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DRAFT OPERABLE UNIT 2 PREDESIGN INVESTIGATION AND SITE SELECTION REPORT FOR THE ON-SITE DISPOSAL FACILITY VOLUME 1 OF 3 - MAIN TEXT - JULY 1995

07/27/95

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REPORT

PREDESIGN INVESTIGATION AND SITE SELECTION REPORT FOR THE ON-SITE DISPOSAL FACILITY

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

VOLUME 1 OF 3
TEXT

JULY 1995

U.S. DEPARTMENT OF ENERGY

Department of Energy
Fernald Environmental Management Project
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JUL 27 1995

DOE-1277-95

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Dear Mr. Saric and Mr. Schneider:

TRANSMITTAL OF THE DRAFT OPERABLE UNIT 2 PREDESIGN INVESTIGATION AND SITE SELECTION REPORT FOR THE ON-SITE DISPOSAL FACILITY

The Department of Energy, Fernald Area Office (DOE-FN) is pleased to submit the Draft Operable Unit 2 Predesign Investigation and Site Selection Report for the On-Site Disposal Facility for your review and approval.

The DOE-FN plans to initiate the detailed engineering design of the On-Site Disposal Facility in August 1995. Therefore, the DOE-FN would greatly appreciate receiving any comments that you might have regarding the Predesign and Site Selection Report by Wednesday, August 30, 1995. In order to assist you with the evaluation of this report, DOE-FN would be happy to arrange for a telephone conference, or to meet with your representatives in person to discuss any issues or concerns.

If you have any questions, please contact Mr. Rod Warner at (513) 648-3156.

Sincerely,

Johnny Reising

for Jack R. Craig
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LIST OF ACRONYMS AND ABBREVIATIONS

ASL	analytical support level
ASTM	American Society for Testing and Materials
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CGM	course granular material
cm/sec	centimeters/second
CPT	cone penetrometer testing
DOE	U.S. Department of Energy
DQO	data quality objective
DTM	digital terrain model
EPA	U.S. Environmental Protection Agency
FEMP	Fernald Environmental Management Project
FERMCO	Fernald Environmental Restoration Management Corporation
FS	Feasibility Study
ft/year	feet per year
GMA	Great Miami Aquifer
GPR	ground penetrating radar
HELP	Hydrologic Evaluation of Landfill Performance
in/year	inches per year
K_d	distribution coefficient
L/kg	liters/kilogram
μg/L	microgram/liter
mg	milligram
mg/kg	milligram/kilogram
mg/L	milligram/liter
MSL	mean sea level
OAC	Ohio Administrative Code
OEPA	Ohio Environmental Protection Agency
pCi/g	picoCuries/gram
ppm	parts per million
psi	pounds per square inch
PSP	Project Specific Plan
PTI	permit to install
PVC	polyvinylchloride
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

SCQ	Site-Wide CERCLA Quality Assurance Project Plan
SED	Site-Wide Environmental Database
TCLP	toxicity characteristic leaching procedure
TU	tritium units
USCS	Unified Soil Classification System
USGS	U.S. Geological Survey
WAC	waste acceptance criteria

EXECUTIVE SUMMARY

The selected remedy for Operable Unit 2 includes on-site disposal of remediation material. The design of a disposal facility is required as part of Operable Unit 2 remediation action plans and the Record of Decision. Operable Units 3 and 5 are also considering on-site disposal of remediation waste, so the disposal facility will be designed to potentially accommodate waste from three operable units. Initial screening for an acceptable location for the disposal facility was performed using available environmental sampling data. This data was evaluated by using an uncertainty kriging model to determine if enough data was available to ensure accurate geological predictions. The initial model results indicated that an unacceptable uncertainty existed in predicting lithologies for locating a disposal facility. Therefore, a Predesign Investigation was performed to define the most suitable location of the disposal facility within an identified best area at the Fernald Environmental Management Project (FEMP) based on Operable Units 2 and 5 Remedial Investigation/Feasibility Study (RI/FS) investigations.

The identified best area is located on the east side of the FEMP and measures approximately 2000 feet east to west by 5300 feet north to south (Figure ES-1). This area of the FEMP is considered the best location for an on-site disposal facility because it has the greatest thickness of gray clay which provides a protective layer over the Great Miami Aquifer. Fate and transport modeling and risk assessments in the Operable Unit 2 Feasibility Study (FS) Report have shown that a disposal facility in this area, based on a feasible facility design and a 12-foot gray clay layer, would be protective of human health and the environment. The identified best area, shown on Figure ES-1, is bounded on the north, east, and south using the Ohio Environmental Protection Agency (OEPA) siting requirements (buffer from property line and water supply wells). The west boundary incorporates areas with greater than 12 feet of gray clay, with the exception of the northern portion of the west boundary line (above the former Production Area), which was determined based on identification of sand lenses within the gray clay.

Based on planning meetings with the U.S. Department of Energy (DOE), Fernald Environmental Restoration Management Corporation (FERMCO), U.S. Environmental Protection Agency (EPA), and OEPA, the Predesign Investigation included three objectives. Objective 1 was to identify the most suitable hydrogeology in this identified best area on site. The field components involved verification of the gray clay thickness and the identification of interbedded granular material.

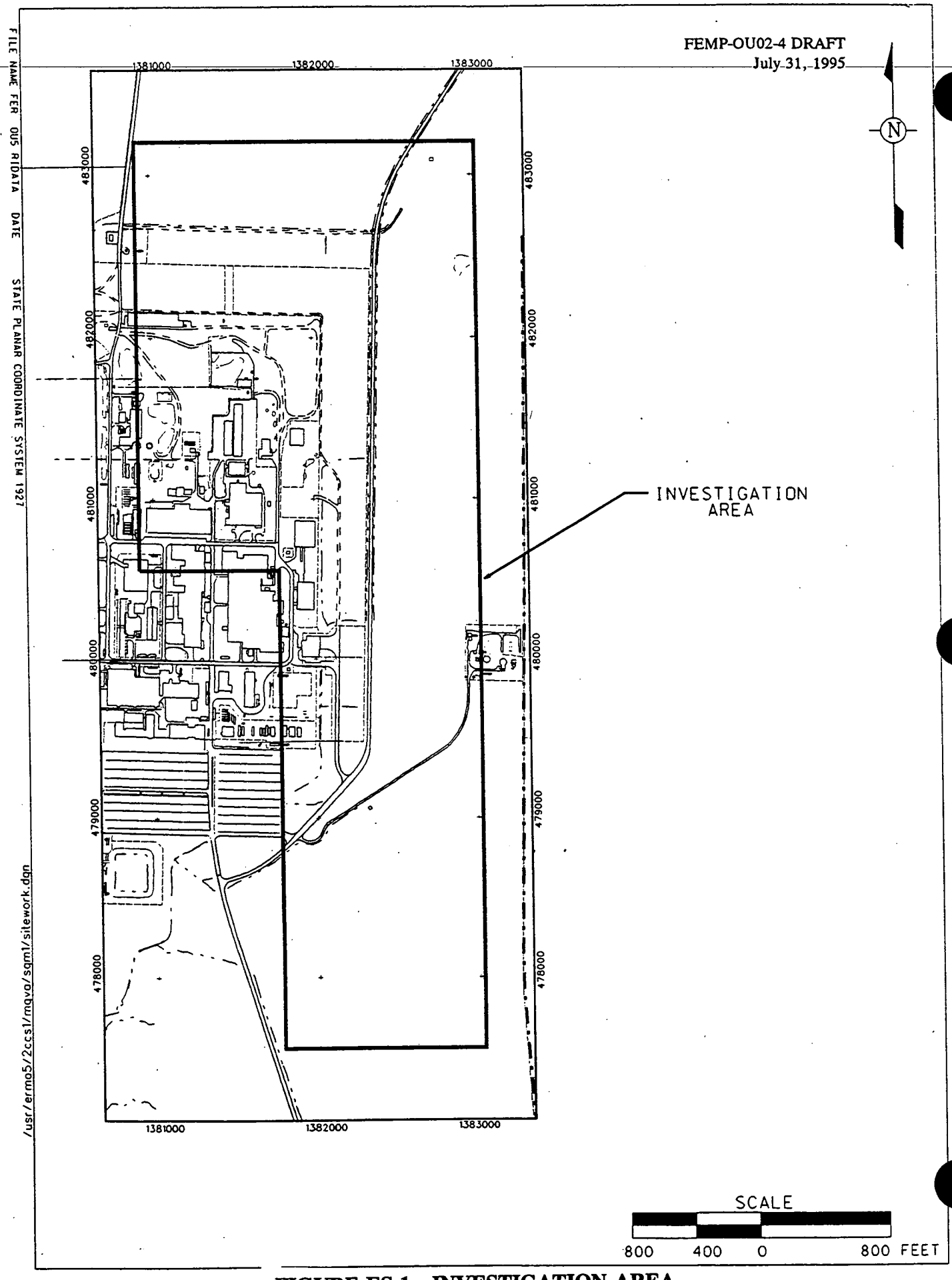

FIGURE ES-1. INVESTIGATION AREA

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Objective 2 was the verification of the protection of human health and the environment. The field components included verification of existing vertical and horizontal uranium contamination; solubility of uranium present; retardation of uranium; lateral and vertical gradients; and background concentrations of uranium in water in the vadose zone (background lysimeters). Objective 3 was to develop field information for the design of the disposal facility. The field components included determining the location and extent of any interbedded granular material and obtaining geotechnical information in the footprint of the disposal facility.

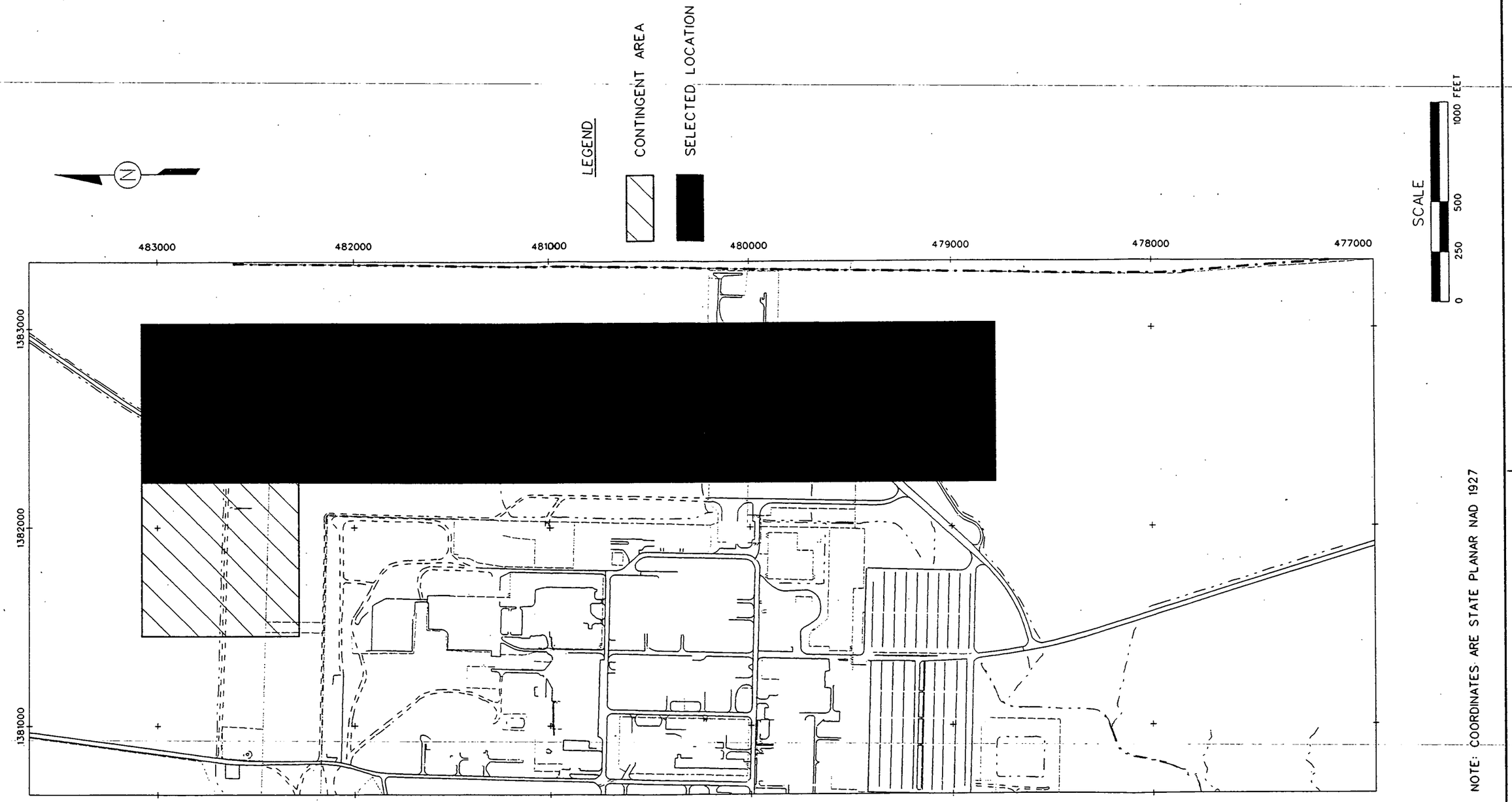
The Predesign Investigation fieldwork was preformed in a phased approach. Phase I included preliminary cone penetrometer testing (CPT) and water level measurements of existing wells. This information was used to obtain a preliminary understanding of the existing lithology and to optimize the sampling locations during the second Phase II. Phase II included the installation and sampling of wells, borings, and lysimeters. Data obtained and analyzed was used to confirm the thickness of the gray clay, identify interbedded course granular materials, verify the protectiveness of human health and environment, and obtain preliminary geotechnical information for the design of the disposal facility. The results of this investigation confirmed that there are no large interconnected bodies of course granular material underlying the selected location. Field and analytical data were obtained and reviewed to verify the protectiveness of human health and the environment. This confirmation was based on a comparison of the hydrogeologic parameters and other assumptions utilized in the FS modeling with the actual field conditions within the selected location and demonstrates that the actual field conditions are more protective of human health and the environment than the assumptions used in FS modeling. A detailed analysis of how the selected location specifically meets the applicable objectives for selecting the best location for the on-site disposal facility is presented in Section 4.0 of this report.

A third phase is being conducted as part of the detailed engineering design, and will be incorporated in the preliminary design submittal. The objective of Phase III is to obtain engineering and geotechnical data necessary for the detailed engineering design of the disposal facility. The data obtained through the Phase III investigation will support engineering analyses for the disposal facility design including: settlement, earthquake stability, structural support, liquefaction potential, slope stability, and other design requirements. Phase III included a CPT program which was completed on time to be included in this report. Additional hydrogeologic data will also be obtained to determine if engineering controls will be required to minimize potential lateral flow pathways.

Based on the results of the Phase I and II investigations, a location has been selected within the identified best area for the on-site disposal facility. This location measures 800 feet by 4300 feet and is shown on Figure ES-2. The location provides suitable space for the anticipated 2.5 million cubic yards of waste and meets applicable OEPA Siting requirements. The gray clay thickness is greater than the minimum 12-foot thickness established in the Operable Unit 2 FS for the protection of the Great Miami Aquifer. The gray clay is actually greater than 15 feet thick within the selected location and approximately 75 percent of the selected location has gray clay that is 20-50 feet thick. The investigation identified minimal amounts of interbedded course granular material and none that would offer a rapid migration pathway through the gray till.

