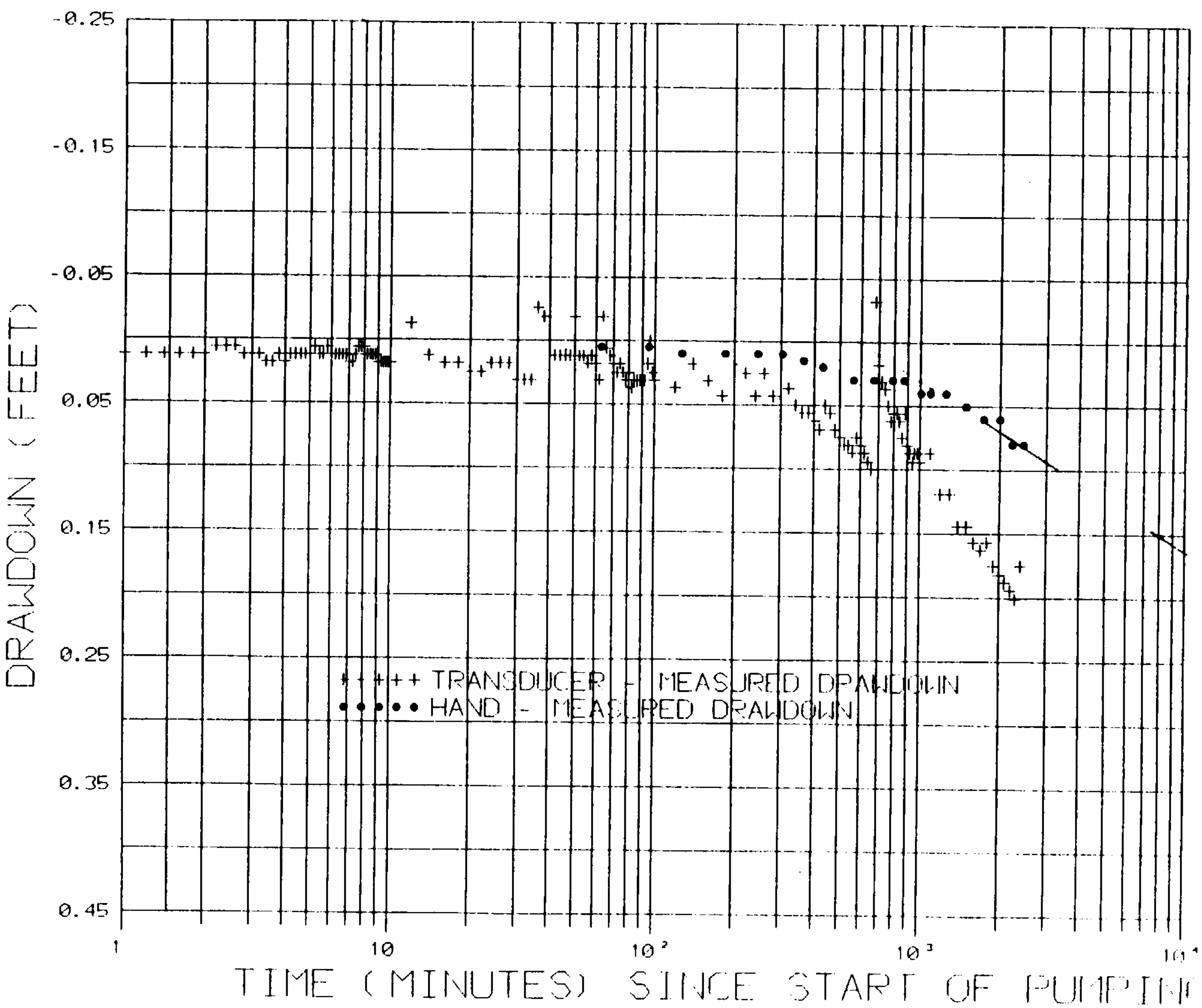


FIGURE E-8

PZ-214 - RECOVERY

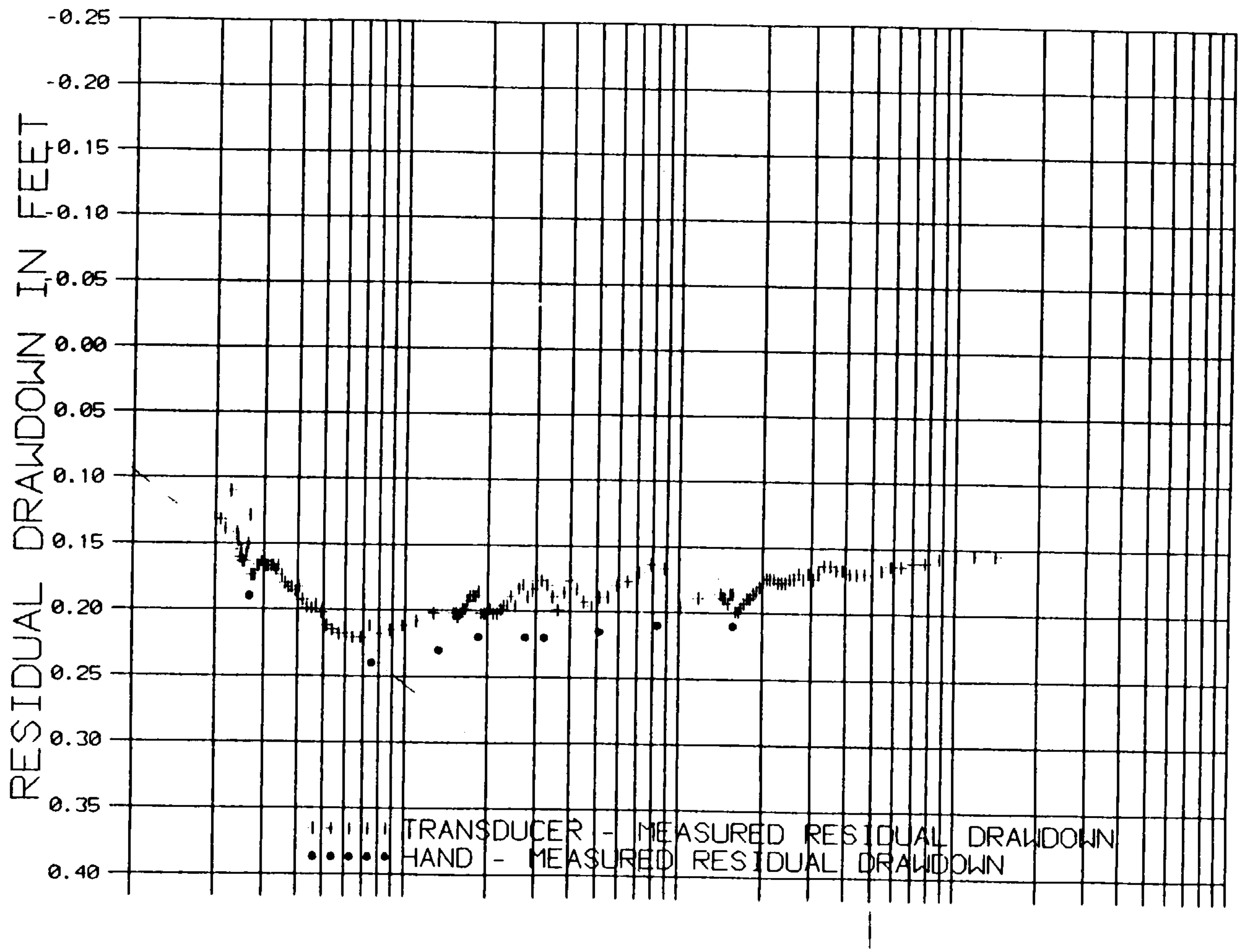


FIGURE E-9

M-18S - RECOVERY

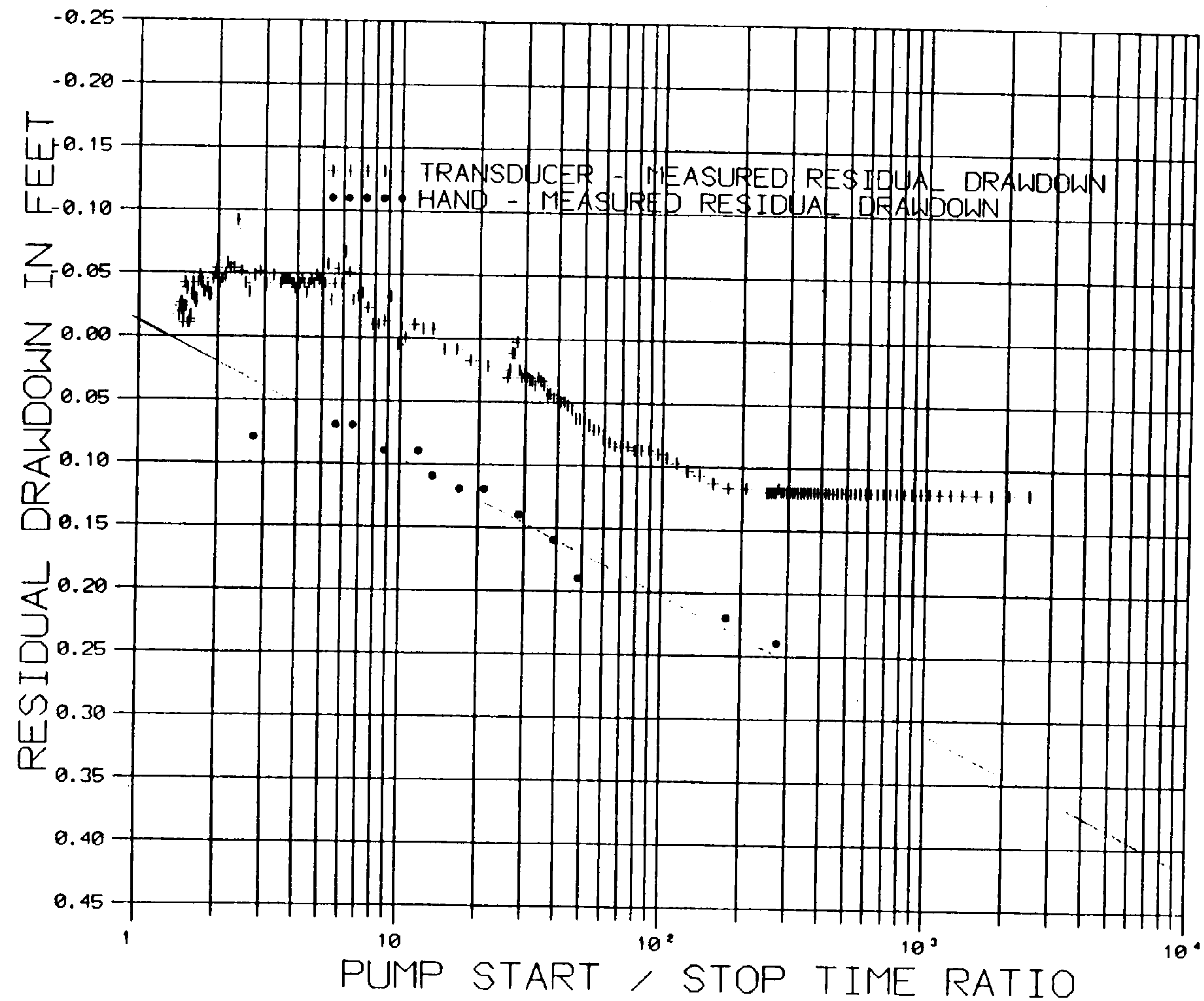


FIGURE E-10

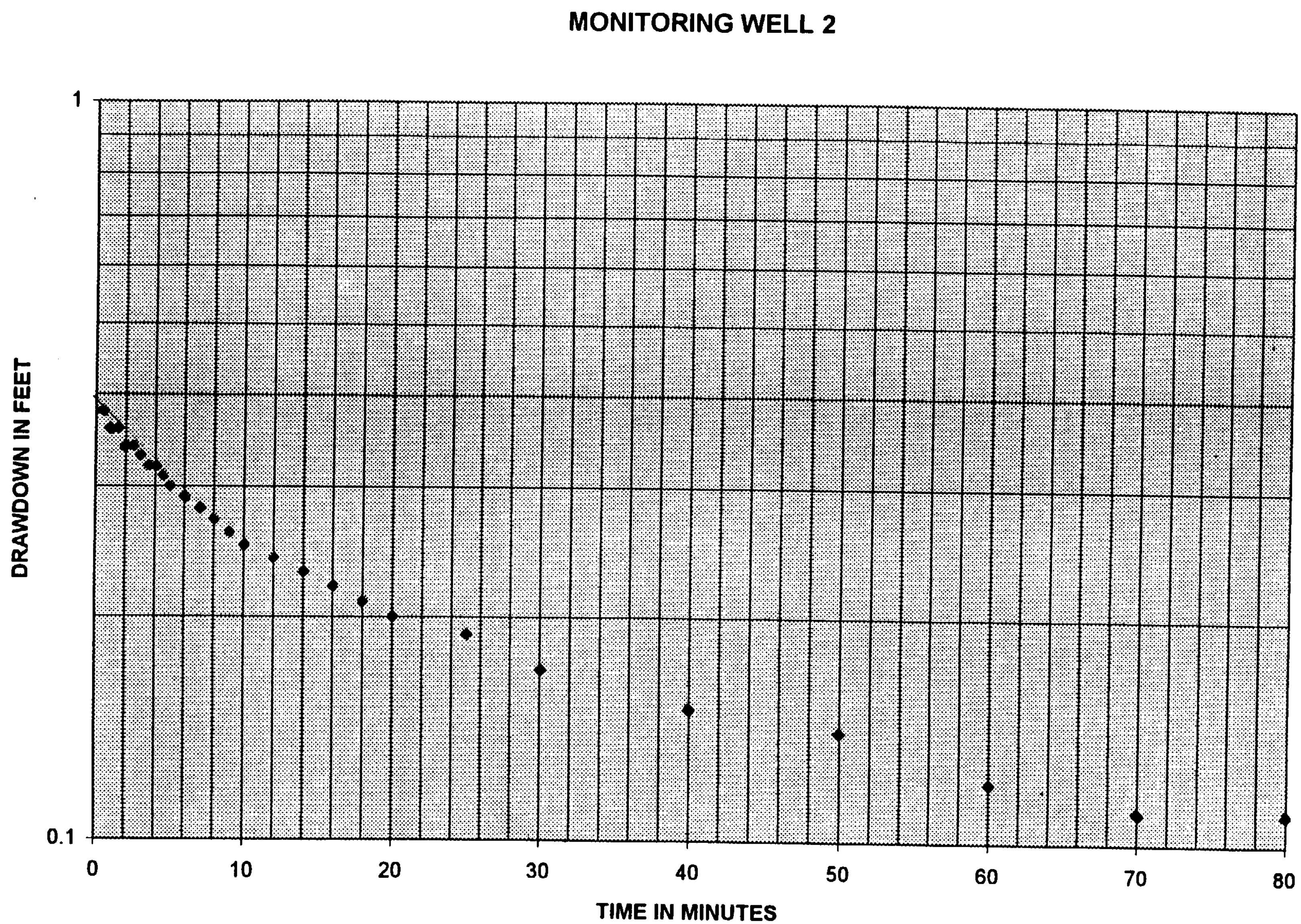

MONITORING WELL 2
DRAWDOWN IN FEET
1
0.1
0
10
20
30
40
50
60
70
80
TIME IN MINUTES

FIGURE E-11

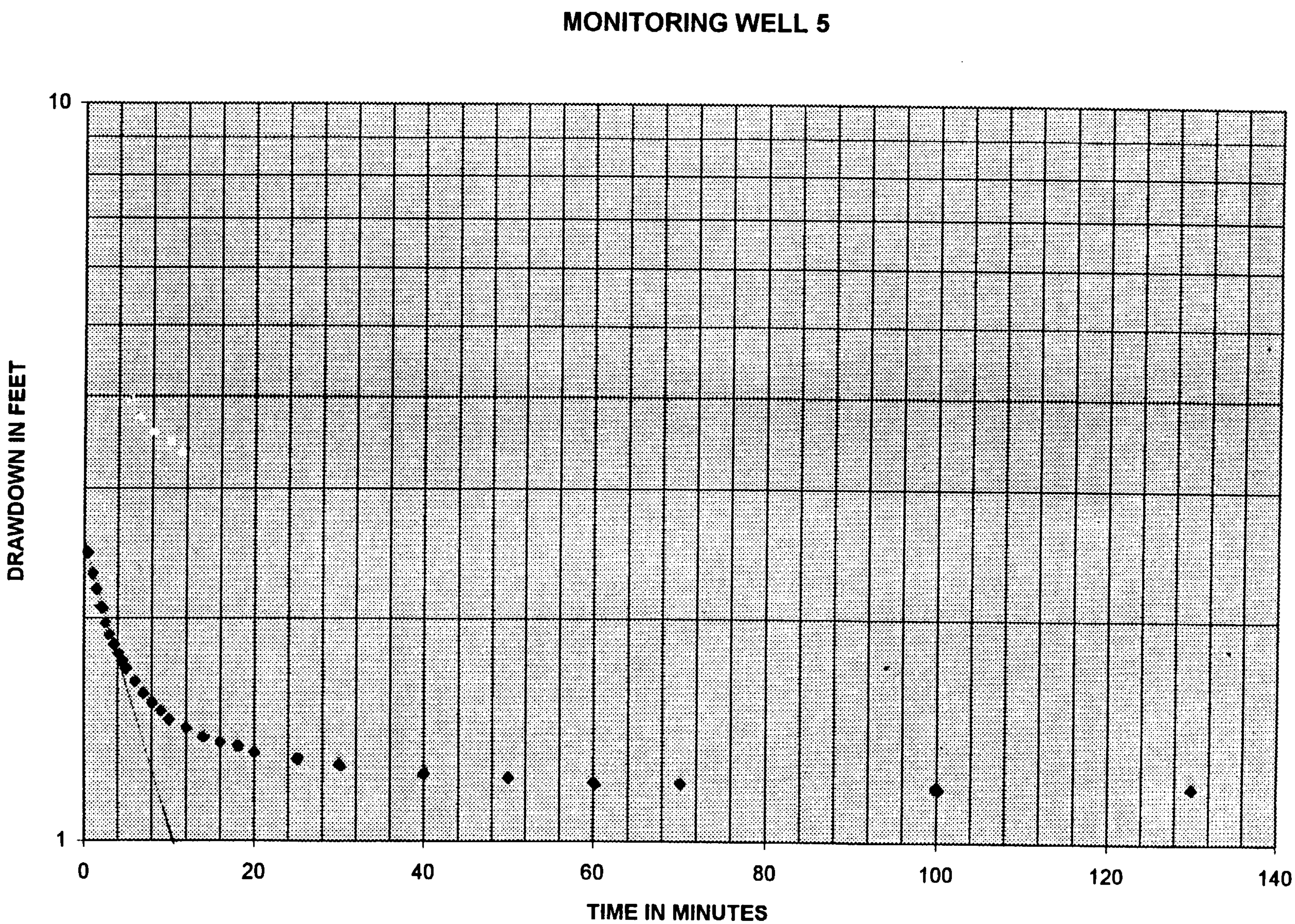
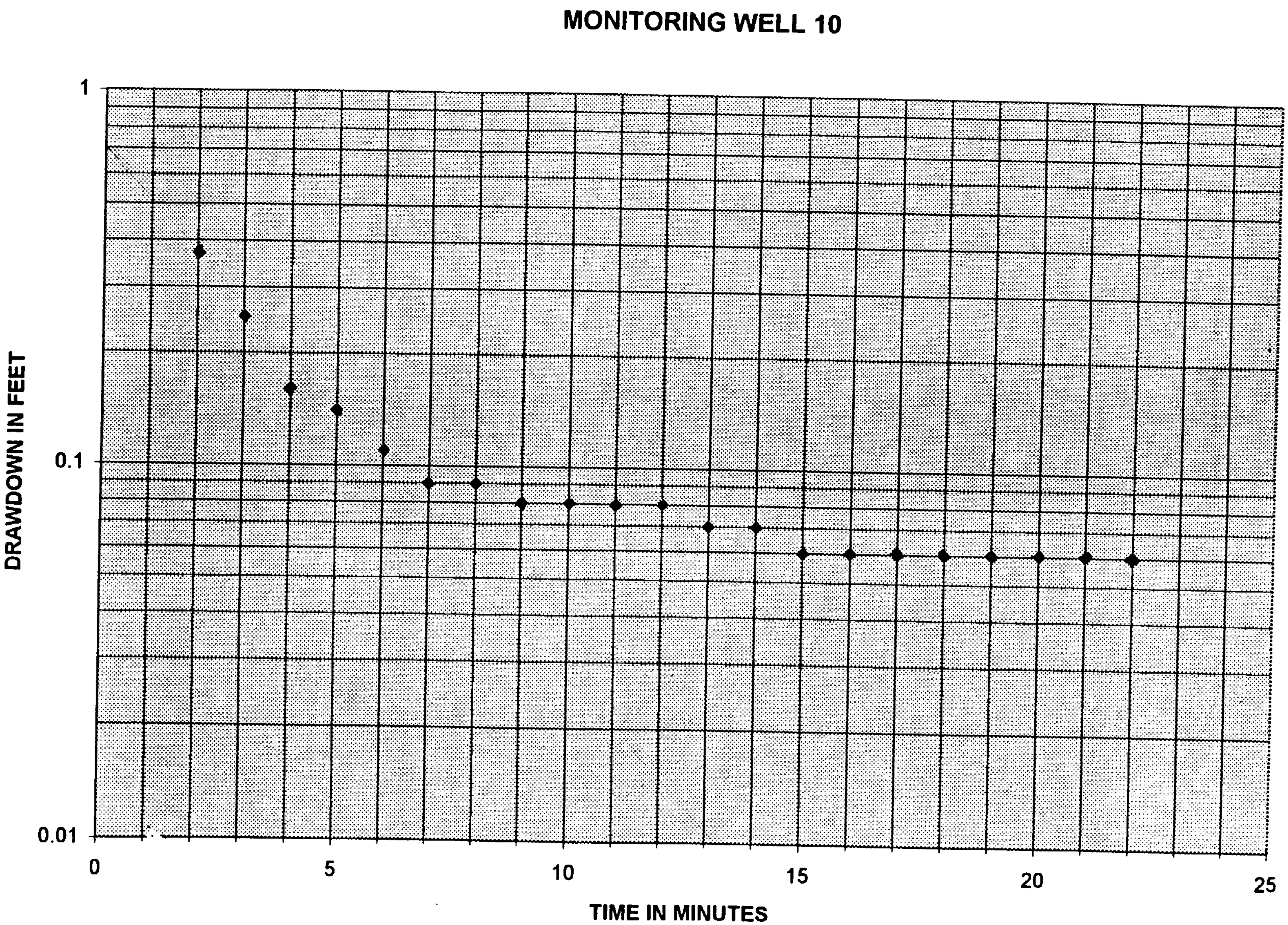