Although a permit to install (PTI), as specified in the Ohio Solid Waste Disposal Regulations, is not required, the on-site disposal facility must meet the substantive requirements of the PTI. Many of the substantive requirements for hydrogeological and geotechnical requirements contained within the PTI are met by this report and other existing reports. An analysis of the achievement of substantive requirements is presented in Section 5.0 of this report.

In order to fully meet the substantive requirements of the PTI and to design the disposal facility, additional activities are needed. A discussion of the upcoming planned field investigations and activities to fully meet the substantive requirements is presented in Section 6.0 of this report.



FERNALD ENVIRONMENTAL RESTORATION MANAGEMENT CORPORATION
FERMC
Fernald Environmental Management Project
U.S. DEPARTMENT OF ENERGY

SELECTED LOCATION FOR THE PROPOSED ON-SITE DISPOSAL FACILITY

DATE 5-2-95
DRAWN R. WILLIAMS

FIGURE ES-2

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1.0

1.0 INTRODUCTION

1.1 PURPOSE

A major component of the selected remedy for Operable Unit 2 is on-site disposal of remediation waste. Operable Units 3 and 5 are also considering on-site disposal of remediation waste, so a disposal facility will be designed to potentially accommodate wastes from three operable units. A predesign investigation was performed to define the most suitable location of the disposal facility within the investigation area at the Fernald Environmental Management Project (FEMP) based on Operable Units 2 and 5 Remedial Investigation/Feasibility Study (RI/FS) investigations.

The investigation area is located on the east side of the FEMP as shown on Figure 1-1. This area of the FEMP is considered the best location for the on-site disposal facility because it has the greatest thickness of gray till, and provides a protective layer over the Great Miami Aquifer (GMA). The brown till thickness was not used in the Operable Unit 2 Feasibility Study (FS) modeling; therefore, any additional protection that the brown till would add to human health and the environment was not included in the FS modeling and will not be addressed in this report.

The purpose of this report is to present the results and conclusions of Phases I and II of the Predesign Investigation and the selection of a disposal facility location. This report summarizes the field investigations, presents the results of related modeling, provides details of the selection process to define the location of the on-site disposal facility and provides a recommended path forward.

An additional investigation, Phase III, is underway to collect information for the detailed design of the disposal facility. This investigation is separate from the Predesign Investigation. However, additional cone penetrometer testing (CPT) data collected during the Phase III investigation has been incorporated into this report to enhance the identification of the most suitable hydrogeology.

1.2 OBJECTIVES OF THE PREDESIGN INVESTIGATION

Based on planning meetings between U.S. Department of Energy (DOE), Fernald Environmental Restoration Management Corporation (FERMCO), U.S. Environmental Protection Agency (EPA), and Ohio Environmental Protection Agency (OEPA), the Predesign Investigation had three objectives. Those objectives were the following:

(1) Verify the most suitable hydrogeology for the disposal facility within the investigation area.

(2) Verify the protectiveness of human health and the environment through a comparison of site-specific parameters to modeling values used in groundwater fate and transport models in the Operable Unit 2 and Operable Unit 5 FSs.

(3) Develop initial information for design of the disposal facility by identifying the initial geotechnical properties of the soil.

The field components and sampling activities associated with each objective are presented in Table 1-1.

TABLE 1-1

OBJECTIVES, FIELD COMPONENTS, AND SAMPLING ACTIVITY

Objective	Field Components	Sampling Activity
1	Verify the gray clay thickness Identify interbedded coarse granular material (CGM)	Define locations for required data by using a kriged three-dimensional model of CGM and the uncertainty of the current model of CGM. Locate first phase of sampling within areas of highest uncertainty. Utilize CPT soundings to minimize damage to the clay and define areas of CGM. Use soil sampling with an auger and "Rotosonic™" drill to confirm CPT interpretations and collect soil samples for analysis, which will be used as data for three-dimensional modeling. Characterize soil borings to locate areas of CGM and the thickest gray clay. Perform water level measurements of existing and new wells to perform inverse modeling to assist in determining connectivity of sands.
2	Verify existing vertical and horizontal uranium contamination. Determine the solubility of uranium. Verify the ability of the brown and gray clay to retard the migration of uranium. Measure the vertical and lateral hydraulic gradients and permeability of the till to estimate vertical flow rates of perched groundwater. Determine the background uranium concentration in the vadose zone	Collect soil samples from the brown and gray clay for total uranium and install nested lysimeters and collect water samples. Analyze samples for chemistry and radioisotopes. Collect soil samples for TCLP uranium analysis. Collect batch samples from the brown and gray clay for the partitioning coefficient (K_d) analysis. Drill and install nested wells to measure hydraulic gradient in brown and gray till. Obtain undisturbed core samples from the borings and test for permeability. Install lysimeters in a background area and collect water samples for total uranium analyses.
3	Identify initial geotechnical properties of the soil	Drill borings and take samples for preliminary geotechnical sampling.

The Predesign Investigation fieldwork was performed in a phased approach. Phase I included preliminary CPT and water level measurements of existing wells. Phase II included the installation and sampling of wells, borings, and lysimeters. Phase III is being conducted as part of the detailed engineering design, and will be incorporated in the preliminary design submittal. The objective of Phase III is to obtain engineering and geotechnical data necessary for the detailed engineering design of the disposal facility. The data obtained through the Phase III investigation will support engineering analyses for the disposal facility design. The only information from Phase III that will be incorporated into this report are the CPTs, which will assist in meeting Objective 1.

1.3 REPORT ORGANIZATION

The results of the Predesign Investigation are presented in Sections 2.0 through 6.0 of this report. The information in this report is organized as follows:

- Section 2.0 describes the field investigation activities and analytical programs, and presents the data and results. Included is a description of the CPT program and how this technology was used to assist in identifying interbedded CGM and optimizing the drilling program.

- Section 3.0 discusses the Inverse Groundwater Modeling and Solid Block Modeling methodologies and results. The inverse modeling results are presented in this section. The discussion of solid block modeling describes how this technology was used to demonstrate the thickness of the gray clay and how the technology enhanced the identification of the location of interbedded CGM.

- Section 4.0 provides a detailed analysis of how the selected location specifically meets the applicable objectives for siting the on-site disposal facility. An analysis of how the presence of extensive areas of CGM was ruled out for the selected location is also presented. Section 4.0 describes how the Predesign Investigation verified the protectiveness of human health and the environment for the actual field conditions for the selected location.

- An analysis of the achievement of substantive requirements is presented in Section 5.0 of this report. Although a Permit to Install (PTI), as specified in the Ohio Solid Waste Disposal Regulations, is not required; the on-site disposal facility must meet the substantive requirements of the PTI. Many of the substantive hydrogeological and geotechnical requirements contained within the PTI are met by this report and other existing reports.

- In order to fully meet the substantive requirements of the PTI, and to design the disposal facility, additional information is needed. A discussion of the upcoming planned activities is presented in Section 6.0 of this report.

2.0

2.0 FIELD ACTIVITIES TO ASSESS POTENTIAL SITES

2.1 INTRODUCTION

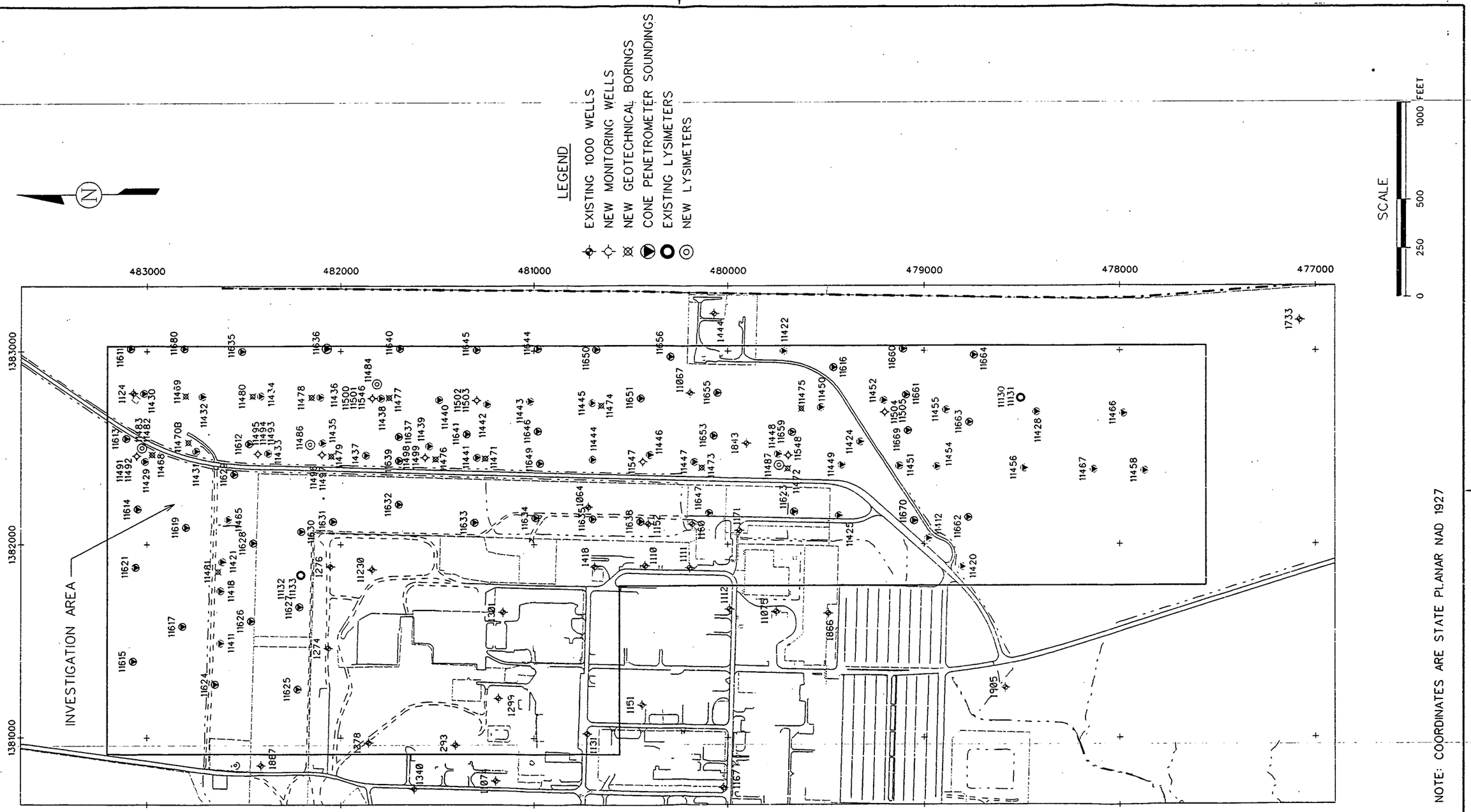
The intent of Section 2.0 is to present a summary of the field activities for the Predesign Field Investigation and the results from those activities.

The field investigation presented in this report was largely conducted in two phases. Phase I consisted of conducting Cone Penetrometer Tests (CPTs) and water level measurements for inverse modeling. Phase II consisted of installing wells, lysimeters, and geotechnical borings. These installations involved the collection of groundwater samples under saturated and unsaturated conditions in the till. These samples were analyzed for total uranium, isotopic uranium, tritium, bromide, chloride, alkalinity, sulfate, nitrate/nitrite, and magnesium. Soil samples were also collected to determine grain size distribution, geotechnical properties, the extent of uranium contamination, and leachability of uranium.

An additional investigation, Phase III, is underway to collect information for the detailed design of the disposal facility. This investigation is separate from the Predesign Investigation. However, additional CPT data collected during the Phase III investigation has been incorporated into this report to enhance the identification of the most suitable hydrogeology.

Prior to the initiation of Phase I and II intrusive sampling activities, the study area was investigated and evaluated for potential cultural resources (as required by Section 106 of the National Historic Preservation Act), as well as any natural resources such as wetlands and threatened or endangered species (as required by the National Environmental Policy Act). The results of the cultural resources investigation demonstrated that there will be no impact on the location or construction of the disposal facility. For a detailed discussion of the cultural and natural resource investigation please refer to Appendix L.

The study area along with the locations of the completed geotechnical borings, wells, lysimeters, and Phase I & III CPTs are shown on Figure 2-1.



FERNALD ENVIRONMENTAL RESTORATION MANAGEMENT CORPORATION
FERMCO
Fernald Environmental Management Project
U.S. DEPARTMENT OF ENERGY

PRE-DESIGN INVESTIGATION
MONITORING WELL, BORING, LYSYMETER, AND CONE PENETROMETER LOCATIONS

DATE 5-2-95
DRAWN R. WILLIAMS

FIGURE 2-1

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2.2 CONE PENETROMETER TESTS

2.2.1 Objectives

CPTs were conducted to assist in locating interbedded coarse granular material in support of identifying the most suitable hydrogeology for the on-site disposal facility as part of Objective 1 (See Section 1.0).