MONITORING WELL 5
10
1
DRAWDOWN IN FEET
0
20
40
60
80
100
120
140
TIME IN MINUTES

FIGURE E-12



MONITORING WELL 10
DRAWDOWN IN FEET
1
0.1
0.01
0
5
10
15
20
25
TIME IN MINUTES

FIGURE E-13

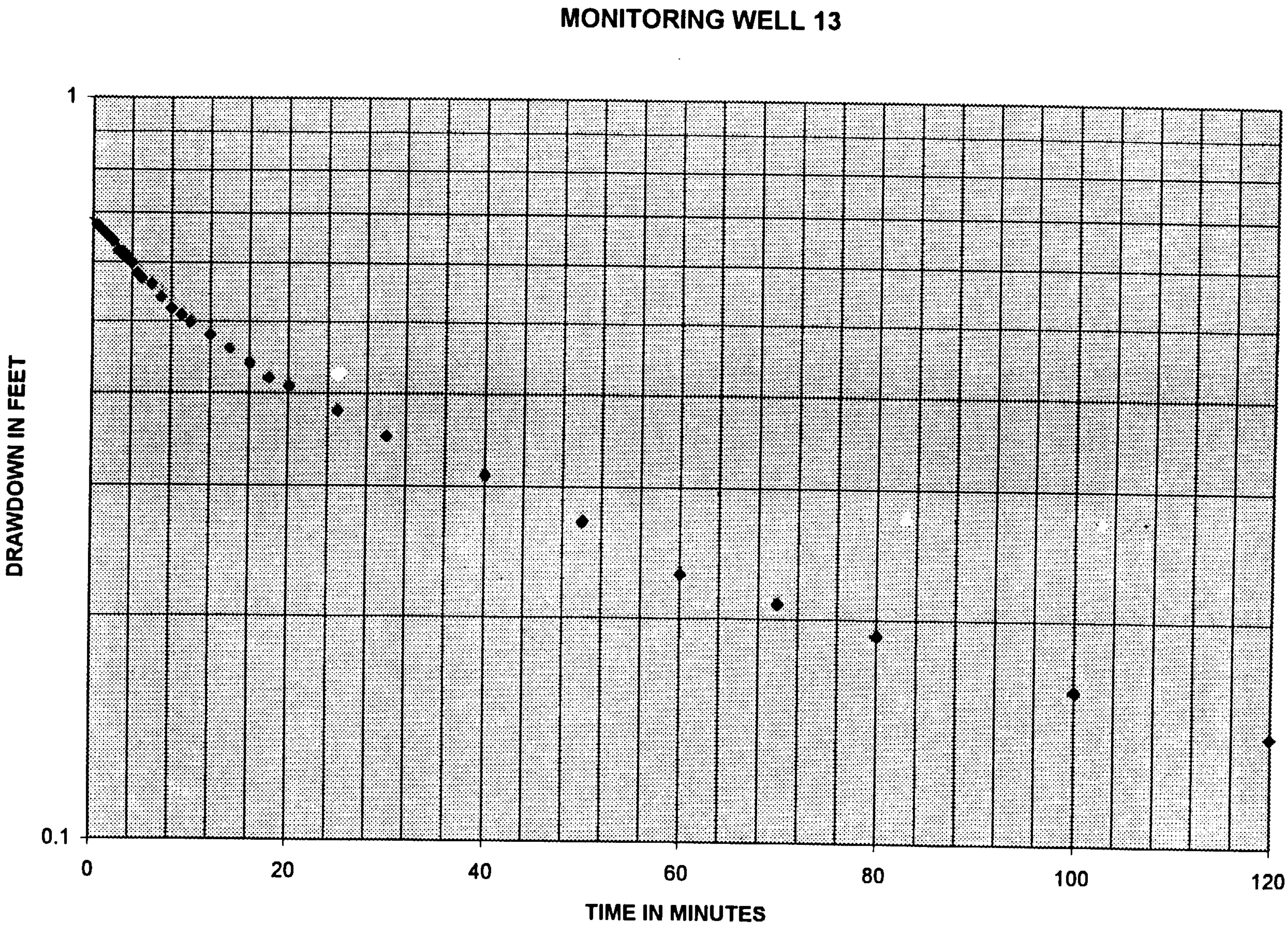

MONITORING WELL 13
1
0.1
DRAWDOWN IN FEET
0
20
40
60
80
100
120
TIME IN MINUTES

FIGURE E-14

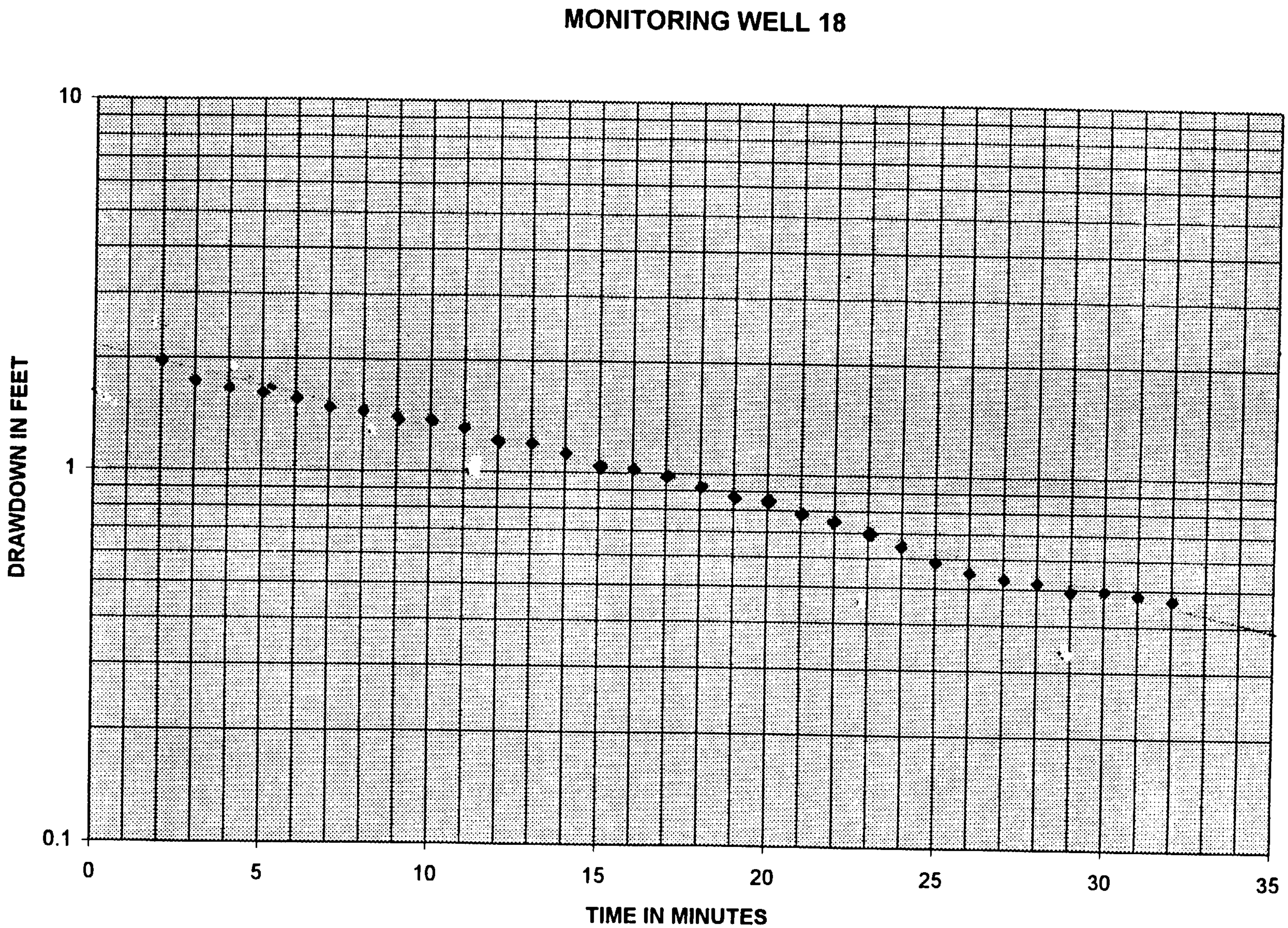

MONITORING WELL 18
10
1
0.1
DRAWDOWN IN FEET
0
5
10
15
20
25
30
35
TIME IN MINUTES

FIGURE E-15

MONITORING WELL 18S

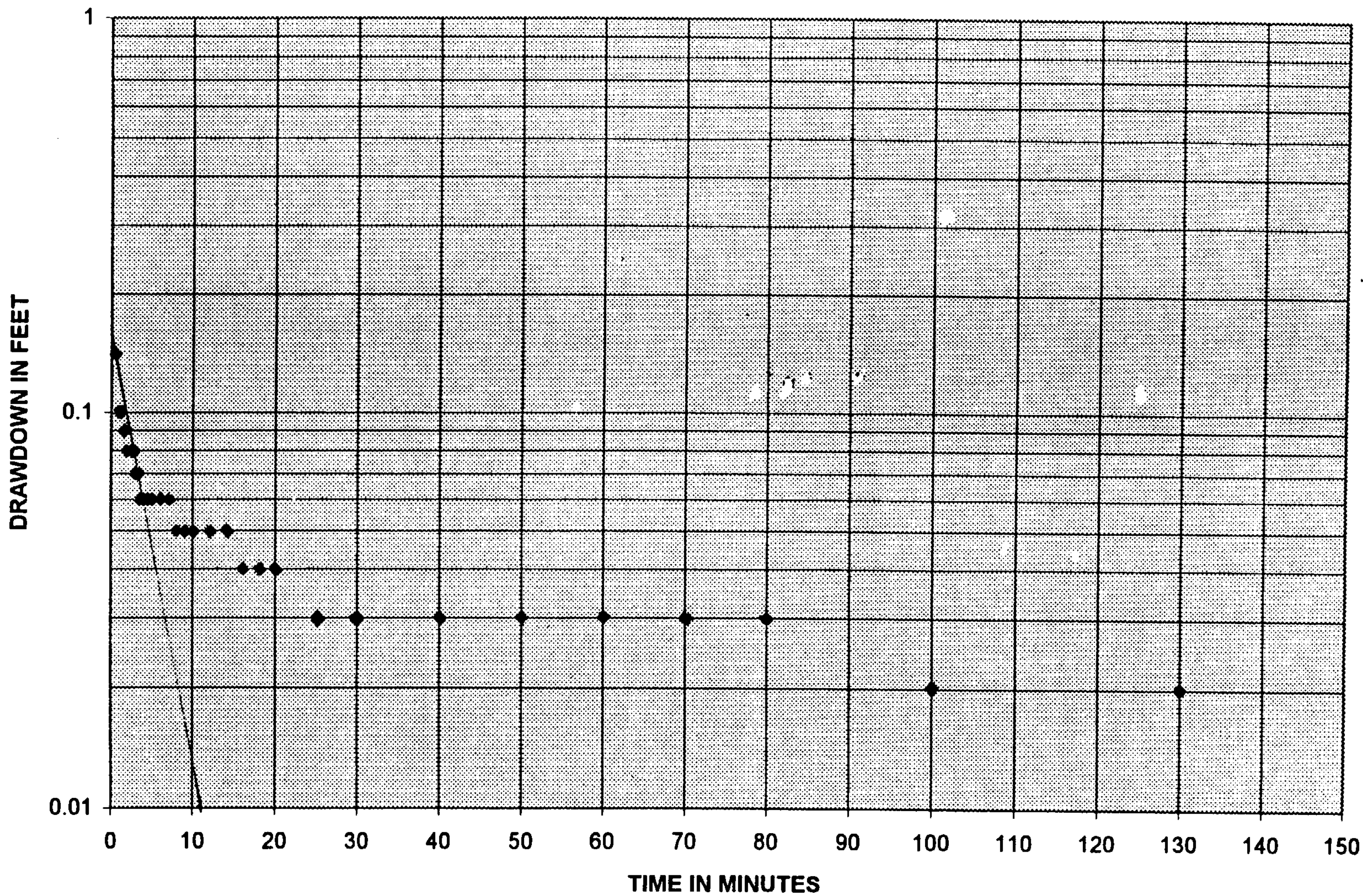


FIGURE E-16

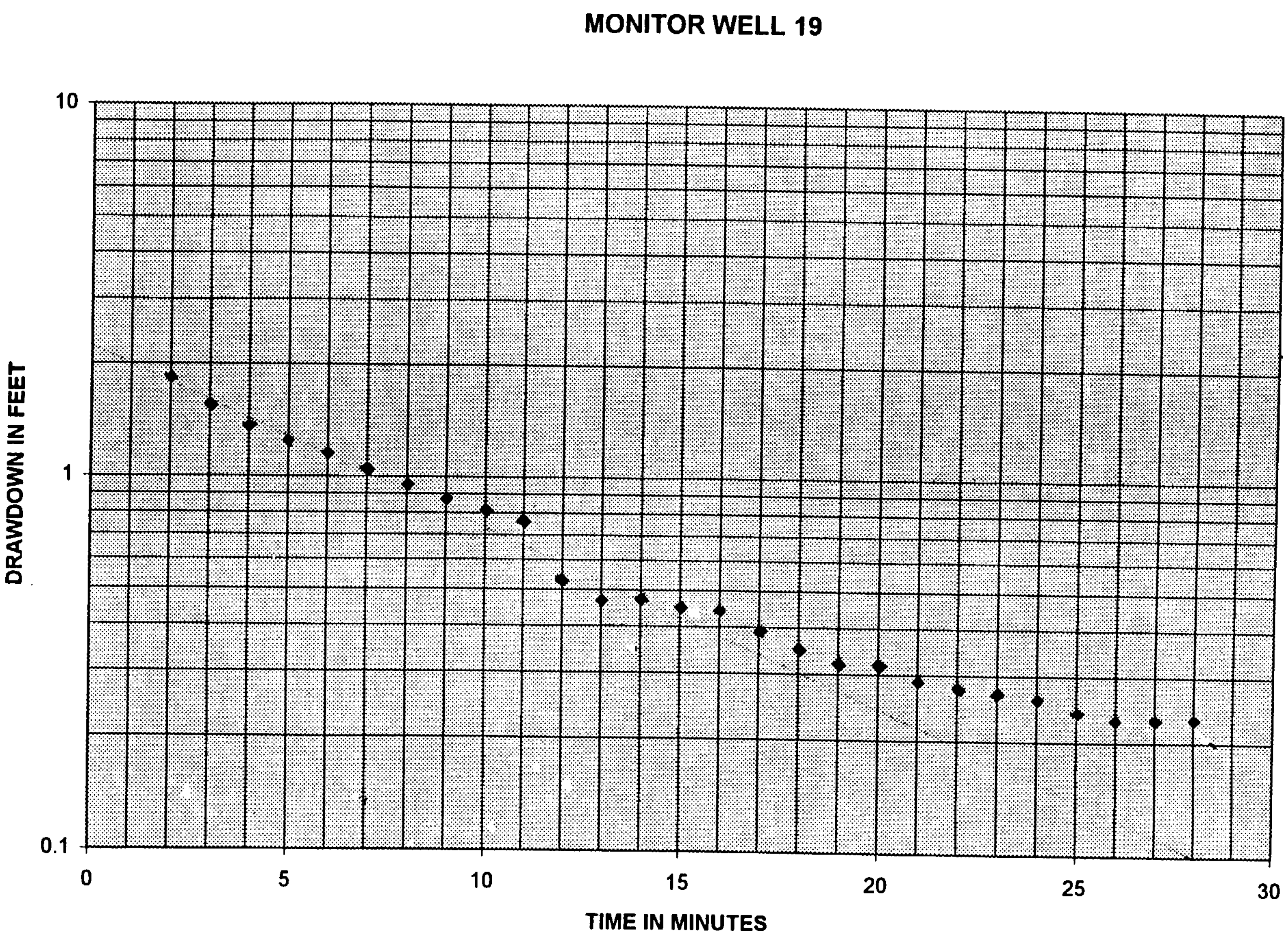

MONITOR WELL 19
DRAWDOWN IN FEET
10
1
0.1
0
5
10
15
20
25
30
TIME IN MINUTES

FIGURE E-17

MONITORING WELL 20

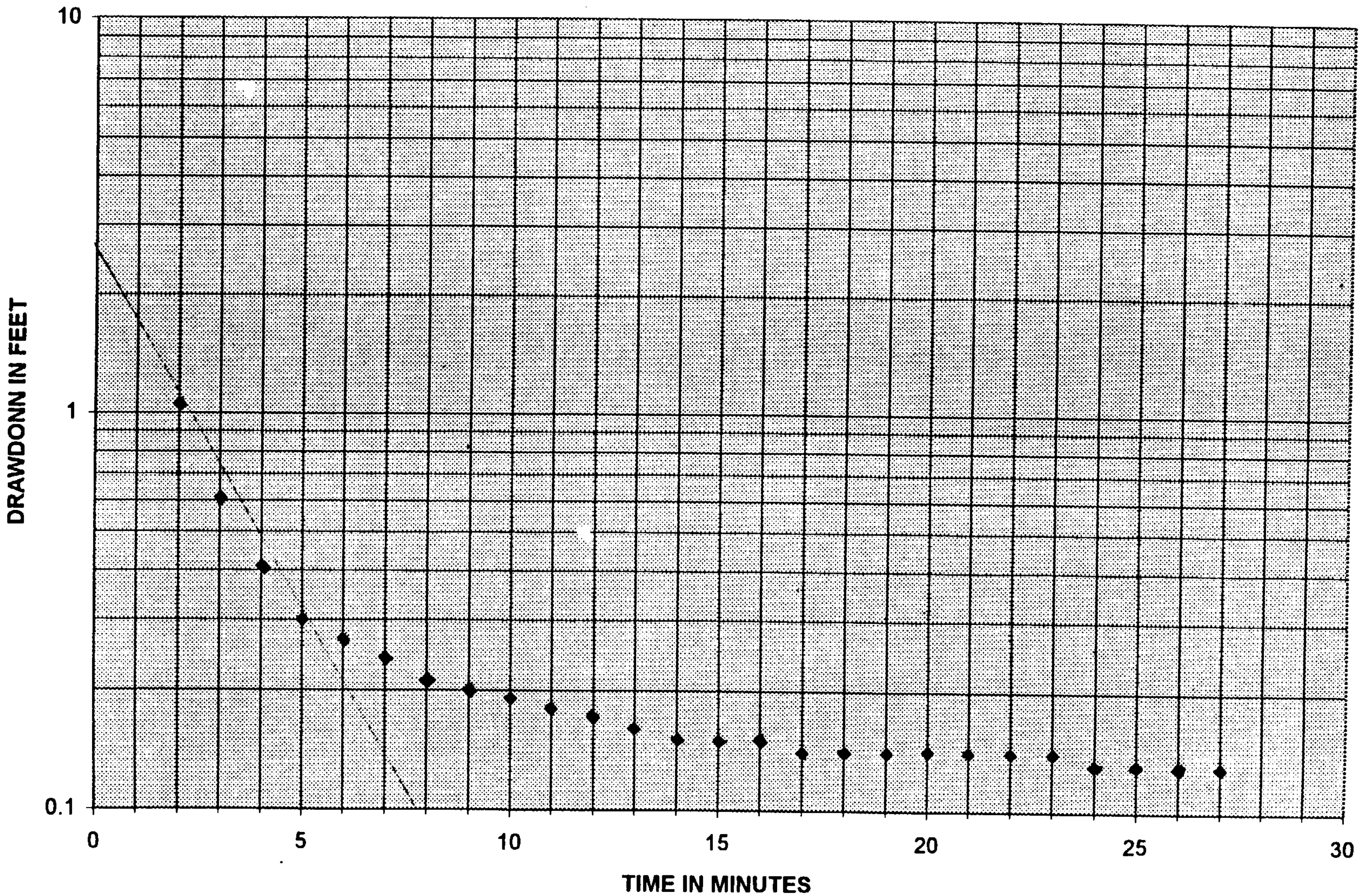


FIGURE E–18

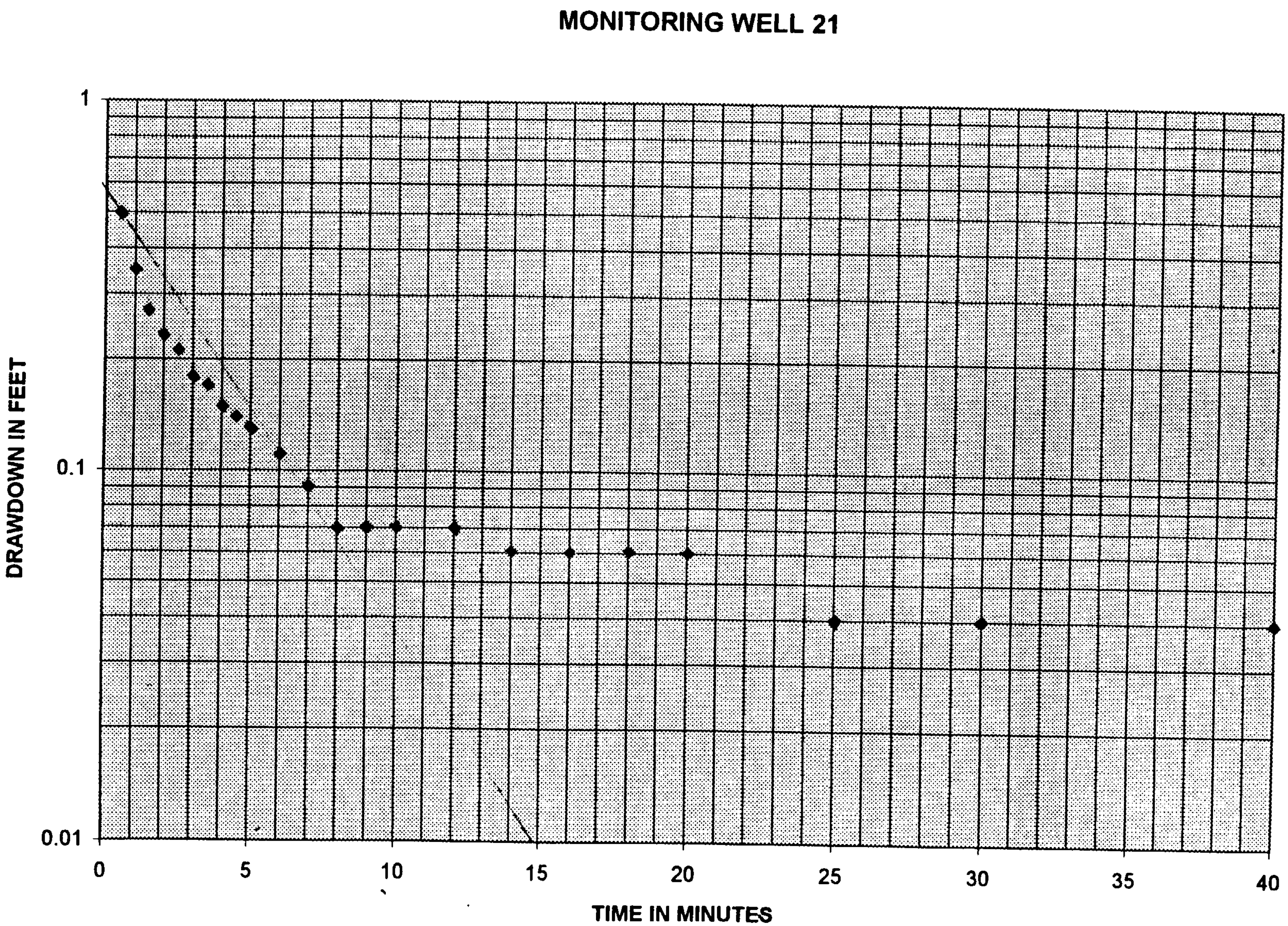

MONITORING WELL 21
DRAWDOWN IN FEET
1
0.1
0.01
0
5
10
15
20
25
30
35
40
TIME IN MINUTES

FIGURE E-19

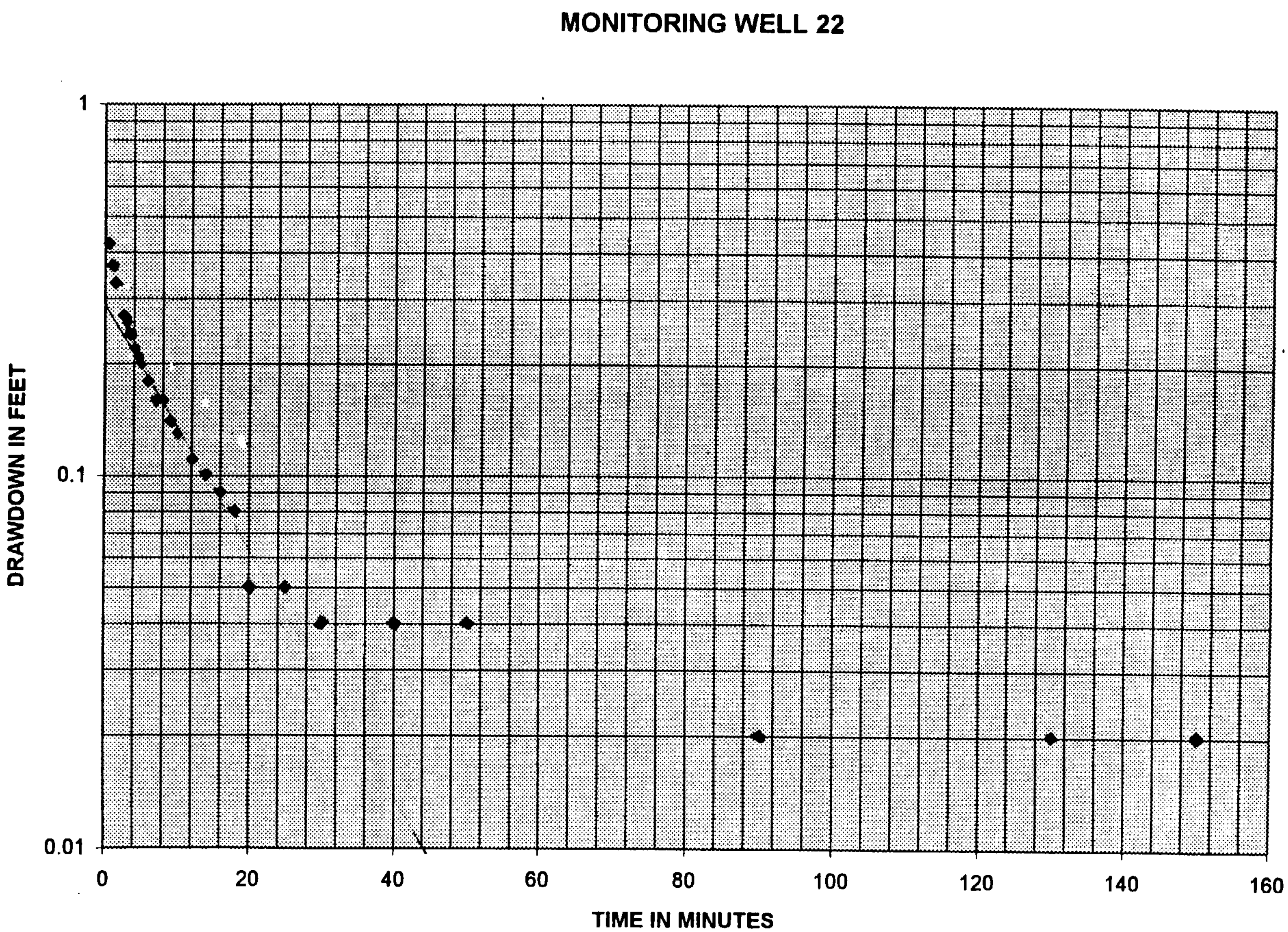

MONITORING WELL 22
DRAWDOWN IN FEET
1
0.1
0.01
0
20
40
60
80
100
120
140
160
TIME IN MINUTES

FIGURE E-20

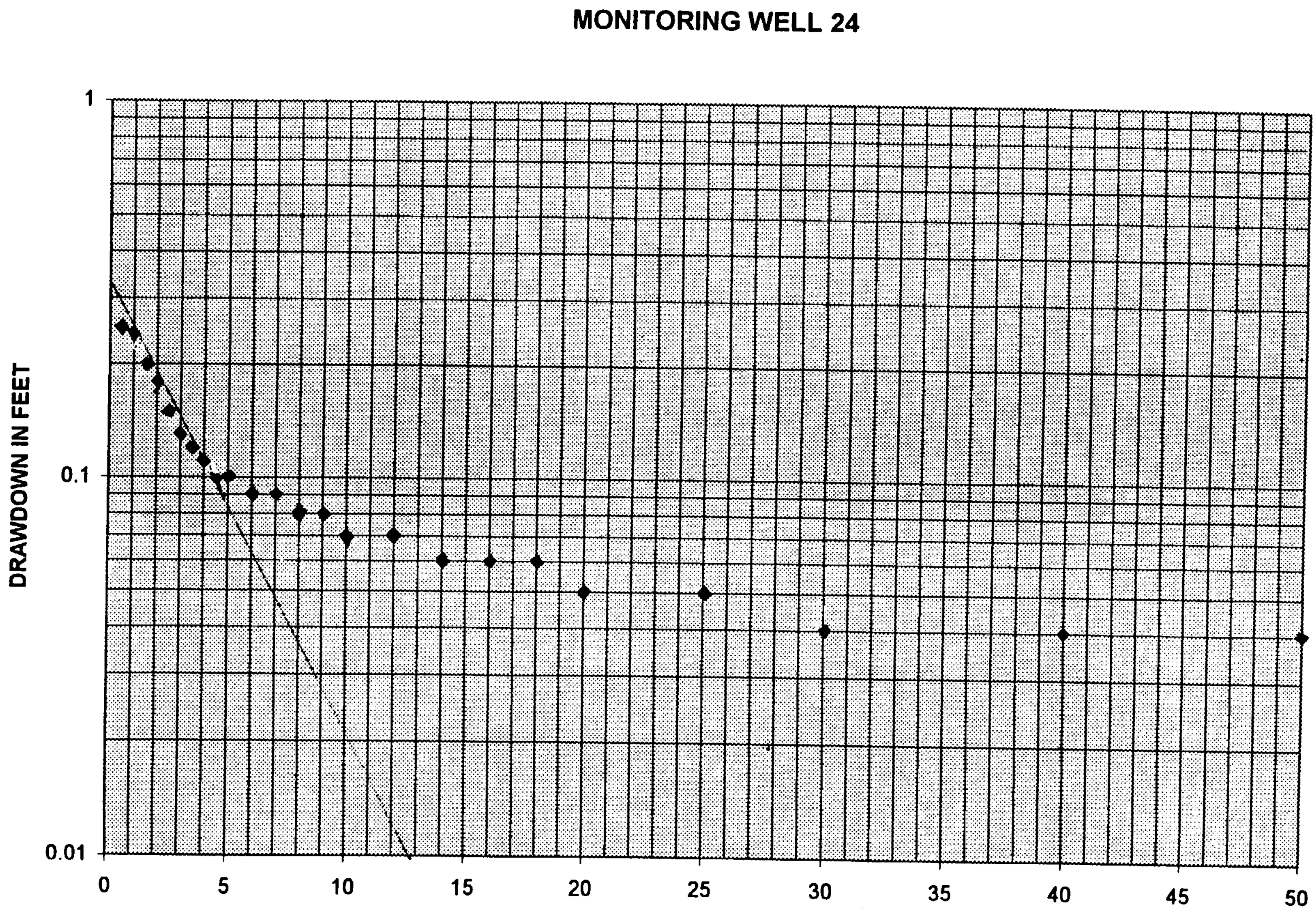

MONITORING WELL 24
DRAWDOWN IN FEET
1
0.1
0.01
0
5
10
15
20
25
30
35
40
45
50
TIME IN MINUTES

FIGURE E-21

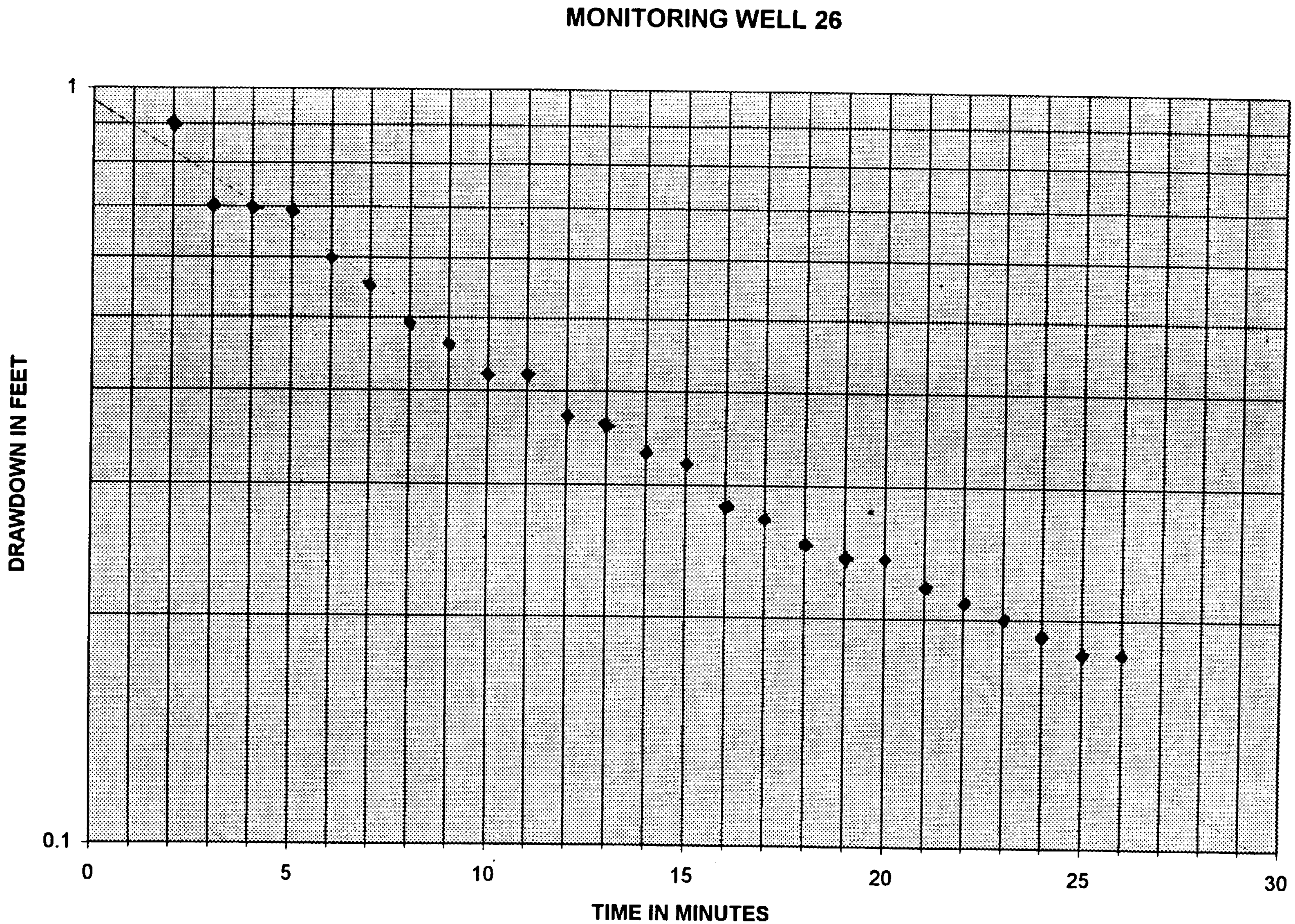

MONITORING WELL 26
1
0.1
DRAWDOWN IN FEET
0
5
10
15
20
25
30
TIME IN MINUTES

FIGURE E-22

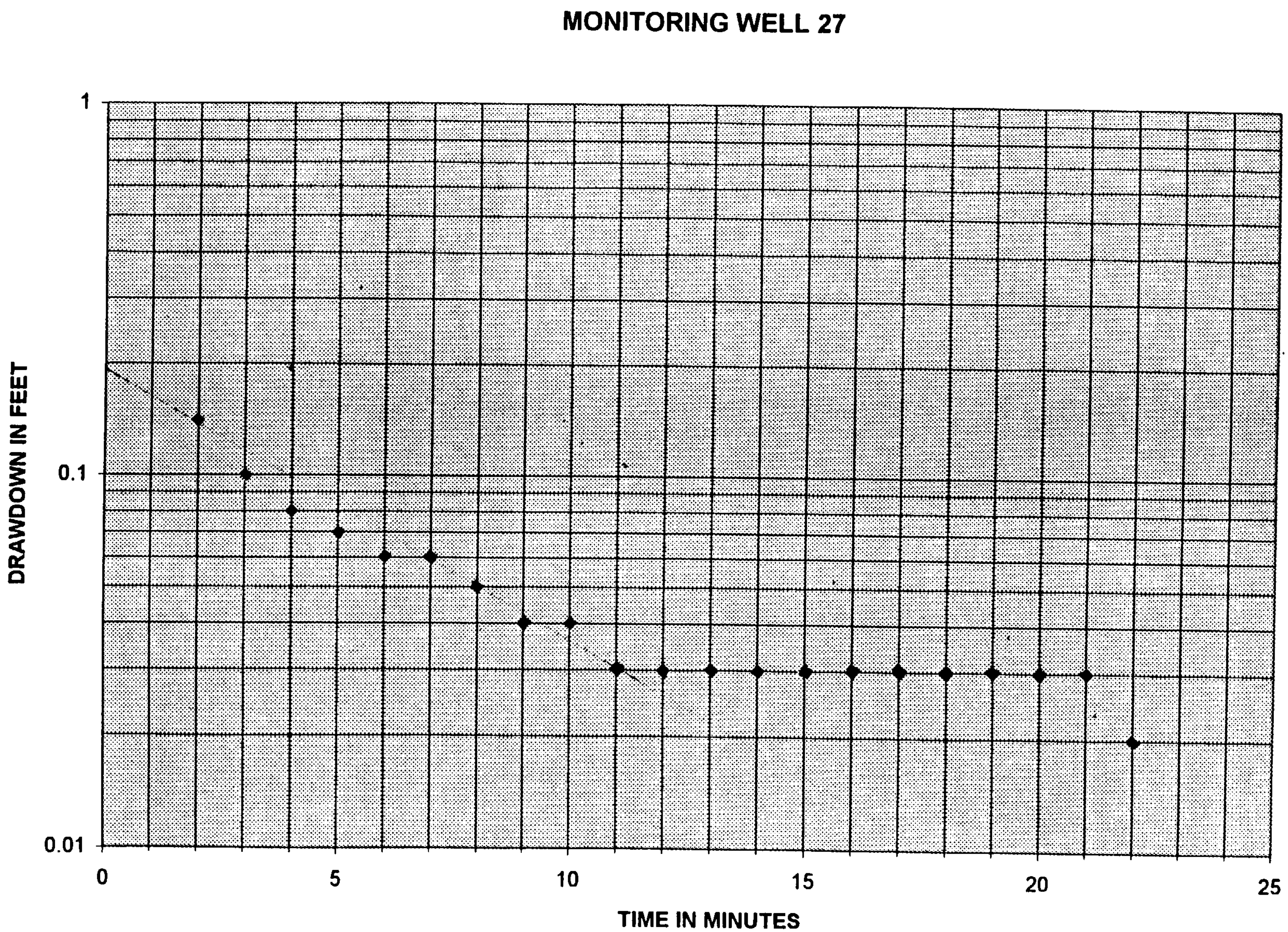

MONITORING WELL 27
1
0.1
0.01
DRAWDOWN IN FEET
0
5
10
15
20
25
TIME IN MINUTES

FIGURE E-23

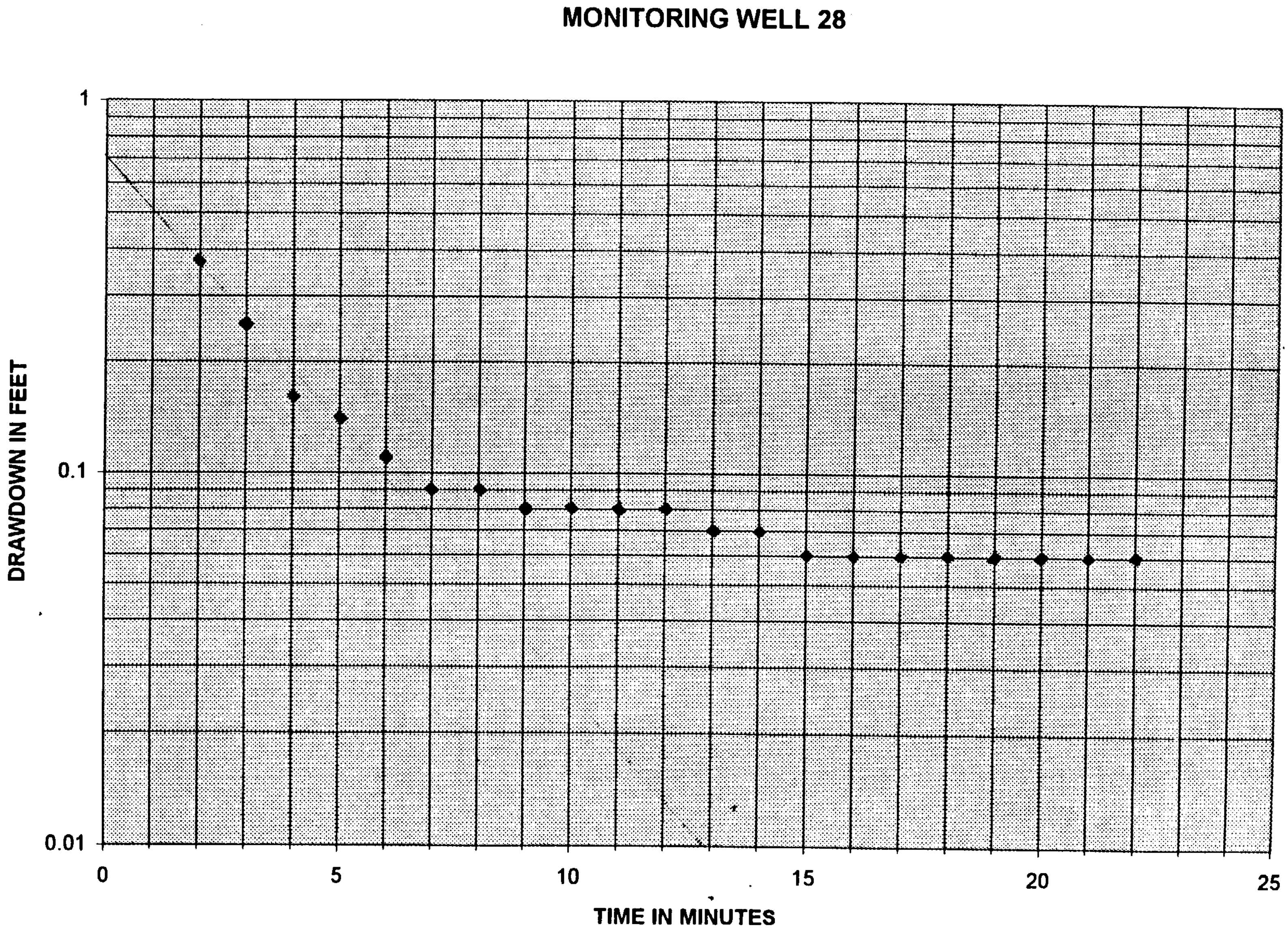

MONITORING WELL 28
1
0.1
0.01
DRAWDOWN IN FEET
0
5
10
15
20
25
TIME IN MINUTES

FIGURE E-24

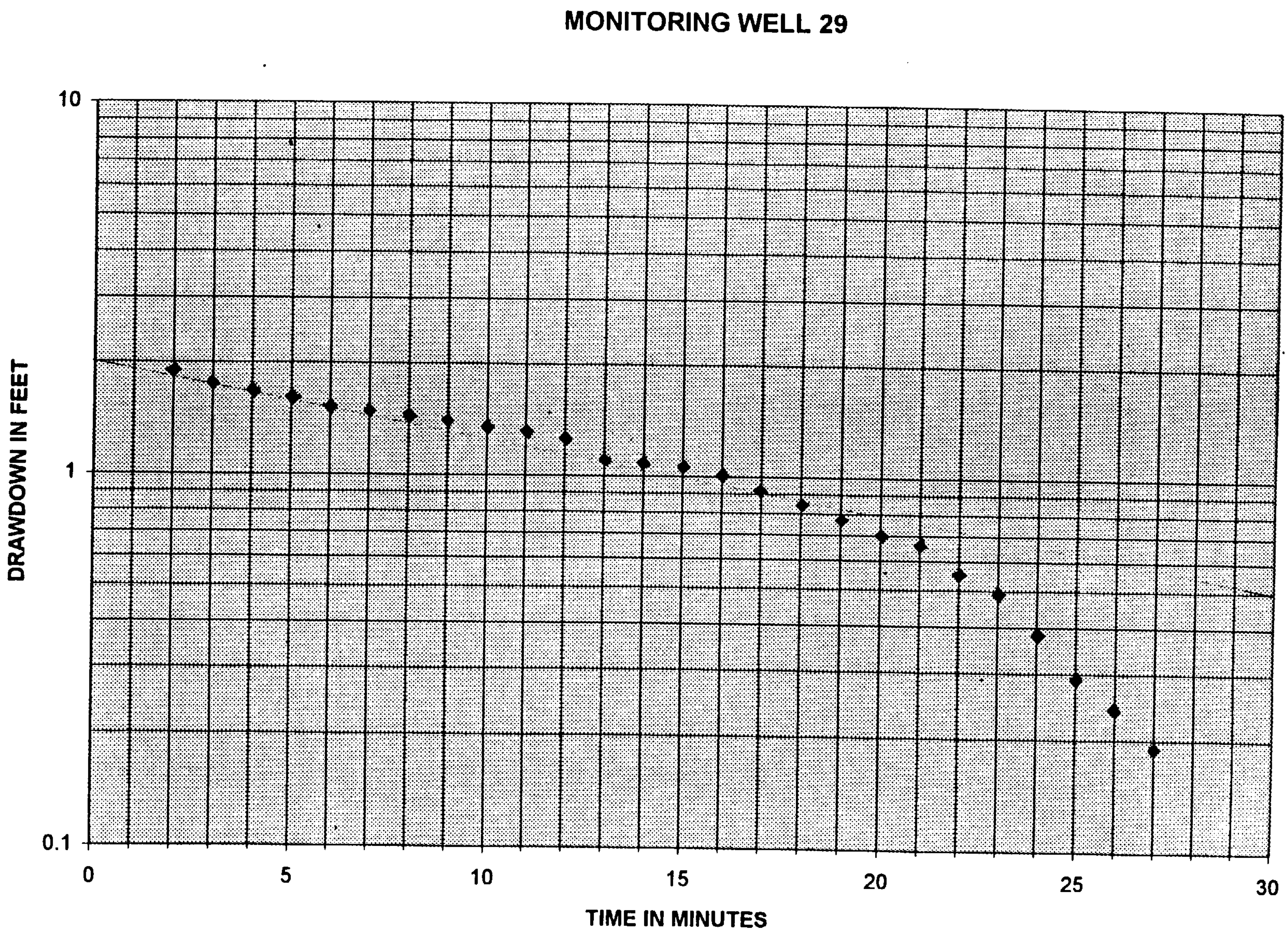

MONITORING WELL 29
10
1
0.1
DRAWDOWN IN FEET
0
5
10
15
20
25
30
TIME IN MINUTES

FIGURE E-25

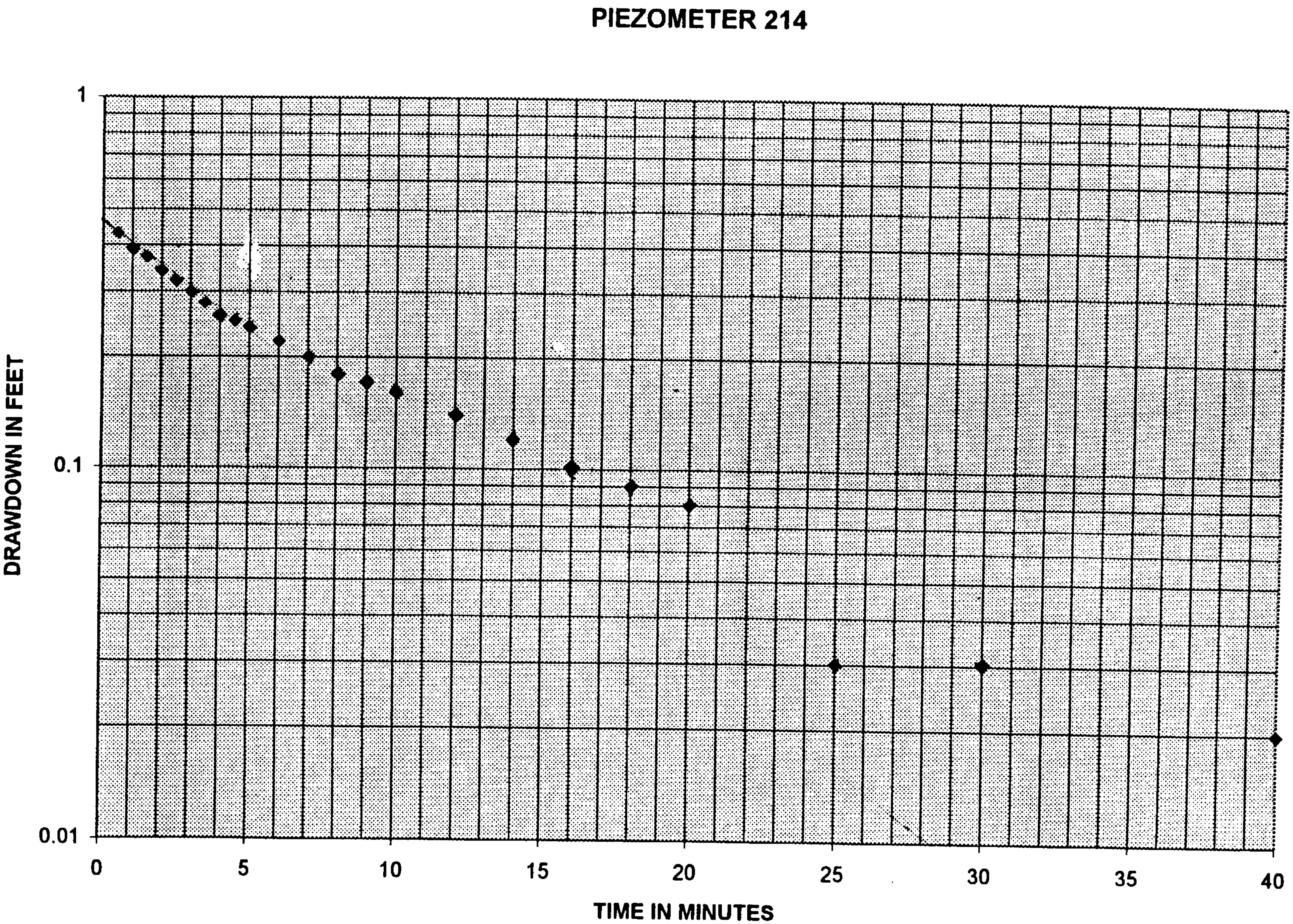
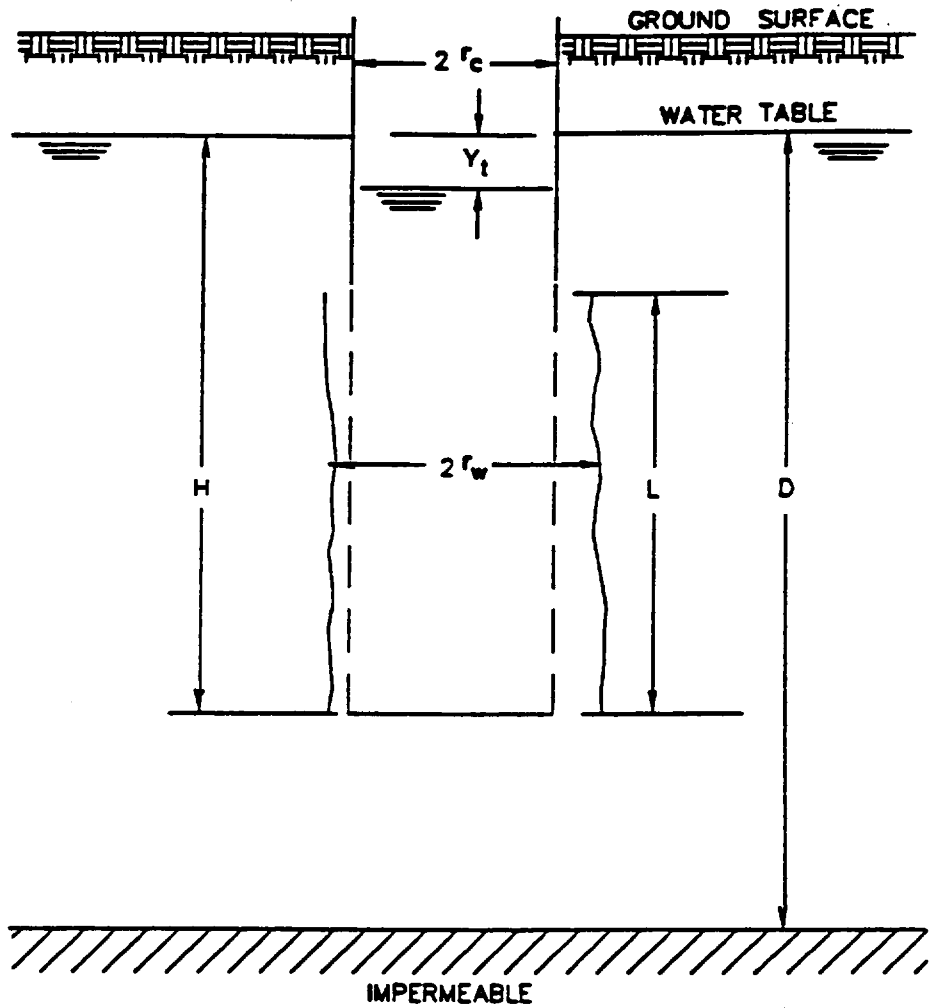

PIEZOMETER 214
1
0.1
0.01
DRAWDOWN IN FEET
0
5
10
15
20
25
30
35
40
TIME IN MINUTES

FIGURE E-26

WELL PARAMETERS USED PARTICULARLY WITH BOUWER AND RICE METHOD



LEGEND

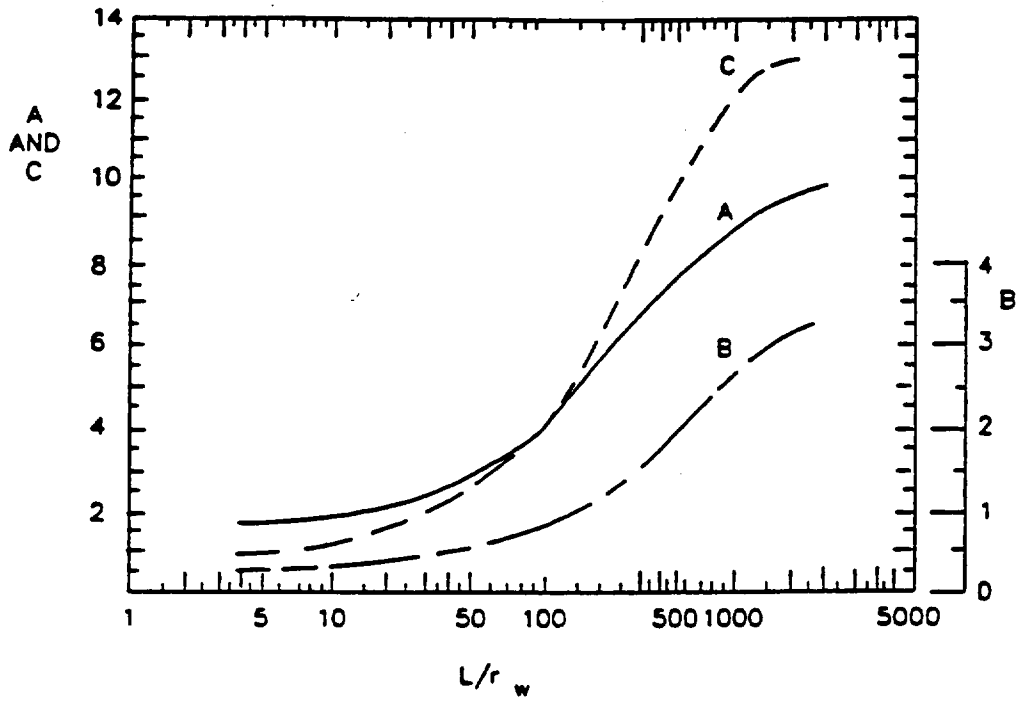
r_c = 0.083 FT
r_w = 0.25 FT
L = 10 FT
H = 9 FT
D = 22 FT

MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE E-27

FOSTER WHEELER ENVIRONMENTAL CORPORATION

TYPE CURVES USED IN BOUWER AND RICE CALCULATION



MOLYCORP, INC.
300 CALDWELL AVENUE
WASHINGTON, PA

FIGURE E-28

FOSTER WHEELER ENVIRONMENTAL CORPORATION

Slug Injection Test - Well BR-1
Hand Measured Drawdown
Hvorslev Method of Analysis

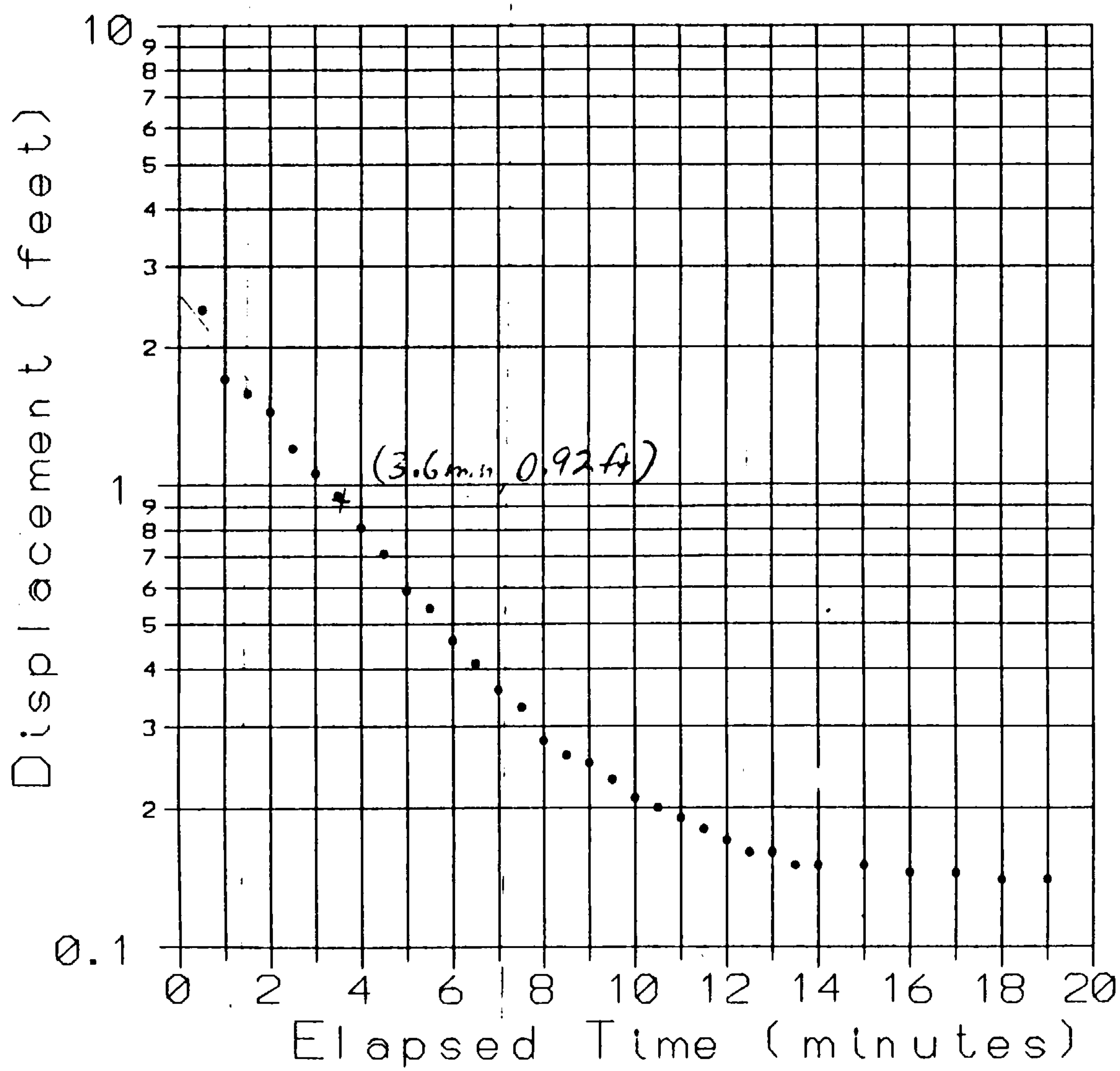
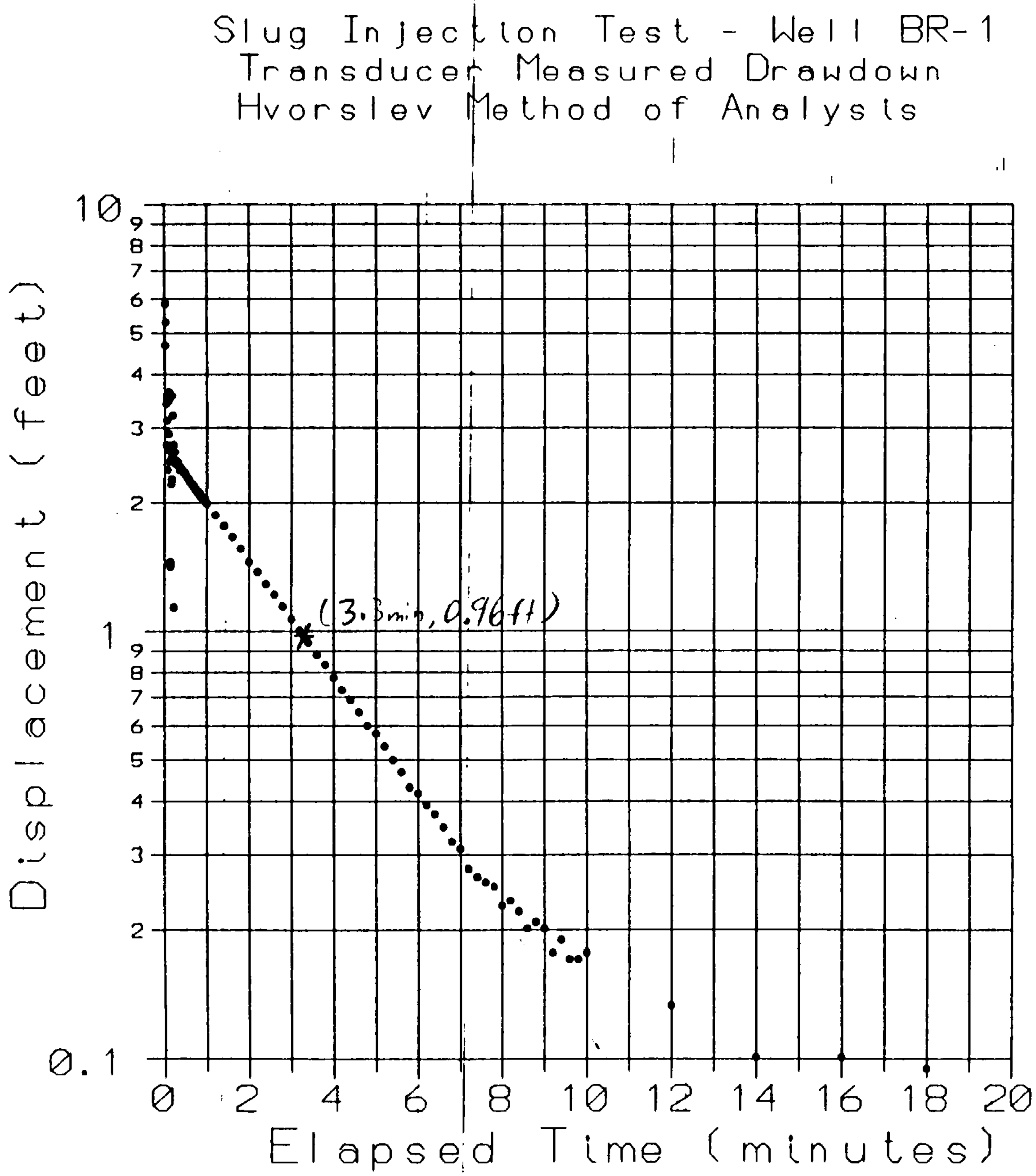


FIGURE E-29



Slug Injection Test - Well BR-1
Transducer Measured Drawdown
Hvorslev Method of Analysis
Displacement (feet)
10
1
0.1
Elapsed Time (minutes)
0 2 4 6 8 10 12 14 16 18 20
(3.3min, 0.96ft)

FIGURE E-30

ATTACHMENT 1

TO APPENDIX E

ATTACHMENT 1 TO APPENDIX E

In-Situ Inc.

210 S. Third Street
P.O. Box I
Laramie, WY 82070-0920 USA

Tel. (307) 742-8213
(800) 446-7488 (4IN-SITU)
FAX: (307) 721-7598

Enserch Environmental Corporation
Mr. George Markt
Mr. Tom Fowler
Et al.
1290 Wall Street West
P.O. Box 661
Lyndhurst, NJ 07071-0661

September 29 1994

Dear Sirs:

At your request I reviewed the data collected by Enserch personnel using our rental equipment to collect pump test data at the Moly Corp location. The data exhibited anomalies in correlation against hand data collected during the test. These anomalies were a background 'noise' that caused the readings to vary by hundredths of a foot around the general trend exhibited by the hand measurements, and on some wells a drift of the readings from hand measurements that increased over time.

These problems were first brought to our attention by Mr. Fowler during the first pump test. At that time we sent out another data logger to your site in an attempt to rectify what we believed was an equipment problem. The second data logger unfortunately also collected data that exhibited the same behavior. The equipment involved is listed as follows:

Original equipment	2K-195
	Transducers
	200708, 203206, 203719
	203822, 204329, 204565
	2501DI, 2543DI
Replacement logger	2K-436

Upon the receipt of the equipment it is tested for operation and serviceability and all the units passed these tests. The units have gone on subsequent rentals with no reported problems.

The only conclusion we can draw from the fact that the problem was exhibited by two different data loggers that have subsequently been tested and exhibited no problems is that the problem was a site specific interference of some variety. The equipment is shielded against normal radio frequence interference so the exact nature of the interference causing these problems is at this point unknown.

If we can be of assistance in any way please fell free to call.

Sincerely,

John C. Kaessinger
Product Support

APPENDIX F

Storm Sewer Base Flow Measurements

APPENDIX F

STORM SEWER BASEFLOW MEASUREMENTS

Baseflow measurements were conducted at two locations in the North Storm Sewer and the two locations in the South Storm Sewer. The measurements were performed on September 9 and November 3, 1994. The purpose of these measurements was to provide data on groundwater leakage to or from the storm sewer. Each set of measurements was performed following at least several days of dry weather to help ensure that direct surface water runoff was not impacting the measurements. The plant site was investigated to verify that there were no discharges by plant to storm sewers.

The storm sewers and sampling locations are shown in Figure 5-24. The four sampling locations are: Station 001-01, which is an upgradient, off-site manhole in the North Storm Sewer; 001-05, the North Storm Sewer Outfall; 002-01, the South Storm Sewer near the guard gate; and 002-02, the South Storm Sewer Outfall.

Because of confined space entry limitations, direct measurement through manhole entry was not feasible. At each of the four locations, the sewer pipe was constructed in such a way that a bucket could be placed under the pipe to capture the entire flow of water from the pipe. To measure the flow, a bucket was placed under the pipe and the time required to fill the bucket was measured. The quantity of water was measured by transferring the water to a graduated cylinder. Each measurement was repeated 14 times at each station on September 9, and seven times at each station on November 3. (It was determined after analysis of the first round that 7 times would be sufficient data.) The measurements were averaged to obtain the average flow rate at each station for each of the two days. The average flow rates were:

Station	September 9, 1994 average flow rate in gpm	November 3, 1994 average flow rate in gpm
001-01	3.85	3.51
001-05	7.29	7.76
002-01	2.03	2.53
002-02	3.65	3.92

These data indicate that on sewer line 001, 7.29 gpm of water flowed from the site to Chartiers Creek at the North Storm Sewer Outfall in September, while 3.85 gpm entered the site through the sewer at the upgradient side of the site. The difference in flows shows that approximately 3.44 gpm of water is entering the storm sewer under the site or from the Findlay Refractories tie-in. Similarly on November 3, 4.25 gpm was found to enter the pipe. At the South Storm Sewer, inflow to the pipe between the guardhouse (002-01) and the outfall (002-02) on September 9 and

November 3 was 1.62 and 1.39 gpm, respectively as calculated by subtracting the flow in 002-01 from that in 002-02 for each day. Unlike the North Storm Sewer all water in the South Storm Sewer is assumed to originate onsite. By adding the South Storm Sewer Outfall (002-02 flow) inflow data (total flow) to the North Sewer inflow data from the site proper (001-07 minus 001-01 flow) on the respective dates, it is calculated that the site contributed approximately 7.09 gpm to the storm sewers on September 9 and 8.17 gpm on November 3.