The 40 CPT Phase I locations were selected by three-dimensional modeling of uncertainties (see Section 3.2) to complement existing data in the following areas:

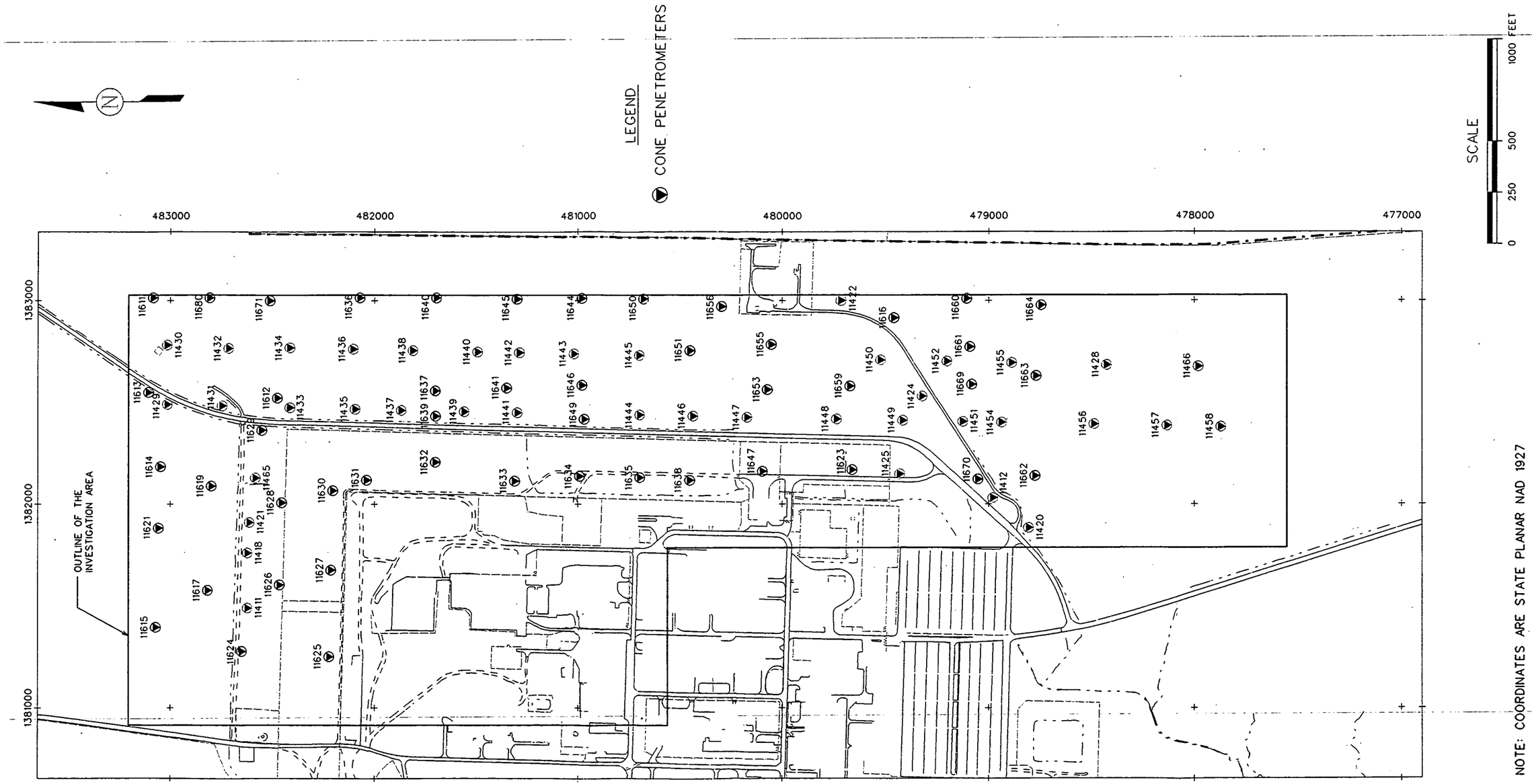
- where existing lithological sampling was sparse, but the existing data were relatively homogenous with respect to the detection of clay or sand materials; and
- where existing data were inconclusive concerning clay or sand. These areas are possibly geologically heterogeneous and were selected for additional characterization.

These sampling locations were selected to increase the certainty in the geological interpretation of the study area.

As part of the detailed design investigation (Phase III), 48 additional CPT soundings were conducted. The additional CPT data from the Phase III investigation were available for lithologic interpretation and were used to update solid block modeling of the coarse granular zones in the study area. The Phase III CPT results enhanced the identification of the best hydrogeology for the disposal facility. The locations of the Phase I and III CPTs are shown on Figure 2-2.

2.2.2 Procedures and Field Activities

A detailed description of the CPT operation is provided in the Project Specific Plan for Phases I and II of the Predesign Investigation. End bearing resistance (tip resistance), friction resistance (sleeve stress), and pore water pressure were measured with a probe. CGM for this investigation is considered soil that is silty sands, sands, and gravels. This distinction was made because it is assumed the CGM has greater hydraulic conductivity than smaller grained material. Instantaneous resistance and pore pressure were recorded by data logging equipment in the truck.



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CONE PENETROMETER LOCATIONS

DATE 4-28-95
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FIGURE 2-2

FILE NAME: /2ccs1/dgn/map/hor/dpth/ph20009.dgn

Adjustments were made to account for the relative positions of each measuring device on the probe so that data were compared at the same depth below ground level at each location. For example, tip resistance was measured approximately 0.3 feet lower on the probe than sleeve stress; therefore, sleeve stress data was adjusted downward 0.3 feet to correlate with tip resistance at the same location.

Calibration of the CPT results was performed by a comparison to soil descriptions from adjacent soil borings and the results of grain size distribution tests. The mechanical/electrical precision for the method is stated to be ± 5 to 10 percent in end bearing resistance and ± 10 to 20 percent in friction resistance. The CPT holes were abandoned by overdrilling with an 8-inch auger and filling with a Type-K expanding portland cement grout, using the Tremie method (ASTM 5299). This overdrilling and filling with expansive grout was done to reduce potential pathways for groundwater migration.

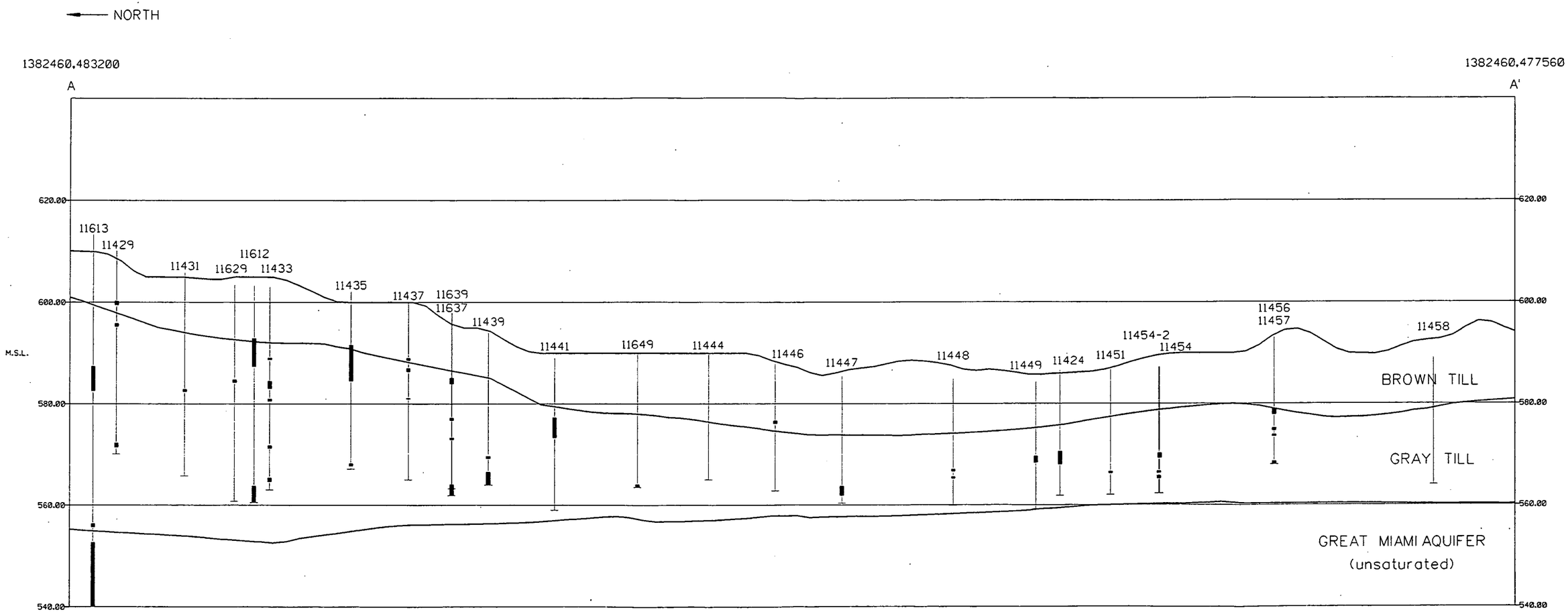
2.2.3 CPT Data Collected

Using data from CPT soundings, zones of potential granular material were identified and used as input for modeling activities and graphical methods to estimate the extent and interconnectiveness of granular material. Figures 2-3 and 2-4 show cross sections that contain the intervals of CGM identified from the CPT locations along the A-A' and B-B' traverses (see Figure 2-6).

During Phase I activities, CPT soundings were advanced at 40 locations. Sounding depths ranged from 25 to 40 feet below ground level. Each sounding was projected to terminate approximately five feet above the top of the GMA. During Phase III activities, CPT soundings were advanced at 48 locations. Each sounding was again projected to terminate approximately five feet above the top of the GMA, except at 12 planned locations where the GMA was penetrated outside of the footprint of the disposal facility. The planned depth at these locations was 100 feet in order to obtain engineering data for the detailed design of the disposal facility.

2.2.4 Results

Data from the CPT soundings were used to identify potential zones of CGM which included gravel, sand, and silt. These inferred granular zones constitute approximately five percent of the CPT sounding profiles in the lithologic sections considered to be above the GMA. These zones may represent encounters with large gravel or cobble size particles in a clay matrix rather than zones of interbedded CGMs. Visual field classifications of Rotasonic™ and geotechnical borings strongly support this assessment.



LEGEND

INTERPRETED LOCATIONS OF COARSE GRAINED MATERIAL

CONE PENETROMETER

HORIZONTAL SCALE: 0 200' 400' 800'

VERTICAL SCALE: 0 10' 20' 40'

NOTE:

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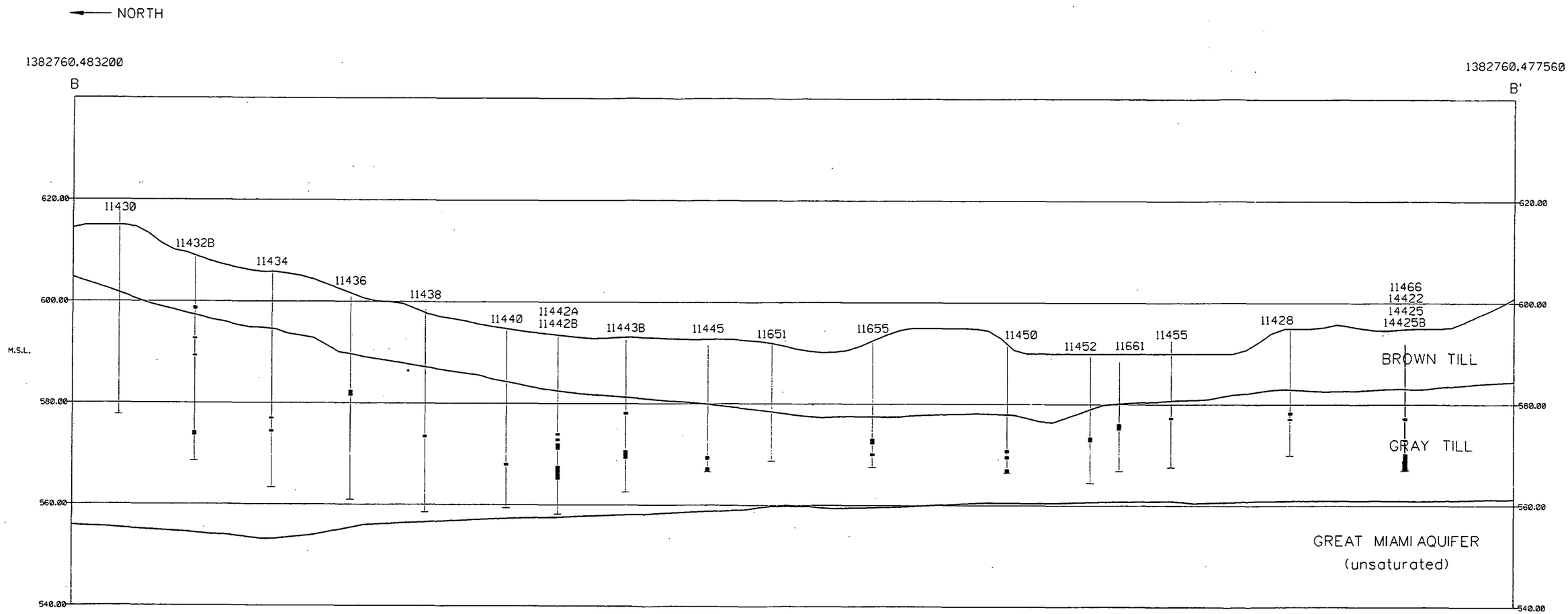
COARSE GRAINED MATERIAL INTERPRETED FROM CONE PENETROMETER RESULTS
SECTION A-A'

DATE 06/06/95
DRAWN DEG

FIGURE 2-3

FILE NAME: /usr/erma5/2ccs1/dgn/sec/geo/dpth/cpt_a.dgn



LEGEND

INTERPRETED LOCATIONS OF COARSE GRAINED MATERIAL

CONE PENETROMETER

HORIZONTAL SCALE: 0 200' 400' 800'
VERTICAL 0 10' 20' 40'

NOTE:

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COARSE GRAINED MATERIAL INTERPRETED FROM CONE PENETROMETER RESULTS
SECTION B-B'

DATE 06/06/95
DRAWN DEG

FIGURE 2-4

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FILE NAME: /usr/erma5/2ccs1/dgn/sec/geo/dpth/cpt_b.dgn

Graphs for each CPT are provided in Appendix E and present sleeve stress, corrected tip resistance, friction ratio, and pore pressure as a function of depth below ground level. An empirical method was used to evaluate CPT data in order to define lithologic profiles at each CPT location and to identify potential zones of CGM.

Multiple CPT soundings were made at 17 CPT locations for lithological confirmation, or because mechanical difficulties prevented penetration to the proposed depth. Each repeat CPT sounding location was approximately two feet from the original sounding. Twenty-nine borings were placed near 16 Phase I CPT soundings. These borings were placed either by Rotasonic™ methods for the purpose of installing monitoring wells or lysimeters, or by conventional hollow-stem auger methods to obtain geotechnical samples for analysis and confirm CPT data. Table 2-1 lists all CPT locations and indicates each peripheral soil boring and its approximate distance from the CPT. Correlation between these borings and CPTs demonstrated that the CGM had a limited areal extent, which indicated the heterogeneity of the till.

Data from closely grouped CPTs were also reviewed to assist in determining the potential extent of CGM. One representative case is the evaluation of CPTs 11442A and B. Similarities exist between these two soundings. However, in CPT 11442A, at the 26- to 28-foot interval, high tip resistance and elevated sleeve stress was interpreted as a sandy zone. Whereas in CPT 11442B, which was only two feet away, evidence of increased tip resistance and sleeve stress was noted. This analysis of grouped or paired CPT data indicates that zones of sand or other coarse fractions apparently have limited areal extent, thereby demonstrating the heterogeneous nature of the till and showing low potential for interconnectability of the coarse grained material over large areas.
One primary lithologic distinction is the brown-gray clay interface, which is defined primarily as a color change from a typically reddish brown color to a gray to olive-gray color. When comparing CPT data to boring logs in which the brown-gray clay interface was defined, no systematic pattern was observed which could be used to accurately predict the location of the brown-gray clay interface.

The CPTs were valuable in helping to determine zones of interbedded CGM within the till. These data were added to the solid block modeling (see Section 3.2) for an enhanced lithologic interpretation. Also, CPT data were significant in demonstrating heterogeneity of the till; the zones of coarse grained material were localized making the potential for interconnectability low.

TABLE 2-1

SUMMARY OF DISTANCES OF SOIL BORINGS FROM ADJACENT CPT LOCATIONS

CPT	Geotech Boring	Distance From CPT	Well	Distance From CPT	Well	Distance From CPT	Well	Distance From CPT	Well	Distance from CPT
11411										
11418										
11420										
11421	11481	40.6								
11422										
11424										
11425										
11428										
11429	11468	5.6	11482	7.4	11483	14.6	11491	12.7	11492	0.3
11430										
11431	11470	32.3								
11432										
11433			11493	5.5	11494	12.5	11495	15.6		
11434	11480	5.3								
11435	11479	4.7	11496	2.9	11497	8.8				
11436	11478	0.9								
11437										
11438	11477	9.6	11500	1.5	11501	14.5				
11439	11476	5.5	11498	9.0	11499	8.9				
11440										
11441	11471	43.2								
11442			11502	8.3	11503	11.8				
11443										
11444										
11445	11474	9.1								
11446										
11447	11473	9.3								
11448	11472	9.5								
11449										
11450	11475	101.3								
11451										
11452			11504	12.0	11505	19.6				
11454										
11455										
11456										
11457										
11458										
11565										
11466										

2.3 WELL INSTALLATION AND SAMPLING

2.3.1 Objectives

There were 18 wells installed as part of the Predesign Investigation Phase II (Figure 2-5). The objectives of the installations were to (1) identify interbedded and interconnected granular material in the till; (2) verify existing uranium concentrations in the till and perched groundwater; (3) identify the solubility of uranium (TCLP) present in the till; and (4) identify lateral and vertical perched groundwater gradients. The locations for these wells were selected using a three-dimensional uncertainty model which was generated from the Site-Wide Environmental Database (SED) and Phase I CPT data, and were determined the best locations for assessing hydrologic conditions of the perched groundwater. A discussion of the three-dimensional uncertainty modeling is included in Section 3.2. The wells were located in areas that had the highest uncertainties for CGM. Consequently, the lithological descriptions from the wells reduced the uncertainty of the location of the CGM.

2.3.2 Drilling Procedures and Field Activities

The wells were installed according to the Site-Wide CERCLA Quality Assurance Project Plan (SCQ) using a Rotasonic™ drill rig. Some of the wells were drilled deeper than the screened intervals. After it was determined what interval was the best for screening, the well boreholes were grouted up to the screened interval. A detailed description of the procedures is in the Project Specific Plan for Phase I and Phase II of the Operable Unit 2 Predesign Investigation and in Appendix L of this report.

2.3.3 Perched Groundwater Sampling for the Predesign Investigation Wells

2.3.3.1 Sample Types Collected and Analyzed

Groundwater sampling was conducted after the newly drilled wells were developed according to the SCQ. Parameter specific and general sample collection procedures were conducted according to the SCQ and RI/FS QAPP. Field measurements of water temperature, pH, conductivity, and dissolved oxygen were taken and recorded. One round of samples was collected and analyzed at a contract laboratory for alkalinity, bromide, chloride, magnesium, nitrate/nitrite, phosphates, sulfate, isotopic uranium, total uranium, carbonate, and tritium.

2.3.3.2 Perched Groundwater Uranium Results

The analytical results for total uranium and isotopic uranium are shown on Table 2-2. Figure 2-6 shows the traverses for cross sections. The results for total uranium are shown on Figures 2-7 and 2-8 which are cross-sectional views of the wells. The results will be discussed as nested groups, which is how these wells were installed. There are a total of seven nests, five which contain two wells, and two which contain three wells. Also, there are two isolated wells, which are screened across the brown/gray till interface.

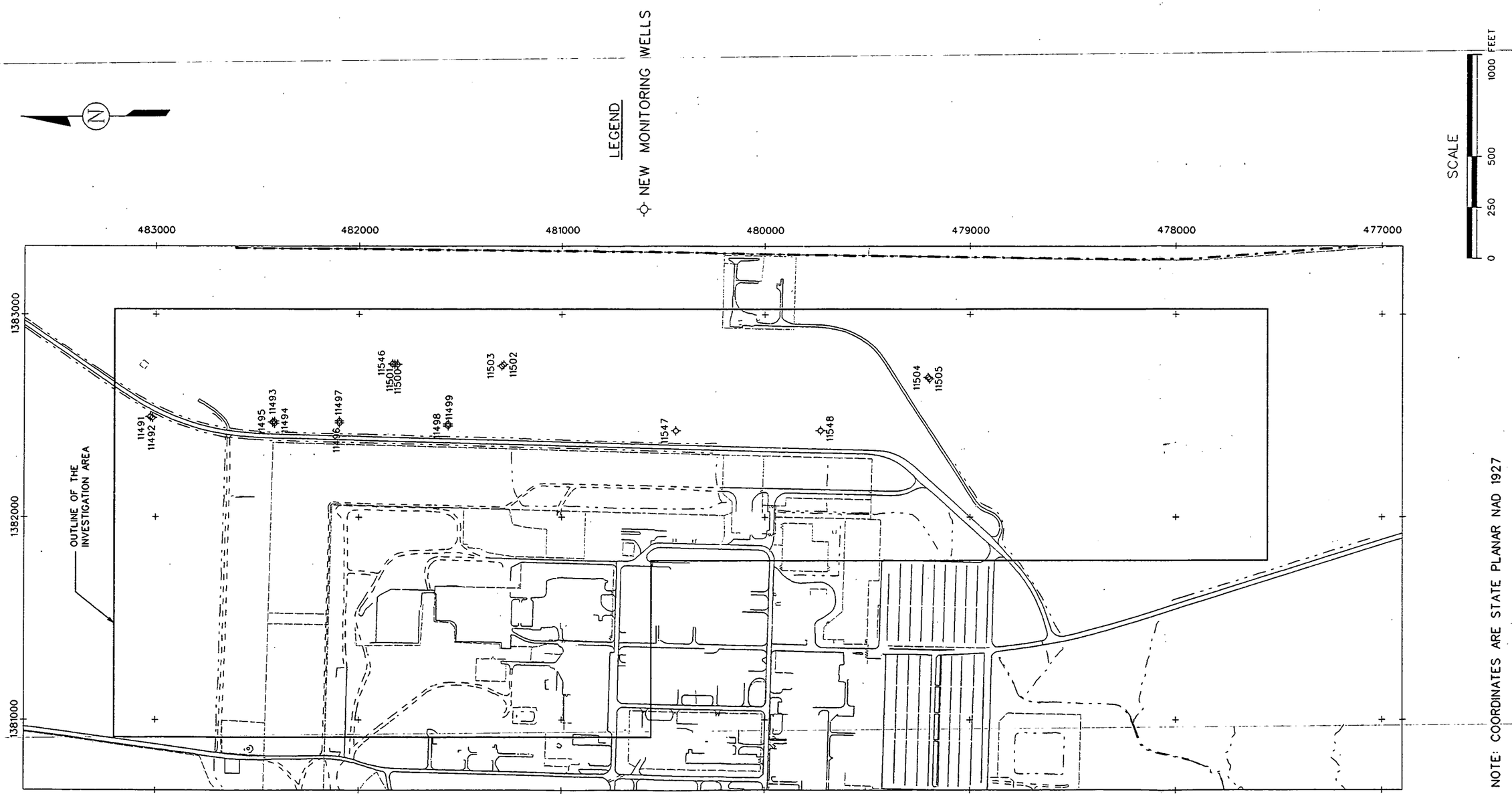
Nest I contains Wells 11491 and 11492. As shown on Table 2-2 and Figure 2-6, total uranium is higher in 11491 (3.1 μg/L) than in 11492 (0.35 μg/L). Well 11491 is screened from 586.13 feet above Mean Sea Level (MSL) to 581.63 feet above MSL; 11492 is screened from 595.53 feet above MSL to 588.53 feet above MSL.

Nest II, which is south of Nest I, is comprised of Wells 11493, 11494, and 11495. Well 11494 is screened from 595.51 feet above MSL to 587.01 above MSL. Well 11495 is dry and screened from 573.18 feet to 566.68 feet above MSL. The total uranium concentration was 14.44 μg/L for 11493 and 5.8 μg/L for 11494 (for reference, the established FEMP 95th percentile background level for total uranium is 4.0 μg/L).

Nest III, which is south of Nest II, contains Wells 11496 and 11497. Well 11496 is screened from 593.65 to 585.65 feet above MSL. It has a total uranium value of 1.7 μg/L (Figure 2-6). Well 11497, which is the deeper well and screened from 574.34 feet to 570.34 feet above MSL, has a total uranium concentration of 5.3 μg/L.

Nest IV, south of Nest III, contains Wells 11498 and 11499. These wells are screened from 567.6 feet to 561.6 feet above MSL and 579.68 feet to 572.68 feet above MSL, respectively. The total uranium value for 11498 is 2.6 μg/L. Well 11499 has a total uranium value of 9.4 μg/L.

Nest V is located east and south of Nest III and is comprised of Wells 11500, 11501, and 11546. The screened intervals are from 579.93 feet to 573.43 feet (11500), 565.97 feet to 561.97 feet (11501), and 589.9 feet to 585.9 (11546) feet above MSL. The total uranium values were 3.4 μg/L for Well 11500 and 0.58 μg/L for well 11501, which is the deeper well. There is no uranium value available for 11546.



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NEW MONITORING WELL LOCATIONS

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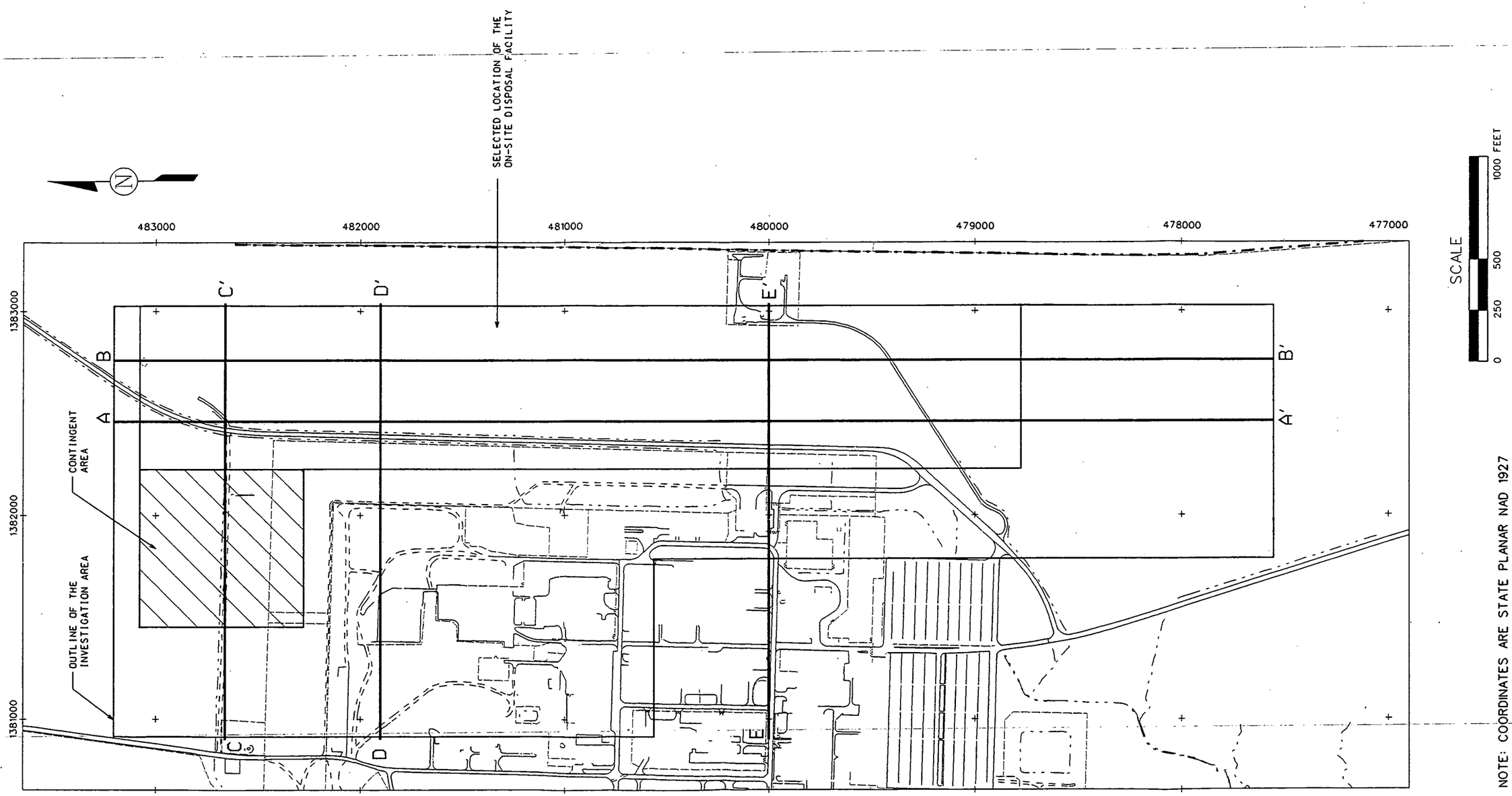
FIGURE 2-5

FILE NAME: /2ccs1/dgn/map/hor/dpth/ph20010.dgn



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CROSS-SECTION LOCATION MAP

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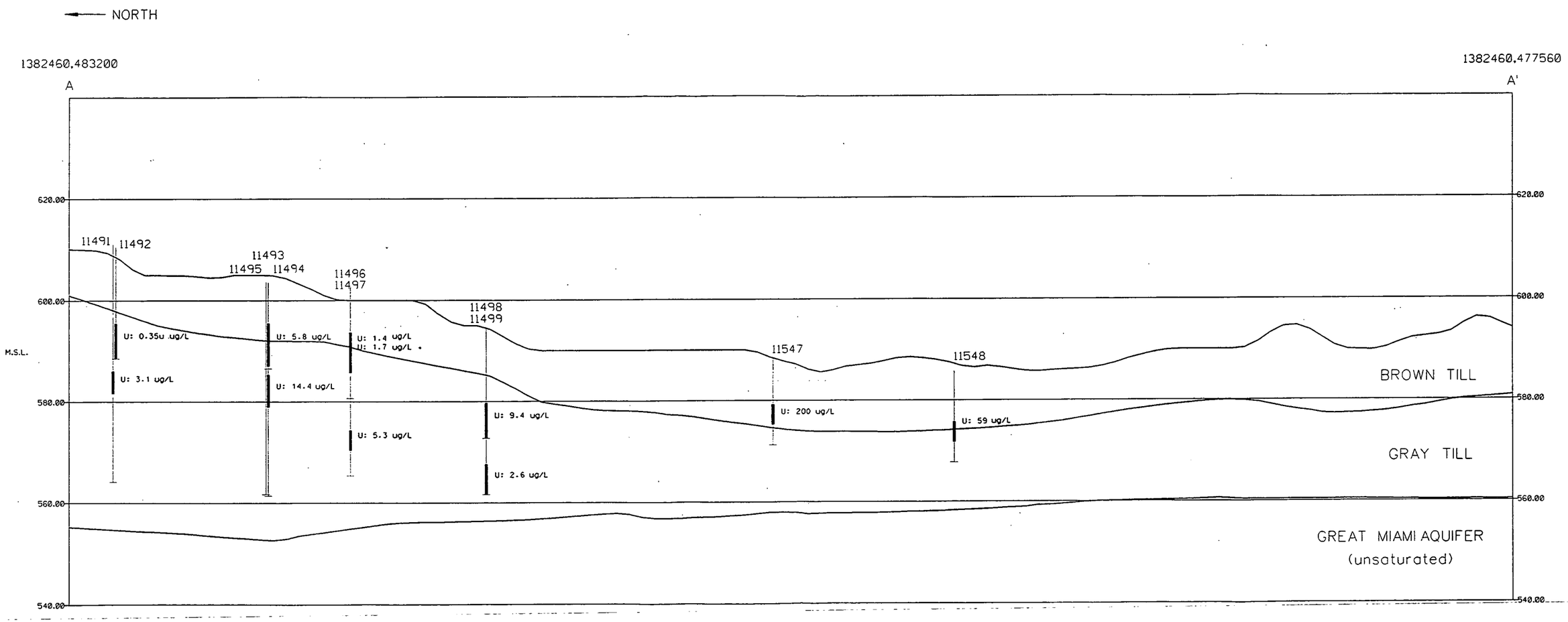
FIGURE 2-6