These data indicate that baseflow to the storm sewers is comparable to the average annual baseflow contribution from the site calculated in Appendix C. The outcome suggests that a significant percentage of the groundwater may be discharged into storm sewers. The sewer lines appear to be at or near the water table at many locations. It is possible that at some locations the excavated zone around the pipe may intercept deeper groundwater from the semiconfined sand and gravel unit, particularly on the South Storm Sewer. In summary, it appears that a significant percentage of the baseflow from the site to Chartiers Creek may be intercepted by the storm sewers.

APPENDIX H

REVIEW OF GAMMA-LOGGING IN SITE CHARACTERIZATION AT MOLYCORP, INC.

H.1 INTRODUCTION

As stated in the SCP, Molycorp's consultant (RSA) utilized gamma logging with NaI scintillation detectors to estimate the thorium concentration in the adjacent soil material at interval depth points in the boreholes. The intervals were six inches. The thorium concentration around each measurement point was estimated by:

- Converting the NaI count rate (cpm) to exposure rate (uR/hr) using detector-specific calibration factors obtained from a series of pressurized ion chamber (PIC) comparisons above ground.
- Calculating the local thorium concentration from the exposure rate using a factor developed by Beck et al. Beck's conversion factor is 2.82 (uR/hr)/(pCi/g) for 2π geometry and 5.64 (uR/hr)/(pCi/g) for 4π geometry.

The NRC (Dec. 1993) has questioned several aspects of this methodology. This appendix is presented in response to the questions (Rahon, J-1974).

H.2 OBJECTIVES

The objectives of this appendix are:

- To assess the appropriateness of the use of the NaI count rate to exposure rate and exposure rate to thorium concentration conversion factors.
- To experimentally derive the exposure rate to concentration conversion factor and compare it to Beck's conversion factor used by Molycorp's consultant RSA.
- To discuss the utility of gamma logging as performed to assist in site characterization.

H.3 METHODOLOGY

Gamma log count rate and thorium concentration data were obtained on the Molycorp site for boreholes SB-056, SB-056A, SB-056B, and SB-056C. As recommended by the NRC, boreholes SB-056A, -B and -C were arranged in a triangular shape, 120 degrees apart, around borehole SB-056. Each of the three outer holes was 5 feet from the inner hole. Soil samples were collected by long split spoon samplers (2 in. diameter x 18 in. long) and were analyzed by RSA using gamma spectroscopy with an 8x8 in. NaI crystal. Each hole was gamma logged at 6-inch intervals.

APPENDIX G

Soil Boring Logs Data

(Provided in Volume 3)

APPENDIX H

Review Of Gamma-Logging In Site Characterization At Molycorp, Inc.

APPENDIX H

REVIEW OF GAMMA-LOGGING IN SITE CHARACTERIZATION AT MOLYCORP, INC.

H.1 INTRODUCTION

As stated in the SCP, Molycorp's consultant (RSA) utilized gamma logging with NaI scintillation detectors to estimate the thorium concentration in the adjacent soil material at interval depth points in the boreholes. The intervals were six inches. The thorium concentration around each measurement point was estimated by:

- Converting the NaI count rate (cpm) to exposure rate (uR/hr) using detector-specific calibration factors obtained from a series of pressurized ion chamber (PIC) comparisons above ground.

- Calculating the local thorium concentration from the exposure rate using a factor developed by Beck et al. Beck's conversion factor is 2.82 (uR/hr)/(pCi/g) for 2π geometry and 5.64 (uR/hr)/(pCi/g) for 4π geometry.

The NRC (Dec. 1993) has questioned several aspects of this methodology. This appendix is presented in response to the questions (Rahon, J-1974).

H.2 OBJECTIVES

The objectives of this appendix are:

- To assess the appropriateness of the use of the NaI count rate to exposure rate and exposure rate to thorium concentration conversion factors.

- To experimentally derive the exposure rate to concentration conversion factor and compare it to Beck's conversion factor used by Molycorp's consultant RSA.

- To discuss the utility of gamma logging as performed to assist in site characterization.

H.3 METHODOLOGY

Gamma log count rate and thorium concentration data were obtained on the Molycorp site for boreholes SB-056, SB-056A, SB-056B, and SB-056C. As recommended by the NRC, boreholes SB-056A, -B and -C were arranged in a triangular shape, 120 degrees apart, around borehole SB-056. Each of the three outer holes was 5 feet from the inner hole. Soil samples were collected by long split spoon samplers (2 in. diameter x 18 in. long) and were analyzed by RSA using gamma spectroscopy with an 8x8 in. NaI crystal. Each hole was gamma logged at 6-inch intervals.

In another test, gamma logging was performed in a uniform mixture of soil/slag in two 55-gallon drums. The thickness of the soil/slag was 18 inches and the diameter of the drum was 23 inches. The detector was centered in the soil/slag layer at a depth of 9 inches.

The gamma log and soil analysis data from these tests were used in this review to calculate conversion factors which were then compared to those used by RSA.

H.4 RESULTS AND DISCUSSION

Count Rate to Exposure Rate Conversion:

The main concern here was that the NaI probes were calibrated to PIC's above ground when they were actually used below ground where the energy spectrum of the gamma radiation field may have been different. This is a valid concern if the final result is to be an exposure rate. However, in gamma logging, the conversion to exposure rate is an intermediate step used to normalize the data for differences in probe response (calibration) factors. Thus, to be technically accurate, the exposure rate calculated from a count rate in a hole could be referred to as "nominal exposure rate".

Exposure Rate to Thorium Concentration Conversion:

The data from the hole-SB-056 experiment are shown in Tables H-1 to H-4. It was apparent that soil sample collection via 18-in. split spoon sampling was not well-registered over the soil column and the recovery in some of the tubes was not complete. Thus, 2-foot averages were calculated and shown in Tables H-1 to H-4. These 2-foot averages were used to calculate the exposure rate to concentration conversion factor in Table H-5. Also included in the analysis in Table H-5 are the two data points from the barrel experiment.

The nominal exposure rate to thorium concentration conversion factor as calculated in Table H-5 is 5.4 + 0.5 (uR/hr)/(pCi/g) 4π. This agrees well with RSA's (Beck's) true exposure rate to thorium concentration factor of 5.64 (ur/hr)/(pCi/g) 4π. It is concluded that the use of above-ground calibration factors for underground measurements does not have a significant impact on the accuracy of the results relative to other uncertainties involved in such measurements. It is also concluded that RSA's use of Beck's exposure rate to concentration factor rather than an experimentally derived factor also does not have a significant impact on the accuracy of the results (i.e., 5.4 versus 5.6 (ur/hr)/(pCi/g)).

The y-intercept in the graph in Table H-5 is 11 uR/hr. This is interpreted as the non-thorium background in the hole due to the uranium series, K-40 and cosmic radiation. That is, if no thorium were present in the soil, there would be a background of 11 uR/hr in the hole.

Concerning the barrel experiment only, the average concentrations of thorium-232 in the two barrels were 33 $\pm$ 4 pCi/g and 30 $\pm$ 5 pCi/g as determined by gamma spectroscopy of six samples from each barrel. The count rates with the detector centered in the soil/slag layers were 16,588 cpm and 16,084 cpm. Using the detector's calibration factor of 0.0111 (uR/hr)/cpm, the nominal exposure rates were 184 uR/hr and 179 uR/hr. Using a background of 11 uR/hr as calculated above, the net exposure rates due to thorium in the center of the slag layers were 173 uR/hr and 168 uR/hr. The nominal exposure rate to concentration conversion factors are then 5.2 (ur/hr)/(pCi/g) and 5.6 (ur/hr)/(pCi/g), respectively. Again this agrees well with RSA's (Beck's) true exposure rate to thorium concentration factor of 5.64 (ur/hr)/(pCi/g) 4π.

<u>The Use of Gamma Logging in Site Characterization:</u>

It is apparent in Tables H-1 to H-4 that gamma logging provides a contamination depth profile that is more reasonable and probably more accurate then soil sampling. This is due to the ability of the gamma logging probe to view undisturbed volumes of soil while the use of the hollow-stemmed auger and split spoon sampler tends to disturb the soil and also tends to provide incomplete sample recoveries. In addition, the volume of soil measured by gamma logging is a sphere approximately 1 foot in radius (approximately 190 kg using a 1.6 soil/slag density) whereas sampling only collects or views approximately 0.2 kg. Obviously, the larger the sample size, the better the coverage of the survey.

The NRC suggested that the three outer holes (56A, 56B, and 56C) be used to predict the concentrations in the center hole (56) which is 5 feet away. Such a prediction is not possible for either gamma logging or soil sampling because the extent of the gamma logging sampling area is about a 1 foot radius and that of soil sampling is a 1 inch radius. Thus, such an analysis is not a fair method in which to assess the adequacy of gamma logging as well as that of soil sampling.

H.5 SURFACE SOIL MEASUREMENTS

To further confirm the use of Beck's exposure rate to thorium-232 concentration conversion (2.82 (uR/hr)/(pCi/g) 2π), RSA has performed 50 exposure rate (with a Reuter-Stokes pressurized ion chamber) and has collected and analyzed 4 surface soil samples around each gamma measurement point. The soil samples were analyzed by gamma spectroscopy. The results are summarized in Tables H-1 through H-5.

The analysis shows a conversion factor of 2.85 + 0.34 (uR/hr)/(pCi/g) which is in excellent agreement with the 2.82 (uR/hr)/(pCi/g) 2π used in the project's gamma logging calculations. The good agreement is especially significant considering that NaI probes are very sensitive to changes in the gamma energy spectrum that may occur by moving the detector from 1 meter above ground to close proximity with the ground.

H.6 CONCLUSION

The data show that gamma logging as performed in the Molycorp site characterization study provides a reasonable estimate of the vertical extent and magnitude of thorium contamination and may provide a more accurate depth profile then soil coring/sampling alone. The use of gamma logging for final clearance surveys is not addressed in this review (Rayon, 1994).

TABLE H-1

SB-056-94

Hole Radius (feet): 0.208

Dept (feet)	Raw Count Rate Data (cpm)		Gamma Log Results (Scaler) Exposure Rate µR/hr	Exposure Rate 2 foot avg µR/hr	Th-232 pCi/g	Th-232 2 foot avg pCi/g	Soil Sample Results (B) Th-232 Conc pCi/g	Th-232 Conc 2 foot avg pCi/g
0.0	3427 ±	59	41	62	10.8	10.5	8.9	13.6
0.5	5089 ±	71	61		9.3		17.7	
1.0	5771 ±	76	70		10.5		14.3	
1.5	6273 ±	79	76		11.5			
2.0	7076 ±	84	85	67	13.2	10.0		5.8
2.5	5599 ±	75	68		10.0			
3.0	4655 ±	68	56		8.0		6.3	
3.5	4910 ±	70	59		8.6		5.2	
4.0	6322 ±	80	76	163	11.6	26.9	9.7	9.8
4.5	7697 ±	88	93		14.5			
5.0	12516 ±	112	151		24.8			
5.5	27388 ±	165	330		56.6		9.9	
6.0	74722 ±	273	901	1575	157.9	277.3		31.2
6.5	143067 ±	378	1725		304.0			
7.0	153903 ±	392	1856		327.2		31.2	
7.5	150653 ±	388	1817		320.3			
8.0	94928 ±	308	1145	408	201.1	70.4		203.0
8.5	28157 ±	168	340		58.3		203.0	
9.0	8674 ±	93	105		16.6			
9.5	3565 ±	60	43		5.7			
10.0	2200 ±	47	27	22	2.8	1.9	50.5	55.3
10.5	1817 ±	43	22		1.9			
11.0	1604 ±	40	19		1.5			
11.5	1674 ±	41	20		1.6		60.1	
12.0	1514 ±	39	18	17	1.3	1.1		9.2
12.5	1534 ±	39	19		1.3			
13.0	1369 ±	37	17		1.0		15.4	
13.5	1346 ±	37	16		0.9		2.9	
14.0	1343 ±	37	16	23	0.9	2.2	2.0	0.7
14.5	1577 ±	40	19		1.4		0.7	
15.0	1916 ±	44	23		2.1		0.1	
15.5	2868 ±	54	35		4.2		0.1	
16.0	6208 ±	79	75	79	11.3	12.1	0.1	0.1
16.5	6954 ±	83	84		12.9			

TABLE H-2

SB-056a-94

Hole Radius (feet): 0.208
Scaler A3

Depth (feet)	Raw Count Rate Data (cpm)		Gamma Log Results: Exposure Rate µR/hr	Exposure Rate 2 foot avg µR/hr	Th-232 Conc. pCi/g	Th-232 Conc. 2 foot avg pCi/g	Soil Sample Results: Th-232 Conc pCi/g	Th-232 Conc 2 foot avg pCi/g
0.0	1495 ±	39	26	35	5.3	4.9	1.6	2.1
0.5	1779 ±	42	31		3.7		0.2	
1.0	2198 ±	47	38		4.9		4.4	
1.5	2493 ±	50	43		5.7			
2.0	2893 ±	54	50	101	7.0	16.0	1.9	21.5
2.5	4043 ±	64	70		10.5		2.1	
3.0	6116 ±	78	106		16.9		0.7	
3.5	10279 ±	101	178		29.7		81.3	
4.0	11904 ±	109	207	104	34.7	16.6	20.0	8.8
4.5	5915 ±	77	103		16.3			
5.0	3755 ±	61	65		9.6		3.8	
5.5	2473 ±	50	43		5.7		2.6	
6.0	2302 ±	48	40	41	5.1	5.4	4.2	4.2
6.5	2341 ±	48	41		5.3			
7.0	2352 ±	48	41		5.3			
7.5	2554 ±	51	44		5.9			
8.0	1533 ±	39	27	20	2.8	1.7	8.7	3.8
8.5	1120 ±	33	19		1.5		2.5	
9.0	1010 ±	32	18		1.2		2.0	
9.5	1023 ±	32	18		1.2		1.8	
10.0	1005 ±	32	17	18	1.1	1.2	2.3	2.0
10.5	1044 ±	32	18		1.3		1.6	
11.0	1087 ±	33	19		1.4			
11.5	979 ±	31	17		1.1			
12.0	831 ±	29	14	14	0.6	0.6		1.1
12.5	830 ±	29	14		0.6		0.5	
13.0	809 ±	28	14		0.5		1.6	
13.5	795 ±	28	14		0.5			
14.0	818 ±	29	14	15	0.6	0.7	2.0	1.0
14.5	777 ±	28	13		0.4		0.7	
15.0	876 ±	30	15		0.7		0.6	
15.5	968 ±	31	17		1.0		0.7	
16.0	933 ±	31	16	15	0.9	0.8	1.6	1.2
16.5	833 ±	29	14		0.6		0.8	
17.0	802 ±	28	14		0.5			

Table H-3

SB-056b-94

Hole Radius (feet): 0.208
Scaler B

Dept (feet)	Raw Count Rate Data (cpm)		Gamma Log Results: Exposure Rate μR/hr	Exposure Rate 2 foot avg μR/hr	Th-232 Conc. pCi/g	Th-232 Conc. 2 foot avg pCi/g	Soil Sample Results: Th-232 Conc pCi/g	Th-232 Conc 2 foot avg pCi/g
0.0	1616 ±	40	19	26	3.0	3.0	4.4	2.5
0.5	1849 ±	43	22		2.1		1.9	
1.0	2263 ±	48	27		2.9		1.0	
1.5	2764 ±	53	33		4.0		2.8	
2.0	3193 ±	57	39	60	4.9	8.6	6.1	5.8
2.5	4190 ±	65	51		7.0		5.1	
3.0	5466 ±	74	66		9.7			
3.5	6936 ±	83	84		12.9		6.2	
4.0	7157 ±	85	86	59	13.4	8.5	9.3	5.3
4.5	5227 ±	72	63		9.2		3.8	
5.0	3924 ±	63	47		6.4		3.6	
5.5	3301 ±	57	40		5.1		4.5	
6.0	3631 ±	60	44	40	5.8	5.1	5.4	6.5
6.5	3877 ±	62	47		6.3		6.8	
7.0	3347 ±	58	40		5.2		7.2	
7.5	2249 ±	47	27		2.9			
8.0	1624 ±	40	20	18	1.5	1.2		2.2
8.5	1513 ±	39	18		1.3		4.4	
9.0	1377 ±	37	17		1.0		1.1	
9.5	1461 ±	38	18		1.2		1.0	
10.0	1454 ±	38	18	18	1.2	1.2	0.5	0.5
10.5	1536 ±	39	19		1.3			
11.0	1479 ±	38	18		1.2			
11.5	1391 ±	37	17		1.0			
12.0	1264 ±	36	15	15	0.8	0.7		1.3
12.5	1303 ±	36	16		0.8			
13.0	1279 ±	36	15		0.8		1.3	
13.5	1203 ±	35	15		0.6		1.3	
14.0	1166 ±	34	14	14	0.5	0.6	0.5	0.8
14.5	1214 ±	35	15		0.6		1.0	
15.0	1182 ±	34	14		0.6			

TABLE H-4

SB-056c-94

Hole Radius (feet): 0.208
Scaler B

Th-Dept (feet)	Raw Count Rate Data (cpm)		Gamma Log Results: Exposure Rate µR/hr	Exposure Rate 2 foot avg µR/hr	Th-232 Conc. pCi/g	Th-232 Conc. 2 foot avg pCi/g	Soil Sample Results: Th-232-Conc pCi/g	Th-232-Conc 2 foot avg pCi/g
0.0	3294 ±	57	40	60	10.2	10.1	2.2	5.7
0.5	5067 ±	71	61		9.2		4.9	
1.0	5401 ±	73	65		9.7		10.0	
1.5	6110 ±	78	74		11.2			
2.0	8134 ±	90	98	132	15.5	21.4	8.8	16.4
2.5	11599 ±	108	140		22.9		5.9	
3.0	15169 ±	123	183		30.5		10.4	
3.5	8755 ±	94	106		16.8		40.5	
4.0	5638 ±	75	68	51	10.1	7.1	5.6	11.5
4.5	3900 ±	62	47		6.4		24.7	
5.0	3407 ±	58	41		5.3		12.8	
5.5	3971 ±	63	48		6.5		3.0	
6.0	4298 ±	66	52	40	7.2	5.1	0.0	4.2
6.5	4021 ±	63	48		6.6		5.7	
7.0	3021 ±	55	36		4.5		7.0	
7.5	1832 ±	43	22		2.0			
8.0	1533 ±	39	18	18	1.3	1.2		4.8
8.5	1484 ±	39	18		1.2			
9.0	1417 ±	38	17		1.1		4.7	
9.5	1476 ±	38	18		1.2		4.8	
10.0	1494 ±	39	18	18	1.2	1.2	5.7	5.2
10.5	1512 ±	39	18		1.3			
11.0	1430 ±	38	17		1.1		6.0	
11.5	1399 ±	37	17		1.0		4.0	
12.0	1345 ±	37	16	16	0.9	0.8	3.5	3.5
12.5	1315 ±	36	16		0.9			
13.0	1327 ±	36	16		0.9			
13.5	1224 ±	35	15		0.7			
14.0	1309 ±	36	16	15	0.8	0.8		1.6
14.5	1249 ±	35	15		0.7			
15.0	1318 ±	36	16		0.9			
15.5	1251 ±	35	15		0.7		1.6	
16.0	1344 ±	37	16	16	0.9	0.9		

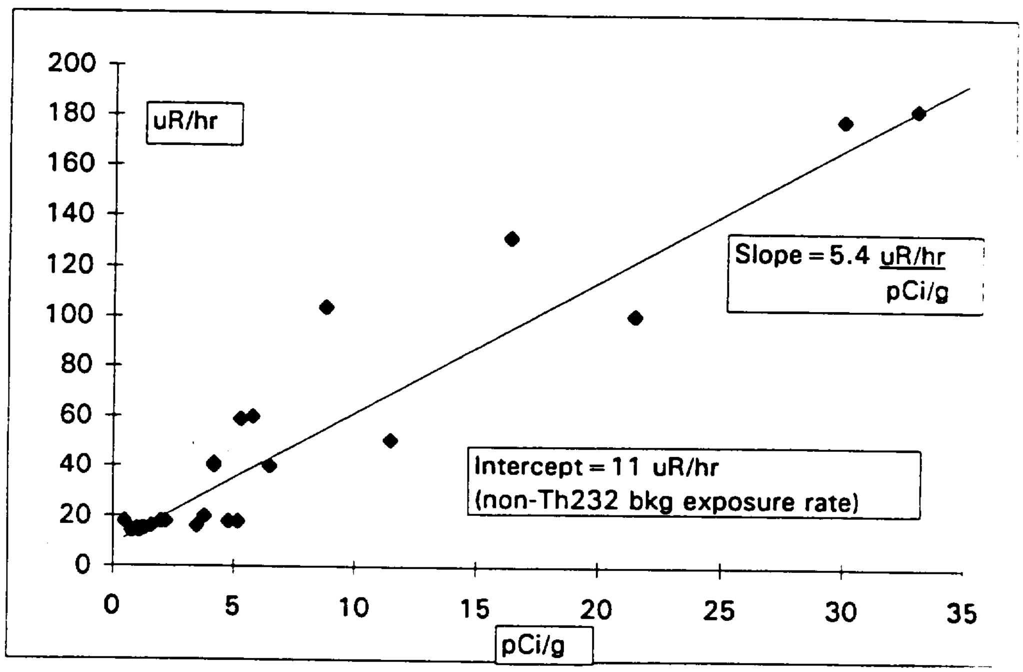
Table H-5

Correlation Between

Measured Exposure Rate
vs
Sampled Th-232 Concentration

for Downhole Gamma Logging

Measurement	EXPOSURE RATE uR/hr	SOIL SAMPLE CONCENTRATION pCi/g
SB-56a-10.0	18	2
SB-56a-12.0	14	1.1
SB-56a-14.0	15	1
SB-56a-16.0	15	1.2
SB-56a-2.0	101	21.5
SB-56a-4.0	104	8.8
SB-56a-6.0	41	4.2
SB-56a-8.0	20	3.8
SB-56b-10.0	18	0.5
SB-56b-12.0	15	1.3
SB-56b-14.0	14	0.8
SB-56b-2.0	60	5.8
SB-56b-4.0	59	5.3
SB-56b-6.0	40	6.5
SB-56b-8.0	18	2.2
SB-56c-10.0	18	5.2
SB-56c-12.0	16	3.5
SB-56c-14.0	16	1.6
SB-56c-2.0	132	16.4
SB-56c-4.0	51	11.5
SB-56c-6.0	40	4.2
SB-56c-8.0	18	4.8
barrel1	184	33
barrel2	179	30



Regression Statistics

Multiple R	0.92
R Square	0.85
Adjusted R Squ	0.85
Standard Error	17.8
Observations	22

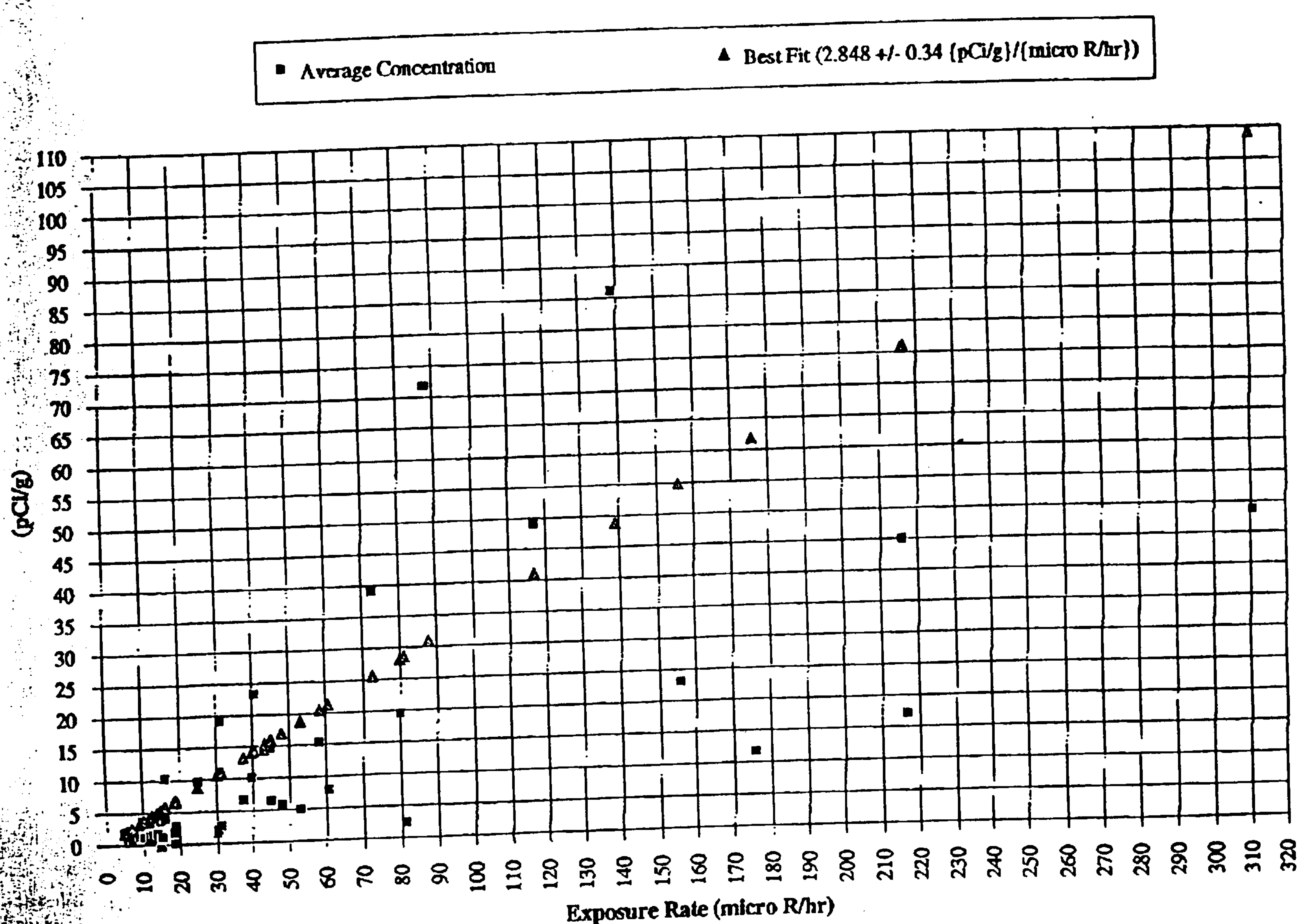
Analysis of Variance

	df	*Squares*	*Mean Square*	*F*	*Significance F*
Regression	1	37336	37336.48	117.6781735	7.91469E-10
Residual	21	6346	317.2761		
Total	22	43682			

	Coefficients	*ard Error*	*t Statistic*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	10.7	4.999	2.145537	0.043756324	0.29784176	21.15525005
x1	5.35	0.493	10.84796	4.57323E-10	4.319746696	6.376545381

Surface Gamma Exposure Rate Correlation with Concentration of Th232 and Daughters						
Sample	R.S.A. Coordinates X	Y	Exposure Rate micro R/hr	Concentration (pCi/g) Mean	±	Error in Mean
SG001	120	220	138.9	86.1	±	40.5
SG002	120	260	116.8	49.0	±	40.7
SG003	160	100	16.3	10.2	±	9.7
SG004	-060	-010	40.6	23.4	±	20.7
SG005	-100	-300	30.3	2.0	±	0.3
SG006	-040	-320	31.4	2.7	±	1.1
SG007	100	000	45.1	6.5	±	3.9
SG008	180	140	12.7	0.5	±	0.4
SG009	220	240	19.1	2.8	±	3.9
SG010	-080	120	31.0	19.1	±	8.8
SG011	-220	-140	37.7	6.6	±	2.6
SG012	-080	-260	43.6	14.3	±	9.6
SG013	-060	-180	14.8	-0.7	±	1.1
SG014	-020	-160	12.6	1.0	±	0.5
SG015	100	-060	58.4	15.4	±	2.9
SG016	-020	180	10.4	1.2	±	0.1
SG017	080	140	11.8	0.5	±	0.2
SG018	-200	-020	81.3	2.3	±	0.3
SG019	-160	-220	18.5	0.1	±	0.3
SG020	-080	-210	39.9	10.1	±	3.7
SG021	260	260	9.0	1.3	±	0.5
SG022	320	240	7.0	1.0	±	0.5
SG023	500	160	5.0	1.8	±	2.5
SG024	600	240	6.0	0.8	±	0.3
SG025	560	-400	7.0	0.8	±	1.1
SG026	240	-360	16.0	4.0	±	2.0
SG027	200	-380	10.0	3.6	±	2.8
SG028	140	-360	12.0	3.3	±	1.0
SG029	060	-360	25.0	9.7	±	10.1
SG030	000	-360	15.0	4.0	±	1.0
SG031	-006	-573	310.7	48.7	±	38.6
SG032	-046	-533	216.5	17.1	±	12.6
SG033	014	-493	175.9	11.7	±	6.9
SG034	-086	-453	215.8	45.1	±	43.8
SG035	014	-633	155.9	23.1	±	23.9
SG036	074	-633	53.2	5.0	±	3.4
SG037	094	-553	30.2	1.7	±	1.0
SG038	054	-473	80.0	19.5	±	18.5
SG039	034	-413	88.0	71.8	±	39.7
SG040	-106	-413	44.9	14.6	±	13.3
SG041	114	-433	18.9	2.5	±	0.9
SG042	174	-453	15.2	1.1	±	0.2
SG043	194	-593	18.5	1.8	±	2.5
SG044	234	-733	14.0	1.6	±	0.5
SG045	294	-673	48.0	5.8	±	6.0
SG046	434	-613	72.5	39.1	±	27.3
SG047	294	-813	11.8	1.3	±	0.6
SG048	214	-833	12.6	1.5	±	0.5
SG049	114	-793	60.6	7.9	±	6.4
SG050	119	-900	15.1	3.6	±	1.7

R.S.A. Inc. 12/26/94


Average Concentration
Best Fit (2.848 +/- 0.34 {pCi/g}/{micro R/hr})
(pCi/g)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
Exposure Rate (micro R/hr)

Regression Statistics						
Multiple R	0.566327676					
R Square	0.320727036					
Adjusted R Square	0.300318873					
Standard Error	52.98211981					
Observations	50					
Analysis of Variance						
	df	*Sum of Squares*	*Mean Square*	*F*	*Significance F*	
Regression	1	64945.03907	64945.03907	23.13594918	1.53498E-05	
Residual	49	137548.1459	2807.105019			
Total	50	202493.185				
	Coefficients	*Standard Error*	*t Statistic*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A
x1	2.848325556	0.338950738	8.403361415	3.98002E-11	2.167178959	3.529472153

APPENDIX I

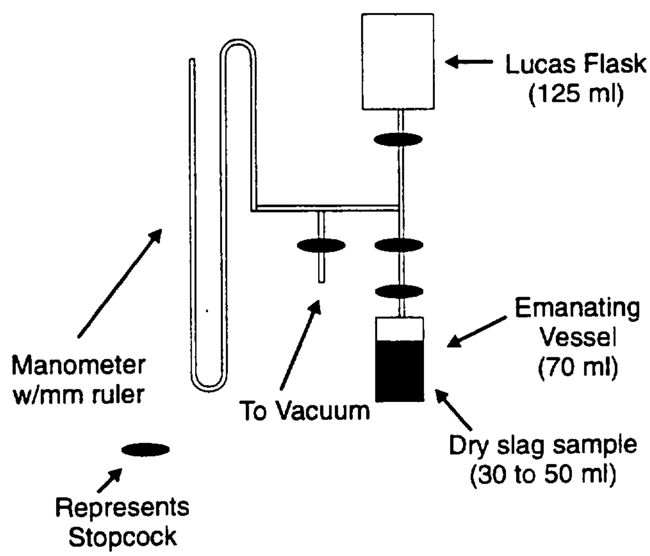
Emanation Study

Appendix I

Emanation Study

Bulk Measurements

The largest available pieces of slag from each of 30 samples were placed in emanation cells. The apparatus used is diagrammed below.



The emanating vessels were evacuated to Salt Lake City atmospheric pressure (minus approximately 680 mm Hg). The vessels were then filled with nitrogen of known background activity (nitrogen simulates air). Even though the empty volumes of the emanation flasks are comparable to the volume of the Lucas flasks, the free air space in the emanating vessels is much lower, approximately 20 to 40 ml. The high ratio between the Lucas flask volume and the emanation flask volume ensures that the vast majority of the emanation product is collected in the Lucas flask.

Radon-220 was allowed to grow in from 15 minutes up to, but not more than, 2 hours. This short ingrowth period prevented any significant amount of uranium daughter radon (radon-222) from growing in. Radon-220 containing nitrogen was collected in a Lucas scintillation flask and the alpha decays of radon-220 were counted for one-minute periods over four minutes (approximately four 55-second half lives). Experimentally, the half life was determined to be 63.96 $\pm$11.79 seconds, which demonstrates that it was radon-220 emanating from the thorium-232 contained in the samples.

Since all of the samples were allowed to experience radon-220 ingrowth for at least 10 half lives, equilibrium was established with its parent thorium-232 and no correction was needed for ingrowth time. Careful note of the time between collection and counting was made to correct for radon-220 decay during this period. The emanating coefficient was taken to be the pCi/g of

TABLE I-1

Bulk Emanation Coefficient of Radon-220

Sample	pCi/g Collected	half life (sec)
TP-1-2	0.67	94.65
TP-1-3	1.56	50.21
TP-1-4	1.46	56.56
TP-1-5	0.8	62.6
TP-1-6	0.82	51.92
TP-2-4	0.29	79.66
TP-2-4	0.36	65.47
TP-3-2	1.18	58.22
TP-3-3	0.84	59.77
TP-3-4	0.6	75.1
TP-3-5	0.17	54.82
TP-3-6	0.49	56.85
TP-3-8	0.2	78.41
TP-4-1	1.25	60.65
TP-4-2	1.06	52.63
TP-4-3	0.64	67.33
TP-5-1	0.74	71.85
TP-5-2	BDL	
TP-5-3	0.69	55.86
TP-6-1	BDL	
TP-6-2	0.38	76.3
TP-6-3	0.44	68.2
TP-6-6	0.91	72.69
TP-6-7	1.47	65.34
TP-6-8	0.87	61.18
TP-7-10	0.58	61.7
TP-7-3	0.26	7.36
TP-7-4	0.18	75.39
TP-7-5	BDL	
TP-7-7	0.12	75.16
TP-7-9	1.7	60.34

BDL = Below detection limit

radon-220 emanated from the solid matrix in equilibrium conditions. Table I-1 shows that this value was found to be 0.64 ± 0.03 pCi/g which is taken as the mean for the bulk slag.

Radon-222 measurements were made in the same manner, but with the following exceptions.

a. Ingrowth was at least 3 days
b. The radon-222 was counted 10 minutes up to 2 hours after collection to allow the short lived radon-220 to decay.
c. Counts were two times for 1/2 hour each.
d. In order to correct for the non equilibrium ingrowth times, a correction of B=1/(1-exp(-(ln(2)/3.84 days) * ingrowth time)) applied.
e. No attempt was made to verify the 3.84 day half life of radon-222

The radon-222 in the 30 bulk samples measured was found to have an average emanating coefficient of 0.17 ± 0.03 pCi/g.

TABLE I-2

Bulk Emanation Coefficient of Radon-222

Sample	pCi/g Collected	Sample	pCi/g Collected
TP-1-2	0.09	TP-5-1	0.26
TP-1-3	0.11	TP-5-2	0.14
TP-1-4	0.12	TP-5-3	0.9
TP-1-5	0.13	TP-6-1	0.03
TP-1-6	0.11	TP-6-2	0.1
TP-2-4	0.05	TP-6-3	0.16
TP-3-2	0.05	TP-6-6	0.11
TP-3-3	0.14	TP-6-7	0.2
TP-3-4	0.11	TP-6-8	0.08
TP-3-5	0.09	TP-7-10	0.21
TP-3-6	0.09	TP-7-3	0.21
TP-3-8	0.08	TP-7-4	0.07
TP-4-1	0.2	TP-7-5	0.06
TP-4-2	0.58	TP-7-7	0.25
TP-4-3	0.09	TP-7-9	0.42

Measurements for Radon 220 in Material less than 100 Mesh

The emanation coefficient for material less than 100 mesh was also measured. The bulk sample was ground as fine as possible and sieved through a #100 mesh sieve. The -100 mesh sample was then analyzed with the same procedure used for bulk samples.

The emanation coefficient was found to be 57.62 $\pm$ 0.1 pCi/g. Relevant data are contained in the table below.

Table I-3

Fine Material Emanation Coefficient for Ra-220

Sample	pCi/g Collected	half life (sec)
TP-1-2	0.19	41.84
TP-1-3	0.32	86.22
TP-1-4	0.38	55.77
TP-1-5	1.06	71.6
TP-1-6	0.25	55.45
TP-2-4	0.26	77.31
TP-3-2	1.01	48.4
TP-3-3	1.06	57.35
TP-3-4	0.64	39.53
TP-3-5	BDL	
TP-3-6	0.55	45.43
TP-3-8	0.92	84.48
TP-4-1	1.17	49.12
TP-4-2	1.14	62.22
TP-4-3	0.69	56.08
TP-5-1	0.58	63.56
TP-5-2	0.11	
TP-5-3	0.66	45.41
TP-6-1	0.09	90.67
TP-6-2	0.44	81.2
TP-6-3	0.39	52.07
TP-6-6	1.06	46.29
TP-6-7	1.13	54.77
TP-6-8	1.24	41.34
TP-7-10	0.98	43.44
TP-7-3	0.52	49.95
TP-7-4	0.26	38.14
TP-7-5	0.13	34.87
TP-7-7	0.06	90
TP-7-9	2.55	50.91

APPENDIX J

On-Site Analysis Of Thorium In Soil Boring Samples By NaI Gamma-Ray Spectroscopy

APPENDIX J

ON-SITE ANALYSIS OF THORIUM IN SOIL BORING SAMPLES BY NaI GAMMA-RAY SPECTROSCOPY

1.0 INTRODUCTION

This procedure outlines the method employed to quantitate Th-232 concentrations in soil samples using a sodium iodide (NaI)-based gamma spectroscopy system.

2.0 EQUIPMENT

The following equipment was utilized in the on-site analysis of thorium in the soil boring samples:

- Portable, 80386-based computer
- Aptec Model 1200, 1024 channel MCA card
- Aptec Model 1HV-PC high voltage supply card
- 3" x 3" NaI gamma radiation detector
- Aptec spectrum acquisition and analysis software
- Weighing scale (0 - 1200g, min. 0.1 g precision)
- NIST-traceable Th-232 standard source (aged with progeny equilibrium)

3.0 METHODOLOGY

3.1 GENERAL

Soil samples in nominal 500 ml plastic containers were placed in a fixed geometry with a gamma radiation detector consisting of a NaI crystal and photomultiplier tube, surrounded by a lead shield. The detector is coupled to a computer-based multichannel analyzer (MCA) which has the ability to quantitate the emission rate of characteristic gamma radiation from the radionuclides of interest. The MCA and detector high voltage supply were situated on two circuit boards (AT-bus compatible) in the portable computer.

This analysis is based on counting the 2.6 MeV gamma-ray emission of Tl-208 and Th-232 quantification. The following sections describe the steps performed during the analysis. All spectrum analyses and mathematics were performed by the software.

3.2 CALIBRATION

Calibration required the use of standards for the specific isotope of thorium followed by the application of a geometry correction factor, as described in 3.2.2.

3.2.1 Standards

The Th-232 standard was obtained from a mass-determined quantity of thorium oxide (ThO_2) aged to greater than 40 years to allow > 98% T1-208 equilibrium with Th-232. The thorium-232 counting efficiency (in counts per disintegration) was then calculated by dividing the net count rate (cpm) in the 2.6 MeV photopeak by the activity in the standard (dpm). The mass of the standard matrix is approximately 450 g.

3.2.2 Geometry Correction

A geometry correction factor was applied if significantly less soil mass was present in the 500 ml plastic sample jar (3"x3") than was present in the calibration standard (450 g). The correction factor was determined by creation of a plot of counting efficiency versus sample mass using a homogenous sample matrix with a known radionuclide concentration. Such a plot is shown in Figure J-1. A quadratic fit to the curve was performed so that the geometry correction factor could be calculated from the sample mass in the equation files for spectrum analysis.

3.3 BACKGROUND SUBTRACTION

There are two types of background to be subtracted from the photopeak of interest: Compton and peak.

Compton background is due to the scatter or escape of photons from higher energy gamma-rays originating mostly from the sample itself. It was calculated by performing a least square or straight-line fit of the Compton continuum under the photopeak (see Figure J-2). The calculated Compton background was then subtracted from the gross photopeak count to obtain the net photopeak count.

Peak background is due to naturally occurring radium and thorium in the surroundings of the counting system. It was determined by performing a count of a deionized water sample and analyzing the resultant spectrum. The net count rate for each background photopeak was subtracted from the corresponding sample photopeaks after Compton background was subtracted.

3.4 RADIONUCLIDE EQUILIBRIUM

The degree of Tl-208 equilibrium with Th-232 is based on the Ra-228 half-life (6.7 years). For ores aged 30-40 years after processing, the degree of equilibrium is greater than 90 percent. Sample mixing or heating will not cause loss of long-term equilibrium if the temperature is low enough to prevent volatilization of Pb-212 (<900 deg. C).

4.0 SAMPLE ANALYSIS PROCEDURE

The sample to be counted was placed into the type of container specified by the counting geometry (i.e., 500 ml plastic sample jar) to determine the net weight. The sample jar was then placed on the NaI detector in its shielded housing and the sample was counted. Samples with mass greater than 500 g were counted for 30 minutes. and those less than 500 g for one hour. Normally, the 1000 counts in the Region of Interest will provide the proper lower limit of detection for environmental sample analysis.

The computer was programmed to acquire and analyze the spectrum and to print out the results in pCi/g Th-232 and their uncertainties.

All analysis parameters such as counting time were preset to provide a lower limit of detection. The equations used to calculate the radionuclide concentrations and uncertainties are listed in the equation template file (see Table J-1). The results of the analyses are located on Table J-2.

5.0 QUALITY ASSURANCE

5.1 BACKGROUND COUNT

Deionized water was used to determine the "background" of the analysis. The software analyzed the spectrum, determined the peak background values and printed out a background analysis report. The background procedure was conducted once per day.

5.2 STANDARDIZATION CHECK

The thorium-232 check source was counted daily to ensure proper operation on a routine basis. All standardization results were within ±10 percent of the initial reference calibration value.

5.3 OTHER QUALITY ASSURANCE TESTS

- Duplicate samples: One out of every twenty samples or one sample from each boring was recounted to estimate the precision of the gamma spectroscopy analysis. All the results fell within 2 standard deviations of each other.

- Blanks: Deionized water was used as a blank. Analysis of the blank provided a means to calculate the lower limit of detection (LLD) for Th-232 and determine any source of contamination. The counting of a daily background check sample met the requirement for analyzing blanks. All results were within ±25% of the mean (the mean was calculated from the previous twenty results).

- Spiked samples: A radioactivity standard sample containing a calibrated quantity of radioactivity was used as a spike. Analysis of the spiked sample provided a means to check the detector efficiency and energy calibration. The performance of daily source checks met the requirement for analyzing spikes. All daily check source results were within ±10% of the initial reference calibration value.

TABLE J-1

EQUATIONS USED IN GAMMA SPECTROSCOPY CALCULATION PROGRAMS

Note: EV1 denotes "Equation Value #1"
RN1 = net count rate for peak 1 (2.6 MeV)

EV1
2.6 EFF TH232
CPM/DPM (ROI1)
1.53e-3 *(2-3./2e-3 * SQ + 2.2e-6 * SQ^2) (quadratic fit of geometry correction vs mass)

EV3
2.6 BKG TH232
CPS (ROI1)
RN1/LT > 0.07
.09
0.045

EV5
TH # OF CHN
104

EV7
TH CNT RATE
cps
RN1/LT

EV9
TH CONC
pCi/g
(RN1/LT-EV3)/EV1 * 60.0 / 2.22 / SQ

EV11
TH BKG VAR (variance)
CPS^2
RB1/LT/LT

TABLE J-1 (Cont'd)

ET13
TH 2-SIGMA
PCI/G
2*SQRT((EV3/LT)+EV11+(RG1/LT^2))*60.0/EV1/2.22/SQ

EV15
TH CRIT LEVEL (LC = Critical Level, or "Less Then Level")
PCI/G
2.33*SQRT((EV3/LT)+EV11+(RG1/LT^2))*60.0/EV1/2.22/SQ

EV17
TH LC CHECK
IF EV9 <EV15
EV15
ELSE
LESS THAN!!!