FILE NAME: /2ccs1/dgn/map/hor/dpth/ph20048.dgn



LEGEND

SAMPLE INTERVAL

MONITORING WELL

U: URANIUM TOTAL

HORIZONTAL SCALE: 0 200' 400' 800'

VERTICAL 0 10' 20' 40'

NOTE:

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URANIUM FOR WATER

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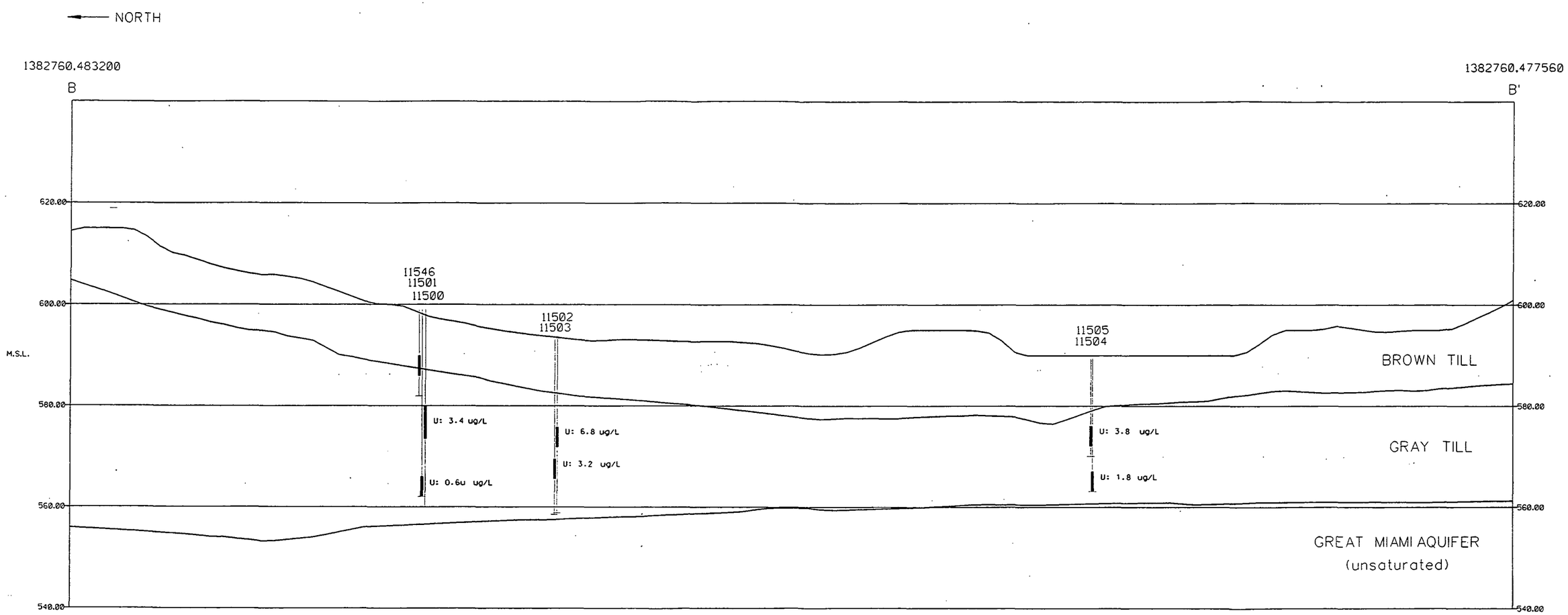
DATE 05/03/95
DRAWN DEG

FIGURE 2-7

FILE NAME: /usr/ermo5/2ccs1/dgn/sec/geo/dpth/chem_u_a.dgn



LEGEND

SAMPLE INTERVAL

MONITORING WELL

U:. URANIUM TOTAL

HORIZONTAL SCALE: 0 200' 400' 800'
VERTICAL 0 10' 20' 40'

NOTE:

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URANIUM FOR WATER
000035

DATE 05/04/95
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FIGURE 2-8

FILE NAME: /usr/erma5/2ccs1/dgn/sec/geo/dpth/chem_u_b.dgn

TABLE 2-2

GROUND WATER RESULTS FOR TOTAL URANIUM, ISOTOPIC URANIUM, AND TRITIUM

Well #	Ground Surface above MSL	Screened Int. (feet) BGL	Brown/Gray Interface (feet) BGL	Total U (ug/L)	U 238 (pCi/L)	U 235/236 (pCi/L)	U 234 (pCi/L)	Tritium (TU)
NEST I								
11491	611.13	25.0 - 29.5	12.5	3.1 J	0.81 J	0.031 U	0.98 J	7.77
11492	610.53	15.0 - 22.0	8.5	0.35 U	0.96 J	0.023 U	1.6 J	2.06
NEST II								
11493	603.38	18.0 - 24.5	13.5	14.44 -	6.04 J	0.332 UJ	13.8 J	5.46
11494	603.51	8.0 - 16.5	10.5	5.8 J	1.2 J	0.044 U	1.2 J	14.5
11495	603.68	30.5 - 37.0	11.0	NA	NA	NA	NA	NA
NEST III								
11496	602.65	9.0 - 17.0	9.5	1.4 J	0.54 J	0.055 U	0.81 J	17.2
11497	602.34	28.0 - 32.0	9.0	5.3 J	2.5 J	0.169 J	4.36 J	1.33
NEST IV								
11498	594.60	27.0 - 33.0	7.0	2.6 J	1.8 J	0.099 J	3.1 J	1.85
11499	594.68	15.0 - 22.0	9.0	9.4 -	3.3 J	0.102 J	6.2 J	4.55
NEST V								
11546	598.90	9.0 - 13.0	13.5	NA	NA	NA	NA	17.3
11500	598.93	19.0 - 25.5	12.0	3.4 J	0.077 J	0.026 J	1.6 J	9.7
11501	598.97	33.0 - 37.0	10.5	0.58 U	0.33 J	0.034 J	0.54 J	21.8
NEST VI								
11502	593.79	18.0 - 22.0	13.5	6.78 J	3.12 J	0.128 J	4.94 J	8.5
11503	593.47	24.0 - 28.0	12.0	3.2 J	1.4 J	0.037 J	1.7 J	12.1
NEST VII								
11504	590.02	14.0 - 18.0	14.8	3.8 J	2 J	0.051 J	2.9 J	15.7
11505	590.08	23.0 - 27.0	9.8	1.8 J	1.1 J	0.042 J	3.2 J	10.9

TABLE 2-2
(Continued)

Well #	Ground Surface above MSL	Screened Int. (feet) BGL	Brown/Gray Interface (feet) BGL	Total U (ug/L)	U 238 (pCi/L)	U 235/236 (pCi/L)	U 234 (pCi/L)	Tritium (TU)	
NONNESTED									
11547	588.22	9.0 - 13.0	11.5	198.91 J	56.6 J	2.50 J	62.3 J		12.2
11548	585.72	10.0 - 14.0	13.0	59.91 J	15.0 J	0.544 J	19.1 J		19.5

MSL = Mean Sea Level
BGL = Below Ground Level
NA = Not Analyzed

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Nest VI, which south of Nest V, is made up of Wells 11502 and 11503. These wells are screened from 575.79 feet to 571.79 feet (Well 11502), and 569.47 feet to 565.47 feet above MSL. The total uranium concentration for 11503 was 3.2 μg/L, and for 11502 was 6.8 μg/L.

Nest VII, which is the nest furthest south, is comprised of Wells 11504 and 11505. The screened intervals for these wells are from 576.02 feet to 572.02 feet (Well 11504), and 567.08 feet to 563.08 feet (Well 11505) above MSL. The total uranium concentrations are 3.8 μg/L for well 11504 and 1.8 μg/L for well 11505.

There were two isolated wells, Wells 11547 and 11548, and the total uranium results were 198.91 μg/L and 58.91 μg/L, respectively. The nature and extent of these elevated total uranium levels need further investigation.

The brown/gray till interface was the only major lithologic feature in the till that could be identified in every borehole. Five wells were screened across this interface during this investigation; Wells 11547, 11548, 11494, 11496, and 11504. As shown on Table 2-2, the total uranium concentrations ranged from 1.4 μg/L to 200 μg/L.

The total uranium concentrations range from 1.4 μg/L to 200 μg/L for all of the new wells and old well in the study area. These results were used in 3-dimensional modeling and presented in Section 4.3. Also, the uranium concentrations were variable vertically; that is, the uranium concentrations were lower at depth in some nests and higher in others. This may be due to the heterogenous nature of the till. However, the conclusions that can be made from the total uranium results are discussed in Section 4.3.

2.3.3.3 Perched Groundwater Tritium Results

Perched groundwater tritium results ranged from 1.33 TU to 21.8 TU. These concentrations were variable laterally and vertically. Background values for tritium in the region of the FEMP have not been established. Furthermore, the loading of tritium for the FEMP has not been determined. However, for the water samples that contained tritium it may be assumed that the age of this water is no more than approximately 40 years. Also, for water samples with no tritium it can be assumed that the water is older than 40 years. The variability of the tritium concentration results confirmed the heterogeneity of the till.

2.3.3.4 Chemical Results

Six ions were analyzed in the till. Background values for bromide, chloride, sulfate, magnesium, nitrate, and phosphate have been investigated at the FEMP (DOE 1993). The range of values measured in wells completed in the till and observed in background glacial till wells is presented in Table 2-3 and summarized in Table 2-4.

There were concentrations above background for sulfate (1,100 mg/L), nitrate/nitrite (4.02 mg/l), and phosphate (518 μg/L), and magnesium (290 mg/kg). These elevated concentrations may be due to prior agricultural practices in the study area. Alkalinity was also sampled and had results ranging from 3 mg/L to 42,000 mg/L; however, background concentrations are not available. Chloride was within the range of background concentrations, and bromide does not have an established background.

2.3.4 Soil Sampling

2.3.4.1 Soil Sample Types Collected and Analyzed

Samples were collected for total uranium, isotopic uranium, TCLP total uranium, and TCLP isotopic uranium. Also, samples for definition of the retardation of uranium (K_d) were collected from seven of the borings: one from the gray till and one from the brown till for a total of 14 samples.

2.3.4.2 Results

The results from the K_d study are discussed in Section 2.7. The radionuclide results are shown on Table 2-5. The total uranium range is from 1.6 mg/kg to 3.7 mg/kg with a 95th percentile of 3.32 mg/kg (for reference, the established FEMP 95th percentile background level for total uranium in soil is 3.4 mg/kg); therefore, the results are considered within the range of background. The total uranium TCLP results, which were used to determine the solubility of uranium (see Section 4.3), ranged from 2.02 μg/L to 27.53 μg/L.

TABLE 2-3

GROUNDWATER CHEMICAL RESULTS

Well #	Ground Surface above MSL	Screened Int. (feet) BGL	Brown/Gray Interface (feet) BGL	Bromide (ug/L)	Chloride (mg/L)	Sulfate (mg/L)	Magnesium (ug/L)	Alkalinity (mg/L)	Nitrate/Nitrite (mg/L)	Total Phosphorus (ug/L)
NEST I										
11491	611.13	25.0 - 29.5	12.5	100 U	27.4 -	153 -	121000 -	347 -	.1 U	82.6 UJ
11492	610.53	15.0 - 22.0	8.5	100 U	14.5 -	108 -	290000 -	366 -	.2 -	197 UJ
NEST II										
11493	603.38	18.0 - 24.5	13.5	740 -	24.1 -	458 -	71800 -	439 -	2.26 -	205 UJ
11494	603.51	8.0 - 16.5	10.5	100 U	231 -	79.0 -	61000 J	310 -	0.2 U	518 -
11495	603.68	30.5 - 37.0	11.0	NA	NA	NA	NA	NA	NA	NA
NEST III										
11496	602.65	9.0 - 17.0	9.5	100 U	8.62 -	59.7 -	58400 J	379 -	.1 U	187 UJ
11496 DUP	602.65	9.0 - 17.0	9.5	100 U	8.27 -	59.3 -	73800 J	376 -	.1 U	238 UJ
11497	602.34	28.0 - 32.0	9.0	2820 -	9.61 -	74.5 -	168000 -	1580 -	.04 U	173 UJ
NEST IV										
11498	594.60	27.0 - 33.0	7.0	2640 -	14.7 -	152 -	62400 -	1700 -	.1 U	87.1 UJ
11499	594.68	15.0 - 22.0	9.0	2390 -	7.54 -	149 -	73000 -	4200 -	.1 U	230 UJ
NEST V										
11546	598.90	9.0 - 13.0	13.5	740 -	10.0 -	145 -	181000 -	700 -	0.2 U	160 -
11500	598.93	19.0 - 25.5	12.0	1585 -	4.52 -	140 -	79500 -	458 -	.1 U	249 UJ
11501	598.97	33.0 - 37.0	10.5	686	3.51 -	118 -	50200 -	920	.1 U	139 UJ
NEST VI										
11502	593.79	18.0 - 22.0	13.5	464 -	8.37 -	129 -	120000 J	928 -	0.2 U	NR
11503	593.47	24.0 - 28.0	12.0	1280 -	3.44 -	56 -	59900 -	680 -	.1 U	217 UJ
NEST VII										
11504	590.02	14.0 - 18.0	14.8	100 U	3.91 -	59.9 -	39800 J	412 -	0.2 U	NR
11505	590.08	23.0 - 27.0	9.8	100 U	4.34 -	126 -	124000 J	598 -	0.2 U	153 -

See footnotes at end of table

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TABLE 2-3
(Continued)

Well #	Ground Surface above MSL	Screened Int. (feet) BGL	Brown/Gray Interface (feet) BGL	Bromide (ug/L)	Chloride (mg/L)	Sulfate (mg/L)	Magnesium (ug/L)	Alkalinity (mg/L)	Nitrate/Nitrite (mg/L)	Total Phosphorus (ug/L)
NONNESTED										
11547	588.22	9.0 - 13.0	11.5	1160 -	12.2 -	1100 -	105000 -	728 -	4.02 -	121 -
11548	585.72	10.0 - 14.0	13.0	1240 -	12.8 -	239 -	122000 -	460 -	O.1 U	126 J
FIELD BLANK	NA	NA	NA	100 U	0.08 -	.3 U	74.0 U	4 U	.02 U	55.6 -
RINSATE	NA	NA	NA	100 U	0.13 -	.3 U	74.0 U	3 U	.02 U	98.9 -

NOTE:

(1) 11495 is a dry well

MSL = Mean Sea Level
BGL = Below Ground Level
NA = Not Applicable
NR = Not Requested
DUP = Duplicate

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TABLE 2-4

CHEMICALS DETECTED IN GLACIAL TILL WELLS COMPARED TO BACKGROUND VALUES

Chemical	Units	Concentration Detected in Wells During this Study	Concentrations Detected During Background Study[a]
Bromide	μg/L	< 100 - 4640	NA
Chloride	mg/L	0.08 - 27.4	1.4 - 50
Sulfate	mg/L	< 0.3 - 1100	3.24 - 175
Magnesium	mg/L	39.8 - 290	7 - 220
Alkalinity	mg/L	3 - 4200	NA
Nitrate/Nitrite	μg/L	< 0.1 - 4.02	0.012 - 0.30
Phosphate	μg/L	55.6 - 518	26 - 180

[a]Background study report in "Characterization of Background Water Quality for Streams and Groundwater," Fernald Environmental Management Project, Fernald, Ohio. May 1993.