TABLE J-2

THORIUM PILE, UNIT 2

SAMPLE #	DEPTH(FT)	MASS (g)	TH-232 CONC (pCI/g dry)
TP-1-01	0 - 1.5	636.1	160 +/- 15
TP-1-02	1.5-3.0	691.9	439 +/- 12
TP-1-03	3.0-4.5	663.9	385 +/- 30
TP-1-04	4.5-6.0	684.4	516 +/- 42
TP-1-05	6.0-7.5	587.3	700 +/- 68
TP-1-06	7.5-9.0	555.3	353 +/- 32
TP-1-07	9.0-10.5	542.5	145 +/- 13
TP-1-08	10.5-12.0	628.1	126 +/- 12
TP-1-09	12.0-13.5	610.7	149 +/- 13
TP-1-10	13.5-15.0	576.4	4.1 +/- 1.2
TP-1-11	15.0-16.5	543.3	28 +/- 3.2
TP-1-12	18.0-19.5	505.2	<1.5
TP-1-13	19.5-21.0	739.2	<1.1
TP-1-14	21.0-22.5	693.0	<1.3
TP-1-15	22.5-24.0	754.9	<1.1
TP-2-01	0-1.5	426.4	268 +/- 16
TP-2-02	1.5-3.0	243.7	559 +/- 33
TP-2-03	3.0-4.5	640.3	176 +/- 11
TP-2-04	4.5-6,0	718.6	277 +/- 16
TP-2-05	6.0-7.5	679.2	218 +/- 13
TP-2-06	7.5-9.0	665.9	114 +/- 6.7
TP-2-08	10.5-12.0	439.9	30 +/- 5.0
TP-2-09	12.0-13.5	615.6	235 +/- 13
TP-2-10	13.5-15.0	304.6	52 +/- 3.5
TP-3-02	1.5-3.0	540.8	692 +/- 40
TP-3-03	3.0-4.5	594.2	694 +/- 43
TP-3-04	4.5-6.0	578.9	602 +/- 34
TP-3-05	6.0-7.5	768.1	379 +/- 21
TP-3-06	7.5-9.0	738.9	830 +/- 52
TP-3-08	10.5-12.0	365.4	610 +/- 40
TP-3-09	12.0-13.5	217.2	266 +/- 16

TABLE J-2

THORIUM PILE, UNIT 2

SAMPLE #	DEPTH(FT)	MASS (g)	TH-232 CONC (pCi/g dry)
TP-3-10	13.5-15.0	339.2	492 +/- 28
TP-3-11	15.0-16.5	318.3	1240 +/- 75
TP-3-12	16.5-18.0	253.6	859 +/- 52
TP-4-01	3.0-4.5	642.1	1530 +/- 80
TP-4-02	4.5-6.0	691.3	1110 +/- 70
TP-4-03	7.5-9.0	421.4	960 +/- 50
TP-5-0	0-1.5	514.4	538 +/- 31
TP-5-01	1.5-3.0	239.2	614 +/- 38
TP-5-02	3.0-4.5	362.4	474 +/- 27
TP-5-03	5.0-6.5	663.6	1120 +/- 70
TP-5-04	6.5-8.0	286.8	960 +/- 56
TP-6-01	3.0-4.5	573.7	98 +/- 6.1
TP-6-02	4.5-6.0	507.2	575 +/- 33
TP-6-03	6.0-7.5	508.2	553 +/- 32
TP-6-04	7.5-9.0	281.2	689 +/- 40
TP-6-05	9.0-10.5	329.0	546 +/- 31
TP-6-06	10.5-12	508.8	1100 +/- 63
TP-6-07	12-13.5	607.8	1150 +/- 64
TP-6-08	13.5-15.0	649.8	860 +/- 54
TP-7-01	0 - 1.5	269.0	305 +/- 19
TP-7-02	1.5-3.0	341.6	727 +/ 41
TP-7-03	3.0-4.5	509.2	279 +/- 18
TP-7-04	4.5-6.0	546.0	249 +/- 15
TP-7-05	6.0-7.5	418.0	460 +/- 26
TP-7-06	7.5-9.0	243.9	552 +/- 30
TP-7-07	9.0-10.5	677.4	105 +/- 6.3
TP-7-08	10.5-12.0	339.7	761 +/- 43
TP-7-09	12.0-13.5	597.1	1130 +/- 61
TP-7-10	13.5-15.0	559.1	847 +/- 51

SOIL BORING(SB212),
UNIT 1, TRUCK TURNAROUND AREA

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-212-01	0-6	137.1	<2.1
SB-212-02	6-12	156.6	<1.9
SB-212-03	12-18	160.8	<1.8
SB-212-04	18-24	162.8	<1.9
SB-212-05	24-36	163.3	<1.9
SB-212-06	36-42	142.5	<2.2
SB-212-07	42-48	152.0	7.5 +/- 1.9
SB-212-08	48-54	123.1	11 +/- 2.3
SB-212-09	54-60	111.1	<2.5
SB-212-10	60-66	248.1	<1.9
SB-212-11	66-72	172.9	<1.8
SB-212-12	72-78	171.3	<1.8
SB-212-13	78-84	131.3	<2.3
SB-212-14	84-90	142.8	<2.1
SB-212-15	90-96	212.6	<2.1
SB-212-16	96-102	123.2	<2.3
SB-212-17	102-108	166.8	<1.9
SB-212-18	108-114	114.6	<2.6
SB-212-19	114-120	161.0	<2.0
SB-212-20	120-126	123.3	<2.3
SB-212-21	126-132	159.5	<1.9
SB-212-22	132-138	110.1	<2.5
SB-212-23	138-144	133.3	<2.2
SB-212-24	144-150	84.3	<3.2
SB-212-26	156-162	144.8	<2.1
SB-212-27	162-168	255.8	<2.0
SB-212-28	168-174	266.7	<2.0
SB-212-29	174-180	196.1	<1.7
SB-212-30	180-186	174.8	<1.8
SB-212-31	186-192	205.7	<2.3
SB-212-32	192-198	249.7	<2.0
SB-212-33	198-204	250.7	<1.9
SB-212-34	204-210	202.1	<2.4
SB-212-35	210-216	113.1	<2.5
SB-212-36	216-222	184.4	<1.7
SB-212-37	222-228	235.3	<2.1
SB-212-38	228-234	134.8	<2.2
SB-212-39	234-240	168.0	<1.8

SOIL BORING(SB-161)
UNIT 1, NEAR POND 8

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC(pCi/g wet)
SB-161-01	0-6	46.0	<5.2
SB-161-04	18-24	160.3	11 +/- 2.0
SB-161-05	24-30	160.9	13 +/- 2.2
SB-161-06	30-36	201.8	8.6 +/- 2.7
SB-161-08	42-48	186.4	2.1 +/- 1.5
SB-161-09	48-54	196.4	1.8 +/- 1.5
SB-161-21	126-132	179.6	<1.9
SB-161-22	132-138	150.1	<1.9
SB-161-23	138-144	228.0	<2.2
SB-161-24	144-150	165.9	<1.9
SB-161-25	150-156	171.3	<1.9
SB-161-26	156-162	166.1	<1.9
SB-161-27	162-168	157.6	<1.9
SB-161-28	168-174	179.9	<1.7
SB-161-29	174-180	224.0	<2.1
SB-161-30	180-186	160.9	<1.9
SB-161-31	186-192	187.1	<1.6
SB-161-32	192-198	253.4	<1.9
SB-161-33	198-204	188.0	<1.7
SB-161-34	204-210	178.7	<1.7
SB-161-35	210-216	222.4	<2.0
SB-161-36	216-222	200.8	<2.3
SB-161-37	222-228	233.4	<2.0
SB-161-38	228-234	225.5	<2.1
SB-161-39	234-240	216.1	<2.1
SB-161-40	240-246	204.4	<2.3
SB-161-41	246-252	151.4	<1.9
SB-161-44	264-270	81.9	<3.2
SB-161-47	282-288	221.2	<2.2

SOIL BORING, (SB-151),
UNIT 1 BETWEEN, PONDS 1 AND 2

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-151-01	0-6	158.6	11 +/- 2.1
SB-151-02	6-12	239.7	<2.2
SB-151-03	12-18	205.6	3.7 +/- 2.0
SB-151-04	18-24	174.4	11 +/- 1.8
SB-151-05	24-30	221.2	12 +/- 2.2
SB-151-06	30-36	146.4	<2.0
SB-151-07	36-42	214.6	<2.2
SB-151-08	42-48	168.8	<1.9
SB-151-09	48-54	136.9	7.6 +/- 1.9
SB-151-10	54-60	245.7	5.4 +/- 2.0
SB-151-11	60-66	214.6	7.2 +/- 2.1
SB-151-12	66-72	204.5	10 +/- 2.4
SB-151-15	84-90	107.1	<2.6
SB-151-18	102-108	123.1	<2.4
SB-151-19	108-114	189.2	2.6 +/- 1.4
SB-151-20	114-120	197.1	<1.7
SB-151-21	120-126	207.9	<2.3
SB-151-22	126-132	208.4	2.2 +/- 1.9
SB-151-23	132-138	183.2	<1.8
SB-151-24	138-144	173.3	<1.8
SB-151-25	144-150	250.1	<1.9
SB-151-26	150-156	198.8	<1.6
SB-151-27	156-162	114.0	<2.4
SB-151-28	162-168	160.7	<1.9
SB-151-29	168-174	161.5	<1.9
SB-151-30	174-180	160.9	<1.9
SB-151-31	180-186	280.1	2.9 +/- 1.6
SB-151-32	186-192	222.7	3.3 +/- 1.8
SB-151-33	192-198	260.2	<1.9
SB-151-34	198-204	289.3	2.7 +/- 1.4
SB-151-35	204-210	170.5	<1.9
SB-151-36	210-216	229.4	<2.1

SOIL BORING(SB-128)
UNIT 1, NEAR CREEK BANK

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-128-01	0-6	213.9	<2.3
SB-128-02	6-12	163.9	3.3 +/- 1.5
SB-128-05	24-30	183.6	3.2 +/- 1.5
SB-128-06	30-36	200.0	<2.5
SB-128-09	48-54	227.3	<2.2
SB-128-10	54-60	233.5	<2.2
SB-128-11	60-66	249.5	<1.9
SB-128-17	102-108	216.2	<2.2
SB-128-18	108-114	140.1	3.2 +/- 1.7
SB-128-19	114-120	149.6	<2.0
SB-128-20	120-126	201.5	<2.2
SB-128-21	126-132	195.8	<1.7
SB-128-22	132-138	139.5	<2.2
SB-128-23	138-144	230.4	<2.1
SB-128-25	150-156	233.3	<2.1
SB-128-26	156-162	204.8	<2.3
SB-128-27	162-168	238.7	<2.1
SB-128-28	168-174	257.2	<2.0
SB-128-29	171-180	194.5	<1.7
SB-128-30	180-186	230.7	<2.1
SB-128-31	186-192	234.6	<2.2
SB-128-32	192-198	238.7	<2.0
SB-128-33	198-204	203.4	<2.3
SB-128-34	204-210	215.5	<2.1
SB-128-35	210-216	291.3	<1.9
SB-128-36	216-222	259.9	<2.0

SOIL BORING(SB-115)
UNIT ONE, PARKING AREA

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-115-01	0-6	66.6	<3.8
SB-115-02	6-12	127.2	<2.3
SB-115-03	12-18	172.8	3.1 +/- 1.7
SB-115-04	18-24	50.0	<5.7
SB-115-05	24-30	86.4	22 +/- 3.6
SB-115-06	30-36	129.6	15 +/- 2.7
SB-115-10	54-60	133.2	<2.3
SB-115-11	60-66	137.0	<2.2
SB-115-12	66-72	176.5	<1.8
SB-115-13	72-78	51.5	<4.9
SB-115-16	90-96	223.0	<2.1
SB-115-17	96-102	225.3	<2.1
SB-115-18	102-108	219.0	<2.2
SB-115-19	108-114	230.8	<2.0
SB-115-20	114-120	265.0	<1.8
SB-115-21	120-126	257.1	<1.9
SB-115-22	126-132	235.3	<2.0
SB-115-23	132-138	214.6	<2.2
SB-115-24	138-144	195.6	<1.6
SB-115-25	144-150	171.4	<1.8
SB-115-26	150-156	267.0	<1.9
SB-115-27	156-162	262.7	<2.0
SB-115-28	162-168	151.6	<1.9
SB-115-29	168-174	103.4	<2.6
SB-115-30	174-180	122.6	<2.2
SB-115-31	180-186	173.8	<1.8
SB-115-32	186-192	228.3	<2.0
SB-115-33	192-198	213.7	<2.2
SB-115-34	198-204	263.0	<1.9

SOIL BORING(SB-108)
UNIT ONE, NEAR M-3

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC(pCi/g wet)
SB-108-02	6-12	223.1	<2.2
SB-108-03	12-18	245.2	3.1 +/- 1.7
SB-108-04	18-24	236.4	23 +/- 3.0
SB-108-05	24-30	128.1	<2.6
SB-108-06	30-36	199.3	<1.6
SB-108-08	42-48	138.1	<2.3
SB-108-09	48-54	193.5	6.6 +/- 1.8
SB-108-10	54-60	173.2	<2.0
SB-108-11	60-66	150.7	<2.1
SB-108-12	66-72	109.6	<2.6
SB-108-15	84-90	111.9	<2.5
SB-108-16	90-96	192.1	3.3 +/- 1.4
SB-108-17	96-102	164.5	<1.9
SB-108-18	102-108	144.9	2.6 +/- 1.7
SB-108-19	1O8-114	283.0	<1.9
SB-108-20	114-120	197.6	<1.6
SB-108-21	120-126	280.7	<1.9
SB-108-22	126-132	313.0	<1.8
SB-108-23	132-138	316.9	<1.8
SB-108-24	138-144	269.5	<1.9
SB-108-25	144-150	328.2	<1.8
SB-108-26	150-156	304.2	<1.8
SB-108-27	156-162	266.6	<1.9
SB-108-28	162-168	174.9	<1.7
SB-108-29	168-174	222.6	2.9 +/- 1.8
SB-108-30	174-180	176.3	<1.8
SB-108-31	180-186	285.4	<1.9
SB-108-32	186-192	279.3	<1.9
SB-108-33	192-198	283.4	<1.8

SOIL BORING(SB280),
UNIT 1, BLDG,32

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-280-02	6-12	160.1	57 +/- 3.3
SB-280-03	12-18	181.6	27 +/- 2.4
SB-280-04	18-24	150.6	<2.1
SB-280-05	24-30	159.0	<2.1
SB-280-06	30-36	149.3	<1.9
SB-280-07	36-42	179.5	<1.7
SB-280-08	42-48	119.9	<2.2
SB-280-09	48-54	216.3	<2.2
SB-280-10	54-60	243.0	3.0 +/- 2.1
SB-280-11	60-66	189.5	6.2 +/- 1.7
SB-280-12	66-72	183.2	8.5 +/- 1.9
SB-280-14	78-84	169.4	6.4 +/- 1.9
SB-280-15	84-90	252.2	14 +/- 2.2
SB-280-17	96-102	130.6	<2.6
SB-280-18	102-108	114.6	<2.6
SB-280-20	114-120	202.2	<2.4
SB-280-21	120-126	155.1	<2.1
SB-280-23	132-138	180.2	2.8 +/- 1.5
SB-280-24	138-144	196.3	<1.7
SB-280-25	144-150	198.8	<1.8
SB-280-26	150-156	206.8	3.5 +/- 2.0
SB-280-27	156-162	142.7	<2.1
SB-280-29	168-174	282.5	<1.8
SB-280-30	174-180	218.5	<2.1
SB-280-32	186-192	236.5	<2.1
SB-280-33	192-198	223.4	<2.3
SB-280-34	198-204	288.7	<1.8
SB-280-35	204-210	269.6	<1.9
SB-280-36	210-216	194.8	<1.6
SB-280-37	216-222	185.1	3.1 +/- 1.4
SB-280-38	222-228	179.8	<1.7
SB-280-39	228-234	191.9	<1.7
SB-280-41	240-246	227.0	<2.0
SB-280-42	246-252	223.8	<2.2
SB-280-45	264-270	184.4	<1.8
SB-280-46	270-276	87.6	<3.2

SOIL BORING(SB28),
UNIT1, NEAR ACID PLANT

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-28-02	6-12	213.7	6.6 +/- 2.2
SB-28-03	12-18	198.1	6.1 +/- 1.5
SB-28-06	30-36	235.1	11 +/- 2.2
SB-28-07	36-42	161.5	6.9 +/- 1.7
SB-28-08	42-48	181.3	3.8 +/- 1.7
SB-28-09	48-54	162.6	7.2 +/- 1.7
SB-28-10	54-60	208.2	6.3 +/- 2.3
SB-28-11	60-66	246.2	<2.2
SB-28-12	66-72	183.8	4.9 +/- 1.6
SB-28-15	84-90	119.4	4.8 +/- 2.2
SB-28-18	102-108	182.6	<1.8
SB-28-19	1O8-114	213.0	<2.3
SB-28-20	114-120	136.7	<2.2
SB-28-21	120-126	168.8	5.5 +/- 1.7
SB-28-22	126-132	122.3	<2.4
SB-28-23	132-138	273.3	<1.9
SB-28-24	138-144	183.6	<1.8
SB-28-25	144-150	239.8	3.5 +/- 1.7
SB-28-26	150-156	286.6	<1.9
SB-28-27	156-162	247.7	<2.0
SB-28-30	174-180	261.9	<2.0
SB-28-31	180-186	202.9	<2.3
SB-28-32	186-190	182.2	<1.8
SB-28-33	190-196	178.5	<1.7
SB-28-34	196-202	245.0	<2.1
SB-28-35	202-208	161.8	<1.9
SB-28-36	208-214	178.3	<1.8
SB-28-37	214-220	197.9	<1.7
SB-28-38	220-226	158.0	<1.9
SB-28-39	226-232	152.2	2.9 +/- 1.7

SOIL BORING(SB279),
UNIT 1, BLDG 32

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-279-02	6-12	217.4	6.1 +/- 1.9
SB-279-03	12-18	133.8	20 +/- 2.6
SB-279-04	18-24	162.2	44 +/- 3.0
SB-279-05	24-30	153.7	82 +/- 3.6
SB-279-06	30-36	128.8	5.3 +/- 2.1
SB-279-07	36-42	255.3	6.4 +/- 2.3
SB-279-08	42-48	174.7	<1.7
SB-279-09	48-54	212.2	<2.1
SB-279-12	66-72	83.3	4.9 +/- 2.8
SB-279-14	78-84	190.6	2.7 +/- 1.6
SB-279-15	84-90	118.20	<2.5
SB-279-17	96-102	72.2	<3.6
SB-279-18	102-108	133.3	<2.2
SB-279-19	108-114	193.5	6.6 +/- 1.6
SB-279-20	114-120	162.9	3.4 +/- 1.9
SB-279-21	120-126	171.4	2.2 +/- 1.7
SB-279-23	132-138	133.8	<2.2
SB-279-24	138-144	171.4	<1.8
SB-279-26	150-156	262.9	<1.9
SB-279-27	156-162	250.8	<2.1
SB-279-28	162-168	259.9	<2.0
SB-279-29	168-174	218.5	<2.2
SB-279-30	174-180	109.4	<2.6
SB-279-31	180-186	303.2	<1.9
SB-279-32	186-192	265.2	<1.9
SB-279-33	192-198	252.8	3.8 +/- 1.7
SB-279-34	198-204	159.8	<2.0
SB-279-35	204-210	238.3	<2.1
SB-279-36	210-216	125.5	<2.1
SB-279-38	222-228	195.0	<1.6
SB-279-39	228-234	185.9	2.6 +/- 1.4
SB-279-40	234-240	119.1	<2.3

SOIL BORING(SB278),
UNIT 3, BLDG. 34

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-278-02	6-12	230.9	19 +/- 2.8
SB-278-03	12-18	164.5	<2.2
SB-278-05	24-30	163.8	<2.1
SB-278-06	30-36	222.0	11 +/- 2.5
SB-278-09	48-54	94.7	6.3 +/- 2.6
SB-278-10	54-60	289.1	23 +/- 2.7
SB-278-11	60-66	239.2	2.3 +/- 1.8
SB-278-12	66-72	216.3	<2.2
SB-278-13	72-78	147.6	<2.2
SB-278-14	78-84	176.2	<1.9
SB-278-15	84-90	101.2	<2.8
SB-278-17	96-102	171.1	<2.0
SB-278-18	102-108	167.9	<2.0
SB-278-24	138-144	251.9	<2.2
SB-278-27	156-162	222.5	<2.2
*SB-278-29	174-180	301.8	<1.8
*SB-278-30	168-174	273.6	<1.8
SB-278-32	186-192	262.0	<2.0
SB-278-33	192-198	145.3	<2.0
SB-278-34	198-204	151.6	<2.0

SOIL BORING(SB265),
UNIT 1, NEXT TO THICKNER

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-265-01	0-6	156.8	27 +/- 2.6
SB-265-02	6-12	194.9	80 +/- 5.3
SB-265-03	12-18	216.2	115 +/- 8.0
SB-265-07	36-42	129.2	56 +/- 5.4
SB-265-08	42-48	124.0	103 +/- 6.4
SB-265-09	48-54	115.4	141 +/- 8.1
SB-265-10	54-60	68.4	46 +/- 6.7
SB-265-11	60-66	96.3	15 +/- 4.3
SB-265-12	66-72	112.5	<2.5
SB-265-13	72-78	103.8	45 +/- 3.8
SB-265-14	78-84	160.4	<1.9
SB-265-15	84-90	97.8	<2.9
SB-265-16	90-96	83.1	23 +/- 3.5
SB-265-17	96-102	105.7	<2.7
SB-265-18	102-108	132.2	<2.2
SB-265-19	108-114	130.1	5.2 +/- 2.0
SB-265-20	114-120	136.1	<2.3
SB-265-21	120-126	200.4	<2.5
SB-265-22	126-132	89.2	<3.2
SB-265-23	132-138	136.9	5.1 +/- 1.8
SB-265-24	138-144	179.7	<1.8
SB-265-25	144-150	137.9	2.3 +/- 1.8
SB-265-26	150-156	164.7	<1.8
SB-265-27	156-162	134.1	<2.1
SB-265-28	162-168	236.0	<2.2
SB-265-29	168-174	177.1	<1.8
SB-265-30	174-180	167.6	<1.9
SB-265-31	180-186	177.1	2.5 +/- 1.5
SB-265-32	186-192	156.4	<1.9
SB-265-33	192-198	144.8	<2.0

SOIL BORING(SB265),
UNIT 1, NEXT TO THICKNER

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-265-34	198-204	195.6	<1.6
SB-265-35	204-210	202.5	<2.4
SB-265-36	210-216	202.4	<2.2
SB-265-37	216-222	187.2	3.4 +/- 1.6
SB-265-38	222-228	226.6	<2.1
SB-265-39	228-234	260.1	<2.0
SB-265-40	234-240	92.3	<2.9
SB-265-41	240-246	133.4	<2.1
SB-265-42	246-252	94.0	<2.9
SB-265-43	252-258	172.6	2.1 +/- 1.6
SB-265-44	258-264	270.6	<1.9
SB-265-45	264-270	170.9	1.9 +/- 1.5
SB-265-46	270-276	119.6	<2.4

SOIL BORING(SB-260), UNIT 1, BETWEEN THICKNER
AND ACID PLANT WASTE
STORAGE UNIT

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-260-02	6-12	202.6	<2.2
SB-260-03	12-18	165.5	14 +/- 2.1
SB-260-04	18-24	170.4	<1.8
SB-260-05	24-30	126.2	<2.3
SB-260-06	30-36	124.4	<2.2
SB-260-07	36-42	194.9	<1.6
SB-260-08	42-48	191.6	92 +/- 3.8
SB-260-09	48-54	166.1	17 +/- 2.5
SB-260-11	60-66	268.0	32 +/- 3.4
SB-260-12	66-72	293.9	23 +/- 3.2
SB-260-13	72-78	232.8	510 +/- 14
SB-260-14	78-84	333.3	900 +/- 25
SB-260-15	84-90	266.7	592 +/- 17
SB-260-16	90-96	324.8	456 +/- 12
SB-260-17	96-102	231.4	574 +/- 15
SB-260-18	102-108	193.3	558 +/- 15
SB-260-21	120-126	240.5	655 +/- 18
SB-260-22	126-132	334.0	685 +/- 19
SB-260-23	132-138	308.7	91 +/- 4.6
SB-260-24	138-144	329.7	8.6 +/- 2.1
SB-260-26	150-156	210.1	6.0 +/- 2.7
SB-260-27	156-162	234.6	14 +/- 2.4
SB-260-29	168-174	225.4	<2.6
SB-260-30	174-180	258.0	<2.4
SB-260-31	180-186	268.0	14 +/- 2.5

SOIL BORING(SB250),
UNIT 1, BTW. THORIUM PILE AND FENCE(FINDLAY PROPERTY)

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-250-01	0-6	258.0	67 +/- 5.2
SB-250-02	6-12	230.6	97 +/- 6.9
SB-250-03	12-18	240.3	74 +/- 5.9
SB-250-04	18-24	200.1	85 +/- 6.6
SB-250-05	24-30	233.3	75 +/ 5.7
SB-250-06	30-36	161.6	<2.1
SB-250-07	36-42	182.2	4.1 +/- 1.9
SB-250-08	42-48	95.4	<3.1
SB-250-09	48-54	119.5	<2.6
SB-250-11	60-66	162.7	7.2 +/- 1.8
SB-250-12	66-72	185.7	2.3 +/- 1.9
SB-250-13	72-78	230.2	12 +/- 2.6
SB-250-14	78-84	118.6	<2.4
SB-250-15	84-90	200.9	<2.5
SB-250-17	96-102	173.3	<2.0
SB-250-18	102-108	164.2	<1.9
SB-250-20	114-120	198.3	<1.7
SB-250-21	120-126	175.7	<1.9
SB-250-22	126-132	131.2	<2.1
SB-250-23	132-138	191.0	<1.6
SB-250-24	138-144	232.1	<1.9
SB-250-27	156-162	249.3	<2.0
SB-250-28	162-168	206.4	<2.5
SB-250-29	168-174	204.9	<2.5
SB-250-30	174-180	206.6	<2.2
SB-250-31	180-186	146.9	<2.0
SB-250-34	198-204	261.3	<2.0
SB-250-35	204-210	229.0	<2.1
SB-250-36	210-216	203.8	<2.4
SB-250-37	216-222	251.7	<1.9
SB-250-40	234-240	267.4	<2.0
SB-250-41	240-246	236.1	<2.1
SB-250-42	246-252	270.0	<1.9
SB-250-43	252-258	321.8	<1.7
SB-250-44	258-264	266.8	<1.9
SB-250-45	264-270	247.8	<2.1

TABSB250.XLS

SOIL BORING(389),
FINDLAY
PROPERTY,NORTH END
OF SITE

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-389-01	0-6	200.0	8.5 +/- 2.9
SB-389-02	6-12	238.3	<2.1
SB-389-03	12-18	205.5	<2.5
SB-389-04	18-24	(NO RECOVERY,	NO ANALYSIS)
SB-389-05	24-30	103.3	<3.0
SB-389-06	30-36	273.2	<1.9
SB-389-07	36-42	256.6	4.0 +/- 1.8
SB-389-08	42-48	235.4	2.6 +/- 2.1
SB-389-09	48-54	235.0	2.5 +/- 2.0
SB-389-10	54-60	172.5	3.6 +/- 1.8
SB-389-11	60-66	208.8	3.5 +/- 2.0
SB-389-12	66-72	220.4	3.2 +/- 1.9
SB-389-13	72-78	NO RECOVERY	NO ANALYSIS)
SB-389-14	78-84	122.5	5.5 +/- 2.1
SB-389-15	84-90	189.2	<1.9
SB-389-16	90-96	(NO RECOVERY,	NO ANALYSIS)
SB-389-17	96-102	(NO RECOVERY,	NO ANALYSIS)
SB-389-18	102-108	242.3	<2.3
SB-389-19	108-114	313.7	<1.9
SB-389-20	114-120	256.9	<1.9

S0IL BORING(386), FINDLAY
PROPERTY, NORTH END OF SITE

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-386-01	0-6	184.4	6.4 +/- 2.0
SB-386-02	6-12	238.3	6.5 +/- 2.6
SB-386-03	12-18	217.1	16 +/- 2.7
SB-386-04	18-24	172.7	27 +/- 2.8
SB-386-05	24-30	258.3	8.7 +/- 2.5
SB-386-06	30-36	247.7	9.1 +/- 2.1
SB-386-07	36-42	234.6	<2.4
SB-386-08	42-48	254.5	<2.1
SB-386-09	48-54	273.7	2.4 +/- 1.8
SB-386-10	54-60	(NO RECOVERY,	NO ANALYSIS)
SB-386-11	60-66	148.6	4.5 +/- 1.9
SB-386-12	66-72	271.7	<2.1
SB-386-13	72-78	(NO RECOVERY,	NO ANALYSIS)
SB-386-14	78-84	(NO RECOVERY,	NO ANALYSIS)
SB-386-15	84-90	(NO RECOVERY,	NO ANALYSIS)
SB-386-16	90-96	196.0	5.1 +/- 1.7
SB-386-17	96-102	198.9	3.0 +/- 1.5
SB-386-18	102-108	265.4	3.0 +/- 2.0
SB-386-19	108-114	266.4	<2.0
SB-386-20	114-120	294.6	2.2 +/- 1.6

SOIL BORING(SB381),
AT FENCE ON EAST SIDE

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-381-01	0-6	134.9	<2.2
SB-381-02	6-12	153.8	<2.0
SB-381-03	12-18	135.6	<2.1
SB-381-05	24-30	196.9	<1.7
SB-381-06	30-36	98.9	<2.7
SB-381-07	36-42	173.3	<1.8
SB-381-08	42-48	127.0	<2.2
SB-381-09	48-54	101.8	<2.6
SB-381-10	54-60	57.2	<4.5
SB-381-14	78-84	110.8	<2.5
SB-381-15	84-90	90.6	<2.9
SB-381-17	96-102	148.4	<1.9
SB-381-18	102-108	145.7	<2.0
SB-381-19	108-114	77.5	<3.4
SB-381-20	114-120	89.0	<3.0
SB-381-24	138-144	126.0	<2.2
SB-381-25	144-150	179.0	<1.7
SB-381-26	150-156	172.1	<1.8
SB-381-27	156-162	156.1	<1.9
SB-381-30	174-180	115.9	<2.3
SB-381-35	204-210	295.6	<1.8
SB-381-36	210-216	191.5	<1.6
SB-381-37	216-222	307.0	<1.8
SB-381-38	222-228	304.3	<1.8
SB-381-39	228-234	247.6	<2.0
SB-381-40	234-240	192.1	<1.6
SB-381-41	240-246	217.4	<2.2
SB-381-42	246-252	265.0	<1.9

SOIL BORING(SB373),
UNIT 2, NEAR SB340

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-373-01	0-6	64.3	7.9 +/- 3.6
SB-373-02	6-12	182.2	2.7 +/- 1.8
SB-373-03	12-18	226.1	6.8 +/- 2.0
SB-373-06	30-36	139.2	<2.2
SB-373-08	42-48	230.9	4.4 +/- 2.0
SB-373-09	48-54	193.9	18 +/- 2.3
SB-373-10	54-60	228.8	<2.6
SB-373-11	60-66	201.8	7.6 +/- 2.6
SB-373-12	66-72	218.4	7.0 +/- 2.3
SB-373-14	78-84	264.5	57 +/- 4.1
SB-373-15	84-90	219.3	174 +/- 11
SB-373-16	90-96	344.3	67 +/- 4.4
SB-373-17	96-102	378.9	102 +/- 7.0
SB-373-18	102-108	304.3	241 +/- 14
SB-373-25	144-150	317.4	143 +/- 8.7
SB-373-26	150-156	370.2	137 +/- 8.6
SB-373-27	156-162	333.7	54 +/- 3.6
SB-373-28	162-168	158.5	116 +/- 4.4
SB-373-29	168-174	260.4	5.3 +/- 1.8
SB-373-30	174-180	258.6	<2.1
SB-373-31	180-186	387.6	<1.6
SB-373-32	186-192	329.5	<1.8
SB-373-33	192-198	293.6	2.1 +/- 1.5
SB-373-35	204-210	125.7	<2.2
SB-373-36	210-216	262.2	<2.0
SB-373-37	216-222	123.1	<3.0
SB-373-38	222-228	282.7	5.8 +/- 1.8
SB-373-39	228-234	236.1	<2.2

SOIL BORING(SB345),
MIDDLE OF UNIT 2

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCl/g wet)
SB-345-02	6-12	229.8	<2.5
SB-345-03	12-18	187.5	7.8 +/- 1.7
SB-345-04	18-24	186.2	<1.9
SB-345-05	24-30	212.0	9.9 +/- 2.4
SB-345-06	30-36	201.8	15.3 +/- 2.8
SB-345-08	42-48	231.2	12.4 +/- 2.4
SB-345-09	48-54	200.1	19.8 +/- 2.8
SB-345-10	54-60	288.1	6.4 +/- 1.9
SB-345-11	60-66	190.7	6.6 +/- 1.8
SB-345-12	66-72	249.9	4.2 +/- 2.1
SB-345-15	84-90	247.4	<2.4
SB-345-16	90-96	211.8	6.1 +/- 2.1
SB-345-17	96-102	244.5	<2.2
SB-345-18	102-108	296.5	<1.8
SB-345-19	108-114	225.4	<2.4
SB-345-20	114-120	299.4	<1.8
SB-345-21	120-126	319.6	<1.8
SB-345-22	126-132	165.0	<1.8
SB-345-23	132-138	233.4	<2.1
SB-345-24	138-144	218.0	<2.2
SB-345-25	144-150	217.7	<2.2
SB-345-26	150-156	207.5	<2.3
SB-345-27	156-162	237.0	<1.9
SB-345-29	168-174	220.8	<2.2
SB-345-30	174-180	206.6	<2.3
SB-345-31	180-186	260.0	<1.9
SB-345-32	186-192	287.1	<1.9
SB-345-33	192-198	253.1	<1.9
SB-345-35	204-210	193.7	<1.6
SB-345-36	210-216	257.6	<2.0
SB-345-38	222-228	230.0	<2.1
SB-345-39	228-234	305.7	<1.7
SB-345-40	234-240	240.3	<2.0

SOIL BORING(SB340),
MIDDLE OF UNIT 2

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-340-01	0-6	128.0	5.8 +/- 2.3
SB-340-02	6-12	228.6	8.6 +/- 2.4
SB-340-03	12-18	253.9	2.6 +/- 2.1
SB-340-05	24-30	149.0	4.4 +/- 1.9
SB-340-06	30-36	149.7	2.2 +/- 1.8
SB-340-07	36-42	244.1	2.5 +/- 2.0
SB-340-08	42-48	278.3	2.8 +/- 2.1
SB-340-09	48-54	265.1	22 +/- 2.6
SB-340-10	54-60	209.5	<2.6
SB-340-11	60-66	207.4	<2.7
SB-340-12	66-72	239.6	514 +/- 32
SB-340-18	102-108	142.5	207 +/- 8.4
SB-340-19	108-114	305.5	53 +/- 3.6
SB-340-20	114-120	325.1	<2.3
SB-340-21	120-126	306.5	2.4 +/- 1.6
SB-340-22	126-132	252.3	45 +/- 3.6
SB-340-23	132-138	222.3	<2.5
SB-340-24	138-144	226.8	<2.2
SB-340-25	144-150	303.9	66 +/- 4.5
SB-340-26	150-156	277.1	<2.1
SB-340-27	156-162	346.1	3.9 +/- 1.5
SB-340-28	162-168	247.8	16 +/- 2.6
SB-340-29	168-174	187.5	<1.7
SB-340-30	174-180	286.0	<1.9
SB-340-31	180-186	296.1	<2.1
SB-340-32	186-192	231.4	25 +/- 2.8
SB-340-33	192-198	274.2	4.5 +/- 1.7
SB-340-34	198-204	258.5	38 +/- 3.3
SB-340-35	204-210	266.0	<2.3
SB-340-36	210-216	297.8	<1.8

SOIL BORING(SB303),
UNIT 2, PARKING AREA

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-303-02	6-12	210.0	<2.2
SB-303-03	12-18	204.7	<2.3
SB-303-06	30-36	149.8	<1.9
SB-303-07	36-42	178.43	<2.0
SB-303-08	42-48	174.5	<1.8
SB-303-09	48-54	151.7	<1.9
SB-303-12	66-72	169.1	<1.8
SB-303-15	84-90	234.3	<2.0
SB-303-17	96-102	192.7	<1.6
SB-303-18	102-108	290.5	<1.8
SB-303-20	114-120	80.7	<3.2
SB-303-21	120-126	204.7	<2.3
SB-303-22	126-132	198.6	<1.6
SB-303-23	132-138	158.3	<1.8
SB-303-24	138-144	92.8	<2.9
SB-303-25	144-150	142.8	<2.1
SB-303-26	150-156	204.7	<2.4
SB-303-27	156-162	135.4	<2.0
SB-303-28	162-168	268.1	<1.9
SB-303-29	168-174	207.9	<2.2
SB-303-30	174-180	240.2	<1.9
SB-303-31	180-186	199.3	<1.6
SB-303-32	186-192	199.9	<1.5

SOIL BORING(SB8A),
UNIT 3, NEAR ACID PLANT.

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-8A-02	6-12	257.6	3.6 +/- 1.6
SB-8A-03	12-18	190.1	<1.6
SB-8A-04	18-24	173.5	1.9 +/- 1.6
SB-8A-05	24-30	168.3	<1.9
SB-8A-06	30-36	225.2	<2.2
SB-8A-07	36-42	247.5	<2.1
SB-8A-08	42-48	206.8	<2.3
SB-8A-09	48-54	221.9	<2.3
SB-8A-11	60-66	160.9	<2.0
SB-8A-12	66-72	213.1	<2.3
SB-8A-15	84-90	118.7	<2.4
SB-8A-16	90-96	192.5	<1.7
SB-8A-17	96-102	202.2	4.2 +/- 2.0
SB-8A-18	102-108	226.2	<2.2
SB-8A-19	108-114	354.0	<1.6
SB-8A-20	114-120	288.5	3.1 +/- 1.4
SB-8A-21	120-126	309.0	<1.9
SB-8A-24	138-144	214.7	2.9 +/- 1.8
SB-8A-25	144-150	328.4	<1.7
SB-8A-26	150-156	300.4	2.8 +/- 1.5
SB-8A-27	156-162	309.0	<1.8
SB-8A-28	162-168	347.5	<1.6
SB-8A-29	168-174	358.4	2.4 +/- 1.4
SB-8A-30	174-180	277.7	<2.0
SB-8A-31	180-186	268.0	<1.9
SB-8A-32	186-192	256.6	<2.0
SB-8A-33	192-198	234.0	2.9 +/- 1.9
SB-8A-34	198-204	194.3	1.8 +/- 1.4
SB-8A-35	204-210	233.9	<2.2

SOIL BORING(SB88),UNIT1,
EDGE OF CREEK BANK

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-88-01	0-6	59.0	<4.3
SB-88-02	6-12	121.7	<2.3
SB-88-03	12-18	163.6	261 +/- 6.2
SB-88-06	30-36	114.1	6.5 +/- 2.6
SB-88-07	36-42	151.0	203 +/- 5.8
SB-88-08	42-48	140.7	39 +/- 3.1
SB-88-09	48-54	136.0	13 +/- 2.6
SB-88-10	54-60	212.2	8.9 +/- 3.1
SB-88-11	60-66	229.1	16 +/- 2.6
SB-88-12	66-72	179.3	11 +/- 1.8
SB-88-13	72-78	142.5	24 +/- 2.6
SB-88-14	78-84	210.0	9.2 +/- 2.6
SB-88-15	84-90	175.7	2.8 +/- 1.7
SB-88-16	90-96	178.9	13 +/- 2.0
SB-88-17	96-102	131.3	<2.3
SB-88-18	102-108	124.6	<2.3
SB-88-19	108-114	244.5	<2.3
SB-88-20	114-120	113.2	<2.5
SB-88-21	120-126	126.2	<2.3
SB-88-22	126-132	140.2	<2.3
SB-88-23	132-138	138.9	<2.1
SB-88-24	138-144	190.3	<1.7

SOIL BORING(SB88),UNIT1,
EDGE OF CREEK BANK

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-88-25	144-150	185.4	<1.7
SB-88-26	150-156	182.1	<1.6
SB-88-27	156-162	147.9	<2.0
SB-88-28	162-168	246.4	<2.1
SB-88-29	168-174	215.3	<2.1
SB-88-30	174-180	213.6	<2.2
SB-88-31	180-186	125.4	<2.2
SB-88-32	186-192	127.9	<2.1
SB-88-33	192-198	101.3	<2.7
SB-88-34	198-204	174.6	<1.8
SB-88-35	204-210	150.8	<2.0
SB-88-36	210-216	129.7	<2.1
SB-88-37	216-222	181.0	<1.7
SB-88-38	222-228	158.5	<1.9
SB-88-39	228-234	160.6	<1.9
SB-88-41	240-246	84.2	<3.2
SB-88-42	246-252	123.8	<2.3

SOIL BORING(SB82),
UNIT2,
BTW THORIUM PILE AND FENCE

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-82-02	6-12	78.3	<3.6
SB-82-03	12-18	265.5	<2.0
SB-82-05	24-30	242.7	<2.1
SB-82-06	30-36	223.8	<2.1
SB-82-07	36-42	170.4	<1.8
SB-82-08	42-48	233.6	<2.1
SB-82-09	48-54	287.7	<1.8
SB-82-11	60-66	227.0	178 +/- 11
SB-82-12	66-72	200.7	<2.5
SB-82-14	78-84	257.5	<1.9
SB-82-15	84-90	303.3	<1.8
SB-82-17	96-102	245.4	<2.0
SB-82-18	102-108	355.7	<1.6
SB-82-21	118-124	94.1	<3.0
SB-82-22	124-130	182.9	<1.8
SB-82-23	130-136	200.3	<2.4
SB-82-24	136-142	306.6	<1.8
SB-82-25	142-148	240.8	<2.0
SB-82-26	148-154	238.9	<2.1
SB-82-27	154-160	201.2	<1.6
SB-82-29	166-172	321.2	<1.7
SB-82-30	172-178	241.5	<2.0
SB-82-31	178-184	70.6	<3.7

SOIL BORING(SBö1), UNIT2,
BTW THORIUM PILE AND FENCE

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-81-08	42-48	234.6	2.3 +/- 1.8
SB-81-09	48-54	288.4	2.9 +/- 1.5
SB-81-11	60-66	316.6	<1.7
SB-81-12	66-72	275.5	5.6 +/- 2.0
SB-81-13	72-78	246.2	<2.0
SB-81-14	78-84	192.4	<1.7
SB-81-15	84-90	305.7	<1.8
SB-81-18	1O2-108	258.4	2.6 +/- 1.6
SB-81-19	108-114	317.6	<1.7
SB-81-20	114-120	303.3	3.1 +/- 1.5
SB-81-21	120-126	290.5	<1.8
SB-81-22	126-132	216.2	<2.1
SB-81-23	132-138	233.4	<2.2
SB-81-24	138-144	277.4	<2.0
SB-81-25	144-150	220.5	<2.2
SB-81-26	150-156	247.1	<2.0
SB-81-27	156-162	233.3	<2.1
SB-81-32	186-192	299.1	<1.8
SB-81-33	192-198	332.0	<1.7

SOIL BORING(SB50),NEAR CORRIGATED,BLDG.

A	B	C	D
SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-50-03	12-18	276.4	7.2 +/- 1.9
SB-50-04	18-24	270.8	<2.3
SB-50-07	36-42	219.2	3.7 +/- 1.9
SB-50-08	42-48	247.4	13 +/- 2.2
SB-50-13	72-78	185.8	6.8 +/- 1.5
SB-50-14	78-84	189.7	60 +/- 2.9
SB-50-25	144-150	116.8	78 +/- 3.9
SB-50-26	150-156	116.4	28 +/- 3.0
SB-50-28	162-168	167.7	40 +/- 2.8
SB-50-29	168-174	150.6	4.9 +/- 1.8
SB-50-30	174-180	241.7	2.7 +/- 1.8
SB-50-32	186-192	294.8	3.6 +/- 1.7
SB-50-33	192-198	168.7	<1.9
SB-50-34	198-204	222.0	<1.5
SB-50-35	204-210	307.8	<1.7
SB-50-36	210-216	298.7	<1.9
SB-50-37	216-222	293.4	<1.9
SB-50-38	222-228	311.2	3.4 +/- 1.7
SB-50-40	234-240	197.0	<1.6
SB-50-41	240-246	231.2	2.4 +/- 1.7
SB-50-42	246-252	166.0	<1.8

SOIL BORING(SB437), ON
TERRACE,BETW. RR LINE
AND UNIT 2 FENCE

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-437-01	0-6	518.6	1.8 +/- 1.3
SB-437-02	6-12	595.9	9.5 +/- 1.5
SB-437-03	12-18	515.5	100 +/- 3.8
SB-437-04	18-24	490.5	<1.6
SB-437-05	24-30	457.6	3.1 +/- 1.3
SB-437-06	30-36	361.0	2.7 +/- 1.4
SB-437-07	36-42	515.7	<1.5
SB-437-08	42-48	502.7	<1.7
SB-437-09	48-54	659.4	<1.3
SB-437-11	60-66	181.7	<1.7
SB-437-12	66-72	126.4	<2.3
SB-437-15	84-90	173.0	<1.8
SB-437-17	96-102	215.8	<2.2
SB-437-18	102-108	118.1	<2.4
SB-437-19	108-114	263.6	<2.0
SB-437-20	114-120	326.5	<1.8
SB-437-21	120-126	255.1	<2.0
SB-437-22	126-132	210.2	<2.3
SB-437-23	132-138	256.3	<2.1

SOIL BORINC (SB414),
ASPHALT AREA,
MAINGATE.

SAMPLE #	DEPTH(IN)	MASS (g)	TH-232 CONC (pCi/g wet)
SB-414-02	6.0- 12	224.5	<2.2
SB-414-03	12.0-18.0	233.6	<2.1
SB-414-06	30.0-36.0	124.1	<2.5
SB-414-09	48.0-54.0	254.9	<2.1
SB-414-10	54.0-60.0	393.1	1.6 +/- 1.3
SB-414-11	60.0-66.0	362.5	<1.7
SB-414-12	66.0-72.0	291.8	<1.9
SB-414-13	72.0-78.0	163.8	<1.8
SB-414-14	78.0-84.0	288.9	<1.8
SB-414-15	84.0-90.0	274.4	<1.9
SB-414-16	90.0-96.0	349.4	<1.7
SB-414-17	96.0-102.0	342.8	<1.6
SB-414-18	102.0-108	216.3	<2.1
SB-414-19	108.0-114	352.0	<1.6
SB-414-20	114.0-120	310.6	<1.8
SB-414-21	120.0-126	224.1	<2.2

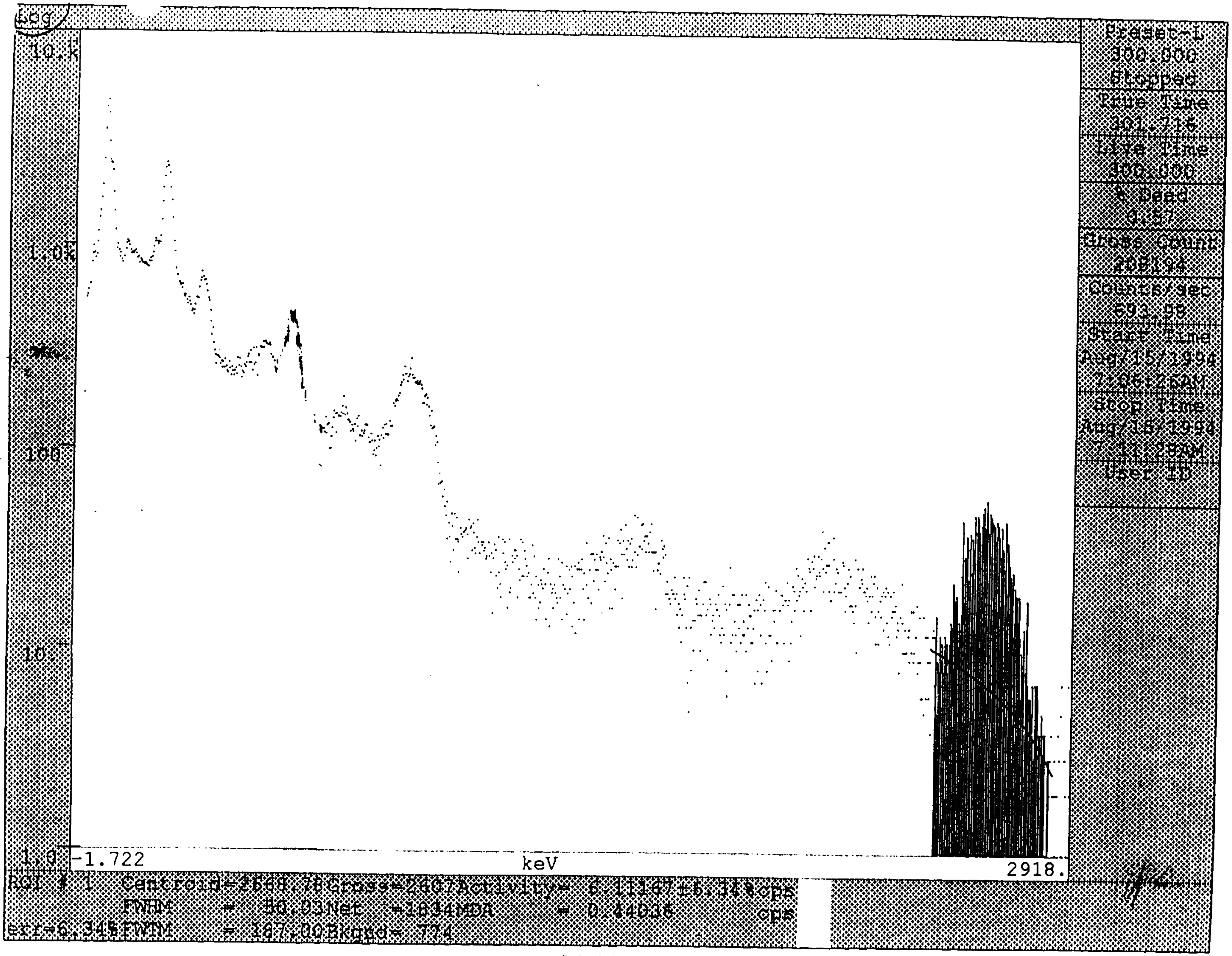


FIGURE J-2
2600 keV PHOTOPEAK SHOWING CALCULATED
BACKGROUND LINES FOR TH-232 STANDARD

Determination of Geometry Correction Factor:

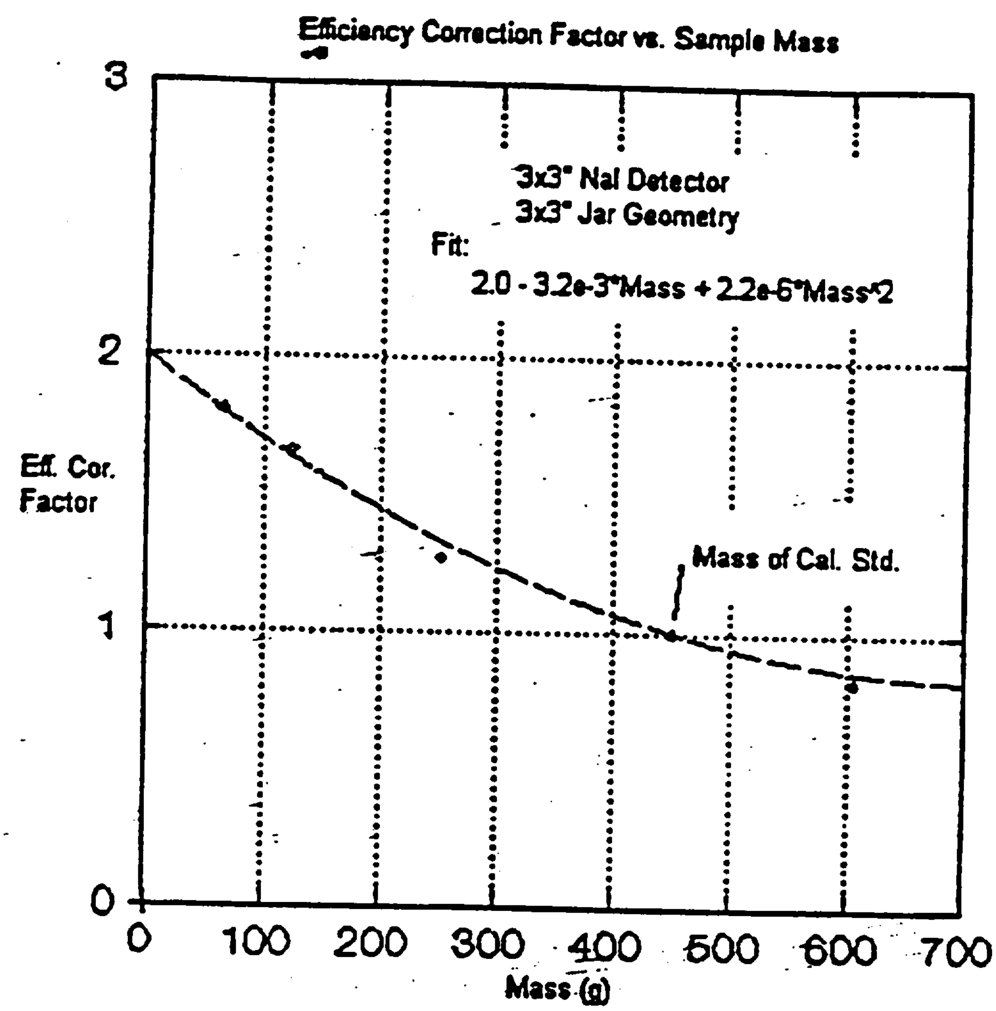


FIGURE J–1

APPENDIX K

Analytical Data

- Radiological Data
- Chemical Data
- Sediment Data - Radiological
- Storm Sewer Data
- Impoundment Data -
  Radiological and Chemical

Radiological Data

MOLYCORP

RADIOLOGICAL RESULTS

Well ID# -->		M-1	M-1	M-2	M-2	M-2	M-3	M-3	M-3
Sampling Date		6/28/94	7/27/94	6/29/94	7/27/94	8/9/94	6/28/94	7/27/94	8/9/94
	Detection								
Radionuclide	Limit(pCi/L)								
Ra-226	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.52+/-0.16	0.52+/-0.19
Ra-228	2	<2	<2	<2	2.65+/-2.58	<2	<2	<2	3.61+/-3.08
Th-228	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Th-230	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Th-232	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-234	0.5	<0.5	<0.5	1.39+/-0.23	1.11+/-0.31	1.34+/-0.27	<0.5	<0.5	<0.5
U-235	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-238	0.5	<0.5	<0.5	1.57+/-0.25	1.27+/-0.33	1.24+/-0.26	<0.5	<0.5	<0.5

FB - Field Blank, TB - Trip Blank, D- Duplicate, F-Dissolved sample, BR- Bedrock Well, CR - Creek Well, UG - Upgradient Well, < - Less than Detection Limit.

RAD.XLS

MOLYCORP

RADIOLOGICAL RESULTS

Well ID# -->		M-4	M-4	M-4	M-5	M-5	M-5D	M-5	M-6
Sampling Date		6/28/94	7/27/94	8/9/94	7/1/94	7/28/94	7/28/94	8/9/94	7/1/94
	Detection								
Radionuclide	Limit(pCi/L)								
Ra-226	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ra-228	2	<2	<2	<2	2.11+/-1.89	<2	<2	2.06+/-2.37	<2
Th-228	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Th-230	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Th-232	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-234	0.5	0.56+/-0.16	0.97+/-0.27	<0.5	<0.5	<0.5	<0.5	<0.5	1.72+/-0.31
U-235	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-238	0.5	<0.5	1.05+/-0.28	<0.5	<0.5	<0.5	<0.5	<0.5	1.55+/-0.29

FB - Field Blank, TB - Trip Blank, D- Duplicate, F-Dissolved sample, BR- Bedrock Well, CR - Creek Well, UG - Upgradient Well, < - Less than Detection Limit.

MOLYCORP

RADIOLOGICAL RESULTS

Well ID# -->		M-6	M-6	M-7	M-7	M-8	M-8	M-9	M-9
Sampling Date		7/28/94	8/9/94	6/30/94	8/1/94	6/29/94	7/26/94	6/30/94	7/26/94
	Detection								
Radionuclide	Limit(pCi/L)								
Ra-226	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ra-228	2	<2	<2	2.24+/-2.46	<2	<2	3.03+/-2.71	4.92+/-3.01	<2
Th-228	0.5	<0.5	0.54+/-0.59	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Th-230	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Th-232	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-234	0.5	0.78+/-0.27	0.74+/-0.18	3.19+/-0.43	2.09+/-0.46	0.58+/-0.15	0.71+/-0.17	1.83+/-0.29	0.87+/-0.2
U-235	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-238	0.5	<0.5	<0.5	2.58+/-0.37	1.46+/-0.37	<0.5	<0.5	1.61+/-0.27	0.86+/-0.2

FB - Field Blank, TB - Trip Blank, D- Duplicate, F-Dissolved sample, BR- Bedrock Well, CR - Creek Well, UG - Upgradient Well, < - Less than Detection Limit.

MOLYCORP

RADIOLOGICAL RESULTS

Well ID# -->		M-9S	M-9S	M-10	M-10	M-10	M-11	M-11	M-12
Sampling Date		6/30/94	7/26/94	7/1/94	7/28/94	8/9/94	6/29/94	7/26/94	7/1/94
	Detection								
Radionuclide	Limit(pCi/L)								
Ra-226	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ra-228	2	<2	<2	<2	<2	<2	<2	<2	3.16+/-1.99
Th-228	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Th-230	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Th-232	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-234	0.5	<0.5	<0.5	1.57+/-0.26	1.45+/-0.32	1.75+/-0.29	3.41+/-0.47	3.58+/-0.49	3.13+/-0.40
U-235	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-238	0.5	<0.5	<0.5	1.63+/-0.27	1.3+/-0.3	1.38+/-0.25	2.6+/-0.39	2.48+/-0.39	2.6+/-0.37

FB - Field Blank, TB - Trip Blank, D- Duplicate, F-Dissolved sample, BR- Bedrock Well, CR - Creek Well, UG - Upgradient Well, < - Less than Detection Limit.

MOLYCORP

RADIOLOGICAL RESULTS

Well ID# -->		M-12	M-13	M-13	M-14	M-14D	M-14	M-15	M-15S
Sampling Date		8/2/94	6/30/94	7/26/94	6/29/94	6/29/94	7/26/94	6/29/94	6/29/94
	Detection								
Radionuclide	Limit(pCi/L)								
Ra-226	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ra-228	2	2.25+/-2.28	4.85+/-2.59	<2	<2	<2	<2	<2	<2
Th-228	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Th-230	0.5	2.97+/-0.97	<0.5	<0.5	<0.5	0.75+/-0.22	<0.5	<0.5	0.93+/-0.23
Th-232	0.5	0.74+/-0.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-234	0.5	1.66+/-0.28	0.52+/-0.15	0.63+/-0.16	<0.5	<0.5	<0.5	<0.5	<0.5
U-235	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-238	0.5	1.36+/-0.25	<0.5	0.68+/-0.16	<0.5	<0.5	<0.5	<0.5	<0.5

FB - Field Blank, TB - Trip Blank, D- Duplicate, F-Dissolved sample, BR- Bedrock Well, CR - Creek Well, UG - Upgradient Well, < - Less than Detection Limit.

RAD.XLS

MOLYCORP

RADIOLOGICAL RESULTS

Well ID# -->		M-15	M-15S	M-16	M-16	M-17	M-17	M-17D	M-18
Sampling Date		7/26/94	7/26/94	6/29/94	7/6/94	6/30/94	8/2/94	8/2/94	7/1/94
	Detection								
Radionuclide	Limit(pCi/L)								
Ra-226	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ra-228	2	<2	<2	<2	<2	<2	<2	<2	<2
Th-228	0.5	<0.5	1.36+/-0.78	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Th-230	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Th-232	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-234	0.5	<0.5	<0.5	<0.5	<0.5	0.92+/-0.19	<0.5	<0.5	1.16+/-0.23
U-235	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-238	0.5	<0.5	<0.5	<0.5	<0.5	0.82+/-0.18	<0.5	<0.5	0.87+/-0.20

FB - Field Blank, TB - Trip Blank, D- Duplicate, F-Dissolved sample, BR- Bedrock Well, CR - Creek Well, UG - Upgradient Well, < - Less than Detection Limit.

MOLYCORP

RADIOLOGICAL RESULTS

Well ID# -->		M-18	M-18S	M-18S	MW19	MW19	MW20	MW20	MW21
Sampling Date		8/3/94	7/1/94	8/3/94	7/6/94	7/26/94	7/7/94	8/1/94	7/12/94
	Detection								
Radionuclide	**Limit(pCi/L)**								
Ra-226	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.92+/-0.27	0.91+/-0.22	<0.5
Ra-228	2	3.6+/-2.11	<2	4.14+/-2.88	<2	<2	<2	3.85+/-2.63	<2
Th-228	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Th-230	0.5	<0.5	<0.5	1.47+/-0.39	<0.5	<0.5	<0.5	<0.5	<0.5
Th-232	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-234	0.5	1.06+/-0.24	<0.5	<0.5	0.80+/-0.18	0.55+/-0.2	<0.5	<0.5	<0.5
U-235	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-238	0.5	0.83+/-0.21	<0.5	<0.5	0.52+/-0.14	<0.5	<0.5	<0.5	<0.5

FB - Field Blank, TB - Trip Blank, D- Duplicate, F-Dissolved sample, BR- Bedrock Well, CR - Creek Well, UG - Upgradient Well, < - Less than Detection Limit.

MOLYCORP

RADIOLOGICAL RESULTS

Well ID# -->		MW21	MW22	MW22	MW23	MW23	MW24	MW24	MW25
Sampling Date		8/3/94	7/12/94	8/3/94	7/7/94	7/29/94	7/12/94	8/2/94	7/12/94
	Detection								
Radionuclide	Limit(pCi/L)								
Ra-226	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ra-228	2	5.32+/-2.20	<2	3.08+/-2.53	<2	<2	<2	<2	<2
Th-228	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Th-230	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Th-232	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-234	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1.01+/-0.25
U-235	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-238	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.73+/-0.23

FB - Field Blank, TB - Trip Blank, D- Duplicate, F-Dissolved sample, BR- Bedrock Well, CR - Creek Well, UG - Upgradient Well, < - Less than Detection Limit.

MOLYCORP

RADIOLOGICAL RESULTS

Well ID# -->		MW25	MW26	MW26	MW27	MW27	MW28	MW28	MW29
Sampling Date		7/28/94	7/8/94	7/29/94	7/6/94	7/29/94	7/6/94	7/29/94	7/8/94
	Detection								
Radionuclide	Limit(pCi/L)								
Ra-226	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ra-228	2	<2	<2	5.16+/-3.55	<2	<2	<2	<2	4.52+/-2.48
Th-228	0.5	1.04+/-0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Th-230	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Th-232	0.5	1.38+/-0.39	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-234	0.5	1.07+/-0.32	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-235	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-238	0.5	0.89+/-0.29	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

FB - Field Blank, TB - Trip Blank, D- Duplicate, F-Dissolved sample, BR- Bedrock Well, CR - Creek Well, UG - Upgradient Well, < - Less than Detection Limit.

MOLYCORP

RADIOLOGICAL RESULTS

Well ID# -->		MW29	MW29	UG2	UG2	UG3	UG3	UGM4	UGM4D
Sampling Date		7/28/94	8/9/94	7/6/94	7/26/94	7/28/94	7/8/94	7/6/94	7/6/94
	Detection								
Radionuclide	Limit(pCi/L)								
Ra-226	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2.23+/-1.88
Ra-228	2	<2	4.52+/-2.48	<2	<2	<2	<2	<2	<2
Th-228	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	NA	<0.5	<0.5
Th-230	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	NA	<0.5	<0.5
Th-232	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	NA	<0.5	<0.5
U-234	0.5	<0.5	<0.5	2.60+/-0.37	1.63+/-0.26	<0.5	0.62+/-0.15	<0.5	<0.5
U-235	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-238	0.5	<0.5	<0.5	2.30+/-0.34	1.41+/-0.24	<0.5	0.60+/-0.15	<0.5	<0.5

FB - Field Blank, TB - Trip Blank, D- Duplicate, F-Dissolved sample, BR- Bedrock Well, CR - Creek Well, UG - Upgradient Well, < - Less than Detection Limit.

MOLYCORP

RADIOLOGICAL RESULTS

Well ID# -->		UG4	CR1F(Dissolved)	CR1 Total	CR1F(Dissolved)	CR4F(Dissolved)	CR4 Total
Sampling Date		7/29/94	7/28/94	7/28/94	8/9/94	7/28/94	7/28/94
	Detection						
Radionuclide	**Limit(pCi/L)**						
Ra-226	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ra-228	2	<2	<2	5.61+/-6.67	5.70+/-2.72	<2	<2
Th-228	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Th-230	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Th-232	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-234	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-235	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-238	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

FB - Field Blank, TB - Trip Blank, D- Duplicate, F-Dissolved sample, BR- Bedrock Well, CR - Creek Well, UG - Upgradient Well, < - Less than Detection Limit.

MOLYCORP

RADIOLOGICAL RESULTS

Well ID# -->		CR4F(Dissolved)	BR1	BR1	FB062994	TB071294
Sampling Date		8/9/94	7/12/94	7/28/94	6/29/94	7/12/94
Radionuclide	Detection Limit(pCi/L)					
Ra-226	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ra-228	2	2.9+/-1.76	<2	<2	2.91+/-3.45	<2
Th-228	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Th-230	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Th-232	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-234	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-235	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-238	0.5	<0.5	<0.5	<0.5	<0.5	<0.5

FB - Field Blank, TB - Trip Blank, D- Duplicate, F-Dissolved sample, BR- Bedrock Well, CR - Creek Well, UG - Upgradient Well, < - Less than Detection Limit.

Chemical Data

Well ID	M-1	M-1	M-2	M-2	M-2	M-3
Sampling Date	**6/28/94**	**7/27/94**	**6/29/94**	**7/27/94**	**8/9/94**	**6/28/94**
Concentration,ug/L						
Analyte						
Aluminum	80.2B	69B	182B	242	174B	<54
Arsenic	13.7	13.8	20	5.8B	11.7	6.5B
Cadmium	6.7	6.9	<3	<3	<3	<3
Chromium	<4	5.5B	<4	<4	<4	<4
Cobalt	12.5B	17.2B	40.3B	37.7B	42.4B	5.6B
Copper	4.6B	<4	5.2B	<4	5.6B	<4
Iron	87.7B	<3	12900	6140	7350	16400
Lead	<1	<1	<1	<1	<2	<1
Magnesium	9410	38200	26500	24900	26000	91100
Manganese	<1	7B	12800	12300	12200	2580
Nickel	<9	<9	14.3B	<9	<9	<9
Selenium	84.6	73.2	1.9B	2.3B	25.6	2.1B
Sodium	210000	212000	39700	41500	39500	84800
Molybdenum	37300	44400	62500	63200	60700	16800
Concentration mg/L						
Chloride	120	120	8.3	8.4	7	50
T-Phenols	<0.005	0.013	<0.005	<0.005	<0.005	0.015
Sulfate	860	780	270	290	230	340
TDS	1800	1800	970	960	990	1100
TOC	18	15	6.3	5.8	6.7	10
TOX	0.02	0.01	0.01	<0.01	<0.01	0.01

B- The Concentration was less than the Contract Det. Limit (CRDL) but greater than the Instrument Det. Limit(IDL).
E- The Concentration is estimated because of interference.
<- The Concentration is less than the IDL
S- The Concentration was determined by the Method of Standard Addition(MSA)
UG- Upgradient Well
BR- Bedrock Well
FB- Field Blank
TB- Trip Blank.
CR- Creek Well

Well ID	M-3	M-3	M-4	M-4	M-4	M-5
Sampling Date	7/27/94	8/9/94	6/28/94	7/27/94	8/9/94	7/1/94
Concentration,ug/L						
Analyte						
Aluminum	64.3B	54.1B	1520	356	128B	9460
Arsenic	5.2B	4.6B	9.5B	5.9B	8B	25.8
Cadmium	<3	3B	7.5	<3	<3	<15
Chromium	<4	<4	<4	<4	<4	<20
Cobalt	6.1B	10.2B	82.5	27.3B	17.5B	269
Copper	<4	<4	<4	<4	<4	<20
Iron	15200	15400	811000	85900	24000	899000E
Lead	<1	<2	<1	2.7B	<2	<1
Magnesium	90300	85100	135000	48900	18200	78700
Manganese	2800	2820	56900	27100	11500	53500
Nickel	<9	<9	<9	<9	<9	45U
Selenium	2.4B	3.4B	16.9	4.5B	4.4B	57.3S
Sodium	80200	78300	351000	149000	107000	352000
Molybdenum	17300	17800	67400	21500	23400	262000
Concentration mg/L						
Chloride	40	49	350	160	44	150
T-Phenols	<0.005	<0.005	<0.005	<0.005	<0.005	0.014
Sulfate	310	310	3000	630	190	5100
TDS	1000	1400	6000	1900	830	7200
TOC	11	15	25	21	23	35
TOX	<0.01	<0.01	0.04	0.02	0.02	0.02

B- The Concentration was less than the Contract Det. Limit (CRDL) but greater than the Instrument Det. Limit(IDL).
E- The Concentration is estimated because of interference.
<- The Concentration is less than the IDL
S- The Concentration was determined by the Method of Standard Addition(MSA)
UG- Upgradient Well
BR- Bedrock Well
FB- Field Blank
TB- Trip Blank.
CR- Creek Well

Well ID	M-5	M-5Duplicate	M-5	M-6	M-6	M-6
Sampling Date	7/28/94	7/28/94	8/9/94	7/28/94	7/1/94	8/9/94
Concentration,ug/L						
Analyte						
Aluminum	8130	8750	7150	<54	<54	<54
Arsenic	13.5	29.1	33	2.7B	5.6B	4.2B
Cadmium	<15	32.2	<30	<3	<3	<3
Chromium	<40	<40	<40	<4	<4	<4
Cobalt	238B	277	246B	13.2B	10.4B	6.5B
Copper	<20	<20	<40	<4	<4	<4
Iron	884000	952000	978000	8610	12500E	17400
Lead	<1	<1	<2	<1	<1	<2
Magnesium	76900	82200	84100	16200	18800	24900
Manganese	51800	55700	54700	9440	10900	8790
Nickel	<45	<45	<90	<9	<9	<9
Selenium	61.5	11	61.8	2.6B	2.9B	2.4B
Sodium	356000	397000	427000	178000	204000	281000
Molybdenum	270000	285000	251000	19600	18400	10100
Concentration mg/L						
Chloride	78	150	240	58	110	99
T-Phenols	0.012	0.012	0.013	<0.005	<0.005	<0.005
Sulfate	4500	4500	4600	710	1000	850
TDS	7400	7500	7700	1900	1800	1800
TOC	33	34	33	6.5	9.4	6.7
TOX	0.02	0.02	0.05	<0.01	0.01	0.01

B- The Concentration was less than the Contract Det. Limit (CRDL) but greater than the Instrument Det. Limit(IDL).
E- The Concentration is estimated because of interference.
<- The Concentration is less than the IDL
S- The Concentration was determined by the Method of Standard Addition(MSA)
UG- Upgradient Well
BR- Bedrock Well
FB- Field Blank
TB- Trip Blank.
CR- Creek Well

Well ID	M-7	M-7	M-8	M-8	M-9	M-9
Sampling Date	6/29/94	8/1/94	6/29/94	7/26/94	6/30/94	7/26/94
Concentration,ug/L						
Analyte						
Aluminum	<54	<54	<54	<54	<54	<54
Arsenic	2B	<2	<2	<2	<2	<2
Cadmium	<3	<3	<3	<3	<3	<3
Chromium	<4	<4	<4	<4	<4	5.3B
Cobalt	<4	<4	<4	<4	<4	8.5B
Copper	<4	<4	<4	<4	<4	4.6B
Iron	336	1080	<3	<3	445	593
Lead	<1	<1	<1	<1	<1	<1
Magnesium	17900	17700	29300	29300	33700	30800
Manganese	7410	7530	79.8	76.3	7680	6420
Nickel	12.9B	<9	<9	<9	11.9B	<9
Selenium	<1	1.9B	<1	<2	<1	<2
Sodium	278000	269000	31300	31100	436000	380000
Molybdenum	701	791	109	70.4B	263	286
Concentration mg/L						
Chloride	280	270	120	120	170	170
T-Phenols	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sulfate	160	120	140	140	1200	1200
TDS	1100	1200	680	660	2400	2200
TOC	8.8	8.3	1.2	1.7	3.6	3.3
TOX	0.03	<0.01	<0.01	<0.01	<0.01	<0.01

B- The Concentration was less than the Contract Det. Limit (CRDL) but greater than the Instrument Det. Limit(IDL).
E- The Concentration is estimated because of interference.
<- The Concentration is less than the IDL
S- The Concentration was determined by the Method of Standard Addition(MSA)
UG- Upgradient Well
BR- Bedrock Well
FB- Field Blank
TB- Trip Blank.
CR- Creek Well

Well ID	M-9S	M-9S	M-10	M-10	M-10	M-11
Sampling Date	6/30/94	7/26/94	7/1/94	7/28/94	8/9/94	6/29/94
Concentration,ug/L						
Analyte						
Aluminum	74.3B	89.2B	<54	<54	70.7B	<54
Arsenic	101	112	4.6B	<2	2.3B	<2
Cadmium	<3	<3	<3	3.3B	<3	<3
Chromium	<4	<4	<4	<4	<4	<4
Cobalt	<4	<4	18.3B	7.3B	16B	4.7B
Copper	<4	<4	<4	<4	<4	<4
Iron	<3	<3	363E	2080	1180	51.4B
Lead	<1	<1	<1	<1	<2	<1
Magnesium	3840B	5030	7030	10200	7750	115000
Manganese	4.8B	1.3B	1380	2220	1550	18600
Nickel	<9	<9	<9	<9	<9	<9
Selenium	1.2B	<2	<2	1.2B	<2	1.7B
Sodium	130000	119000	49800	73000	50800	191000
Molybdenum	4980	5160	32000	14000	24600	199
Concentration mg/L						
Chloride	290	300	56	120	60	2000
T-Phenols	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sulfate	360	420	110	39	48	350
TDS	1200	1200	460	630	520	4900
TOC	2.9	4	5.4	4.4	4.8	3.6
TOX	<0.01	<0.01	<0.01		<0.01	<0.01

B- The Concentration was less than the Contract Det. Limit (CRDL) but greater than the Instrument Det. Limit(IDL).
E- The Concentration is estimated because of interference.
<- The Concentration is less than the IDL
S- The Concentration was determined by the Method of Standard Addition(MSA)
UG- Upgradient Well
BR- Bedrock Well
FB- Field Blank
TB- Trip Blank.
CR- Creek Well

Well ID	M-11	M-12	M-12	M-13	M-13	M-14
Sampling Date	7/26/94	7/1/94	8/2/94	6/30/94	7/26/94	6/29/94
Concentration,ug/L						
Analyte						
Aluminum	<54	97.4B	116B	<54	<54	<54
Arsenic	<2	5.5B	5.6B	<2	<2	2.2B
Cadmium	<3	<3	6.1	<3	<3	3.6B
Chromium	<4	<4	<4	<4	<4	<4
Cobalt	<4	60.2	56	8.5B	8.6B	<4
Copper	<4	7.7B	9.8	<4	<4	<4
Iron	337	1260E	7520	5.1B	<3	189
Lead	<1	<1	<2	<1	<1	<1
Magnesium	112000	15000	15700	63900	65600	50B
Manganese	19100	4140	5900	4420	4260	1.3B
Nickel	<9	14B	9.8B	<9	<9	<9
Selenium	<2	11.7	8	3.5B	<2	46.4
Sodium	187000	119000	124000	56700	57900	50600
Molybdenum	169	97200	92600	85.1	137	10500
Concentration mg/L						
Chloride	2000	190	190	210	230	230
T-Phenols	<0.005	0.049	0.041	<0.005	<0.005	0.009
Sulfate	370	1100	960	730	160	820
TDS	4800	1800	1800	1600	1500	2500
TOC	3.4	18	24	2	2.6	6.2
TOX	<0.01	0.03	0.03	<0.01	0.03	<0.01

B- The Concentration was less than the Contract Det. Limit (CRDL) but greater than the Instrument Det. Limit(IDL).
E- The Concentration is estimated because of interference.
<- The Concentration is less than the IDL
S- The Concentration was determined by the Method of Standard Addition(MSA)
UG- Upgradient Well
BR- Bedrock Well
FB- Field Blank
TB- Trip Blank.
CR- Creek Well

Well ID	M-14Duplicate	M-14	M-15	M-15	M-15S	M-15S
Sampling Date	6/29/94	7/26/94	6/29/94	7/26/94	6/29/94	7/26/94
Concentration,ug/L						
Analyte						
Aluminum	60.4B	<54	<54	<54	4710	5990
Arsenic	2.7B	<2	<2	<2	15.2	26
Cadmium	<3	<3	<3	<3	8.6	5.7
Chromium	<4	<4	<4	<4	15	46.8
Cobalt	<4	<4	6.9B	5.4B	14.9B	17.4B
Copper	<4	<4	<4	<4	20.6B	22.9B
Iron	195	157	3510	2410	3710	5680
Lead	<1	<1	<1	<1	<1	3.4
Magnesium	48.7B	<45	30200	30200	16100	15300
Manganese	2B	<1	3060	2560	2790	2960
Nickel	<9	<9	<9	<9	33.3B	29.4B
Selenium	39.4	38.4	<1	<2	204	142
Sodium	49900	52000	122000	121000	12200	12600
Molybdenum	10600	10500	477	187	20600	31900
Concentration mg/L						
Chloride	240	250	170	190	8.7	11
T-Phenols	0.009	0.008	<0.005	<0.005	<0.005	<0.005
Sulfate	820	950	630	650	1300	1300
TDS	2400	2400	1500	1500	2500	2500
TOC	6.2	6.8	1.8	1.7	4.6	6.1
TOX	0.01	<0.01	<0.01	<0.01	0.01	0.01

B- The Concentration was less than the Contract Det. Limit (CRDL) but greater than the Instrument Det. Limit(IDL).
E- The Concentration is estimated because of interference.
<- The Concentration is less than the IDL
S- The Concentration was determined by the Method of Standard Addition(MSA)
UG- Upgradient Well
BR- Bedrock Well
FB- Field Blank
TB- Trip Blank.
CR- Creek Well

Well ID	M-16	M-16	M-17	M-17Duplicate	M-17	M-18
Sampling Date	6/29/94	7/26/94	6/30/94	8/2/94	8/2/94	7/1/94
Concentration,ug/L						
Analyte						
Aluminum	64.8B	<54	<54	80B	75.9B	97.8B
Arsenic	<2	<2	3.5B	4.9B	4.1B	10
Cadmium	<3	<3	4.5B	9	10.5	5.1
Chromium	<4	<4	<4	10.1	9.4B	<4
Cobalt	<4	4.6B	<4	<4	4.4B	19.7B
Copper	<4	<4	<4	7.5B	5.7B	<4
Iron	2580	3610	29.8B	12.8B	14.4B	97.5BE
Lead	<1	<1	<1	<2	<2	<1
Magnesium	32200	30600	9290	2200B	2470B	842B
Manganese	9410	12100	26.1	4.1B	4.4B	96.3
Nickel	11.2B	<9	<9	<9	<9	9.7B
Selenium	1.5B	2B	59.1	102	96.6	46S
Sodium	66500	66600	93200	89700	88600	201000
Molybdenum	1280	1170	13000	19900	20300	41300
Concentration mg/L						
Chloride	280	280	150	160	160	170
T-Phenols	<0.005	<0.005	0.005	<0.005	<0.005	0.005
Sulfate	620	670	360	320	330	680
TDS	1700	1500	1000	940	920	1400
TOC	3.2	3.6	8.8	8.3	8.1	15
TOX	0.01	<0.01	<0.01	<0.01	0.01	0.02

B- The Concentration was less than the Contract Det. Limit (CRDL) but greater than the Instrument Det. Limit(IDL).
E- The Concentration is estimated because of interference.
<- The Concentration is less than the IDL
S- The Concentration was determined by the Method of Standard Addition(MSA)
UG- Upgradient Well
BR- Bedrock Well
FB- Field Blank
TB- Trip Blank.
CR- Creek Well

Well ID	M-18	M-18S	M-18S	MW19	MW19	MW20
Sampling Date	8/3/94	7/1/94	8/3/94	7/6/94	7/26/94	7/7/94
Concentration,ug/L						
Analyte						
Aluminum	232	118B	169B	175B	<54	<54
Arsenic	12.4	220	225	<2	<2	10.8
Cadmium	<3	27.8	29.4	<3	<3	<3
Chromium	<4	<4	28.7	<4	<4	<4
Cobalt	21.9B	<4	<4	<4	<4	<4
Copper	4.4B	11B	10.8B	<4	<4	<4
Iron	166	100E	201	153E	12.8B	5950E
Lead	<2	<1	<2	<1	<1	<1
Magnesium	1090B	9800	7340	36300	34300	13500
Manganese	91.1	3.1B	6.4B	3710	3140	1220
Nickel	<9	34.8B	37.4B	<9	<9	<9
Selenium	49.2	144	130	<2	<2	3.5B
Sodium	212000	201000	209000	34300	32100	212000
Molybdenum	45200	55200	47200	183	379	1210
Concentration mg/L						
Chloride	160	310	340	140	130	200
T-Phenols	0.005	0.007	0.007	<0.005	<0.005	<0.005
Sulfate	590	2400	1700	150	110	140
TDS	1400	3700	3800	770	670	1000
TOC	15	18	19	1.1	1.1	14
TOX	0.03	0.03	0.05	<0.01	<0.01	<0.01

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E- The Concentration is estimated because of interference.
<- The Concentration is less than the IDL
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UG- Upgradient Well
BR- Bedrock Well
FB- Field Blank
TB- Trip Blank.
CR- Creek Well

Well ID	MW20	MW21	MW21	MW22	MW22	MW23
Sampling Date	8/1/94	7/12/94	8/3/94	7/12/94	8/3/94	7/7/94
Concentration,ug/L						
Analyte						
Aluminum	54	<54	<54	<54	83B	65.8B
Arsenic	12.8	5.2B	4.2B	28	30.5	8.2B
Cadmium	<3	<3	<3	<3	5.1	<3
Chromium	<4	<4	<20	<4	<4	<4
Cobalt	<4	29.7B	38.3B	14.5B	13.1B	21.1B
Copper	<4	<4	<4	<4	<4	<4
Iron	9710	453000	839000	62.1B	8.9B	<3E
Lead	<1	<1	<2	1B	<2	<1
Magnesium	13800	137000	230000	2600B	4470B	9980
Manganese	1240	44000	60700	21.2	20.6	9.9B
Nickel	<9	<9	<9	<9	<9	<9
Selenium	3B	5.3	10.1	80.6	74.7	55.4S
Sodium	214000	337000	470000	51700	52700	94800
Molybdenum	894	37000	44000	24300	27200	39400
Concentration mg/L						
Chloride	220	280	350	24	25	75
T-Phenols	<0.005	<0.005	<0.005	0.014	0.011	<0.005
Sulfate	120	2800	3600	850	620	860
TDS	970	4400	7000	1400	1300	2000
TOC	13	22	30	4.7	6.4	7.6
TOX	<0.01	0.02	0.03	0.01	0.01	0.01

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<- The Concentration is less than the IDL
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BR- Bedrock Well
FB- Field Blank
TB- Trip Blank.
CR- Creek Well

Well ID	MW23	MW24	MW24	MW25	MW25	MW26
Sampling Date	**7/29/94**	**7/12/94**	**8/2/94**	**7/12/94**	**7/28/94**	**7/8/94**
Concentration,ug/L						
Analyte						
Aluminum	99B	<54	98.3B	71.4B	87.8B	<54
Arsenic	9.5B	15.1	20.3	25.6	66	2.7B
Cadmium	3.8B	<3	4.6B	<3	5.1	<3
Chromium	<4	<4	6.7B	<4	<4	<4
Cobalt	16.4B	12.5B	12.2B	35.4B	41.5B	11.7B
Copper	<4	<4	<4	<4	<4	<4
Iron	<3	8.7B	22.9B	63400	79300	484E
Lead	<1	<1	<2	<1	<1	<1
Magnesium	10300	621B	159B	54400	49600	13300
Manganese	10.2B	5.3B	2.3B	25200	24200	844
Nickel	<9	<9	<9	17.1B	<9	<9
Selenium	16.7	83.9	70.6	3.6B	4.2B	<2
Sodium	95000	102000	68300	283000	284000	26300
Molybdenum	35600	24200	25100	35500	43800	19100
Concentration mg/L						
Chloride	83	40	42	85	130	18
T-Phenols	<0.005	0.025	0.027	<0.005	<0.005	<0.005
Sulfate	690	730	820	2300	1800	200
TDS	2000	1800	1700	3200	3200	520
TOC	6.8	6.9	8.2	13	11	3.5
TOX	0.01	0.02	0.01	0.02	0.02	<0.01

B- The Concentration was less than the Contract Det. Limit (CRDL) but greater than the Instrument Det. Limit(IDL).
E- The Concentration is estimated because of interference.
<- The Concentration is less than the IDL
S- The Concentration was determined by the Method of Standard Addition(MSA)
UG- Upgradient Well
BR- Bedrock Well
FB- Field Blank
TB- Trip Blank.
CR- Creek Well

Well ID	MW26	MW27	MW27	MW28	MW28	MW29
Sampling Date	7/29/94	7/6/94	7/29/94	7/6/94	7/29/94	7/8/94
Concentration,ug/L						
Analyte						
Aluminum	802	65.7B	127B	<54	<54	336
Arsenic	4.5B	13.5	13	73.4	78.2	8.8B
Cadmium	<3	<3	3.5B	<3	<3	<3
Chromium	<4	<4	<4	<4	<4	<4
Cobalt	8.8B	11.1B	10B	<4	<4	11.5B
Copper	<4	<4	<4	<4	<4	<4
Iron	3910	<3E	38.1B	3860E	3810	4990E
Lead	<1	<1	<1	<1	<1	<1
Magnesium	12400	443B	395B	27900	26900	7840
Manganese	1460	16.3	15.8	398	378	4390
Nickel	<9	<9	<9	<9	<9	<9
Selenium	1B	<2	2.3B	<2	1B	<2
Sodium	33700	27000	27800	102000	95400	206000
Molybdenum	14700	17500	17400	2170	1770	10200
Concentration mg/L						
Chloride	28	35	38	88	94	190
T-Phenols	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sulfate	110	230	240	160	76	200
TDS	610	630	630	740	710	740
TOC	9.9	6.2	7.1	9.8	9.1	12
TOX	<0.01	<0.01	<0.01	0.01	0.01	0.02

B- The Concentration was less than the Contract Det. Limit (CRDL) but greater than the Instrument Det. Limit(IDL).
E- The Concentration is estimated because of interference.
<- The Concentration is less than the IDL
S- The Concentration was determined by the Method of Standard Addition(MSA)
UG- Upgradient Well
BR- Bedrock Well
FB- Field Blank
TB- Trip Blank.
CR- Creek Well

Well ID	MW-29	MW29	UG2	UG2	UG3	UG3
Sampling Date	7/28/94	8/9/94	7/6/94	7/27/94	7/8/94	7/28/94
Concentration,ug/L						
Analyte						
Aluminum	<54	327	<54	<54	<54	63.1B
Arsenic	14.7	16.6	2.5B	2.8B	<2	2.1B
Cadmium	<3	<3	<3	<3	<3	<3
Chromium	<4	<4	<4	<4	<4	<4
Cobalt	8.3B	9.8B	7.7B	<4	4.1B	<4
Copper	<4	<4	<4	<4	<4	<4
Iron	4960	9640	<3E	<3	1200E	2610
Lead	<1	<2	<1	<1	<1	<1
Magnesium	7890	8170	24100	17500	15000	14500
Manganese	3760	3020	417	253	9080	8950
Nickel	<9	<9	<9	<9	<9	<9
Selenium	1.2B	2.2B	16.9	15.4	<2	<2
Sodium	228000	249000	29300	20400	27600	27300
Molybdenum	7510	6090	11900	10700	80.1	46B
Concentration mg/L						
Chloride	240	390	30	18	47	48
T-Phenols	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sulfate	28	32	260	230	170	69
TDS	890	940	760	600	500	480
TOC	N/A	13	3.4	3	3.5	2.9
TOX	<0.01	0.02	<0.01	<0.01	<0.01	<0.01

B- The Concentration was less than the Contract Det. Limit (CRDL) but greater than the Instrument Det. Limit(IDL).
E- The Concentration is estimated because of interference.
<- The Concentration is less than the IDL
S- The Concentration was determined by the Method of Standard Addition(MSA)
UG- Upgradient Well
BR- Bedrock Well
FB- Field Blank
TB- Trip Blank
CR- Creek Well

Well ID	UG4	UG4-Duplicate	UG4	CR1F(Dissolved)	CR1,Total	CR1F(Dissolved)
Sampling Date	7/6/94	7/6/94	7/29/94	7/28/94	7/28/94	8/9/94
Concentration,ug/L						
Analyte						
Aluminum	<54	<54	<54	<54	246	<54
Arsenic	<2	<2	<2	8B	7.3B	4.7B
Cadmium	<3	<3	<3	<3	<3	<3
Chromium	<4	<4	<4	<4	<4	<4
Cobalt	<4	<4	<4	<4	<4	<4
Copper	<4	<4	<4	<4	<4	<4
Iron	<3E	<3E	<3	70.3B	664	17B
Lead	<1	<1	<1	<1	2.9B	2.4B
Magnesium	43300	43400	42400	14600	13500	13200
Manganese	51.5	51.3	63.5	586	577	313
Nickel	<9	<9	<9	<9	<9	<9
Selenium	<2	<2	<1	<1	1B	2.3B
Sodium	92900	91600	97000	49500	46700	40000
Molybdenum	166	26.9B	41.1	1070	15.4	43.7
Concentration mg/L						
Chloride	310	310	300		74	56
T-Phenols	<0.005	<0.005	<0.005			<0.005
Sulfate	180	190	140		99	79
TDS	1000	1000	910		470	480
TOC	BQL	1	BQL		6.7	4
TOX	<0.01	<0.01	<0.01			0.02

B- The Concentration was less than the Contract Det. Limit (CRDL) but greater than the Instrument Det. Limit(IDL).
E- The Concentration is estimated because of interference.
<- The Concentration is less than the IDL
S- The Concentration was determined by the Method of Standard Addition(MSA)
UG- Upgradient Well
BR- Bedrock Well
FB- Field Blank
TB- Trip Blank.
CR- Creek Well

Well ID	CR2F(Dissolved)	CR2,Total	CR2F(Dissolved)	CR2,Total	CR3F(Dissolved)	CR3,Total
Sampling Date	7/28/94	7/28/94	8/9/94	8/9/94	7/28/94	7/28/94
Concentration,ug/L						
Analyte						
Aluminum	<54	212	<54	616	<54	126B
Arsenic	7.9B	10.1	5.1B	6.2B	8.1B	9.7B
Cadmium	<3	<3	<3	<3	<3	<3
Chromium	<4	<4	<4	<4	<4	<4
Cobalt	<4	<4	<4	<4	<4	<4
Copper	<4	<4	<4	<4	<4	7.9B
Iron	25.1B	725	18.4B	725	178	801
Lead	<1	3.8	<2	3.4	<1	3.8
Magnesium	14500	13800	13100	12700	14800	13500
Manganese	863	802	326	345	892	861
Nickel	<9	<9	<9	<9	<9	<9
Selenium	1.4B	<1	<2	<2	1.2B	1.5B
Sodium	49700	47600	40400	39500	52400	49000
Molybdenum	136	120	137	122	845	797
Concentration mg/L						
Chloride		73		57		74
T-Phenols						
Sulfate		73		84		100
TDS						
TOC						
TOX						