NA = Not analyzed.

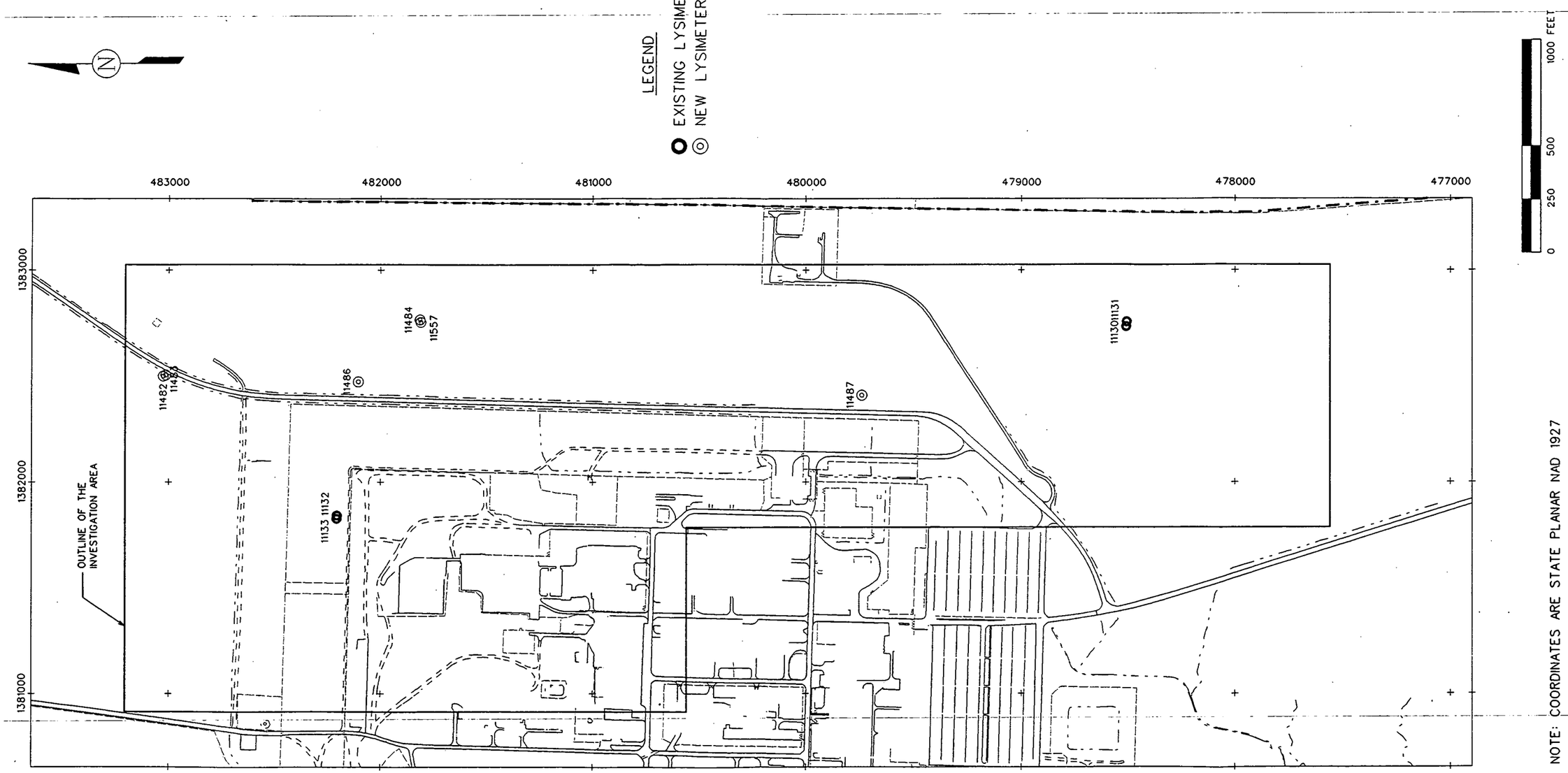
2.4 LYSIMETER INSTALLATION AND SAMPLING

2.4.1 Objectives

Eight lysimeters were installed and sampled. The primary objective was to determine the nature and concentration of uranium in the vadose zone of the till and the unsaturated GMA for the eastern site and for one off-site location. Lysimeters were used in addition to wells since lysimeters can collect samples from unsaturated areas. The data from the off-site location were intended to establish background lysimeter uranium concentrations. Bromide was added as an installation tracer to the lysimeter installation water. Samples were analyzed for bromide and chloride to possibly estimate when the lysimeters were purged of the installation water. A secondary objective was to establish general chemical properties of water collected from the vadose zone.

2.4.2 Procedures and Completed Field Activities

Locations for the lysimeters are shown in Figure 2-9. These locations were selected using three-dimensional solid block modeling (Section 3.2) of the analytical data from the SED and the data collected from CPT. Some of the lysimeters were placed in clusters to monitor the fluid characteristics



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EXISTING AND NEW LYSIMETER LOCATIONS

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FIGURE 2-9

FILE NAME: /2ccs1/dgn/map/hor/dpth/ph20013.dgn

at multiple depths at one location. There are three on-site locations which include two nested lysimeters, one stand-alone lysimeter and one off-site location with three lysimeters. The lysimeters were installed using hand augers and Rotasonic™ drilling, and were completed to depths summarized in Table 2-6. Details of the lysimeter installation is in Appendix E and the PSP for the Operable Unit 2 Predesign Investigation.

2.4.3 Lysimeter Water Sampling and Results

After installing and purging the new lysimeters, samples were collected and analyzed for bromide, chloride, sulfate, magnesium, alkalinity, uranium, and tritium (Table 2-7). During purging, a sample was collected on three occasions and analyzed for bromide, chloride, sulfate, magnesium, and alkalinity. The results of the analyses were used to estimate when, or if, the lysimeters were purged of installation water. Also, existing lysimeters were sampled for the same aforementioned parameters, which assisted in determining ion concentrations. The new lysimeters that were not purged of installation water will have a final round of sampling conducted for the aforementioned parameters, and total uranium and tritium. Installation water was not purged from all of the lysimeters because the yield volumes from the lysimeter sample cups were low; therefore, the required sample volumes could not be obtained for the final round of sampling. However, sampling of these lysimeters will continue as discussed in the Path Forward. The conclusions for the newly installed lysimeters are discussed in Section 4.3.3.

2.4.4 Lysimeter Soil Sampling and Results

During the drilling for the lysimeter installation, soil samples were collected continuously, and described according to ASTM D2488. Soil samples were collected from the interval selected for placement of the lysimeter and analyzed for total uranium, isotopic uranium, TCLP total uranium, and TCLP isotopic uranium. The uranium analytical results assisted in determining the vertical and horizontal extent of uranium contamination and the solubility of detected uranium. All samples were visually described and all sample collection points were surveyed to define the surface elevation and the northing and easting location.

The results of the lysimeter soil sampling are summarized on Table 2-8. Total uranium ranged from 1.5 mg/kg to 2.3 mg/kg (for reference, the established FEMP 95th percentile background level in soil for total uranium is 3.4 mg/kg). The TCLP total uranium concentration of these soils ranged from 1.3 μg/L to 9.9 μg/L. These TCLP results were used to assist in determining the leachability of uranium, which is discussed in Section 4.0.

TABLE 2-5

RADIONUCLIDE RESULTS FOR SOIL FROM WELL BORINGS

Well #	Surface Elevation above MSL (feet)	Sample Interval (feet) BGL	Total U (mg/kg)	U 238 (pCi/g)	U 235/236 (pCi/g)	U 234 (pCi/g)	TCLP Total U (ug/L)	TCLP U 238 (pCi/L)	TCLP U 235/236 (pCi/L)	TCLP U 234 (pCi/L)
NEST I										
11491	611.13	13	3.15 J	0.881 J	0.031 J	0.847 J	2.97 J	2.02 J	0.055 J	3.05 J
		13.5	3.21 J	0.949 J	0.043 U	0.678 U	4.46 J	3.20 J	0.12 J	5.01 J
		27.0 - 29.0	1.89 J	1.06 J	0.052 U	1.01 -	10.92 J	6.90 J	0.332 J	9.88 J
11492	610.53	20.0	2.47 J	0.900 J	0.057 U	0.981 -	2.97 J	2.97 J	0.068 J	3.79 J
NEST II										
11493	603.38	13.0 - 13.5	2.82 -	0.822 J	0.088 J	0.686 -	5.95 J	2.52 J	0.081 J	3.81 J
		13.5 - 14.0	3.32 -	1.12 J	0.032 U	0.947 -	9.84 J	3.72 J	0.120 J	4.98 J
		21.0	2.04 J	0.805 J	0.017 U	0.987 -	8.52 J	3.52 J	0.127 J	5.55 J
11494	603.51	11.0 - 11.5	1.77 J	0.826 J	0.023 U	0.767 -	6.15 J	3.02 J	0.074 J	4.73 J
11495	603.68	33.0	2.64 J	1.05 J	0.018 U	0.969 -	17.48 J	4.36 J	0.155 J	8.04 J
NEST III										
11496	602.65	8.0 - 8.5	2.57 -	0.751 J	0.045 J	0.831 J	5.12 J	1.95 J	0.127 J	2.99 J
		8.5 - 9.0	3.04 -	1.00 J	0.050 U	0.894 J	7.19 J	2.71 J	0.144 J	4.59 J
		13.0	1.94 J	0.605 J	0.051 U	0.599 -	5.71 J	2.70 J	0.157 J	4.60 J
11497	602.34	30.0 - 32.0	1.99 -	0.947 -	0.022 U	0.98 -	10.26 J	3.61 J	0.325 J	5.94 J
		30.0 - 32.0 Dup	2.00 -	0.86 -	0.016 U	0.881 -	NA	NA	NA	NA

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TABLE 2-5
(Continued)

Well #	Surface Elevation above MSL (feet)	Sample Interval (feet) BGL	Total U (mg/kg)	U 238 (pCi/g)	U 235/236 (pCi/g)	U 234 (pCi/g)	TCLP Total U (ug/L)	TCLP U 238 (pCi/L)	TCLP U 235/236 (pCi/L)	TCLP U 234 (pCi/L)
NEST IV										
11498	594.6	6.5 - 7.0	2.69 J	0.846 J	0.082 J	1.03 J	4.64 J	2.03 J	0.077 J	2.39 J
		7.0 - 7.5	2.74 J	0.937 J	0.039 J	0.963 J	5.93 J	2.77 J	0.191 J	3.80 J
		30.0	1.77 -	0.898 J	0.021 U	0.799 -	7.20 J	3.53 J	0.130 J	4.99 J
11499	594.68	18.0	1.69 -	0.704 J	0.06 U	0.845 -	10.29 J	3.31 J	0.294 J	5.45 J
NEST V										
11546	598.9	NA	NA	NA	NA	NA	NA	NA	NA	NA
11500	598.93	10.5 - 11.0	NA	NA	NA	NA	0.010 UJ	2.33 J	0.10 J	3.60 J
		11.0 - 12.0	3.18 -	1.16 -	0.06 J	1.13 -	NA	NA	NA	NA
		12.0 - 12.5	2.59 -	0.757 -	0.015 U	0.825 -	NA	NA	NA	NA
		12.5 - 13.0	NA	NA	NA	NA	7.59 J	2.76 J	0.0156 J	4.62 J
		21.0 - 22.0	1.92 J	0.829 J	0.019 U	0.809 -	6.94 J	2.99 J	0.154 J	4.13 J
11501	598.97	35.0	2.24 J	0.804 J	0.022 U	1.08 -	7.30 J	2.79 J	0.178 J	4.81 J
NEST VI										
11502	593.79	13.0 - 13.5	3.57 -	1.03 J	0.042 J	0.645 -	3.91 J	4.53 J	0.144 J	6.36 J
		13.5 - 14.0	3.35 -	0.968 J	0.056 U	0.837 -	2.40 J	5.35 J	0.238 J	7.63 J
		21.0	1.96 J	1.11 J	0.042 U	0.865 U	5.35 J	3.81 J	0.135 J	6.20 J
11503	593.47	27.0	1.92 J	1.01 J	0.073 J	0.983 -	27.53 J	10.5 J	0.725 J	13.30 J

000046

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TABLE 2-5
(Continued)

Well #	Surface Elevation above MSL (feet)	Sample Interval (feet) BGL	Total U (mg/kg)	U 238 (pCi/g)	U 235/236 (pCi/g)	U 234 (pCi/g)	TCLP Total U (ug/L)	TCLP U 238 (pCi/L)	TCLP U 235/236 (pCi/L)	TCLP U 234 (pCi/L)
NEST VII										
11504	590.02	14.0 - 15.0	2.88 -	1.02 J	0.041 U	0.84 -	3.14 J	2.06 J	0.122 J	2.89 J
		15.0 - 16.0	2.96 J	0.939 J	0.021 U	1.36 -	NA	NA	NA	NA
		15.0 - 16.0	3.71 -	0.941 J	0.035 J	1.09 -	NA	NA	NA	NA
		16.0 - 18.0	1.59 J	0.706 J	0.022 U	0.706 -	2.89 J	2.24 J	0.128 J	3.39 J
11505	590.08	25.0 - 27.0	2.00 J	1.38 J	0.051 J	1.06 -	3.15 J	2.16 J	0.058 J	3.12 J
NONNESTED										
11547	588.22	NA	NA	NA	NA	NA	NA	NA	NA	NA
11548	585.72	NA	NA	NA	NA	NA	NA	NA	NA	NA

Note:
(1) Wells 11546, 11547, 11548 were added as contingency wells to better define the hydrogeologic conditions of the brown/gray till interface, and environmental soil samples were not taken from these locations.