B- The Concentration was less than the Contract Det. Limit (CRDL) but greater than the Instrument Det. Limit(IDL).
E- The Concentration is estimated because of interference.
<- The Concentration is less than the IDL
S- The Concentration was determined by the Method of Standard Addition(MSA)
UG- Upgradient Well
BR- Bedrock Well
FB- Field Blank
TB- Trip Blank.
CR- Creek Well

Well ID	CR3F(Dissolved)	CR3,Total	CR4F(Dissolved)	CR4,Total	CR4F(Dissolved)	BR1	BR1
Sampling Date	8/9/94	8/9/94	7/28/94	7/28/94	8/9/94	7/12/94	7/28/94
Concentration,ug/L							
Analyte							
Aluminum	56B	372	<54	183B	1120	<54	521
Arsenic	4.1B	6B	7.8B	9B	4.4B	<2	<2
Cadmium	<3	<3	<3	<3	<3	<3	3.6B
Chromium	5B	<4	<4	<4	<4	<4	<20
Cobalt	<4	<4	<4	<4	<4	58.4	66.8
Copper	<4	<4	4.2B	13.6B	33	6.8B	12.7B
Iron	31.3B	831	302	843	90.5B	86500	90300
Lead	<2	3.2	<1	3.2	<2	<1	<1
Magnesium	13200	12500	15000	13400	13400	97800	108000
Manganese	351	361	926	853	373	21600	23400
Nickel	<9	<9	<9	<9	<9	14.7B	<9
Selenium	<2	2B	<1	3B	<2	2.2B	1.3B
Sodium	41500	40100	52900	48000	42100	429000	414000
Molybdenum	256	267	1500	1320	420	98600	126000
Concentration mg/L							
Chloride		58		74	58	370	340
T-Phenols				<0.005	<0.005	<0.005	<0.005
Sulfate		89		97	91	2800	2100
TDS				500	500	4300	4600
TOC				7.6	4.2	10	16
TOX				0.02	0.02	0.02	0.01

B- The Concentration was less than the Contract Det. Limit (CRDL) but greater than the Instrument Det. Limit(IDL).
E- The Concentration is estimated because of interference.
<- The Concentration is less than the IDL
S- The Concentration was determined by the Method of Standard Addition(MSA)
UG- Upgradient Well
BR- Bedrock Well
FB- Field Blank
TB- Trip Blank.
CR- Creek Well

Well ID	TB0712(Trip.Blk.)	TB0727(Trip. Blk.)	TB0803F(Trip. Blk.)	FB0629(Field Blk.)	FB0728F(Field Blk.)
Sampling Date	7/12/94	7/27/94	8/3/94	6/29/94	7/28/94
Concentration,ug/L					
Analyte					
Aluminum	<54	<54	<54	<54	<54
Arsenic	<2	<2	<2	<2	<2
Cadmium	<3	<3	<3	<3	<3
Chromium	<4	<4	<4	<4	<4
Cobalt	<4	<4	<4	<4	<4
Copper	<4	<4	<4	<4	<4
Iron	<3	<3	3.7B	32.2B	119
Lead	<1	<1	<2	<1	<1
Magnesium	<45	<45	<45	<45	<45
Manganese	<1	2.1B	<1	8.6B	11B
Nickel	<9	<9	<9	<9	<9
Selenium	<2	<2	<2	<1	<1
Sodium	<25	<25	27.6B	<25	56.2B
Molybdenum	18.4B	111	134	8	1340
Concentration mg/L					
Chloride	<1.0	<1.0	<1.0	<1.0	<1.0
T-Phenols	<0.005	<0.005	<0.005	<0.005	<0.005
Sulfate	<2.0	<2.0	<2.0	<2.0	<2.0
TDS	<16	<16	<16	<16	<16
TOC	<1.0	<1.0	<1.0	<1.0	<1.0
TOX	<0.1	<0.1	<0.1	<0.1	<0.1

B- The Concentration was less than the Contract Det. Limit (CRDL) but greater than the Instrument Det. Limit(IDL).
E- The Concentration is estimated because of interference.
<- The Concentration is less than the IDL
S- The Concentration was determined by the Method of Standard Addition(MSA)
UG- Upgradient Well
BR- Bedrock Well
FB- Field Blank
TB- Trip Blank.
CR- Creek Well

Sediment Data - Radiological

MOLYCORP

Thorium-232
(SEDIMENT SAMPLES, SS1-SS7)

Sediment ID#	Th-232 (pCi/g
SS1A	.34+/-.09
SS1B	.34+/-.11
SS1C	.29+/-.09
SS1D	.51+/-.12
SS2A	.31+/-.09
SS2B	.37+/-.10
SS2C	.29+/-.09
SS2D	.49+/-.11
SS3A	.35+/-.09
SS3B	.25+/-.07
SS3C	.37+/-.10
SS3D	.34+/-.09
SS4A	.35+/-.08
SS4B	.23+/-.06
SS4C	.33+/-.08
SS4D	.33+/-.08
SS5A	.45+/-.11

MOLYCORP

Thorium-232
(SEDIMENT SAMPLES, SS1-SS7)

Sediment ID#	Th-232 (pCi/g
SS5B	.33+/-.08
SS5C	.35+/-.09
SS5D	.28+/-.08
SS6A	.36+/-.08
SS6B	.22+/-.06
SS6C	.26+/-.68
SS6D	.36+/-.10
SS7A	.86+/-.18
SS7B	.35+/-.09
SS7C	.33+/-.08
SS7D	.43+/-.10

Storm Sewer Data

MOLYCO
STORM SEWER
ANALYTICAL RESULTS(mg/L)

Storm Sewer ID	001-01'	001-02'	001-03'	001-04'	001-05'	002-01'	002-02'
Sample Date	34639	34639	34639	34639	34639	34639	34639
ANALYTES							
Aluminum	0.32	0.42	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Calcium	130	150	140	140	140	150	84
Chromium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Iron	1.3	1.2	0.52	0.52	0.51	0.44	0.35
Lead	0.008	0.005	<0.003	<0.003	<0.003	<0.003	<0.003
Magnesium	18	16	18	15	15	10	9.9
Manganese	0.46	0.45	0.5	0.55	0.56	0.039	0.035
Nickel	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Selenium	<0.005	<0.005	0.007	0.013	0.015	<0.005	0.009
Sodium	49	51	53	49	48	63	50
Molybdenum	0.99	2.7	3.2	4.7	4.9	0.41	2.7
Zinc	0.07	0.09	0.11	0.1	0.12	0.12	0.36
Chloride	10	99	110	87	90	110	50
Sulfate	200	250	250	250	290	420	270
TDS	640	710	720	660	680	820	340
pH(No units)	7.2	7.6	7.7	7.7	7.8	8.6	8.9

< - Less than the Detection Limit

Impoundment Data - Radiological and Chemical

MCL...
IMPOUND... NT
ANALYTICAL RESULTS(mg/L)

Impoundment ID#	Impoundment 1	Impoundment 2	Impoundment 3	Impoundment 4	Impoundment 5	Impoundment 6	Impoundment 7	Impoundment 8
Sample Date	*8/18/94*	*8/18/94*	*8/18/94*	*8/18/94*	*8/18/94*	*8/18/94*	*8/18/94*	*8/18/94*
ANALYTES								
Aluminum	0.47	1.6	11	2.5	1.9	2.1	0.59	0.33
Arsenic	0.047	<0.004	<0.003	0.004	0.007	0.016	0.005	<0.003
Cadmium	0.011	<0.005	<0.005	<0.005	0.007	0.005	0.009	0.009
Chromium	<0.05	<0.02	0.01	<0.01	<0.02	<0.04	<0.05	<0.05
Cobalt	<0.2	<0.1	<0.1	<0.05	<0.1	<0.1	<0.1	<0.1
Copper	0.1	0.06	0.1	0.06	0.05	0.07	0.06	0.06
Iron	0.61	0.9	3	2.7	1.5	6.5	0.57	0.22
Lead	<0.2	<0.5	<0.5	<0.05	<0.5	<0.05	<0.5	<0.5
Magnesium	2.2	3.9	9.3	5.5	7.9	9	7.8	7.1
Manganese	0.24	0.95	1.4	0.88	1.1	1.4	0.48	0.19
Nickel	0.05	0.09	0.14	0.04	0.06	0.04	0.03	<0.02
Selenium	0.49	0.064	0.098	0.059	0.038	0.056	0.039	0.035
Sodium	380	120	16	100	180	270	220	300
Molybdenum	110	49	49	35	49	64	79	77
Chloride	18	54	16	51	44	37	39	42
T-Phenols	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sulfate	620	820	340	800	910	1100	780	1100
TDS	1300	1400	670	1400	1500	1700	1400	1800
TOC	17	7	8	7	9	14	10	6
TOX	0.033	0.036	0.022	0.042	0.027	0.025	0.023	0.018

< - Less than the detection limit

MOLYCORP

RADIOLOGICAL ANALYSIS

IMPOUNDMENT

CONCENTRATION(pCi/L)

Impoundment I.D.	Impoundment 1	Impoundment 2	Impoundment 3	Impoundment 4	Impoundment 5	Impoundment 6	Impoundment 7	Impoundment 8
Sample Date	8/18/94	8/18/94	8/18/94	8/18/94	8/18/94	8/18/94	8/18/94	8/18/94
Radionuclide								
Ra-226	0.5+/-0.2	<0.2	0.4+/-0.2	<0.3	<0.3	0.4+/-0.3	22+/-3	0.9+/-0.3
Ra-228	<1	<1	<1	<1	<1	<2	<1	<2
Th-228	<0.2	<0.09	<0.1	0.15+/-0.09	<0.09	0.21+/-0.10	<0.09	0.74+/-0.2
Th-230	<0.2	<0.09	0.12+/-0.08	0.17+/-0.10	<0.2	0.32+/-0.15	<0.2	0.31+/-0.12
Th-232	<0.2	<0.09	<0.1	0.15+/-0.09	<0.09	0.21+/-0.10	<0.09	0.74+/-0.2
U-233/234	0.53+/-0.12	.079+/-.049	0.20+/-0.07	0.11+/-0.05	0.39+/-0.11	.082+/-.049	0.32+/-0.10	0.66+/-0.15
U-235	<0.05	<0.05	<0.05	<0.05	<0.06	<0.05	<0.08	<0.06
U-238	0.44+/-0.11	0.15+/-0.07	0.16+/-0.06	.098+/-.050	0.24+/-0.08	0.11+/-0.05	0.40+/-0.12	0.72+/-0.16

< - Less than the detection limit.

RAD3 XLS

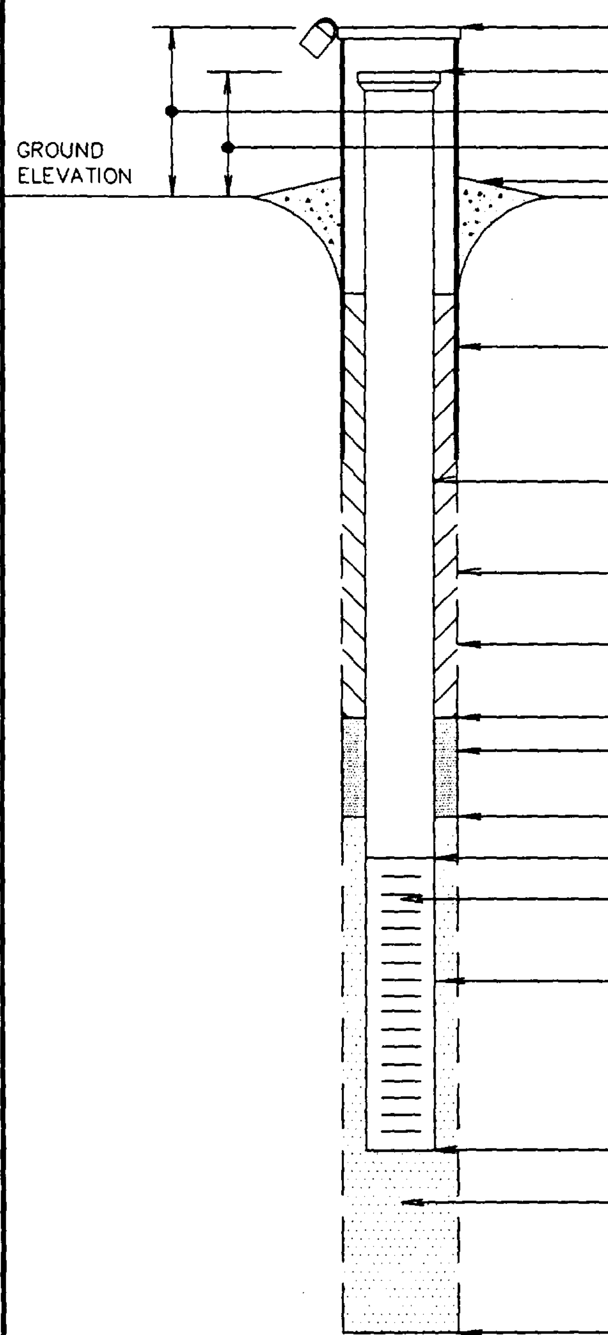
APPENDIX L

Well Construction Diagrams

WELL NO. PW-1

MONITORING WELL CONSTRUCTION DIAGRAM

PROJECT: MOLYCORP INC.	DRILLER: TERRA TESTING
PROJECT NO. 5330.001 BORING NO. NA	DRILLING METHOD: EXCAVATION
ELEVATION: 1027.6 FT. MSL DATE: 6/29/94	DEVELOPMENT METHOD: PUMP/SURGE
FIELD GEOLOGIST: P. ANDERSON	



NOT TO SCALE

ELEVATION OF TOP OF SURFACE CASING: NA

ELEVATION OF TOP OF RISER PIPE: 1032.7 FT MSL

STICK-UP TOP OF SURFACE CASING: NA

STICK-UP RISER PIPE: 5 FT.

TYPE OF SURFACE SEAL: NA

GROUND SURFACE ELEVATION: 1027.6 FT MSL

I.D. OF SURFACE CASING: NA

TYPE OF SURFACE CASING: NA

RISER PIPE I.D. 3 FT.

TYPE OF RISER PIPE: BLACK PLASTIC

BOREHOLE DIAMETER: TRENCH

TYPE OF BACKFILL: EXCAVATED MATERIAL

ELEVATION/DEPTH TOP OF SEAL: NA

TYPE OF SEAL: NA

DEPTH TOP OF SAND PACK: 3.5 FT

ELEVATION/DEPTH TOP OF SCREEN: 5.5 FT

TYPE OF SCREEN: NA

SLOT SIZE X LENGTH: HAND SLOTTED

TYPE OF SAND PACK: 20/40 SAND

ELEVATION/DEPTH BOTTOM OF SCREEN: 9.5 FT

ELEVATION/DEPTH BOTTOM OF SAND PACK: 9.5 FT

TYPE OF BACKFILL BELOW OBSERVATION WELL: 20/40 BEST SAND

DEPTH OF HOLE: 9.5 FT

DATE: 01/05/95
TIME: 9:58 AM

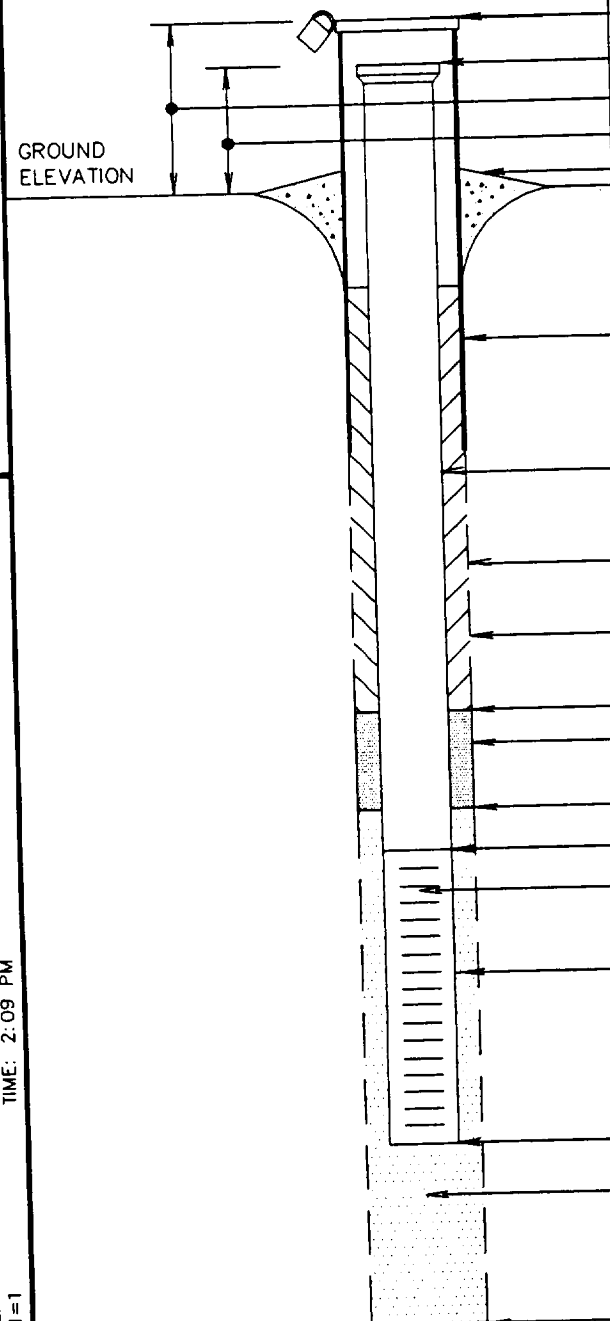
CAD FILE NAME: MOLYPWI.DWG
PLOT SCALE: 1=1

WELL NO. PW-2

MONITORING WELL CONSTRUCTION DIAGRAM

PROJECT: MOLYCORP INC.
PROJECT NO.: 5330.001
BORING NO.: PW-2
ELEVATION: 1027.88 FT MSL
DATE: 7/7/94
FIELD GEOLOGIST: A. LAFFERTY

DRILLER: TERRA TESTING, INC
DRILLING METHOD: 6 1/4 I.D. HOLLOW STEM AUGERS
DEVELOPMENT METHOD: PUMP/SURGE



ELEVATION OF TOP OF SURFACE CASING: 1030.4 FT MSL
ELEVATION OF TOP OF RISER PIPE: 1029.68 FT MSL
STICK-UP TOP OF SURFACE CASING: 2.5 FT.
STICK-UP RISER PIPE: 1.8 FT.
TYPE OF SURFACE SEAL: CONCRETE
GROUND SURFACE ELEVATION: 1027.88 FT MSL

I.D. OF SURFACE CASING: 6 INCHES
TYPE OF SURFACE CASING: STEEL, 5 FT.

RISER PIPE I.D. 4 INCHES
TYPE OF RISER PIPE: SCHEDULE 40 PVC

BOREHOLE DIAMETER: 10 INCHES

TYPE OF BACKFILL: CEMENT/BENTONITE GROUT

ELEVATION/DEPTH TOP OF SEAL: 2 FT.
TYPE OF SEAL: BENTONITE PELLETS

DEPTH TOP OF SAND PACK: 3 FT.
ELEVATION/DEPTH TOP OF SCREEN: 5 FT.
TYPE OF SCREEN: SCHEDULE 40 PVC
SLOT SIZE X LENGTH: 0.010 x 10 FT.
TYPE OF SAND PACK: 20/40 SILICA SAND

ELEVATION/DEPTH BOTTOM OF SCREEN: 15 FT.
ELEVATION/DEPTH BOTTOM OF SAND PACK: 16 FT.
TYPE OF BACKFILL BELOW OBSERVATION WELL: 20/40 SILICA SAND

DEPTH OF HOLE: 16 FT.

NOT TO SCALE

DATE: 01/18/95
TIME: 2:09 PM

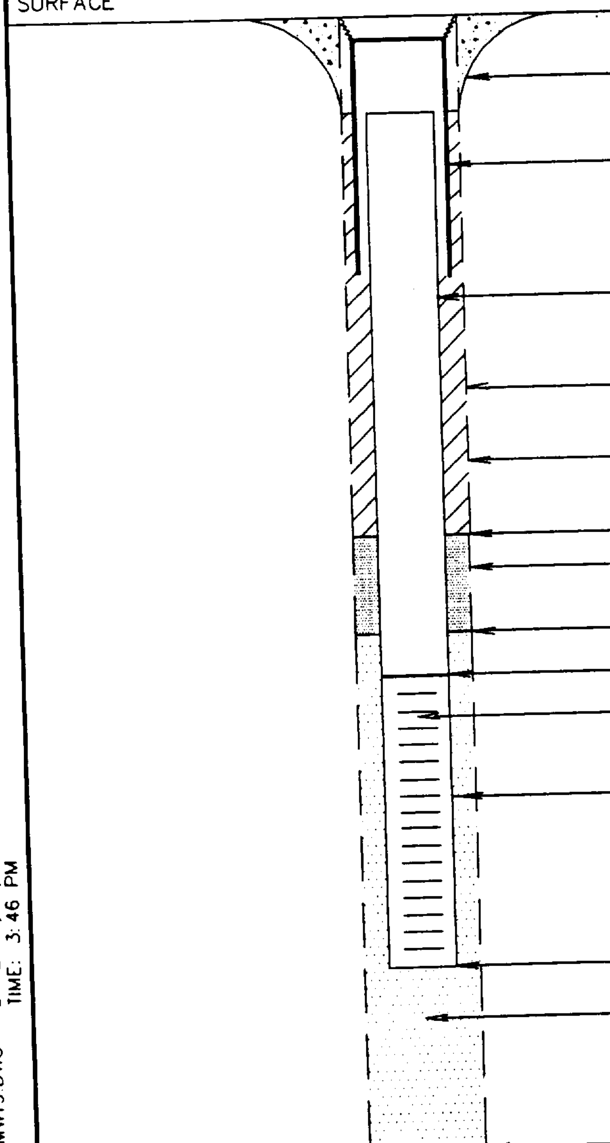
CAD FILE NAME: MOLYPW2.DWG
PLOT SCALE: 1=1

WELL NO. MW-19

MONITORING WELL CONSTRUCTION DIAGRAM

PROJECT: MOLYCORP INC.
PROJECT NO.: 5330.001 BORING NO.: MW-19
ELEVATION: 1032.462 FT. MSL DATE: 5/9/94
FIELD GEOLOGIST: P. ANDERSON

DRILLER: B. LAWRENCE, TERRA TESTING
DRILLING METHOD: HOLLOW STEM AUGER
DEVELOPMENT METHOD: PUMP/SURGE



ELEVATION OF TOP OF WELL CASING: 1032.21 FT. MSL
STICK-UP TOP OF WELL CASING: -0.23 FT
TYPE OF SURFACE SEAL: CONCRETE
GROUND SURFACE ELEVATION: 1032.462 FT. MSL

I.D. OF SURFACE CASING: 6 INCHES
TYPE OF SURFACE CASING: STEEL FLUSH MOUNT

RISER PIPE I.D. 2 INCHES
TYPE OF RISER PIPE: SCHEDULE 40, PVC

BOREHOLE DIAMETER: 7 INCHES

TYPE OF BACKFILL: GROUT

ELEVATION/DEPTH TOP OF SEAL: 7 FT.
TYPE OF SEAL: BENTONITE PELLETS

ELEVATION/DEPTH TOP OF SAND PACK: 8 FT.
ELEVATION/DEPTH TOP OF SCREEN: 9 FT.
TYPE OF SCREEN: SCHEDULE 40, PVC
SLOT SIZE X LENGTH: 0.010 x 8 FT.
TYPE OF SAND PACK: 20/40 BEST SAND

ELEVATION/DEPTH BOTTOM OF SCREEN: 17.0 FT.
ELEVATION/DEPTH BOTTOM OF SAND PACK: 17.8 FT.
TYPE OF BACKFILL BELOW OBSERVATION WELL: 20/40 BEST SAND

ELEVATION/DEPTH OF HOLE 17.8 FT.

NOT TO SCALE

CAD FILE NAME: MOLYMW19.DWG DATE: 01/18/95
PLOT SCALE: 1=1 TIME: 3:46 PM

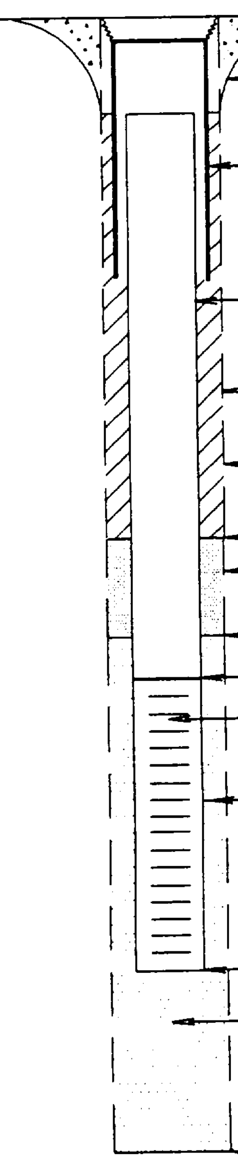
WELL NO. MW-20

MONITORING WELL CONSTRUCTION DIAGRAM

PROJECT MOLYCORP INC.
PROJECT NO. 5330.001 BORING NO. SB-35
ELEVATION 1027.1 FT. MSL DATE 5/9/94
FIELD GEOLOGIST P. ANDERSON

DRILLER B. LAWRENCE, TERRA TESTING
DRILLING METHOD HOLLOW STEM AUGER
DEVELOPMENT METHOD PUMP/SURGE

GROUND SURFACE



ELEVATION OF TOP OF WELL CASING: 1026.9 FT. MSL
STICK-UP TOP OF WELL CASING: − 0.26 FT. (PVC RISER)
TYPE OF SURFACE SEAL: CONCRETE
GROUND SURFACE ELEVATION: 1027.1 FT. MSL

I.D. OF SURFACE CASING: 6 INCHES
TYPE OF SURFACE CASING: STEEL FLUSH MOUNT

RISER PIPE I.D. 2 INCHES
TYPE OF RISER PIPE: SCHEDULE 40, PVC

BOREHOLE DIAMETER: 7 INCHES

TYPE OF BACKFILL: CEMENT/BENTONITE GROUT

ELEVATION/DEPTH TOP OF SEAL: 13.7 FT
TYPE OF SEAL: BENTONITE PELLETS

ELEVATION/DEPTH TOP OF SAND PACK: 15.5 FT
ELEVATION/DEPTH TOP OF SCREEN: 16.7 FT
TYPE OF SCREEN: SCHEDULE 40, PVC
SLOT SIZE X LENGTH: 0.01 x 5 FT.
TYPE OF SAND PACK: 20/40 BEST SAND

ELEVATION/DEPTH BOTTOM OF SCREEN: 21.7 FT
ELEVATION/DEPTH BOTTOM OF SAND PACK: 23.0 FT
TYPE OF BACKFILL BELOW OBSERVATION WELL: 20/40 BEST SAND

ELEVATION/DEPTH OF HOLE 23.0 FT

NOT TO SCALE

DATE: 01/09/95
TIME: 8:47 AM

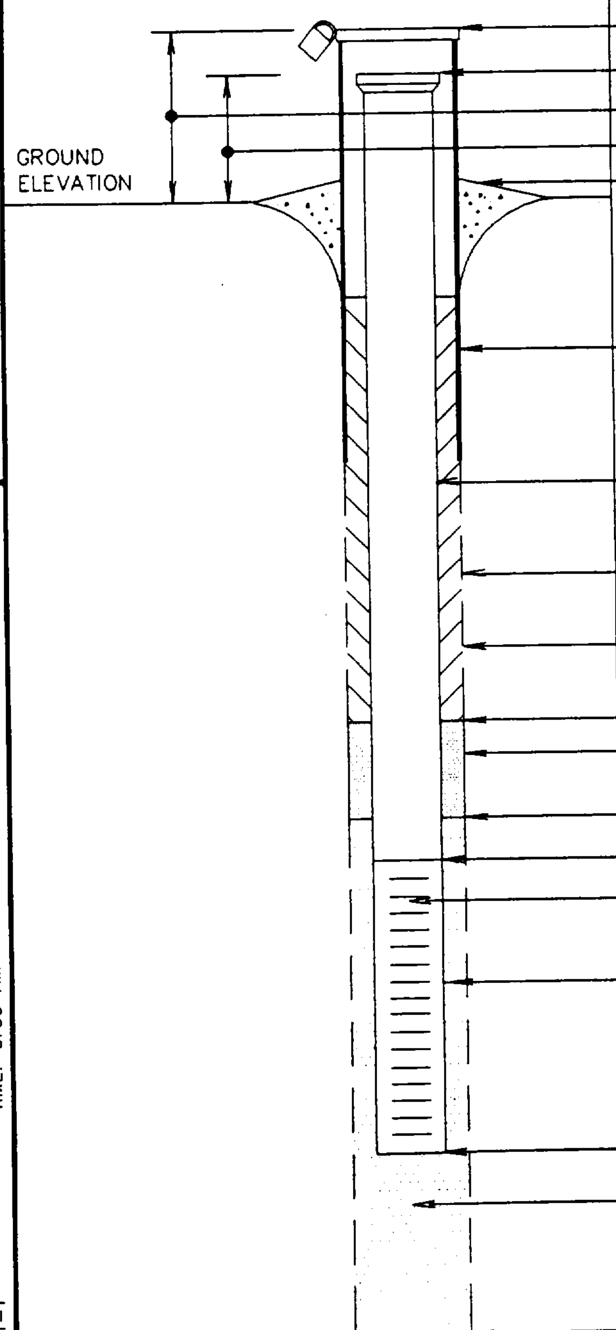
CAD FILE NAME: MOLYMW20.DWG
PLOT SCALE: 1=1

WELL NO. MW-21

MONITORING WELL CONSTRUCTION DIAGRAM

PROJECT: MOLYCORP INC.
PROJECT NO.: 5330.001
BORING NO.: SB-123
ELEVATION: 1022.4 FT MSL
DATE: 5/12/94
FIELD GEOLOGIST: P. ANDERSON

DRILLER: B. LAWRENCE, TERRA TESTING
DRILLING METHOD: HSA (HOLLOW STEM AUGER)
DEVELOPMENT METHOD: PUMP/SURGE



ELEVATION OF TOP OF SURFACE CASING: 1023.8 FT MSL
ELEVATION OF TOP OF RISER PIPE: 1023.62 FT MSL
STICK-UP TOP OF SURFACE CASING: 1.4 FT.
STICK-UP RISER PIPE: 1.23 FT.
TYPE OF SURFACE SEAL: CONCRETE
GROUND SURFACE ELEVATION: 1022.4 FT MSL

I.D. OF SURFACE CASING: 6 INCHES
TYPE OF SURFACE CASING: STEEL

RISER PIPE I.D. 2 INCHES
TYPE OF RISER PIPE: SCHEDULE 40, PVC

BOREHOLE DIAMETER: 7 INCHES

TYPE OF BACKFILL: GROUT

ELEVATION/DEPTH TOP OF SEAL: 5.7 FT.
TYPE OF SEAL: BENTONITE PELLETS

DEPTH TOP OF SAND PACK: 7.5 FT
ELEVATION/DEPTH TOP OF SCREEN: 9 FT.
TYPE OF SCREEN: SCHEDULE 40, PVC
SLOT SIZE X LENGTH: 0.010" x 10 FT.
TYPE OF SAND PACK: 20/40 BEST SAND

ELEVATION/DEPTH BOTTOM OF SCREEN: 19 FT.
ELEVATION/DEPTH BOTTOM OF SAND PACK: 19.5 FT.
TYPE OF BACKFILL BELOW OBSERVATION WELL: 20/40 BEST SAND

ELEVATION/DEPTH OF HOLE: 19.5 FT.

NOT TO SCALE

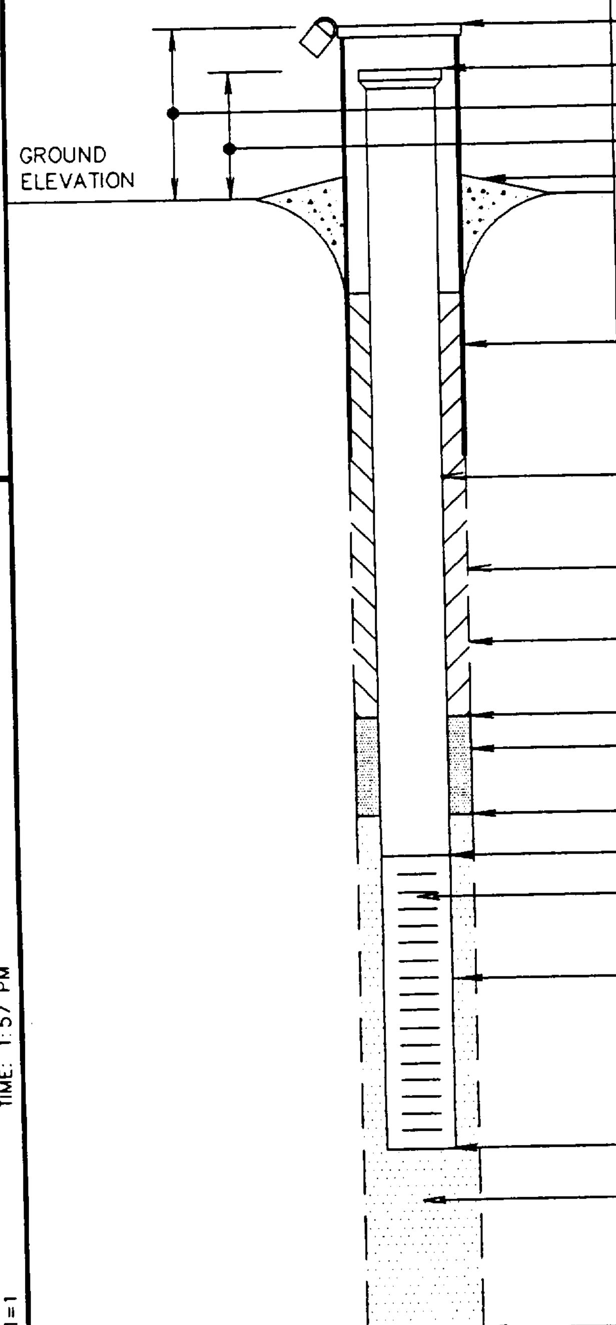
CAD FILE NAME: MOLYMW21.DWG
PLOT SCALE: 1=1
DATE: 01/09/95
TIME: 8:53 AM

WELL NO. MW-22

OVERBURDEN MONITORING WELL CONSTRUCTION DIAGRAM

PROJECT MOLYCORP INC.
PROJECT NO. 5330.001 BORING NO. SB-248
ELEVATION 1025.9 FT. MSL DATE 6/2/94
FIELD GEOLOGIST P. ANDERSON

DRILLER B. LAWRENCE, TERRA TESTING
DRILLING METHOD HOLLOW STEM AUGER
DEVELOPMENT METHOD PUMP/SURGE



ELEVATION OF TOP OF SURFACE CASING: 1028.1 FT. MSL
ELEVATION OF TOP OF RISER PIPE: 1028.0 FT. MSL
STICK-UP TOP OF SURFACE CASING: 2.2 FT.
STICK-UP RISER PIPE: 2.1 FT.
TYPE OF SURFACE SEAL: CONCRETE
GROUND SURFACE ELEVATION: 1025.9 FT. MSL

I.D. OF SURFACE CASING: 6 INCHES
TYPE OF SURFACE CASING: STEEL

RISER PIPE I.D. 2 INCHES
TYPE OF RISER PIPE: SCHEDULE 40, PVC

BOREHOLE DIAMETER: 7 INCHES

TYPE OF BACKFILL: GROUT

ELEVATION/DEPTH TOP OF SEAL: 3.0 FT.
TYPE OF SEAL: BENTONITE PELLETS

DEPTH TOP OF SAND PACK: 4.0 FT.
ELEVATION/DEPTH TOP OF SCREEN: 5.0 FT.
TYPE OF SCREEN: SCHEDULE 40, PVC
SLOT SIZE X LENGTH: 0.010" x 10 FT.
TYPE OF SAND PACK: 20/40 BEST SAND

ELEVATION/DEPTH BOTTOM OF SCREEN: 15.0 FT.
ELEVATION/DEPTH BOTTOM OF SAND PACK: 15.0 FT.
TYPE OF BACKFILL BELOW OBSERVATION WELL: BENTONITE PELLETS

ELEVATION/DEPTH OF HOLE 17.0 FT.

NOT TO SCALE

CAD FILE NAME: MOLYMW22.DWG
PLOT SCALE: 1=1
DATE: 01/18/95
TIME: 1:57 PM

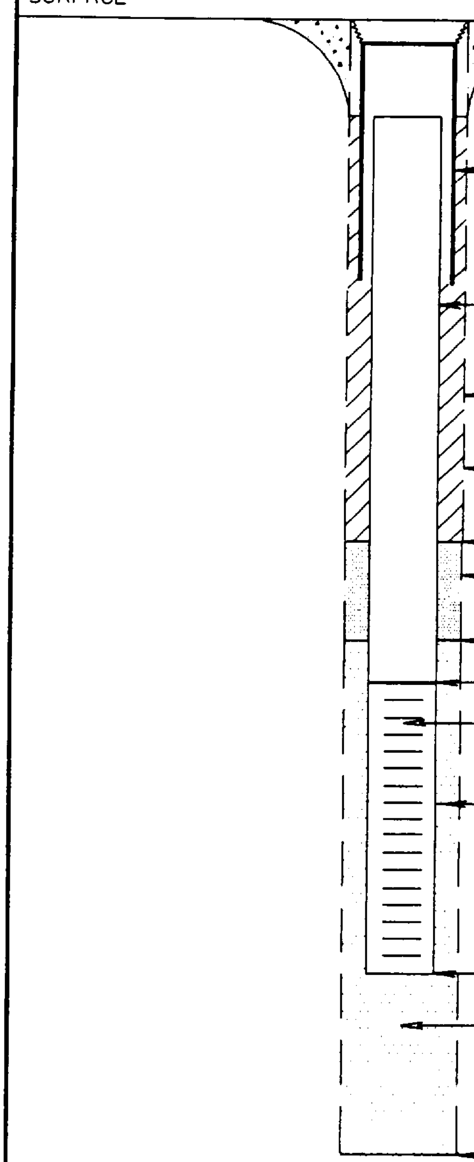
WELL NO. MW-23

MONITORING WELL CONSTRUCTION DIAGRAM

PROJECT MOLYCORP INC.
PROJECT NO. 5330.001 BORING NO. SB-218
ELEVATION 1026.0 FT. MSL DATE 6/2/94
FIELD GEOLOGIST P. ANDERSON

DRILLER B. LAWRENCE, TERRA TESTING
DRILLING METHOD HOLLOW STEM AUGER
DEVELOPMENT METHOD PUMP/SURGE

GROUND SURFACE



ELEVATION OF TOP OF WELL CASING: 1025.6 FT. MSL
STICK-UP TOP OF WELL CASING: -0.36 FT.
TYPE OF SURFACE SEAL: CONCRETE
GROUND SURFACE ELEVATION: 1026.0 FT. MSL

I.D. OF SURFACE CASING: 8" INCHES
TYPE OF SURFACE CASING: CAST IRON AND SHEET METAL

RISER PIPE I.D. 2 INCHES
TYPE OF RISER PIPE: SCHEDULE 40, PVC

BOREHOLE DIAMETER: 7 INCHES

TYPE OF BACKFILL: CEMENT/BENTONITE GROUT

ELEVATION/DEPTH TOP OF SEAL: 3.0 FT.
TYPE OF SEAL: BENTONITE PELLETS

ELEVATION/DEPTH TOP OF SAND PACK: 4.0 FT.
ELEVATION/DEPTH TOP OF SCREEN: 5.0 FT.
TYPE OF SCREEN: SCHEDULE 40, PVC
SLOT SIZE x LENGTH: 0.01 x 10 FT.
TYPE OF SAND PACK: 20/40 BEST SAND

ELEVATION/DEPTH BOTTOM OF SCREEN: 15.0 FT.
ELEVATION/DEPTH BOTTOM OF SAND PACK: 15.0 FT.
TYPE OF BACKFILL BELOW OBSERVATION WELL: BENTONITE PELLETS

ELEVATION/DEPTH OF HOLE 15.5 FT.

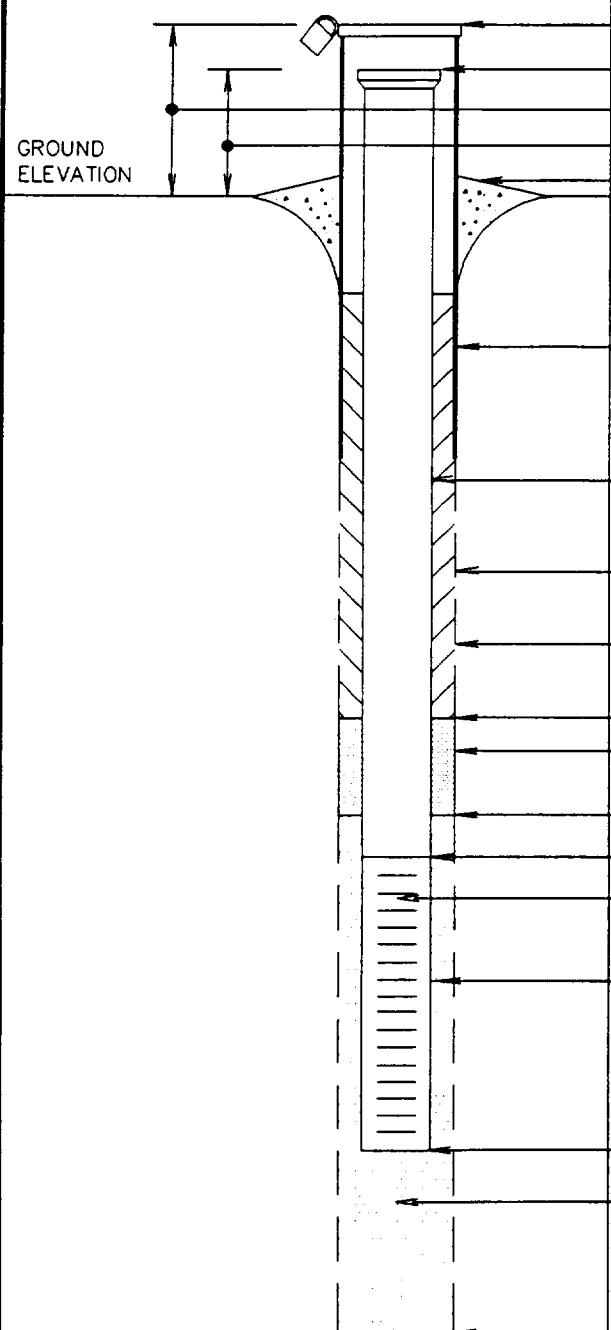
NOT TO SCALE

CAD FILE NAME: MOLYMW23.DWG
PLOT SCALE: 1=1
DATE: 01/09/95
TIME: 9:00 AM

WELL NO. MW-25

MONITORING WELL CONSTRUCTION DIAGRAM

PROJECT	MOLYCORP INC.	DRILLER	B. LAWRENCE, TERRA TESTING
PROJECT NO.	5330.001	BORING NO.	SB-181
ELEVATION	1022.2 FT. MSL	DATE	6/3/94
FIELD GEOLOGIST	P. ANDERSON		
DRILLING METHOD	HOLLOW STEM AUGER	DEVELOPMENT METHOD	PUMP/SURGE



ELEVATION OF TOP OF SURFACE CASING:	1024.8 FT. MSL
ELEVATION OF TOP OF RISER PIPE:	1023.8 FT. MSL
STICK-UP TOP OF SURFACE CASING:	2.6 FT.
STICK-UP RISER PIPE:	1.6 FT.
TYPE OF SURFACE SEAL:	CEMENT
GROUND SURFACE ELEVATION:	1022.2 FT. MSL
I.D. OF SURFACE CASING:	6 INCHES
TYPE OF SURFACE CASING:	STEEL
RISER PIPE I.D.	2 INCHES
TYPE OF RISER PIPE:	SCHEDULE 40, PVC
BOREHOLE DIAMETER:	7 INCHES
TYPE OF BACKFILL:	GROUT
ELEVATION/DEPTH TOP OF SEAL:	1.0 FT.
TYPE OF SEAL:	BENTONITE PELLETS
DEPTH TOP OF SAND PACK:	2.0 FT
ELEVATION/DEPTH TOP OF SCREEN:	3.0 FT.
TYPE OF SCREEN:	SCHEDULE 40, 2"PVC
SLOT SIZE X LENGTH:	0.010" x 10 FT.
TYPE OF SAND PACK:	20/40 BEST SAND
ELEVATION/DEPTH BOTTOM OF SCREEN:	13.0 FT.
ELEVATION/DEPTH BOTTOM OF SAND PACK:	13.0 FT.
TYPE OF BACKFILL BELOW OBSERVATION WELL:	BENTONITE PELLETS
ELEVATION/DEPTH OF HOLE	14.0 FT.

NOT TO SCALE

CAD FILE NAME: MOLYMW25.DWG DATE: 01/09/95
PLOT SCALE: 1=1 TIME: 9:07 AM

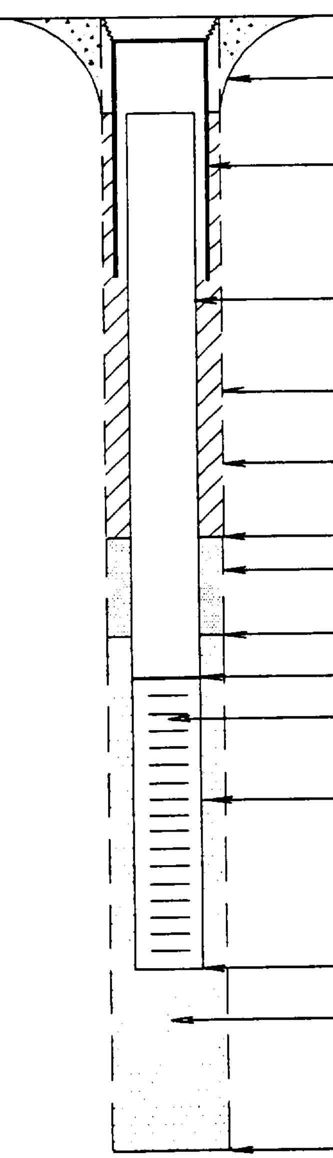
WELL NO. MW-26

MONITORING WELL CONSTRUCTION DIAGRAM

PROJECT: MOLYCORP INC.
PROJECT NO.: 5330.001 BORING NO.: SB-59
ELEVATION: 1022.6 FT. MSL DATE: 5/9/94
FIELD GEOLOGIST: P. ANDERSON

DRILLER: B. LAWRENCE, TERRA TESTING
DRILLING METHOD: HOLLOW STEM AUGER
DEVELOPMENT METHOD: PUMP/SURGE

GROUND SURFACE



ELEVATION OF TOP OF WELL CASING: 1022.23 FT. MSL
STICK-UP TOP OF WELL CASING: -0.26 FT.
TYPE OF SURFACE SEAL: CONCRETE
GROUND SURFACE ELEVATION: 1022.6 FT. MSL

I.D. OF SURFACE CASING: 8 INCHES
TYPE OF SURFACE CASING: CAST IRON AND SHEET METAL

RISER PIPE I.D. 2 INCHES
TYPE OF RISER PIPE: SCHEDULE 40, PVC

BOREHOLE DIAMETER: 7 INCHES

TYPE OF BACKFILL: SEE DEPTH OF SEAL BELOW

ELEVATION/DEPTH TOP OF SEAL: SURFACE
TYPE OF SEAL: BENTONITE PELLETS

ELEVATION/DEPTH TOP OF SAND PACK: 0.6 FT.
ELEVATION/DEPTH TOP OF SCREEN: 1.0 FT.
TYPE OF SCREEN: 2" PVC, SCHEDULE 40
SLOT SIZE X LENGTH: 0.01 x 10 FT.
TYPE OF SAND PACK: 20/40 BEST SAND

ELEVATION/DEPTH BOTTOM OF SCREEN: 11.0 FT.
ELEVATION/DEPTH BOTTOM OF SAND PACK: 12.0 FT.
TYPE OF BACKFILL BELOW OBSERVATION WELL: BENTONITE CHIPS

ELEVATION/DEPTH OF HOLE 14.5 FT.

NOT TO SCALE

CAD FILE NAME: MOLYMW26.DWG
PLOT SCALE: 1=1
DATE: 01/09/95
TIME: 9:10 AM

WELL NO. MW-27

MONITORING WELL CONSTRUCTION DIAGRAM

PROJECT: MOLYCORP INC.

PROJECT NO.: 5330.001 BORING NO.: SB-55

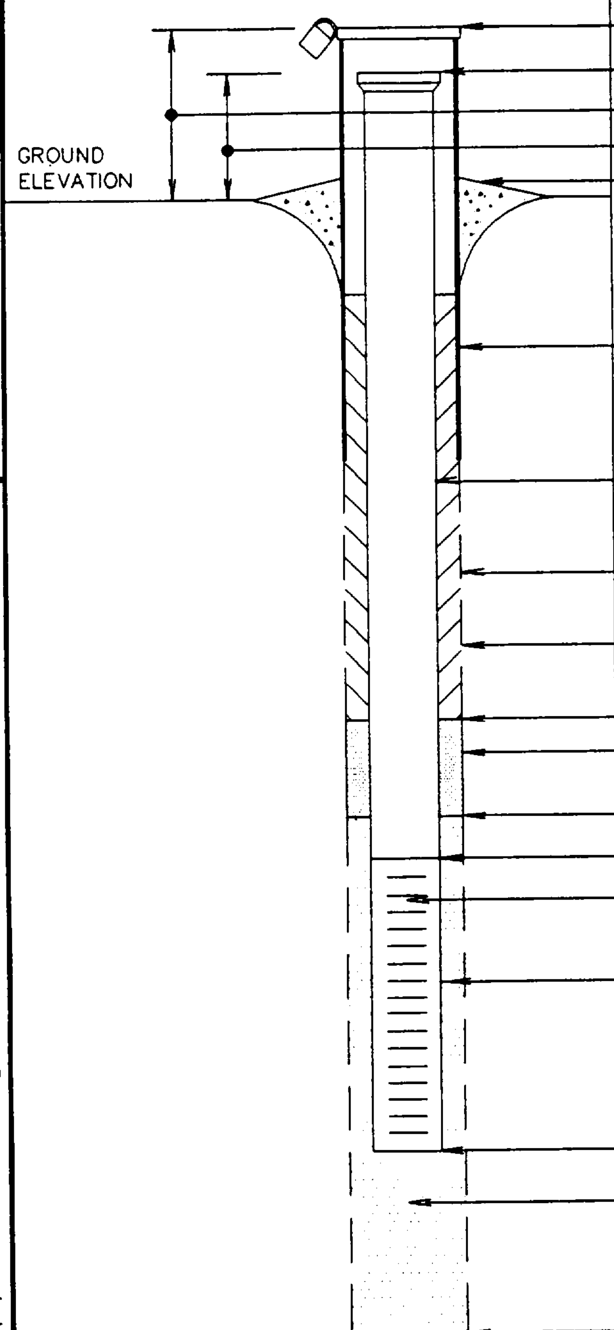
ELEVATION: 1024.5 FT. MSL DATE: 6/10/94

FIELD GEOLOGIST: P. ANDERSON

DRILLER: B. LAWRENCE, TERRA TESTING

DRILLING METHOD: HOLLOW STEM AUGER

DEVELOPMENT METHOD: PUMP/SURGE



ELEVATION OF TOP OF SURFACE CASING: 1027.2 FT. MSL

ELEVATION OF TOP OF RISER PIPE: 1026.2 FT. MSL

STICK-UP TOP OF SURFACE CASING: 2.6 FT

STICK-UP RISER PIPE: 1.6 FT

TYPE OF SURFACE SEAL: CONCRETE

GROUND SURFACE ELEVATION: 1024.5 FT. MSL

I.D. OF SURFACE CASING: 6 INCHES

TYPE OF SURFACE CASING: STEEL

RISER PIPE I.D. 2 INCHES

TYPE OF RISER PIPE: SCHEDULE 40, PVC

BOREHOLE DIAMETER: 7 INCHES

TYPE OF BACKFILL: SEE DEPTH OF SEAL (BELOW)

ELEVATION/DEPTH TOP OF SEAL: SURFACE

TYPE OF SEAL: BENTONITE PELLETS

DEPTH TOP OF SAND PACK: 2.5 FT

ELEVATION/DEPTH TOP OF SCREEN: 3.0 FT.

TYPE OF SCREEN: SCHEDULE 40, 2"PVC

SLOT SIZE X LENGTH: 0.010" x 10 FT.

TYPE OF SAND PACK: 20/40 BEST SAND

ELEVATION/DEPTH BOTTOM OF SCREEN: 13.0 FT.

ELEVATION/DEPTH BOTTOM OF SAND PACK: 14.0 FT.

TYPE OF BACKFILL BELOW OBSERVATION WELL: BENTONITE CHIPS

ELEVATION/DEPTH OF HOLE 15.0 FT.

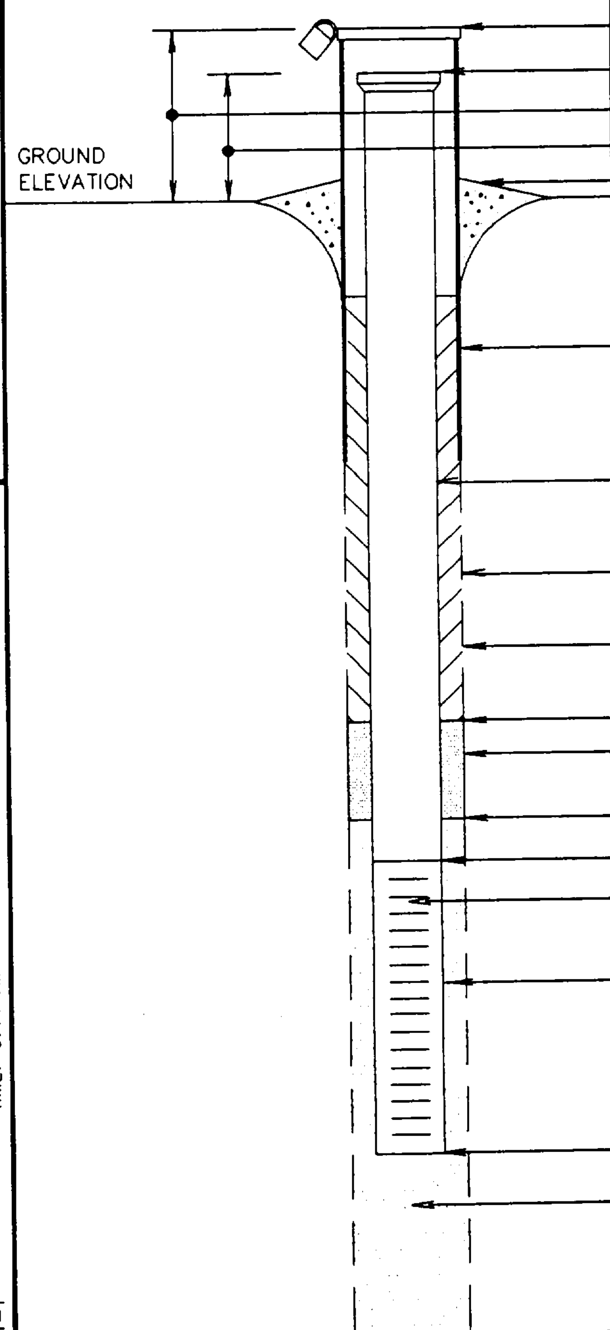
NOT TO SCALE

CAD FILE NAME: MOLYMW27.DWG
PLOT SCALE: 1=1
DATE: 01/09/95
TIME: 9:12 AM

WELL NO. MW-28

MONITORING WELL CONSTRUCTION DIAGRAM

PROJECT: MOLYCORP INC.	DRILLER: B.LAWRENCE, TERRA TESTING
PROJECT NO.: 5330.001	BORING NO.: SB-62
ELEVATION: 1024.9 FT MSL	DATE: 6/10/94
FIELD GEOLOGIST: P. ANDERSON	DRILLING METHOD: HOLLOW STEM AUGER
	DEVELOPMENT METHOD: PUMP/SURGE



ELEVATION OF TOP OF SURFACE CASING: 1026.9 FT MSL
ELEVATION OF TOP OF RISER PIPE: 1026.8 FT MSL
STICK-UP TOP OF SURFACE CASING: 2.0 FT.
STICK-UP RISER PIPE: 1.8 FT.
TYPE OF SURFACE SEAL: CONCRETE
GROUND SURFACE ELEVATION: 1024.9 FT MSL

I.D. OF SURFACE CASING: 6 INCHES
TYPE OF SURFACE CASING: STEEL

RISER PIPE I.D. 2 INCHES
TYPE OF RISER PIPE: SCHEDULE 40, PVC

BOREHOLE DIAMETER: 7 INCHES

TYPE OF BACKFILL: GROUT CEMENT/ BENTONITE

ELEVATION/DEPTH TOP OF SEAL: 6.0 FT.
TYPE OF SEAL: BENTONITE PELLETS

DEPTH TOP OF SAND PACK: 8.5 FT
ELEVATION/DEPTH TOP OF SCREEN: 10.5 FT.
TYPE OF SCREEN: SCHEDULE 40, PVC, 2"I.D.
SLOT SIZE X LENGTH: 0.010" x 10 FT.
TYPE OF SAND PACK: 20/40 BEST SAND

ELEVATION/DEPTH BOTTOM OF SCREEN: 20.5 FT.
ELEVATION/DEPTH BOTTOM OF SAND PACK: 21.0 FT.
TYPE OF BACKFILL BELOW OBSERVATION WELL: 20/40 BEST SAND

ELEVATION/DEPTH OF HOLE 21.0 FT.

NOT TO SCALE

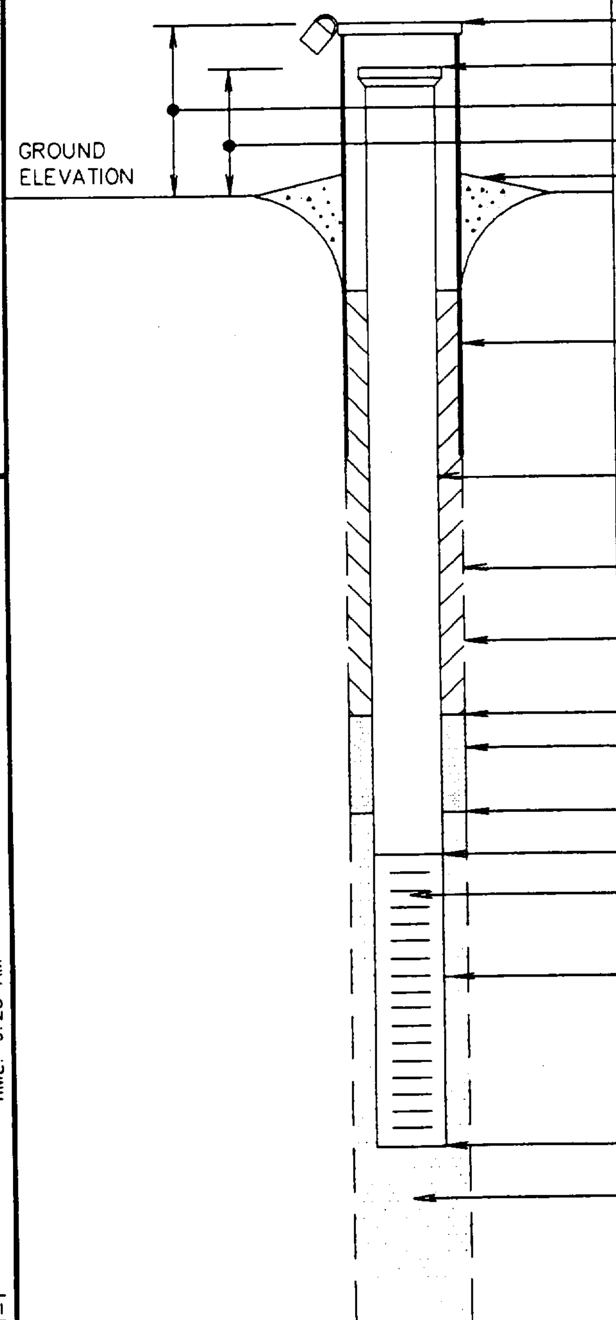
CAD FILE NAME: MOLYMW28.DWG
PLOT SCALE: 1=1

DATE: 01/09/95
TIME: 9:14 AM

WELL NO. UG-3

MONITORING WELL CONSTRUCTION DIAGRAM

PROJECT: MOLYCORP INC.	DRILLER: B. LAWRENCE, TERRA TESTING
PROJECT NO.: 5330.001 BORING NO.: UG-3	DRILLING METHOD: HOLLOW STEM AUGER
ELEVATION: 1016.37 FT. MSL DATE:	DEVELOPMENT METHOD: PUMP/SURGE
FIELD GEOLOGIST: P. ANDERSON	



ELEVATION OF TOP OF SURFACE CASING: 1018.5 FT. MSL

ELEVATION OF TOP OF RISER PIPE: 1018.02 FT. MSL

STICK-UP TOP OF SURFACE CASING: 2.1 FT.

STICK-UP RISER PIPE: 1.6 FT.

TYPE OF SURFACE SEAL: CEMENT GROUT

GROUND SURFACE ELEVATION: 1016.37 FT. MSL

I.D. OF SURFACE CASING: 6 INCHES

TYPE OF SURFACE CASING: STEEL

RISER PIPE I.D. 2 INCHES

TYPE OF RISER PIPE: SCHEDULE 40, PVC

BOREHOLE DIAMETER: 7 INCHES

TYPE OF BACKFILL: NONE

ELEVATION/DEPTH TOP OF SEAL: SURFACE

TYPE OF SEAL: BENTONITE PELLETS

DEPTH TOP OF SAND PACK: 0.8 FT.

ELEVATION/DEPTH TOP OF SCREEN: 2.0 FT.

TYPE OF SCREEN: 2" PVC

SLOT SIZE X LENGTH: 0.010" x 10 FT.

TYPE OF SAND PACK: 20/40, BEST SAND

ELEVATION/DEPTH BOTTOM OF SCREEN: 11.0 FT.

ELEVATION/DEPTH BOTTOM OF SAND PACK: 12.8 FT.

TYPE OF BACKFILL BELOW OBSERVATION WELL: 20/40 BEST SAND

ELEVATION/DEPTH OF HOLE 12.8 FT.

NOT TO SCALE

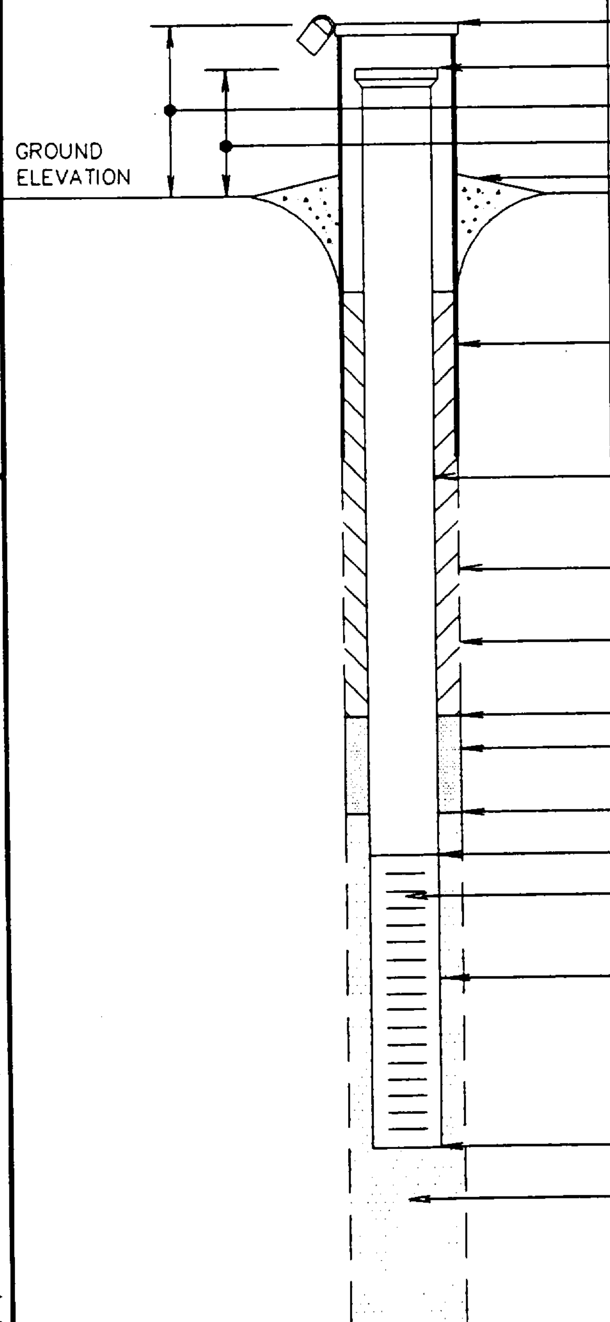
CAD FILE NAME: MOLYUG-3.DWG
PLOT SCALE: 1=1

DATE: 01/09/95
TIME: 9:25 AM

WELL NO. UG-4

MONITORING WELL CONSTRUCTION DIAGRAM

PROJECT: MOLYCORP INC.	DRILLER: B. LAWRENCE, TERRA TESTING
PROJECT NO. 5330.001	BORING NO. UG-4
ELEVATION: 1026.69 FT. MSL	DATE: 6/22/94
FIELD GEOLOGIST: P. ANDERSON	DRILLING METHOD: HOLLOW STEM AUGER
	DEVELOPMENT METHOD: PUMP/SURGE



ELEVATION OF TOP OF SURFACE CASING: 1029.1 FT. MSL
ELEVATION OF TOP OF RISER PIPE: 1028.84 FT. MSL
STICK-UP TOP OF SURFACE CASING: 2.4 FT
STICK-UP RISER PIPE: 2.1 FT
TYPE OF SURFACE SEAL: CONCRETE
GROUND SURFACE ELEVATION: 1026.69 FT. MSL

I.D. OF SURFACE CASING: 6 INCHES
TYPE OF SURFACE CASING: STEEL

RISER PIPE I.D. 2 INCHES
TYPE OF RISER PIPE: SCHEDULE 40, PVC

BOREHOLE DIAMETER: 7 INCHES

TYPE OF BACKFILL: CEMENT/CONCRETE GROUT

ELEVATION/DEPTH TOP OF SEAL: 3.0 FT
TYPE OF SEAL: BENTONITE PELLETS

DEPTH TOP OF SAND PACK: 4.5 FT.
ELEVATION/DEPTH TOP OF SCREEN: 5.5 FT.
TYPE OF SCREEN: SCHEDULE 40, 2"PVC
SLOT SIZE X LENGTH: 0.010" x 10 FT.
TYPE OF SAND PACK: 20/40 BEST SAND

ELEVATION/DEPTH BOTTOM OF SCREEN: 15.5 FT.
ELEVATION/DEPTH BOTTOM OF SAND PACK: 16.0 FT.
TYPE OF BACKFILL BELOW OBSERVATION WELL: 20/40 SAND

ELEVATION/DEPTH OF HOLE 16.0 FT.

NOT TO SCALE

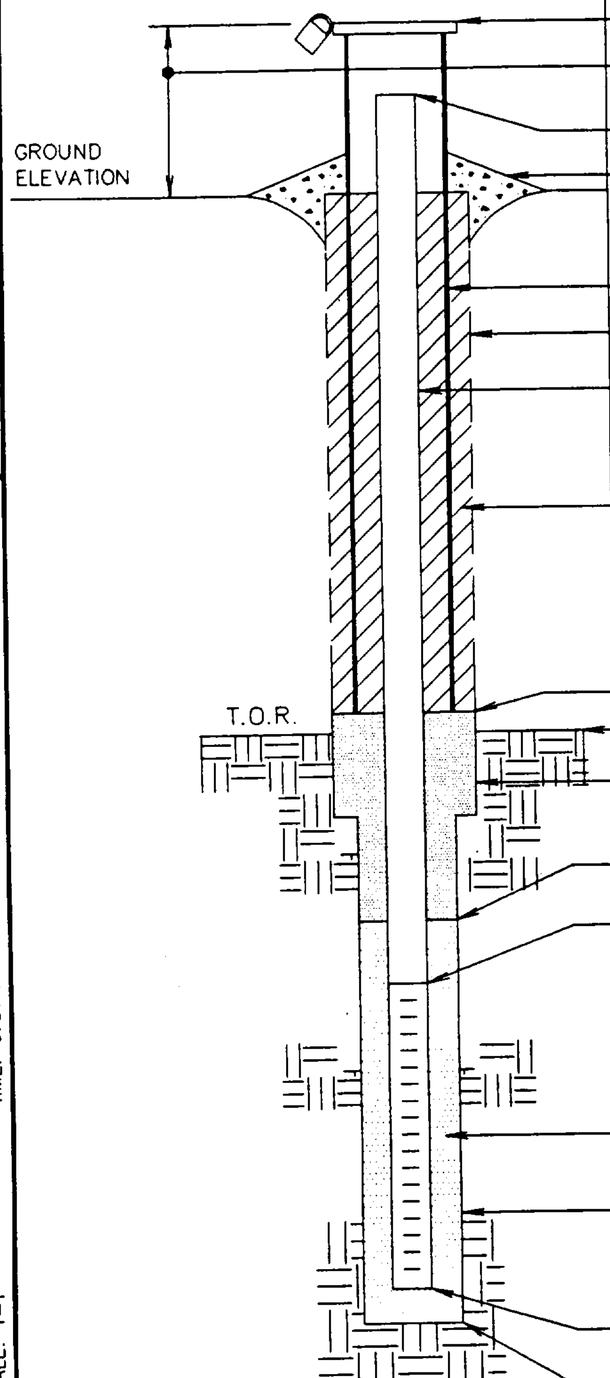
CAD FILE NAME: MOLYUG-4.DWG
PLOT SCALE: 1=1
DATE: 01/09/95
TIME: 6:14 PM

WELL NO. BR-1

BEDROCK
MONITORING WELL CONSTRUCTION DIAGRAM
WELL INSTALLED IN BEDROCK

PROJECT: MOLYCORP INC.
PROJECT NO.: 5330.001 BORING NO.: SB-183A
ELEVATION: 1021.6 FT. MSL DATE: 6/20 - 6/22/94
FIELD GEOLOGIST: A. LAFFERTY

DRILLER: TERRA TESTING, INC.
DRILLING METHOD: 8 1/4" I.D. HSA 4 7/8" WATER ROTARY
DEVELOPMENT METHOD: PUMP/SURGE



NOT TO SCALE

ELEVATION OF TOP OF CASING:	1023.1 FT. MSL
STICK-UP OF CASING ABOVE GROUND SURFACE:	1.5 FT.
ELEVATION TOP OF RISER:	1022.9 FT. MSL
TYPE OF SURFACE SEAL:	GROUT
GROUND SURFACE ELEVATION:	1021.6 FT. MSL
I.D. OF CASING:	6" STEEL
DIAMETER OF HOLE:	10 INCHES
RISER PIPE I.D.:	2 INCHES
TYPE OF RISER PIPE:	SCHEDULE 40 PVC
TYPE OF GROUT:	CEMENT/BENTONITE GROUT
DEPTH TOP OF SEAL:	20.0 FT.
DEPTH TOP OF BEDROCK:	17.0 FT.
TYPE OF SEAL:	BENTONITE, CHIPS
DEPTH TOP OF SAND:	22.0 FT.
DEPTH TOP OF SCREEN:	24.5 FT.
TYPE OF SCREEN:	
SLOT SIZE x LENGTH:	0.10 x 10 FT.
I.D. SCREEN:	2 INCHES
TYPE OF SAND PACK:	2040 SAND
DIAMETER OF HOLE IN BEDROCK: REAM:	4 7/8 INCHES
DEPTH BOTTOM SCREEN:	34.5 FT.
DEPTH BOTTOM OF HOLE:	38.0 FT

CAD FILE NAME: MOLYBR-1.DWG DATE: 01/09/95
PLOT SCALE: 1=1 TIME: 9:31 AM

APPENDIX M

Groundwater Flow Model Output

```
1               U S  GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER MODEL
                0
2 LAYERS      60 ROWS      60 COLUMNS
2 STRESS PERIOD(S) IN SIMULATION
MODEL TIME UNIT IS DAYS
0I/O UNITS
ELEMENT OF IUNIT   1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
I/O UNIT  11 23  0 14  0  0 17 18 19  0  0 22  0  0  0 26  0  0  0  0  0 99  0  0
0BAS1 -- BASIC MODEL PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 10
ARRAYS RHS AND BUFF WILL SHARE MEMORY.
START HEAD WILL BE SAVED
68528 ELEMENTS IN X ARRAY ARE USED BY BAS
68528 ELEMENTS OF X ARRAY USED OUT OF 1750000
0BCF2 -- BLOCK-CENTERED FLOW PACKAGE, VERSION 2, 7/1/91 INPUT READ FROM UNIT 11
TRANSIENT SIMULATION
HEAD AT CELLS THAT CONVERT TO DRY=  1.0000
WETTING CAPABILITY IS NOT ACTIVE
LAYER  AQUIFER TYPE
---------  ---------
1       1
2       0
14402 ELEMENTS IN X ARRAY ARE USED BY BCF
82930 ELEMENTS OF X ARRAY USED OUT OF 1750000
0WEL1 -- WELL PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM 23
MAXIMUM OF    2 WELLS
8 ELEMENTS IN X ARRAY ARE USED FOR WELLS
82938 ELEMENTS OF X ARRAY USED OUT OF 1750000
0RCH1 -- RECHARGE PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 18
OPTION 1 -- RECHARGE TO TOP LAYER
3600 ELEMENTS OF X ARRAY USED FOR RECHARGE
86538 ELEMENTS OF X ARRAY USED OUT OF 1750000
0RIV1 -- RIVER PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 14
MAXIMUM OF   60 RIVER NODES
360 ELEMENTS IN X ARRAY ARE USED FOR RIVERS
86898 ELEMENTS OF X ARRAY USED OUT OF 1750000
0GHB1 -- GHB PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 17
MAXIMUM OF  210 HEAD-DEPENDENT BOUNDARY NODES
1050 ELEMENTS IN X ARRAY ARE USED FOR HEAD-DEPENDENT BOUNDARIES
87948 ELEMENTS OF X ARRAY USED OUT OF 1750000
0SIP1 -- STRONGLY IMPLICIT PROCEDURE SOLUTION PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 19
MAXIMUM OF 200 ITERATIONS ALLOWED FOR CLOSURE
5 ITERATION PARAMETERS
29607 ELEMENTS IN X ARRAY ARE USED BY SIP
117555 ELEMENTS OF X ARRAY USED OUT OF 1750000
A TOTAL OF   25 HORIZONTAL FLOW BARRIERS
125 ELEMENTS IN X ARRAY ARE USED FOR HORIZONTAL FLOW BARRIERS
117680 ELEMENTS OF X ARRAY USED OUT OF 1750000
                1
                0


BOUNDARY ARRAY FOR LAYER  1 WILL BE READ ON UNIT 59 USING FORMAT: (60I3)
---------------------------------------------------------------------------
                0


BOUNDARY ARRAY FOR LAYER  2 WILL BE READ ON UNIT 59 USING FORMAT: (60I3)
---------------------------------------------------------------------------
0AQUIFER HEAD WILL BE SET TO  55.555     AT ALL NO-FLOW NODES (IBOUND=0)
                0


INITIAL HEAD FOR LAYER  1 WILL BE READ ON UNIT 76 USING FORMAT: (60F10.3)
---------------------------------------------------------------------------
                0


INITIAL HEAD FOR LAYER  2 WILL BE READ ON UNIT 76 USING FORMAT: (60F10.3)
---------------------------------------------------------------------------
0HEAD PRINT FORMAT IS FORMAT NUMBER   0    DRAWDOWN PRINT FORMAT IS FORMAT NUMBER   0
0HEADS WILL BE SAVED ON UNIT 30    DRAWDOWNS WILL BE SAVED ON UNIT 31
0OUTPUT CONTROL IS SPECIFIED EVERY TIME STEP
0                                COLUMN TO ROW ANISOTROPY =   1.000000
0                                              DELR =   25.00000
```

0 DELC = 25.00000
0 PRIMARY STORAGE COEF = 0.3000000 FOR LAYER 1
0 HYD. COND. ALONG ROWS = 11.36000 FOR LAYER 1
0

BOTTOM FOR LAYER 1 WILL BE READ ON UNIT 77 USING FORMAT: (60F10.3)

0

VERT HYD COND /THICKNESS FOR LAYER 1 WILL BE READ ON UNIT 78 USING FORMAT: (60F10.6)

0

PRIMARY STORAGE COEF FOR LAYER 2 WILL BE READ ON UNIT 75 USING FORMAT: (60F8.3)

---

0 TRANSMIS. ALONG ROWS = 0.0000000E+00 FOR LAYER 2

HORIZONTAL FLOW BARRIERS -- LISTED BY LAYERS. WITHIN EACH LAYER, THE LOCATION OF A BARRIER IS IDENTIFIED BY THE 2 CELLS ON BOTH SIDES OF THE BARRIER. THE ROW AND COLUMN NUMBER OF THE TWO CELLS ARE RESPECTIVELY IROW1, ICOL1, AND IROW2, ICOL2.
0 25 HORIZONTAL FLOW BARRIERS IN LAYER 1

IROW1	ICOL1	IROW2	ICOL2	HYD. COND./WIDTH	BARRIER NO.
13	13	14	13	0.1000E-05	1
14	12	15	12	0.1000E-05	2
14	11	15	11	0.1000E-05	3
14	10	15	10	0.1000E-05	4
15	9	15	10	0.1000E-05	5
16	9	16	10	0.1000E-05	6
17	9	17	10	0.1000E-05	7
18	9	18	10	0.1000E-05	8
19	9	19	10	0.1000E-05	9
20	9	20	10	0.1000E-05	10
21	9	21	10	0.1000E-05	11
22	9	22	10	0.1000E-05	12
23	9	23	10	0.1000E-05	13
24	9	24	10	0.1000E-05	14
25	9	25	10	0.1000E-05	15
26	9	26	10	0.1000E-05	16
27	9	27	10	0.1000E-05	17
28	9	28	10	0.1000E-05	18
29	9	29	10	0.1000E-05	19
30	9	30	10	0.1000E-05	20
31	9	31	10	0.1000E-05	21
32	10	31	10	0.1000E-05	22
32	11	31	11	0.1000E-05	23
32	12	31	12	0.1000E-05	24
32	13	31	13	0.1000E-05	25

0 0 HORIZONTAL FLOW BARRIERS IN LAYER 2
0

SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE

---

0 MAXIMUM ITERATIONS ALLOWED FOR CLOSURE = 200
ACCELERATION PARAMETER = 1.0000
HEAD CHANGE CRITERION FOR CLOSURE = 0.10000E-02
SIP HEAD CHANGE PRINTOUT INTERVAL = 5
0 CALCULATE ITERATION PARAMETERS FROM MODEL CALCULATED WSEED
1 STRESS PERIOD NO. 1, LENGTH = 30.00000

NUMBER OF TIME STEPS = 1

MULTIPLIER FOR DELT = 1.000

INITIAL TIME STEP SIZE = 30.00000
0 2 WELLS
LAYER ROW COL STRESS RATE WELL NO.

2	32	35	-0.44600E-01	1
2	16	30	-0.22300E-01	2

0

RECHARGE WILL BE READ ON UNIT 18 USING FORMAT: (60e12.4)

0

60 RIVER REACHES

0	LAYER	ROW	COL	STAGE	CONDUCTANCE	BOTTOM ELEVATION	RIVER REACH
1	1	11	1010.	4260.	1010.	1	
1	2	11	1010.	4260.	1009.	2	
1	3	12	1010.	4260.	1009.	3	
1	4	12	1010.	5680.	1009.	4	
1	5	12	1010.	5680.	1009.	5	
1	6	12	1010.	4260.	1009.	6	
1	7	12	1010.	4260.	1009.	7	
1	8	12	1010.	4260.	1009.	8	
1	9	12	1010.	4260.	1009.	9	
1	10	11	1010.	5680.	1009.	10	
1	11	10	1010.	4260.	1009.	11	
1	12	10	1010.	3408.	1009.	12	
1	13	9	1010.	3408.	1009.	13	
1	14	8	1010.	3408.	1009.	14	
1	15	7	1010.	4260.	1009.	15	
1	16	7	1010.	4260.	1009.	16	
1	17	6	1010.	4544.	1009.	17	
1	18	5	1010.	4828.	1009.	18	
1	19	5	1010.	4828.	1009.	19	
1	20	4	1011.	5112.	1009.	20	
1	21	3	1011.	5680.	1009.	21	
1	22	3	1011.	7100.	1009.	22	
1	23	3	1011.	6248.	1009.	23	
1	24	3	1011.	4260.	1009.	24	
1	25	3	1011.	5112.	1010.	25	
1	26	4	1011.	7100.	1010.	26	
1	27	4	1011.	555.0	1010.	27	
1	28	5	1011.	249.8	1010.	28	
1	29	5	1011.	83.25	1010.	29	
1	30	6	1011.	111.0	1010.	30	
1	31	7	1011.	111.0	1010.	31	
1	32	7	1011.	166.5	1010.	32	
1	33	7	1011.	166.5	1010.	33	
1	34	7	1011.	305.3	1011.	34	
1	35	7	1011.	305.3	1011.	35	
1	36	8	1011.	277.5	1010.	36	
1	37	9	1011.	249.8	1010.	37	
1	38	9	1011.	2840.	1010.	38	
1	39	10	1011.	2840.	1010.	39	
1	40	10	1011.	3124.	1009.	40	
1	41	11	1011.	3124.	1009.	41	
1	42	11	1011.	3692.	1009.	42	
1	43	11	1011.	4544.	1010.	43	
1	44	12	1012.	3976.	1010.	44	
1	45	12	1012.	3976.	1010.	45	
1	46	13	1012.	5112.	1010.	46	
1	47	14	1012.	3976.	1011.	47	
1	48	14	1012.	4544.	1011.	48	
1	49	15	1012.	5112.	1010.	49	
1	50	15	1012.	4828.	1010.	50	
1	51	16	1012.	3408.	1010.	51	
1	52	16	1012.	3408.	1010.	52	
1	53	16	1012.	4828.	1010.	53	
1	54	16	1012.	5112.	1011.	54	
1	55	16	1012.	5396.	1011.	55	
1	56	16	1012.	5680.	1010.	56	
1	57	16	1012.	5964.	1010.	57	
1	58	16	1012.	6248.	1009.	58	
1	59	16	1012.	6248.	1009.	59	
1	60	16	1012.	6532.	1008.	60	

0

210 HEAD-DEPENDENT BOUNDARY NODES

0 LAYER ROW COL ELEVATION CONDUCTANCE BOUND NO.

1	2	12	1003.	907.0	1
1	2	13	1004.	907.0	2
1	2	14	1005.	408.0	3
1	2	15	1007.	108.0	4
1	2	16	1008.	708.0	5
1	2	17	1009.	8.000	6
1	2	18	1010.	609.0	7
1	2	19	1011.	409.0	8
1	2	20	1012.	9.000	9
1	2	21	1013.	4010.	10
1	2	22	1014.	5010.	11
1	2	23	1014.	2010.	12
1	2	24	1015.	8011.	13
1	2	25	1015.	2011.	14
1	2	26	1015.	7012.	15
1	2	27	1016.	5012.	16
1	2	28	1016.	5013.	17
1	2	29	1016.	9014.	18
1	2	30	1016.	8014.	19
1	2	31	1016.	2015.	20
1	2	32	1016.	2016.	21
1	2	33	1016.	1017.	22
1	2	34	1015.	2018.	23
1	2	35	1015.	9020.	24
1	2	36	1015.	7021.	25
1	2	37	1016.	23.00	26
1	2	38	1016.	25.00	27
1	2	39	1017.	9028.	28
1	2	40	1017.	5031.	29
1	2	41	1018.	7035.	30
1	2	42	1019.	4040.	31
1	2	43	1021.	2047.	32
1	2	44	1022.	2056.	33
1	2	45	1023.	2071.	34
1	2	46	1025.	94.00	35
1	2	47	1026.	0.6014E+05	36
1	2	48	1028.	0.1028E+05	37
1	3	48	1030.	0.3028E+05	38
1	4	48	1031.	0.9028E+05	39
1	5	48	1032.	0.8028E+05	40
1	6	48	1034.	284.0	41
1	7	48	1035.	0.6028E+05	42
1	8	48	1036.	0.6028E+05	43
1	9	48	1037.	0.7028E+05	44
1	10	48	1038.	0.1028E+05	45
1	11	48	1039.	0.5028E+05	46
1	12	48	1040.	284.0	47
1	13	48	1041.	0.5028E+05	48
1	14	48	1042.	0.1028E+05	49
1	15	48	1042.	0.8028E+05	50
1	16	48	1043.	0.6028E+05	51
1	17	48	1043.	0.8028E+05	52
1	18	48	1043.	0.4028E+05	53
1	19	48	1044.	0.5028E+05	54
1	20	48	1044.	0.3028E+05	55
1	21	48	1044.	0.9028E+05	56
1	22	48	1044.	0.3028E+05	57
1	23	48	1045.	0.6028E+05	58
1	24	48	1045.	0.9028E+05	59
1	25	48	1045.	0.1028E+05	60
1	26	47	1044.	0.5014E+05	61
1	27	47	1044.	0.1014E+05	62
1	28	46	1043.	1094.	63
1	29	45	1041.	71.00	64
1	30	45	1042.	2071.	65
1	31	45	1042.	4071.	66
1	32	45	1043.	1071.	67
1	33	45	1044.	5071.	68
1	34	45	1044.	5071.	69
1	35	45	1044.	5071.	70

1	36	45	1044.	7071.	71
1	37	45	1044.	4071.	72
1	37	44	1043.	4056.	73
1	37	43	1042.	2047.	74
1	37	42	1040.	1040.	75
1	37	41	1038.	3035.	76
1	38	40	1036.	0.4028E+05	77
1	39	40	1036.	0.5028E+05	78
1	40	40	1035.	0.6028E+05	79
1	41	39	1033.	0.6028E+05	80
1	42	39	1032.	0.4028E+05	81
1	43	38	1030.	0.8028E+05	82
1	44	37	1028.	0.7028E+05	83
1	45	36	1026.	284.0	84
1	46	35	1024.	0.3028E+05	85
1	47	34	1023.	0.8028E+05	86
1	48	34	1022.	0.7028E+05	87
1	49	33	1021.	0.4028E+05	88
1	50	32	1020.	0.9028E+05	89
1	51	31	1019.	0.9028E+05	90
1	52	30	1018.	0.8028E+05	91
1	53	30	1018.	0.1028E+05	92
1	54	29	1018.	0.2028E+05	93
1	55	28	1017.	0.7028E+05	94
1	56	27	1017.	0.9028E+05	95
1	57	26	1016.	0.5028E+05	96
1	58	26	1016.	0.2028E+05	97
1	59	25	1015.	0.6028E+05	98
1	59	24	1015.	0.2014E+05	99
1	59	23	1015.	5094.	100
1	59	22	1014.	3071.	101
1	59	21	1014.	5056.	102
1	59	20	1014.	2047.	103
1	59	19	1013.	2040.	104
1	59	18	1013.	7035.	105
2	2	12	1002.	600.0	106
2	2	13	1004.	400.0	107
2	2	14	1006.	0.0000E+00	108
2	2	15	1008.	700.0	109
2	2	16	1010.	800.0	110
2	2	17	1012.	700.0	111
2	2	18	1013.	0.0000E+00	112
2	2	19	1015.	500.0	113
2	2	20	1016.	0.0000E+00	114
2	2	21	1017.	500.0	115
2	2	22	1018.	100.0	116
2	2	23	1018.	800.0	117
2	2	24	1019.	800.0	118
2	2	25	1019.	400.0	119
2	2	26	1020.	700.0	120
2	2	27	1020.	0.0000E+00	121
2	2	28	1020.	700.0	122
2	2	29	1020.	900.0	123
2	2	30	1020.	800.0	124
2	2	31	1020.	800.0	125
2	2	32	1020.	100.0	126
2	2	33	1020.	800.0	127
2	2	34	1020.	0.0000E+00	128
2	2	35	1020.	0.0000E+00	129
2	2	36	1020.	800.0	130
2	2	37	1021.	400.0	131
2	2	38	1021.	0.0000E+00	132
2	2	39	1022.	500.0	133
2	2	40	1023.	0.0000E+00	134
2	2	41	1023.	400.0	135
2	2	42	1024.	700.0	136
2	2	43	1025.	800.0	137
2	2	44	1026.	801.0	138
2	2	45	1027.	501.0	139
2	2	46	1028.	801.0	140
2	2	47	1029.	802.0	141
2	2	48	1031.	305.0	142
2	3	48	1032.	805.0	143
2	4	48	1032.	905.0	144

2	5	48	1033.	505.0	145
2	6	48	1034.	805.0	146
2	7	48	1035.	805.0	147
2	8	48	1036.	605.0	148
2	9	48	1037.	5.000	149
2	10	48	1037.	105.0	150
2	11	48	1038.	5.000	151
2	12	48	1039.	405.0	152
2	13	48	1039.	505.0	153
2	14	48	1040.	105.0	154
2	15	48	1040.	105.0	155
2	16	48	1041.	405.0	156
2	17	48	1041.	105.0	157
2	18	48	1041.	105.0	158
2	19	48	1042.	305.0	159
2	20	48	1042.	805.0	160
2	21	48	1042.	705.0	161
2	22	48	1042.	905.0	162
2	23	48	1042.	605.0	163
2	24	48	1042.	905.0	164
2	25	48	1042.	705.0	165
2	26	47	1040.	202.0	166
2	27	47	1040.	302.0	167
2	28	46	1039.	201.0	168
2	29	45	1038.	901.0	169
2	30	45	1038.	401.0	170
2	31	45	1037.	901.0	171
2	32	45	1037.	401.0	172
2	33	45	1037.	801.0	173
2	34	45	1037.	101.0	174
2	35	45	1036.	501.0	175
2	36	45	1036.	801.0	176
2	37	45	1036.	101.0	177
2	37	44	1035.	901.0	178
2	37	43	1034.	600.0	179
2	37	42	1033.	500.0	180
2	37	41	1032.	300.0	181
2	38	40	1031.	405.0	182
2	39	40	1031.	505.0	183
2	40	40	1031.	805.0	184
2	41	39	1030.	705.0	185
2	42	39	1029.	105.0	186
2	43	38	1028.	705.0	187
2	44	37	1028.	805.0	188
2	45	36	1027.	305.0	189
2	46	35	1026.	205.0	190
2	47	34	1025.	405.0	191
2	48	34	1025.	5.000	192
2	49	33	1024.	905.0	193
2	50	32	1024.	5.000	194
2	51	31	1023.	505.0	195
2	52	30	1022.	105.0	196
2	53	30	1022.	605.0	197
2	54	29	1022.	605.0	198
2	55	28	1021.	705.0	199
2	56	27	1021.	905.0	200
2	57	26	1020.	5.000	201
2	58	26	1020.	205.0	202
2	59	25	1020.	405.0	203
2	59	24	1019.	902.0	204
2	59	23	1018.	101.0	205
2	59	22	1017.	1.000	206
2	59	21	1016.	601.0	207
2	59	20	1016.	800.0	208
2	59	19	1015.	700.0	209
2	59	18	1014.	400.0	210