MSL = Mean Sea Level
BGL = Below Ground Level
NA = Not Applicable

TABLE 2-6

PREDESIGN INVESTIGATION LYSIMETER COMPLETION DEPTHS

Lysimeter	Northing (27)	Easting (27)	Ground Surface (feet) MSL	B/G Interface (feet) BGL	Bottom of Boring (feet) BGL	Lysimeter Depth (feet) BGL
11129	478223.14	1378790.47	566.3	7.0	22.5	22.0
11130	478511.04	1382733.42	592.8	11.0	23.0	22.5
11131	478508.32	1382755.64	592.8	11.0	39.0	36.0
11132	482206.62	1381840.99	591.5	10.0	27.0	26.0
11133	482207.87	1381825.52	591.5	10.0	49.0	48.0
11234	478223.42	1378773.37	566.6	7.0	15.8	14.0
11482	483014.42	1382497.15	610.68	-	7.0	5.0
11483	483025.66	1382500.45	611.07	12.0	40.0	34.5
11484	481816.79	1382765.73	598.86	11.2	40.0	37.5
11557	481813.29	1382745.76	598.89	-	8.0	6.6
11486	482104.79	1382474.03	602.31	16.0	39.0	36.5
11487	479740.98	1382409.74	584.99	16.0	27.0	26.5
BACKGROUND LYSIMETERS						
11488	482819.92	1375993.84	579.84	-	7.0	7.0
11558	482821.93	1375959.49	579.99	11.3	47.0	33.5
11559	482819.05	1376008.82	580.22	12.2	48.0	45.5
DELETED BACKGROUND LYSIMETERS						
11489	482819.81	1375991.80	579.87	9.0	37.0	36.0
11490	482820.02	1375989.04	579.92	9.0	48.0	46.5

MSL = Mean Sea Level
BGL = Below Ground Level
B/G = Brown/Gray Till Interface

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2.5 GEOTECHNICAL BORING INSTALLATION AND SAMPLING

2.5.1 Objectives

Fourteen borings (see Figure 2-10) were advanced to collect soil samples to characterize the preliminary engineering properties (geotechnical properties) of the soil for the preliminary design of the disposal facility. These samples were also used to verify existing vertical and horizontal extent of uranium contamination and assist in identifying interbedded CGM. The geotechnical boring locations were determined from three-dimensional uncertainty modeling using data from the SED and data collected during the CPT investigation (Phase I). The modeling discussion is included in Section 3.2. Geotechnical samples were collected from both the brown and the gray till. The lithologic information collected from these geotechnical borings reduced the uncertainty of the location of the CGM.

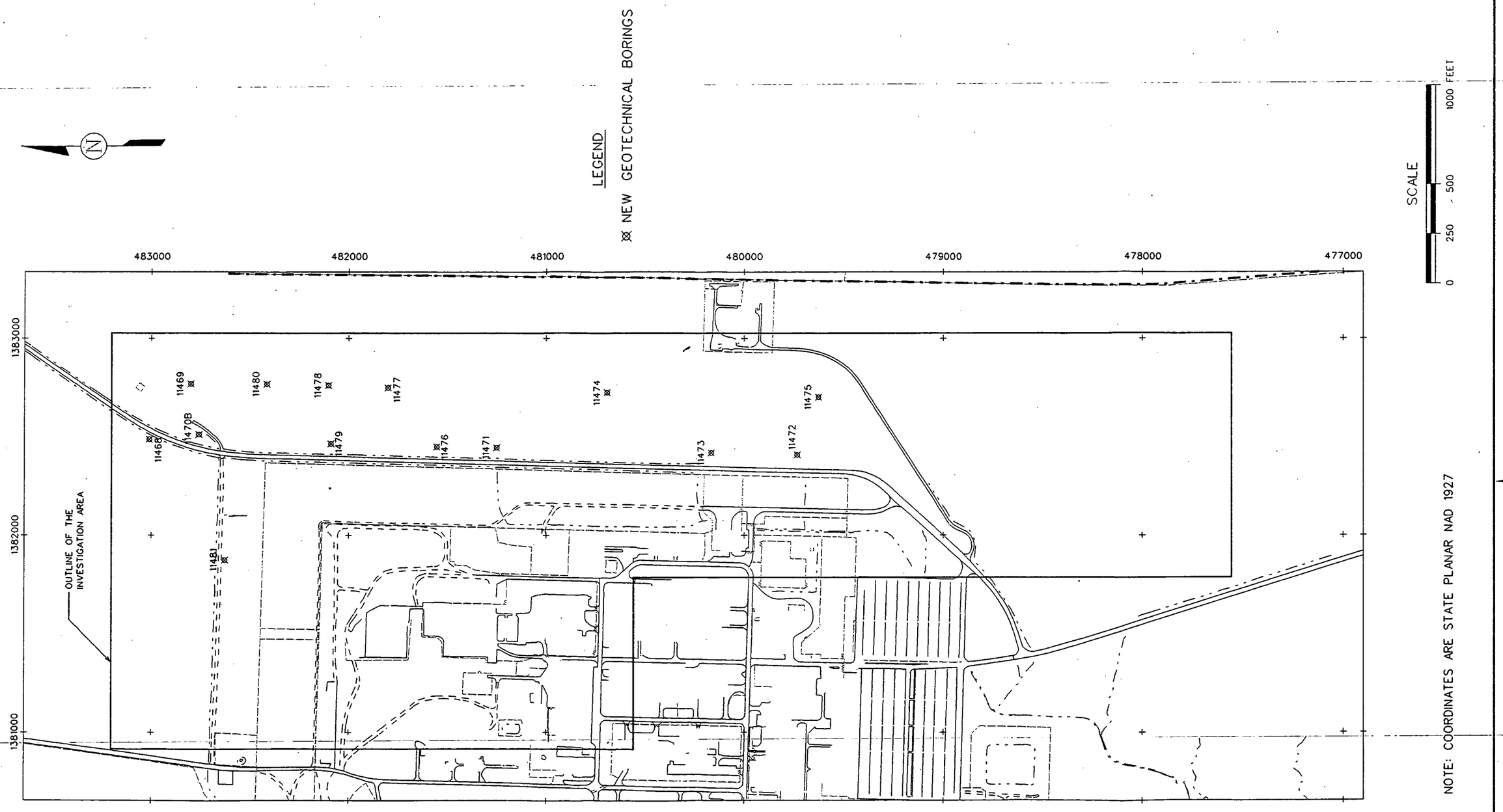
2.5.2 Procedures and Completed Field Activities

Soil samples were collected from 14 soil borings using split-spoon or Shelby tube type samplers. A more detailed discussion for the geotechnical field procedures is included in Appendix L.

2.5.3 Results of Geotechnical Testing

Geotechnical analyses utilized in this study comprise Atterberg Limits, particle size measurements, water content measurements, and permeability tests. The data were graphically analyzed to reveal possible relationships between depth, grain size distribution and permeability. Unit weights and measured water content for soils were used to define percent saturation, which was compared to water levels.

Grain size analyses which assisted in identifying CGM for use in the 3-dimensional modeling (Section 3.2), are provided in Appendix D and are summarized in Table 2-9. Soil samples were poorly-sorted mixtures of clay and silt with variable percentages of sand and gravel. Eighty-one percent of the samples were classified as clay; i.e., lean clay, lean clay with sand, sandy lean clay, and fat clay. Silt and clay percentages are displayed on cross sections (Figures 2-11 and 2-12; Figure 2-6 shows the traverses for these sections) to demonstrate the lateral and vertical distribution of the clay and silt. The cross sections demonstrated that the clay and silt percentages vary vertically and laterally which illustrates the heterogeneity of the till. Graphs of percent 'clay plus silt' and 'sand plus gravel' with depth are provided in Figures 2-13 and 2-14. These graphs indicate that the till from 0 to 10 feet (brown till) contained significantly less sand and gravel than the gray till. This is indicated by the 80 percent silt plus clay from 0 to 10 feet on Figure 2-13. The average grain size distribution for samples collected from 10 to 30 feet



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GEOTECHNICAL BORING LOCATIONS

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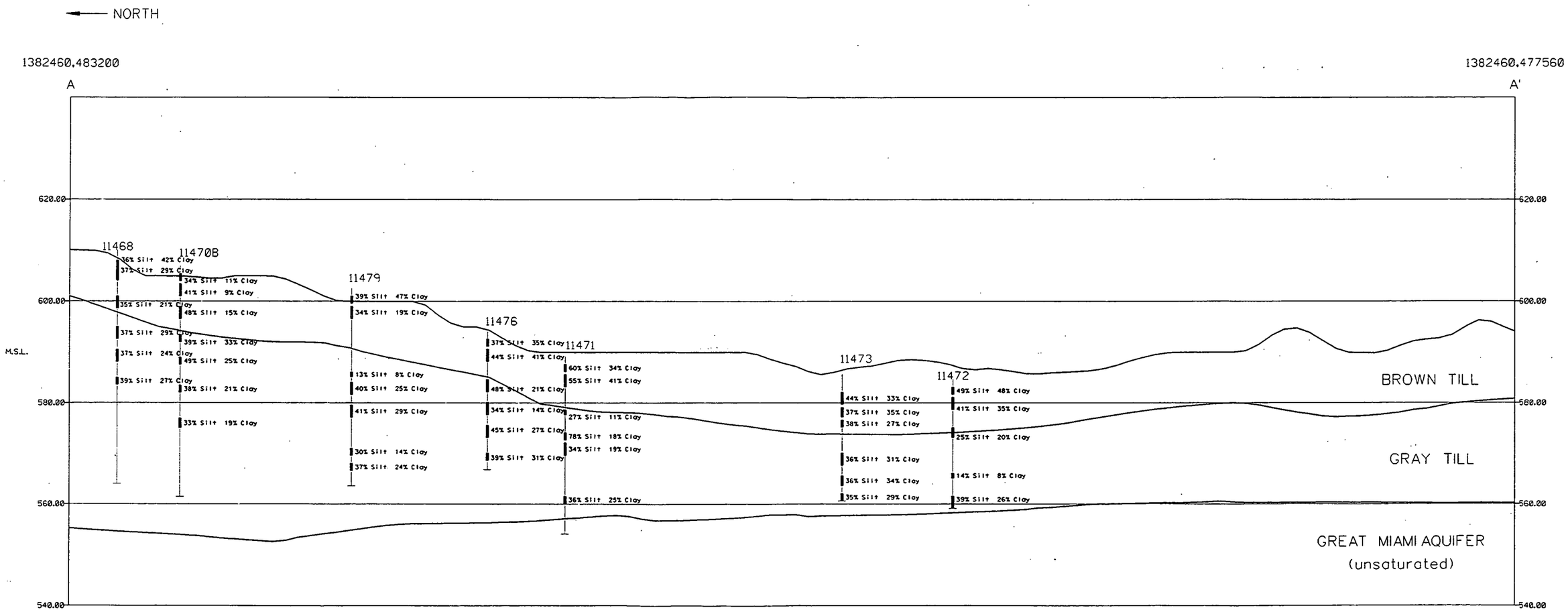
FIGURE 2-10

FILE NAME: /2ccs1/dgn/map/hor/dpth/ph20012.dgn



LEGEND

SAMPLE INTERVAL

GEOTECHNICAL BORING

HORIZONTAL SCALE: 0 200' 400' 800'
VERTICAL 0 10' 20' 40'

NOTE:

COORDINATES ARE STATE PLANAR NAD 1927

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LITHOLOGICAL CROSS-SECTION
SECTION A-A'

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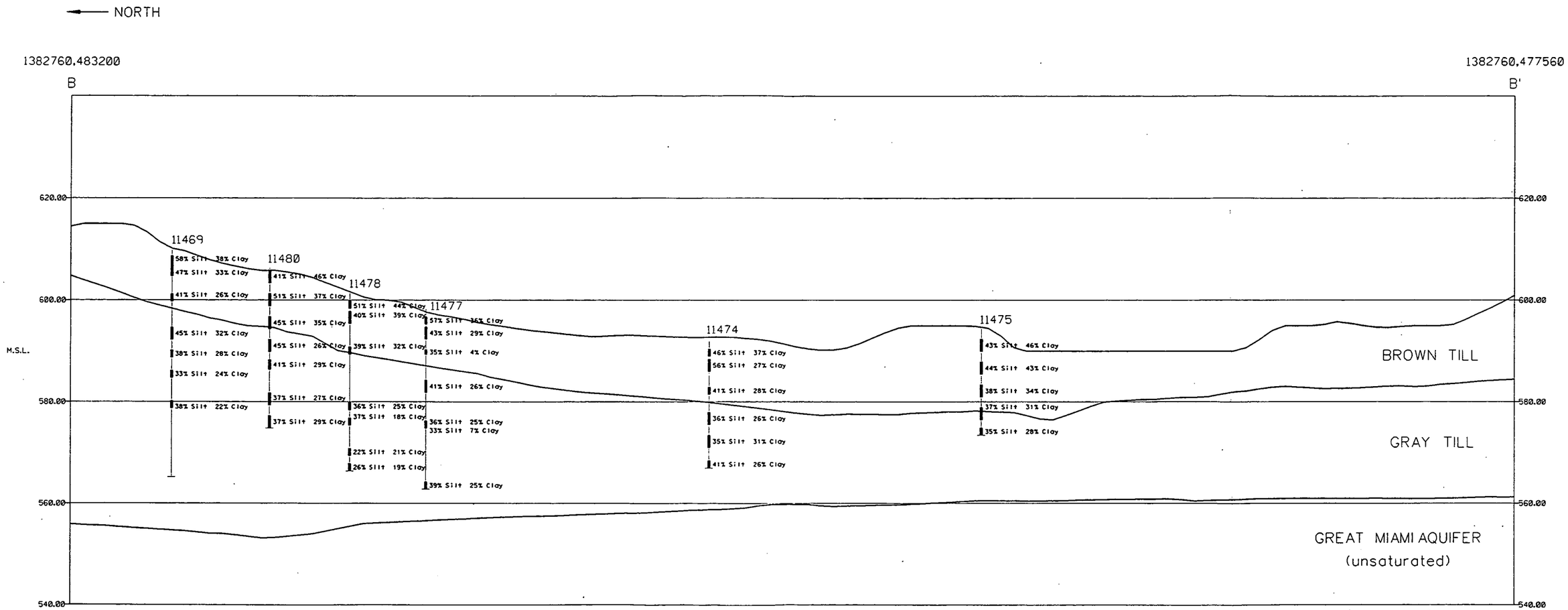
DRAWN DEG

FIGURE 2-11

FILE NAME: /usr/erma5/2ccs1/dgn/sec/geo/dpth/traverse_a.dgn



LEGEND

SAMPLE INTERVAL

GEOTECHNICAL BORING

HORIZONTAL SCALE: 0 200' 400' 800'
VERTICAL 0 10' 20' 40'

NOTE:

COORDINATES ARE STATE PLANAR NAD 1927

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LITHOLOGICAL CROSS-SECTION
SECTION B-B'