0CELL CONVERSIONS FOR ITERATION= 1 LAYER= 1 TIME STEP= 1 STRESS PERIOD= 1 (ROW,COL)

```
DRY( 2,31)  DRY( 2,32)  DRY( 2,33)  DRY( 2,34)  DRY( 2,35)  DRY( 2,36)  DRY( 2,37)  DRY( 2,38)
DRY( 2,39)  DRY( 2,40)  DRY( 2,41)  DRY( 2,42)  DRY( 2,43)  DRY( 2,44)  DRY( 2,45)  DRY( 2,46)
DRY( 2,47)  DRY( 2,48)  DRY( 3,31)  DRY( 3,32)  DRY( 3,33)  DRY( 3,34)  DRY( 3,35)  DRY( 3,36)
DRY( 3,37)  DRY( 3,38)  DRY( 3,39)  DRY( 3,40)  DRY( 3,41)  DRY( 3,42)  DRY( 3,43)  DRY( 3,44)
DRY( 3,45)  DRY( 3,46)  DRY( 3,47)  DRY( 3,48)  DRY( 4,32)  DRY( 4,33)  DRY( 4,34)  DRY( 4,35)
DRY( 4,36)  DRY( 4,37)  DRY( 4,38)  DRY( 4,39)  DRY( 4,40)  DRY( 4,41)  DRY( 4,42)  DRY( 4,43)
DRY( 4,44)  DRY( 4,45)  DRY( 4,46)  DRY( 4,47)  DRY( 4,48)  DRY( 5,33)  DRY( 5,34)  DRY( 5,35)
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DRY(5, 36) DRY(5, 37) DRY(5, 38) DRY(5, 39) DRY(5, 40) DRY(5, 41) DRY(5, 42) DRY(5, 43)
DRY(5, 44) DRY(5, 45) DRY(5, 46) DRY(5, 47) DRY(5, 48) DRY(6, 33) DRY(6, 34) DRY(6, 35)
DRY(6, 36) DRY(6, 37) DRY(6, 38) DRY(6, 39) DRY(6, 40) DRY(6, 41) DRY(6, 42) DRY(6, 43)
DRY(6, 44) DRY(6, 45) DRY(6, 46) DRY(6, 47) DRY(6, 48) DRY(7, 34) DRY(7, 35) DRY(7, 36)
DRY(7, 37) DRY(7, 38) DRY(7, 39) DRY(7, 40) DRY(7, 41) DRY(7, 42) DRY(7, 43) DRY(7, 44)
DRY(7, 45) DRY(7, 46) DRY(7, 47) DRY(7, 48) DRY(8, 35) DRY(8, 36) DRY(8, 37) DRY(8, 38)
DRY(8, 39) DRY(8, 40) DRY(8, 41) DRY(8, 42) DRY(8, 43) DRY(8, 44) DRY(8, 45) DRY(8, 46)
DRY(8, 47) DRY(8, 48) DRY(9, 37) DRY(9, 38) DRY(9, 39) DRY(9, 40) DRY(9, 41) DRY(9, 42)
DRY(9, 43) DRY(9, 44) DRY(9, 45) DRY(9, 46) DRY(9, 47) DRY(9, 48) DRY(10, 41) DRY(10, 42)
DRY(10, 43) DRY(10, 44) DRY(10, 45) DRY(10, 46) DRY(10, 47) DRY(10, 48) DRY(11, 11) DRY(11, 44)
DRY(11, 45) DRY(11, 46) DRY(11, 47) DRY(11, 48) DRY(20, 8) DRY(39, 37) DRY(39, 38) DRY(39, 39)
DRY(39, 40) DRY(40, 36) DRY(40, 37) DRY(40, 38) DRY(40, 39) DRY(40, 40) DRY(41, 36) DRY(41, 37)
DRY(41, 38) DRY(41, 39) DRY(41, 40) DRY(42, 36) DRY(42, 37) DRY(42, 38) DRY(42, 39) DRY(43, 11)
DRY(43, 35) DRY(43, 36) DRY(43, 37) DRY(43, 38) DRY(44, 12) DRY(44, 35) DRY(44, 36) DRY(44, 37)
DRY(45, 12) DRY(45, 35) DRY(45, 36) DRY(46, 13) DRY(46, 35) DRY(47, 14) DRY(47, 15) DRY(48, 14)
DRY(53, 16)
0AVERAGE SEED = 0.52452350
MINIMUM SEED = 0.00000000
0
7 ITERATION PARAMETERS CALCULATED FROM AVERAGE SEED:

0.0000000E+00 0.1019632E+00 0.1935298E+00 0.2757601E+00 0.3496059E+00 0.4159221E+00
4.75E-01
0CELL CONVERSIONS FOR ITERATION= 2 LAYER= 1 TIME STEP= 1 STRESS PERIOD= 1 (ROW,COL)
DRY(10, 11) DRY(11, 10) DRY(11, 43) DRY(12, 10) DRY(12, 46) DRY(12, 47) DRY(12, 48) DRY(13, 9)
DRY(20, 7) DRY(38, 38) DRY(38, 39) DRY(42, 35) DRY(49, 15) DRY(50, 15) DRY(51, 16) DRY(52, 16)
DRY(54, 16)
0CELL CONVERSIONS FOR ITERATION= 4 LAYER= 1 TIME STEP= 1 STRESS PERIOD= 1 (ROW,COL)
DRY(39, 36)
0
33 ITERATIONS FOR TIME STEP 1 IN STRESS PERIOD 1
0MAXIMUM HEAD CHANGE FOR EACH ITERATION:
0 HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL I

23.93 (1, 6, 12) -21.44 (1, 6, 12) -1.434 (1, 7, 14) -0.8114 (2, 7, 14) -0.1054 (1, 6, 14)
-0.1217 (2, 43, 19) -0.5029E-01 (1, 16, 39) -0.5039E-01 (2, 17, 39) -0.3075E-01 (1, 21, 7) -0.3473E-01 (2, 17, 37)
-0.2426E-01 (1, 21, 7) -0.2427E-01 (2, 17, 37) -0.1767E-01 (1, 21, 7) -0.1631E-01 (2, 17, 36) -0.1222E-01 (1, 21, 7)
0.1103E-01 (1, 21, 7) -0.9982E-02 (1, 21, 7) 0.8758E-02 (1, 21, 7) -0.7629E-02 (1, 21, 7) 0.6412E-02 (1, 21, 7)
-0.5326E-02 (1, 21, 7) 0.4673E-02 (1, 21, 7) -0.4244E-02 (1, 21, 7) 0.3751E-02 (1, 21, 7) -0.3279E-02 (1, 21, 7)
0.2829E-02 (1, 21, 7) -0.2442E-02 (1, 21, 7) 0.2015E-02 (1, 21, 7) -0.1695E-02 (1, 21, 7) 0.1548E-02 (1, 21, 7)
-0.1369E-02 (1, 21, 7) 0.1166E-02 (1, 21, 7) -0.9968E-03 (1, 21, 7)
0
0HEAD/DRAWDOWN PRINTOUT FLAG = 1 TOTAL BUDGET PRINTOUT FLAG = 1 CELL-BY-CELL FLOW TERM FLAG = 1
0OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:
HEAD DRAWDOWN HEAD DRAWDOWN
PRINTOUT PRINTOUT SAVE SAVE

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1 0 1 0

HEADS AND FLOW TERMS SAVED ON UNIT 99 FOR USE BY MT3D TRANSPORT MODEL
1 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	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60

...

0 1 55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56
55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56
55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56
55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56
55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56
55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56
0 2 55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56
1009. 1005. 1005. 1006. 1007. 1008. 1010. 1011. 1013. 1014.
1013. 1014. 1014. 1015. 1015. 1015. 1016. 1016. 1016. 1016.
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 55.56 55.56
55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56
0 3 55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56 55.56
55.56 1009. 1008. 1007. 1008. 1009. 1011. 1012. 1014. 1015.

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1015.  1015.  1015.  1016.  1016.  1016.  1016.  1017.  1017.  1018.
1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000
1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  55.56  55.56
55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
0 4  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
55.56  1010.  1009.  1009.  1009.  1010.  1012.  1013.  1014.  1015.
1016.  1016.  1016.  1016.  1017.  1017.  1017.  1018.  1018.  1019.
1020.  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000
1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  55.56  55.56
55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
0 5  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
55.56  1010.  1010.  1010.  1010.  1011.  1013.  1014.  1015.  1016.
1016.  1017.  1017.  1017.  1017.  1018.  1018.  1018.  1019.  1020.
1020.  1020.  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000
1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  55.56  55.56
55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
0 6  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
55.56  1010.  1010.  1010.  1011.  1013.  1014.  1015.  1016.  1016.
1017.  1017.  1017.  1017.  1018.  1018.  1018.  1019.  1019.  1020.
1020.  1020.  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000
1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  55.56  55.56
55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
0 7  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
55.56  1010.  1011.  1011.  1013.  1014.  1015.  1016.  1016.  1017.
1017.  1018.  1018.  1018.  1018.  1019.  1019.  1019.  1020.  1020.
1020.  1021.  1021.  1.000  1.000  1.000  1.000  1.000  1.000  1.000
1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  55.56  55.56
55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
0 8  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
55.56  1010.  1011.  1013.  1015.  1015.  1016.  1016.  1017.  1017.
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0 21 55.56	55.56	1011.	1011.	1012.	1013.	1015.	1015.	1015.	1018.	
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1016.   1017.   1017.   1017.   1017.   1017.   1017.   1017.   55.56   55.56
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1016.   1016.   1017.   1017.   1017.   1017.   1017.   55.56   55.56   55.56
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1015.   1016.   1016.   1016.   1016.   1016.   55.56   55.56   55.56   55.56
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1015.   1015.   1016.   1016.   1016.   1016.   55.56   55.56   55.56   55.56
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55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
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    17    18    19    20
21    22    23    24    25    26    27    28    29    30
31    32    33    34    35    36    37    38    39    40
41    42    43    44    45    46    47    48    49    50
51    52    53    54    55    56    57    58    59    60
..........................................................................
0 1  55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
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55.56   1009.   1008.   1007.   1008.   1010.   1012.   1013.   1015.   1016.
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0 9	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56
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0 10	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56
1013.	1014.	1015.	1017.	1017.	1018.	1018.	1018.	1018.	1018.	
1018.	1018.	1019.	1019.	1019.	1019.	1019.	1019.	1020.	1020.	
1021.	1022.	1023.	1024.	1024.	1025.	1026.	1026.	1027.	1028.	
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0 11	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	1013.
1014.	1016.	1016.	1018.	1018.	1018.	1018.	1018.	1018.	1018.	
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0 12	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	1014.
1016.	1016.	1017.	1018.	1019.	1019.	1018.	1018.	1018.	1018.	
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0 13	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	1013.	1015.
1016.	1016.	1017.	1018.	1018.	1018.	1018.	1018.	1018.	1018.	
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0 16	55.56	55.56	55.56	55.56	55.56	55.56	1010.	1011.	1012.	1017.
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0 17	55.56	55.56	55.56	55.56	55.56	1011.	1011.	1012.	1013.	1017.
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0 19	55.56	55.56	55.56	55.56	1011.	1011.	1012.	1014.	1015.	1017.
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0 20	55.56	55.56	55.56	1011.	1012.	1012.	1015.	1015.	1015.	1017.
1017.	1018.	1018.	1018.	1018.	1019.	1019.	1019.	1020.	1020.	
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0 21	55.56	55.56	1013.	1013.	1014.	1013.	1015.	1015.	1015.	1017.
1017.	1017.	1018.	1018.	1018.	1019.	1019.	1019.	1020.	1020.	
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0 22	55.56	55.56	1013.	1013.	1013.	1014.	1015.	1015.	1015.	1017.
1017	1017.	1018.	1018.	1018.	1019.	1019.	1019.	1020.	1020.	
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0 23	55.56	55.56	1013.	1013.	1013.	1013.	1014.	1015.	1016.	1017.
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0 24	55.56	55.56	1014.	1013.	1013.	1014.	1014.	1015.	1016.	1017.
1018	1018.	1018.	1018.	1019.	1019.	1019.	1019.	1019.	1020.	
1020	1020.	1021.	1021.	1022.	1022.	1023.	1023.	1024.	1025.	
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0 25	55.56	55.56	1011.	1013.	1013.	1014.	1014.	1015.	1016.	1017.
1018.	1018.	1018.	1018.	1019.	1019.	1019.	1019.	1019.	1020.	
1020.	1020.	1020.	1021.	1021.	1022.	1023.	1023.	1024.	1025.	
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55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 26	55.56	55.56	55.56	1011.	1012.	1013.	1014.	1015.	1015.	1017.
1017.	1018.	1018.	1018.	1018.	1019.	1019.	1019.	1019.	1019.	
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1035.	1036.	1037.	1039.	1040.	1042.	1041.	55.56	55.56	55.56	
55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 27	55.56	55.56	55.56	1012.	1012.	1013.	1014.	1015.	1015.	1017.
1017.	1017.	1018.	1018.	1018.	1019.	1019.	1019.	1019.	1019.	
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1035.	1036.	1038.	1039.	1040.	1042.	1041.	55.56	55.56	55.56	
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0 28	55.56	55.56	55.56	55.56	1012.	1013.	1014.	1014.	1015.	1017.
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0 29	55.56	55.56	55.56	55.56	1012. -	1013.	1014.	1014.	1015.	1016.
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1019.	1020.	1020.	1020.	1021.	1021.	1022.	1023.	1023.	1024.	
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0 30	55.56	55.56	55.56	55.56	55.56	1013.	1014.	1014.	1014.	1016.
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0 32	55.56	55.56	55.56	55.56	55.56	55.56	1012.	1013.	1014.	1015.
1015.	1016.	1016.	1017.	1017.	1018.	1017.	1018.	1018.	1019.	
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0 36	55.56	55.56	55.56	55.56	55.56	55.56	55.56	1012.	1012.	1013.
1013.	1014.	1015.	1016.	1017.	1017.	1017.	1017.	1017.	1018.	
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1018.	1018.	1019.	1019.	1020.	1020.	1021.	1021.	1022.	1022.	
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55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
0 59  55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   1013.   1014.   1015.   1015.
1016.   1015.   1018.   1019.   1019.   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
0 60  55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
0HEAD WILL BE SAVED ON UNIT 30 AT END OF TIME STEP  1, STRESS PERIOD  1
          0

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  1 IN STRESS PERIOD  1
------------------------------------------------------------------------------
0          CUMULATIVE VOLUMES     L**3                RATES FOR THIS TIME STEP     L**3/T
--------------                    ------------------

IN:                                     IN:
---                                     ---
STORAGE =  0.27020E+06                       STORAGE =  9006.7
CONSTANT HEAD =  0.00000E+00                      CONSTANT HEAD =  0.00000E+00
WELLS =  0.00000E+00                       WELLS =  0.00000E+00
RECHARGE =  55558.                          RECHARGE =  1851.9
RIVER LEAKAGE =  79727.                      RIVER LEAKAGE =  2657.6
HEAD DEP BOUNDS =  0.49506E+06                     HEAD DEP BOUNDS =  16502.
0            TOTAL IN =  0.90054E+06                       TOTAL IN =  30018.
0            OUT:                                 OUT:
---                                     ---
STORAGE =  0.23734E+06                       STORAGE =  7911.4
CONSTANT HEAD =  0.00000E+00                      CONSTANT HEAD =  0.00000E+00
WELLS =  2.0070                          WELLS =  0.66900E-01
RECHARGE =  0.00000E+00                       RECHARGE =  0.00000E+00
```

```
RIVER LEAKAGE =    71156.                         RIVER LEAKAGE =    2371.9
HEAD DEP BOUNDS =  0.59156E+06                       HEAD DEP BOUNDS =   19719.
0                TOTAL OUT =  0.90006E+06                       TOTAL OUT =   30002.
0                 IN - OUT =   480.69                          IN - OUT =   16.023
0          PERCENT DISCREPANCY =          0.05          PERCENT DISCREPANCY =          0.05


            0

TIME SUMMARY AT END OF TIME STEP  1 IN STRESS PERIOD  1
SECONDS      MINUTES       HOURS        DAYS        YEARS
-----------------------------------------------------------
TIME STEP LENGTH      0.259200E+07   43200.0    720.000    30.0000    0.821355E-01
STRESS PERIOD TIME     0.259200E+07   43200.0    720.000    30.0000    0.821355E-01
TOTAL SIMULATION TIME     0.259200E+07   43200.0    720.000    30.0000    0.821355E-01
            1
1                             STRESS PERIOD NO.  2, LENGTH =  1826.000
----------------------------------------------

NUMBER OF TIME STEPS =    1

MULTIPLIER FOR DELT =    1.000

INITIAL TIME STEP SIZE =  1826.000
0REUSING WELLS FROM LAST STRESS PERIOD
0REUSING RECH FROM LAST STRESS PERIOD
0REUSING RIVER REACHES FROM LAST STRESS PERIOD
0REUSING HEAD-DEPENDENT BOUNDS FROM LAST STRESS PERIOD
0CELL CONVERSIONS FOR ITERATION=  2  LAYER= 1  TIME STEP=  1  STRESS PERIOD=  2     (ROW,COL)
DRY( 12, 45)   DRY( 19,  8)   DRY( 21,  7)   DRY( 23,  5)
0CELL CONVERSIONS FOR ITERATION=  3  LAYER= 1  TIME STEP=  1  STRESS PERIOD=  2     (ROW,COL)
DRY( 11, 42)   DRY( 17,  8)   DRY( 29,  8)   DRY( 38, 37)
0CELL CONVERSIONS FOR ITERATION=  5  LAYER= 1  TIME STEP=  1  STRESS PERIOD=  2     (ROW,COL)
DRY( 21,  8)   DRY( 23,  9)   DRY( 24,  9)
0CELL CONVERSIONS FOR ITERATION=  6  LAYER= 1  TIME STEP=  1  STRESS PERIOD=  2     (ROW,COL)
DRY( 41, 35)
0CELL CONVERSIONS FOR ITERATION=  7  LAYER= 1  TIME STEP=  1  STRESS PERIOD=  2     (ROW,COL)
DRY( 23,  8)
0CELL CONVERSIONS FOR ITERATION= 10  LAYER= 1  TIME STEP=  1  STRESS PERIOD=  2     (ROW,COL)
DRY( 44, 34)
0CELL CONVERSIONS FOR ITERATION= 11  LAYER= 1  TIME STEP=  1  STRESS PERIOD=  2     (ROW,COL)
DRY( 11, 41)
0CELL CONVERSIONS FOR ITERATION= 13  LAYER= 1  TIME STEP=  1  STRESS PERIOD=  2     (ROW,COL)
DRY( 25,  9)   DRY( 26,  9)
0CELL CONVERSIONS FOR ITERATION= 15  LAYER= 1  TIME STEP=  1  STRESS PERIOD=  2     (ROW,COL)
DRY( 12, 44)
0CELL CONVERSIONS FOR ITERATION= 17  LAYER= 1  TIME STEP=  1  STRESS PERIOD=  2     (ROW,COL)
DRY( 22,  5)
0CELL CONVERSIONS FOR ITERATION= 23  LAYER= 1  TIME STEP=  1  STRESS PERIOD=  2     (ROW,COL)
DRY( 45, 34)
0CELL CONVERSIONS FOR ITERATION= 29  LAYER= 1  TIME STEP=  1  STRESS PERIOD=  2     (ROW,COL)
DRY( 10, 40)
0CELL CONVERSIONS FOR ITERATION= 31  LAYER= 1  TIME STEP=  1  STRESS PERIOD=  2     (ROW,COL)
DRY( 12, 43)
0CELL CONVERSIONS FOR ITERATION= 32  LAYER= 1  TIME STEP=  1  STRESS PERIOD=  2     (ROW,COL)
DRY( 12, 42)
0CELL CONVERSIONS FOR ITERATION= 51  LAYER= 1  TIME STEP=  1  STRESS PERIOD=  2     (ROW,COL)
DRY( 11, 40)
            0
183 ITERATIONS FOR TIME STEP   1 IN STRESS PERIOD  2
0MAXIMUM HEAD CHANGE FOR EACH ITERATION:
0 HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL H
---------------------------------------------------------------------------------------------------------
-2.229     ( 2, 21,  3)  1.144     ( 2, 45, 13)  1.219     ( 2, 29,  8) -0.7306   ( 1, 17,  9)  6.706     ( 1, 44, 34)
-6.049     ( 1, 44, 34)  1.467     ( 2, 23,  8)  2.250     ( 1, 44, 34) -2.559    ( 2, 44, 34)  1.981     ( 2, 44, 34)
0.6159     ( 1, 26,  9) -0.8613    ( 1, 26,  9)  2.792     ( 2, 26,  9) -0.3915   ( 1, 22,  5)  0.6543    ( 1, 22,  5)
-0.7497    ( 1, 22,  5)  1.633     ( 2, 22,  5) -0.3916    ( 1, 45, 34)  0.5806   ( 1, 45, 34) -0.6017    ( 1, 45, 34)
0.8104     ( 1, 45, 34) -0.8720    ( 1, 45, 34)  1.452     ( 2, 45, 34)  0.2264   ( 2, 12, 41)  0.1773    ( 2, 29,  9)
-0.2308    ( 2, 12, 42)  0.1577    ( 1, 29,  9)  0.4725    ( 2, 12, 42)  0.5897   ( 2, 10, 40) -0.4742    ( 2, 12, 42)
0.6349     ( 2, 12, 43)  0.9779    ( 2, 12, 42)  0.1624    ( 1, 13, 41)  0.1335   ( 2, 12, 40)  0.6001E-01 ( 1, 29,  9)
-0.4917E-01 ( 1, 29,  9)  0.4197E-01 ( 2, 29,  9)  0.3478E-01 ( 2, 45, 13)  0.2757E-01 ( 1, 29,  9)  0.3490E-01 ( 2, 45, 13)
0.2124E-01 ( 1, 31, 14)  0.3518E-01 ( 2, 31, 10)  0.1636E-01 ( 1, 31, 14)  0.2655E-01 ( 2, 48, 15)  0.2315E-01 ( 1, 11, 40)
```

```
-0.3920E-01 ( 1, 11, 40) 0.6157E-01 ( 1, 11, 40) -0.9200E-01 ( 1, 11, 40) 0.2343    ( 1, 11, 40) -0.3322    ( 1, 11, 40)
1.154    ( 2, 11, 40) -0.5511E-01 ( 2, 10, 39) 0.1403E-01 ( 1, 31, 14) 0.2385E-01 ( 2, 31, 10) 0.1469E-01 ( 1, 31, 14)
0.2470E-01 ( 2, 31, 10) 0.1136E-01 ( 1, 31, 14) 0.1870E-01 ( 2, 27, 10) 0.1151E-01 ( 1, 31, 14) 0.1971E-01 ( 2, 31, 10)
0.1206E-01 ( 1, 31, 14) 0.2050E-01 ( 2, 31, 10) 0.1270E-01 ( 1, 31, 13) 0.1665E-01 ( 2, 28, 10) 0.9393E-02 ( 1, 31, 14)
0.1636E-01 ( 2, 31, 10) 0.9949E-02 ( 1, 31, 14) 0.1706E-01 ( 2, 31, 10) 0.1049E-01 ( 1, 31, 13) 0.1774E-01 ( 2, 31, 10)
0.8118E-02 ( 1, 31, 14) 0.1356E-01 ( 2, 27, 10) 0.8258E-02 ( 1, 31, 14) 0.1424E-01 ( 2, 31, 10) 0.8691E-02 ( 1, 31, 13)
0.1486E-01 ( 2, 31, 10) 0.9215E-02 ( 1, 31, 13) 0.1248E-01 ( 2, 27, 10) 0.6811E-02 ( 1, 31, 14) 0.1194E-01 ( 2, 31, 10)
0.7239E-02 ( 1, 31, 14) 0.1249E-01 ( 2, 31, 10) 0.7686E-02 ( 1, 31, 13) 0.1303E-01 ( 2, 31, 10) 0.5947E-02 ( 1, 31, 14)
0.1004E-01 ( 2, 27, 10) 0.6068E-02 ( 1, 31, 14) 0.1052E-01 ( 2, 31, 10) 0.6424E-02 ( 1, 31, 13) 0.1102E-01 ( 2, 31, 10)
0.6833E-02 ( 1, 31, 13) 0.9104E-02 ( 2, 27, 10) 0.5049E-02 ( 1, 31, 14) 0.8895E-02 ( 2, 31, 10) 0.5382E-02 ( 1, 31, 14)
0.9335E-02 ( 2, 31, 10) 0.5745E-02 ( 1, 31, 13) 0.9767E-02 ( 2, 31, 10) 0.4445E-02 ( 1, 31, 14) 0.7583E-02 ( 2, 27, 10)
0.4547E-02 ( 1, 31, 14) 0.7924E-02 ( 2, 31, 10) 0.4837E-02 ( 1, 31, 13) 0.8317E-02 ( 2, 31, 10) 0.5158E-02 ( 1, 31, 13)
0.6921E-02 ( 2, 27, 10) 0.3810E-02 ( 1, 31, 14) 0.6748E-02 ( 2, 31, 10) 0.4079E-02 ( 1, 31, 13) 0.7094E-02 ( 2, 31, 10)
0.4365E-02 ( 1, 31, 13) 0.7447E-02 ( 2, 28, 10) 0.3381E-02 ( 1, 31, 13) 0.5810E-02 ( 2, 27, 10) 0.3458E-02 ( 1, 31, 14)
0.6059E-02 ( 2, 27, 10) 0.3695E-02 ( 1, 31, 13) 0.6376E-02 ( 2, 27, 10) 0.3948E-02 ( 1, 31, 13) 0.5330E-02 ( 2, 27, 10)
0.2913E-02 ( 1, 31, 14) 0.5185E-02 ( 2, 27, 10) 0.3132E-02 ( 1, 31, 13) 0.5462E-02 ( 2, 27, 10) 0.3356E-02 ( 1, 31, 13)
0.5755E-02 ( 2, 27, 10) 0.2604E-02 ( 1, 31, 13) 0.4498E-02 ( 2, 27, 10) 0.2660E-02 ( 1, 31, 14) 0.4697E-02 ( 2, 27, 10)
0.2852E-02 ( 1, 31, 13) 0.4950E-02 ( 2, 27, 10) 0.3052E-02 ( 1, 31, 13) 0.4142E-02 ( 2, 26, 10) 0.2254E-02 ( 1, 30, 12)
0.4032E-02 ( 2, 27, 10) 0.2426E-02 ( 1, 31, 13) 0.4253E-02 ( 2, 27, 10) 0.2602E-02 ( 1, 31, 13) 0.4489E-02 ( 2, 26, 10)
0.2021E-02 ( 1, 31, 13) 0.3509E-02 ( 2, 27, 10) 0.2066E-02 ( 1, 31, 13) 0.3667E-02 ( 2, 27, 10) 0.2218E-02 ( 1, 31, 13)
0.3870E-02 ( 2, 26, 10) 0.2375E-02 ( 1, 31, 13) 0.3241E-02 ( 2, 25, 10) 0.1762E-02 ( 1, 26, 14) 0.3155E-02 ( 2, 27, 10)
0.1891E-02 ( 1, 31, 13) 0.3329E-02 ( 2, 26, 10) 0.2029E-02 ( 1, 31, 13) 0.3520E-02 ( 2, 26, 10) 0.1577E-02 ( 1, 31, 13)
0.2750E-02 ( 2, 27, 10) 0.1617E-02 ( 1, 26, 14) 0.2878E-02 ( 2, 26, 10) 0.1733E-02 ( 1, 31, 13) 0.3038E-02 ( 2, 26, 10)
0.1857E-02 ( 1, 31, 13) 0.2548E-02 ( 2, 25, 10) 0.1385E-02 ( 1, 26, 14) 0.2480E-02 ( 2, 25, 10) 0.1480E-02 ( 1, 31, 13)
0.2617E-02 ( 2, 26, 10) 0.1589E-02 ( 1, 31, 13) 0.2768E-02 ( 2, 26, 10) 0.1236E-02 ( 1, 31, 13) 0.2161E-02 ( 2, 27, 10)
0.1272E-02 ( 1, 26, 14) 0.2264E-02 ( 2, 26, 10) 0.1360E-02 ( 1, 31, 13) 0.2392E-02 ( 2, 26, 10) 0.1457E-02 ( 1, 31, 13)
0.2007E-02 ( 2, 25, 10) 0.1090E-02 ( 1, 26, 14) 0.1955E-02 ( 2, 25, 10) 0.1165E-02 ( 1, 26, 14) 0.2061E-02 ( 2, 26, 10)
0.1248E-02 ( 1, 31, 13) 0.2181E-02 ( 2, 26, 10) 0.9717E-03 ( 1, 31, 13)
          0
0HEAD/DRAWDOWN PRINTOUT FLAG = 1    TOTAL BUDGET PRINTOUT FLAG = 1    CELL-BY-CELL FLOW TERM FLAG = 1
0OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:
HEAD     DRAWDOWN  HEAD  DRAWDOWN
PRINTOUT PRINTOUT  SAVE  SAVE
------------------------------
1    0    1    0

HEADS AND FLOW TERMS SAVED ON UNIT 99 FOR USE BY MT3D TRANSPORT MODEL
1              HEAD IN LAYER  1 AT END OF TIME STEP  1 IN STRESS PERIOD  2
------------------------------------------------------------------------

1      2      3      4      5      6      7      8      9      10
11     12     13     14     15     16     17     18     19     20
21     22     23     24     25     26     27     28     29     30
31     32     33     34     35     36     37     38     39     40
41     42     43     44     45     46     47     48     49     50
51     52     53     54     55     56     57     58     59     60
................................................................................
0 1  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
0 2  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
1009.  1005.  1005.  1006.  1007.  1008.  1010.  1010.  1012.  1013.
1013.  1014.  1014.  1015.  1015.  1015.  1016.  1016.  1016.  1016.
1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000
1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  55.56  55.56
55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
0 3  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
55.56  1009.  1008.  1008.  1008.  1009.  1010.  1011.  1013.  1014.
1014.  1015.  1015.  1016.  1016.  1016.  1016.  1017.  1017.  1018.
1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000
1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  55.56  55.56
55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
0 4  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
55.56  1010.  1009.  1009.  1009.  1010.  1011.  1013.  1014.  1015.
1015.  1016.  1016.  1016.  1017.  1017.  1017.  1018.  1018.  1018.
1019.  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000
1.000  1.000  1.000  1.000  1.000  1.000  1.000  1.000  55.56  55.56
55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
0 5  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56  55.56
55.56  1010.  1010.  1010.  1010.  1011.  1013.  1014.  1015.  1015.
1016.  1016.  1017.  1017.  1017.  1018.  1018.  1018.  1019.  1019.
```

1020.	1020.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	55.56	55.56	
55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 6	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56
55.56	1010.	1010.	1010.	1011.	1013.	1014.	1015.	1016.	1016.	
1016.	1017.	1017.	1017.	1018.	1018.	1018.	1019.	1019.	1020.	
1020.	1020.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	55.56	55.56	
55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 7	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56
55.56	1010.	1010.	1011.	1013.	1014.	1015.	1016.	1016.	1017.	
1017.	1017.	1018.	1018.	1018.	1019.	1019.	1019.	1020.	1020.	
1021.	1021.	1022.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	55.56	55.56	
55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 8	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56
55.56	1010.	1011.	1013.	1014.	1015.	1016.	1016.	1017.	1017.	
1017.	1018.	1018.	1018.	1019.	1019.	1019.	1020.	1020.	1021.	
1021.	1022.	1023.	1024.	1.000	1.000	1.000	1.000	1.000	1.000	
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	55.56	55.56	
55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 9	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56
55.56	1010.	1013.	1014.	1015.	1016.	1016.	1017.	1017.	1017.	
1018.	1018.	1018.	1019.	1019.	1019.	1020.	1020.	1020.	1021.	
1022.	1023.	1024.	1024.	1025.	1026.	1.000	1.000	1.000	1.000	
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	55.56	55.56	
55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 10	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56
1.000	1014.	1015.	1016.	1016.	1016.	1017.	1017.	1018.	1018.	
1018.	1018.	1019.	1019.	1019.	1020.	1020.	1020.	1021.	1022.	
1022.	1023.	1024.	1025.	1026.	1026.	1026.	1027.	1027.	1.000	
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	55.56	55.56	
55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 11	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	1.000
1.000	1016.	1016.	1016.	1017.	1017.	1017.	1018.	1018.	1018.	
1018.	1019.	1019.	1019.	1020.	1020.	1020.	1021.	1021.	1022.	
1023.	1024.	1025.	1025.	1026.	1026.	1027.	1027.	1027.	1.000	
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	55.56	55.56	
55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 12	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	1.000
1016.	1016.	1016.	1017.	1017.	1017.	1018.	1018.	1018.	1019.	
1019.	1019.	1019.	1020.	1020.	1020.	1021.	1021.	1022.	1023.	
1023.	1024.	1025.	1026.	1026.	1027.	1027.	1027.	1028.	1029.	
1030.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	55.56	55.56	
55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 13	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	1.000	1016.
1016.	1017.	1017.	1017.	1018.	1018.	1018.	1018.	1019.	1019.	
1019.	1019.	1020.	1020.	1020.	1021.	1021.	1022.	1022.	1023.	
1024.	1025.	1025.	1026.	1026.	1027.	1027.	1028.	1028.	1029.	
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55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 14	55.56	55.56	55.56	55.56	55.56	55.56	55.56	1010.	1012.	1015.
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1019.	1020.	1020.	1020.	1021.	1021.	1022.	1022.	1023.	1023.	
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0 15	55.56	55.56	55.56	55.56	55.56	55.56	1010.	1011.	1011.	1019.
1019.	1019.	1019.	1019.	1019.	1019.	1019.	1019.	1019.	1019.	
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1031.	1033.	1034.	1036.	1037.	1039.	1040.	1042.	55.56	55.56	
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0 16	55.56	55.56	55.56	55.56	55.56	55.56	1010.	1011.	1011.	1020.
1019.	1019.	1019.	1019.	1019.	1019.	1019.	1019.	1020.	1020.	
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55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 17	55.56	55.56	55.56	55.56	55.56	1010.	1010.	1.000	1012.	1020.
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0 18	55.56	55.56	55.56	55.56	1010.	1010.	1011.	1011.	1012.	1020.
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0 19	55.56	55.56	55.56	55.56	1010.	1011.	1011.	1.000	1013.	1020.
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0 20	55.56	55.56	55.56	1011.	1011.	1011.	1.000	1.000	1014.	1020.
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0 21	55.56	55.56	1011.	1011.	1011.	1011.	1.000	1.000	1014.	1020.
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0 22	55.56	55.56	1011.	1011.	1.000	1012.	1013.	1014.	1014.	1020.
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0 23	55.56	55.56	1011.	1011.	1.000	1013.	1013.	1.000	1.000	1020.
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0 24	55.56	55.56	1011.	1011.	1011.	1012.	1012.	1013.	1.000	1020.
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0 25	55.56	55.56	1011.	1011.	1011.	1012.	1012.	1012.	1.000	1020.
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0 26	55.56	55.56	55.56	1011.	1011.	1012.	1012.	1012.	1.000	1020.
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1021.	1021.	1022.	1022.	1022.	1023.	1023.	1024.	1025.	1025.	
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0 27	55.56	55.56	55.56	1011.	1011.	1011.	1012.	1012.	1013.	1020.
1020.	1020.	1020.	1020.	1020.	1020.	1021.	1021.	1021.	1021.	
1021.	1021.	1022.	1022.	1022.	1023.	1023.	1024.	1025.	1025.	
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1035.	1036.	1038.	1039.	1040.	1042.	1044.	55.56	55.56	55.56	
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0 28	55.56	55.56	55.56	55.56	1011.	1011.	1012.	1012.	1013.	1020.
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1021.	1021.	1022.	1022.	1022.	1023.	1024.	1024.	1025.	1025.	
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0 29	55.56	55.56	55.56	55.56	1011.	1011.	1011.	1.000	1013.	1020.
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1021.	1021.	1022.	1022.	1023.	1023.	1023.	1024.	1025.	1025.	
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1036.	1037.	1038.	1040.	1041.	55.56	55.56	55.56	55.56	55.56	
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0 30	55.56	55.56	55.56	55.56	55.56	1011.	1011.	1012.	1013.	1020.

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1021.	1021.	1022.	1022.	1023.	1023.	1023.	1024.	1025.	1025.	
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1036.	1037.	1039.	1040.	1042.	55.56	55.56	55.56	55.56	55.56	
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0 31	55.56	55.56	55.56	55.56	55.56	55.56	1011.	1012.	1013.	1020.
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1021.	1021.	1022.	1022.	1023.	1023.	1023.	1024.	1024.	1025.	
1026.	1026.	1027.	1028.	1029.	1030.	1031.	1032.	1034.	1035.	
1036.	1038.	1039.	1041.	1042.	55.56	55.56	55.56	55.56	55.56	
55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 32	55.56	55.56	55.56	55.56	55.56	55.56	1011.	1012.	1014.	1015.
1016.	1017.	1018.	1019.	1019.	1020.	1020.	1020.	1021.	1021.	
1021.	1021.	1022.	1022.	1022.	1023.	1023.	1024.	1024.	1025.	
1025.	1026.	1027.	1028.	1029.	1030.	1031.	1032.	1034.	1035.	
1036.	1038.	1039.	1041.	1043.	55.56	55.56	55.56	55.56	55.56	
55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 33	55.56	55.56	55.56	55.56	55.56	55.56	1011.	1013.	1014.	1015.
1016.	1017.	1018.	1019.	1019.	1019.	1020.	1020.	1020.	1021.	
1021.	1021.	1022.	1022.	1022.	1023.	1023.	1024.	1024.	1025.	
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1037.	1038.	1040.	1041.	1043.	55.56	55.56	55.56	55.56	55.56	
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0 34	55.56	55.56	55.56	55.56	55.56	55.56	1011.	1012.	1014.	1015.
1016.	1017.	1018.	1018.	1019.	1019.	1020.	1020.	1020.	1021.	
1021.	1021.	1022.	1022.	1022.	1023.	1023.	1024.	1024.	1024.	
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1037.	1038.	1040.	1042.	1044.	55.56	55.56	55.56	55.56	55.56	
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0 35	55.56	55.56	55.56	55.56	55.56	55.56	1011.	1012.	1013.	1015.
1016.	1017.	1018.	1018.	1019.	1019.	1019.	1020.	1020.	1021.	
1021.	1021.	1022.	1022.	1022.	1023.	1023.	1023.	1024.	1024.	
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1037.	1039.	1040.	1042.	1044.	55.56	55.56	55.56	55.56	55.56	
55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 36	55.56	55.56	55.56	55.56	55.56	55.56	55.56	1011.	1013.	1014.
1015.	1016.	1017.	1018.	1019.	1019.	1019.	1020.	1020.	1021.	
1021.	1021.	1022.	1022.	1022.	1023.	1023.	1023.	1024.	1024.	
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1037.	1039.	1041.	1042.	1044.	55.56	55.56	55.56	55.56	55.56	
55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 37	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	1012.	1014.
1015.	1016.	1017.	1018.	1019.	1019.	1019.	1020.	1020.	1020.	
1021.	1021.	1022.	1022.	1022.	1022.	1023.	1023.	1023.	1024.	
1024.	1025.	1025.	1026.	1027.	1028.	1030.	1032.	1034.	1036.	
1038.	1040.	1041.	1043.	1044.	55.56	55.56	55.56	55.56	55.56	
55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 38	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	1011.	1013.
1015.	1016.	1017.	1018.	1018.	1019.	1019.	1020.	1020.	1020.	
1021.	1021.	1021.	1022.	1022.	1022.	1023.	1023.	1023.	1023.	
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55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 39	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	1011.
1015.	1016.	1017.	1018.	1018.	1019.	1019.	1020.	1020.	1020.	
1021.	1021.	1021.	1022.	1022.	1022.	1022.	1023.	1023.	1023.	
1024.	1024.	1024.	1025.	1025.	1.000	1.000	1.000	1.000	1.000	
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55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 40	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	1011.
1014.	1016.	1017.	1018.	1018.	1019.	1019.	1019.	1020.	1020.	
1020.	1021.	1021.	1021.	1022.	1022.	1022.	1022.	1023.	1023.	
1023.	1024.	1024.	1024.	1025.	1.000	1.000	1.000	1.000	1.000	
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55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 41	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56
1011.	1016.	1017.	1018.	1018.	1019.	1019.	1019.	1020.	1020.	
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55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 42	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56
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55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 43	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56
1.000	1017.	1018.	1018.	1018.	1019.	1019.	1019.	1020.	1020.	
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55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 44	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56
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55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 45	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56
55.56	1.000	1018.	1018.	1019.	1019.	1019.	1019.	1019.	1020.	
1020.	1020.	1020.	1020.	1021.	1021.	1021.	1021.	1021.	1021.	
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55.56	55.56	1.000	1019.	1019.	1019.	1019.	1019.	1019.	1019.	
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1021.	1022.	1022.	1022.	1.000	55.56	55.56	55.56	55.56	55.56	
55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
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0 47	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56
55.56	55.56	55.56	1.000	1.000	1019.	1019.	1019.	1019.	1019.	
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0 48	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56
55.56	55.56	55.56	1.000	1019.	1019.	1019.	1019.	1019.	1019.	
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1021.	1021.	1021.	1022.	55.56	55.56	55.56	55.56	55.56	55.56	
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0 49	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56
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55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 50	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56
55.56	55.56	55.56	55.56	1.000	1018.	1018.	1018.	1019.	1019.	
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55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 51	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56
55.56	55.56	55.56	55.56	55.56	1.000	1018.	1018.	1018.	1018.	
1018.	1019.	1019.	1019.	1019.	1019.	1019.	1019.	1019.	1019.	
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55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 52	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56
55.56	55.56	55.56	55.56	55.56	1.000	1018.	1018.	1018.	1018.	
1018.	1018.	1018.	1018.	1019.	1019.	1019.	1019.	1019.	1018.	
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55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 53	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56
55.56	55.56	55.56	55.56	55.56	1.000	1018.	1018.	1018.	1018.	
1018.	1018.	1018.	1018.	1018.	1018.	1018.	1018.	1018.	1018.	
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55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	
0 54	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56	55.56
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1017.	1018.	1018.	1018.	1018.	1018.	1018.	1018.	1018.	55.56	
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1016.   1016.   1016.   1016.   1016.   1016.   55.56   55.56   55.56   55.56
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0 60  55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
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55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
1            HEAD IN LAYER  2 AT END OF TIME STEP  1 IN STRESS PERIOD  2
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1     2     3     4     5     6     7     8     9     10
11    12    13    14    15    16    17    18    19    20
21    22    23    24    25    26    27    28    29    30
31    32    33    34    35    36    37    38    39    40
41    42    43    44    45    46    47    48    49    50
51    52    53    54    55    56    57    58    59    60
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0 1  55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
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0 36	55.56	55.56	55.56	55.56	55.56	55.56	55.56	1011.	1013.	1014.
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55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
56.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
0 56  55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   1016.   1016.   1016.   1016.
1017.   1017.   1017.   1017.   1017.   1017.   1021.   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
0 57  55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   1015.   1016.   1016.   1016.
1016.   1016.   1016.   1016.   1016.   1017.   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
0 58  55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   1015.   1015.   1015.   1015.
1015.   1015.   1016.   1016.   1016.   1020.   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
0 59  55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   1014.   1014.   1015.   1015.
1016.   1015.   1018.   1019.   1019.   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
0 60  55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56   55.56
0HEAD WILL BE SAVED ON UNIT 30 AT END OF TIME STEP  1, STRESS PERIOD  2
          0

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  1 IN STRESS PERIOD  2
-----------------------------------------------------------------------------
0          CUMULATIVE VOLUMES     L**3                RATES FOR THIS TIME STEP     L**3/T
---------------                   -------------------

IN:                               IN:
---                               ---
STORAGE =  0.69012E+06                   STORAGE =  229.96
CONSTANT HEAD =  0.00000E+00                   CONSTANT HEAD =  0.00000E+00
WELLS =  0.00000E+00                    WELLS =  0.00000E+00
RECHARGE =  0.33652E+07                     RECHARGE =  1812.5
RIVER LEAKAGE =  0.47099E+07                  RIVER LEAKAGE =  2535.7
HEAD DEP BOUNDS =  0.31071E+08                   HEAD DEP BOUNDS =  16745.
0             TOTAL IN =  0.39836E+08                     TOTAL IN =  21323.
0            OUT:                                  OUT:
----                              ----
STORAGE =  0.13888E+07                   STORAGE =  630.60
CONSTANT HEAD =  0.00000E+00                   CONSTANT HEAD =  0.00000E+00
WELLS =  124.17                       WELLS =  0.66900E-01
RECHARGE =  0.00000E+00                     RECHARGE =  0.00000E+00
RIVER LEAKAGE =  0.26302E+07                  RIVER LEAKAGE =  1401.5
HEAD DEP BOUNDS =  0.35760E+08                   HEAD DEP BOUNDS =  19260.
0             TOTAL OUT =  0.39779E+08                     TOTAL OUT =  21292.
0              IN - OUT =  57540.                       IN - OUT =  31.248
0        PERCENT DISCREPANCY =          0.14              PERCENT DISCREPANCY =          0.15


          0


TIME SUMMARY AT END OF TIME STEP  1 IN STRESS PERIOD  2
SECONDS     MINUTES     HOURS     DAYS     YEARS
```

TIME STEP LENGTH	0.157766E+09	0.262944E+07	43824.0	1826.00	4.99932
STRESS PERIOD TIME	0.157766E+09	0.262944E+07	43824.0	1826.00	4.99932
TOTAL SIMULATION TIME	0.160358E+09	0.267264E+07	44544.0	1856.00	5.08145

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