DATE 05/03/95
DRAWN DEG

FIGURE 2-12

FILE NAME: /usr/erma5/2ccs1/dgn/sec/geo/dpth/traverse_b.dgn

FIGURE 2-13
CLAY PLUS SILT VS DEPTH

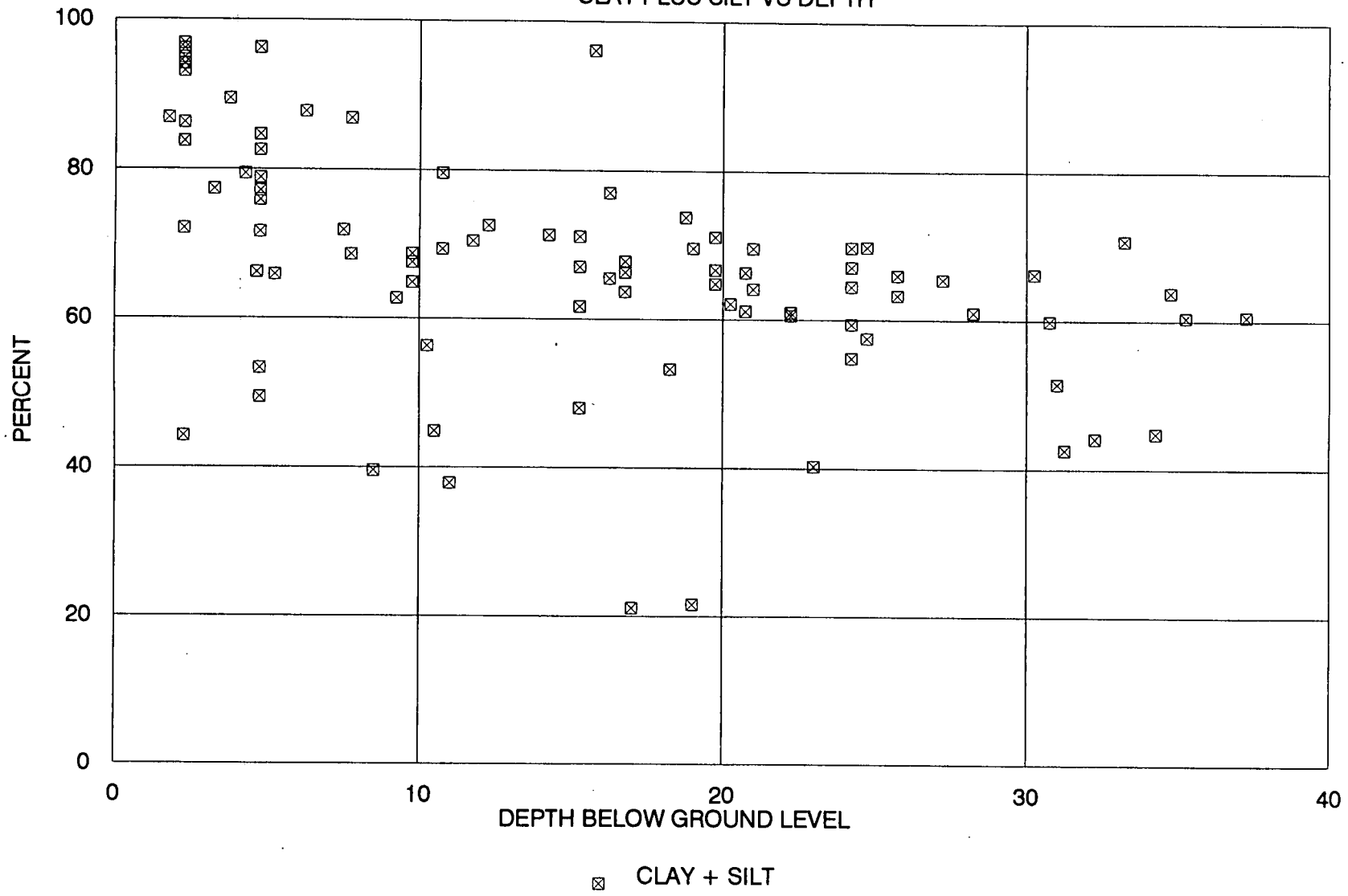

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FIGURE 2-14
SAND PLUS GRAVEL VS DEPTH

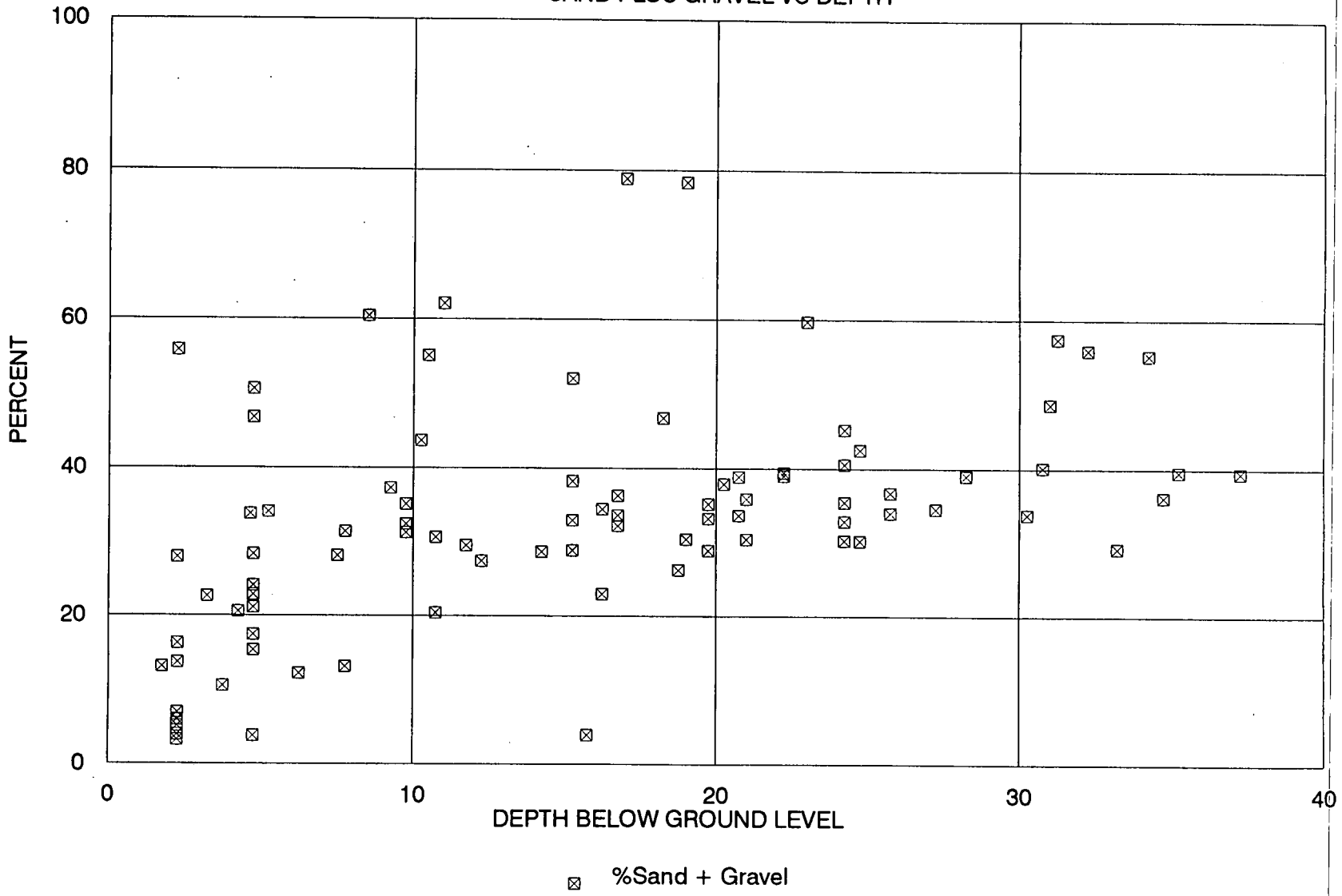

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FIGURE 2–15
GEOTECHNICAL SAMPLES – WATER CONTENT VS DEPTH

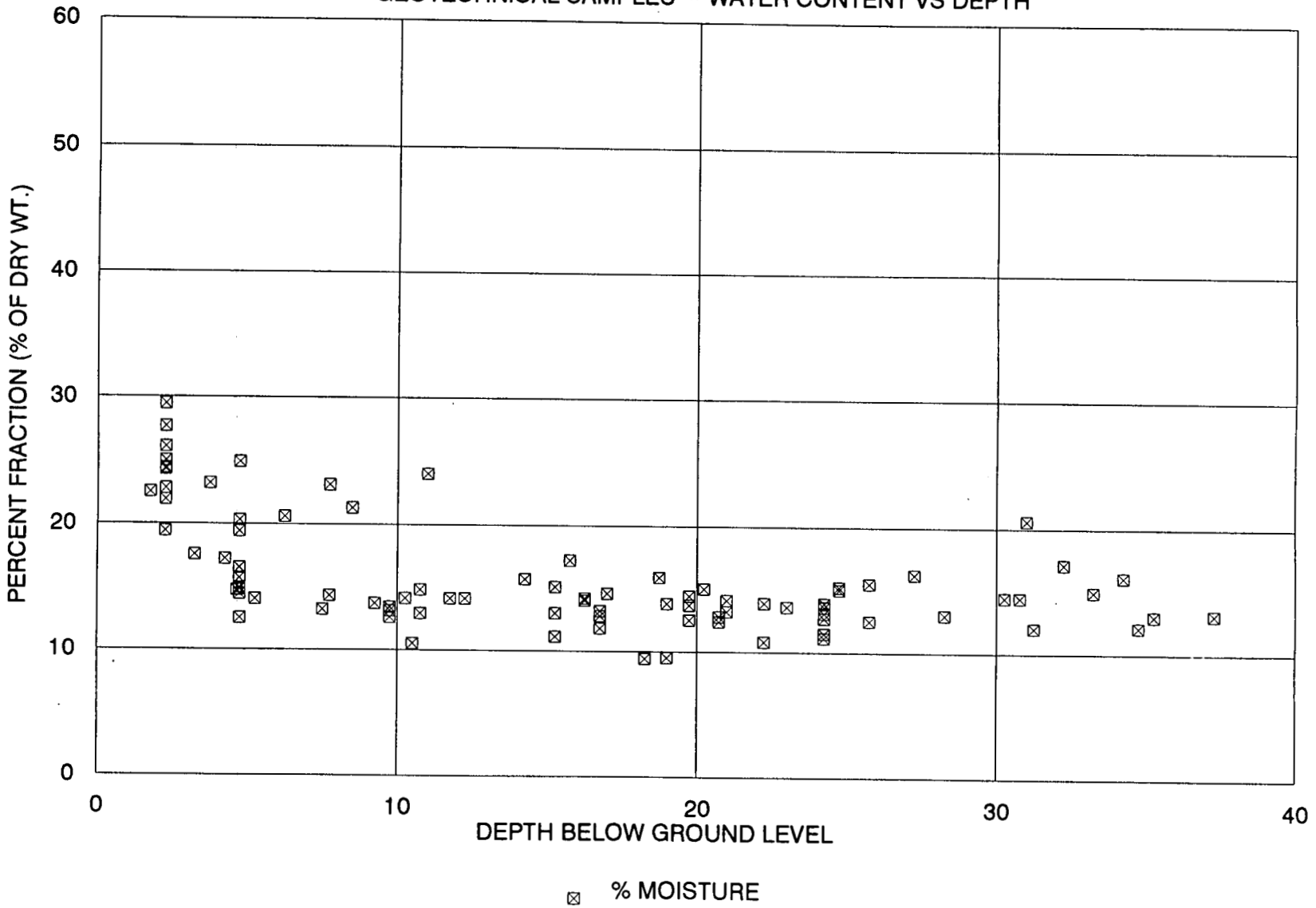

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FIGURE 2-16
GEOTECHNICAL SAMPLES – PORE SPACE VS DEPTH

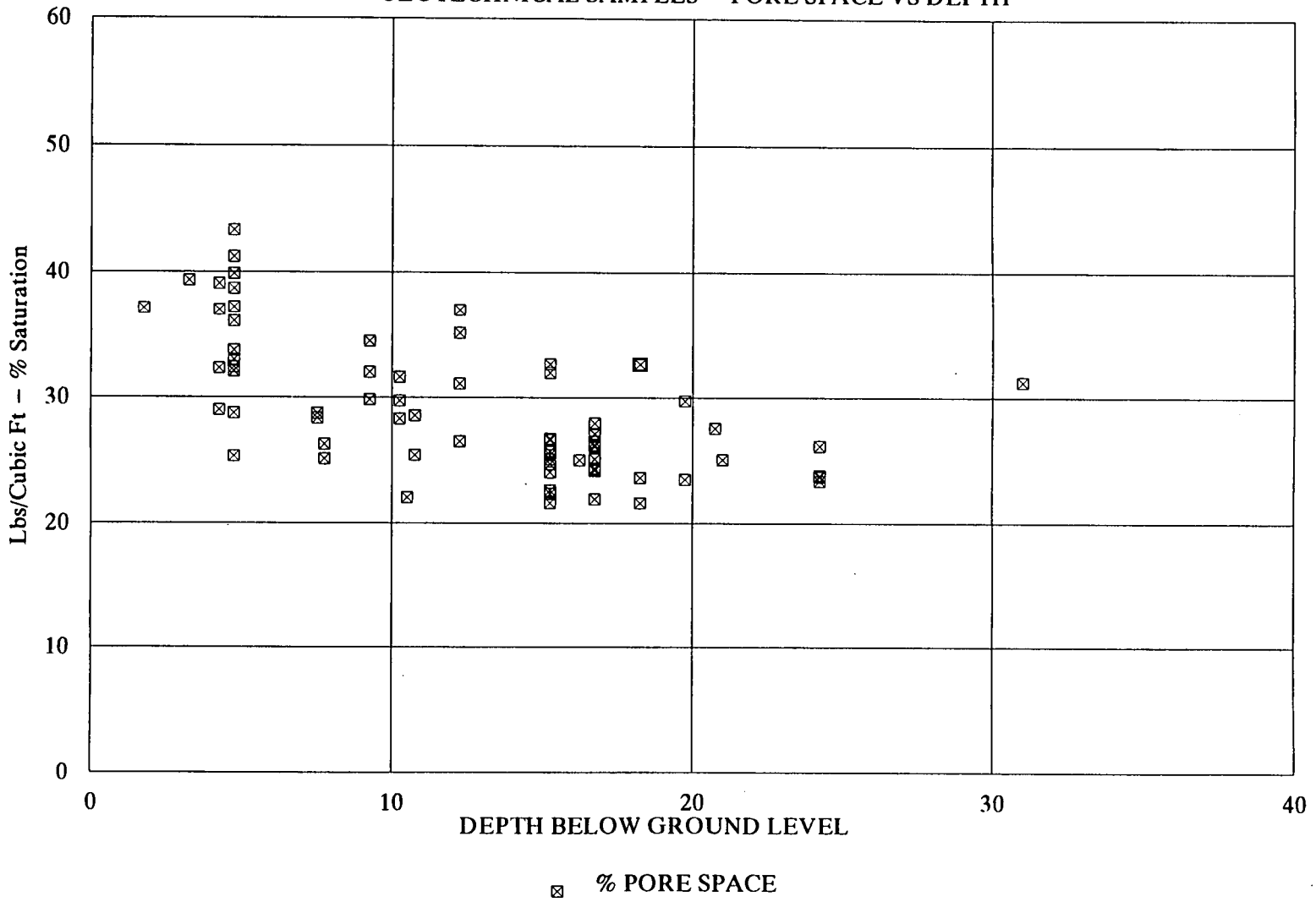

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FIGURE 2-17
GEOTECHNICAL SAMPLES – PERMEABILITY VS DEPTH

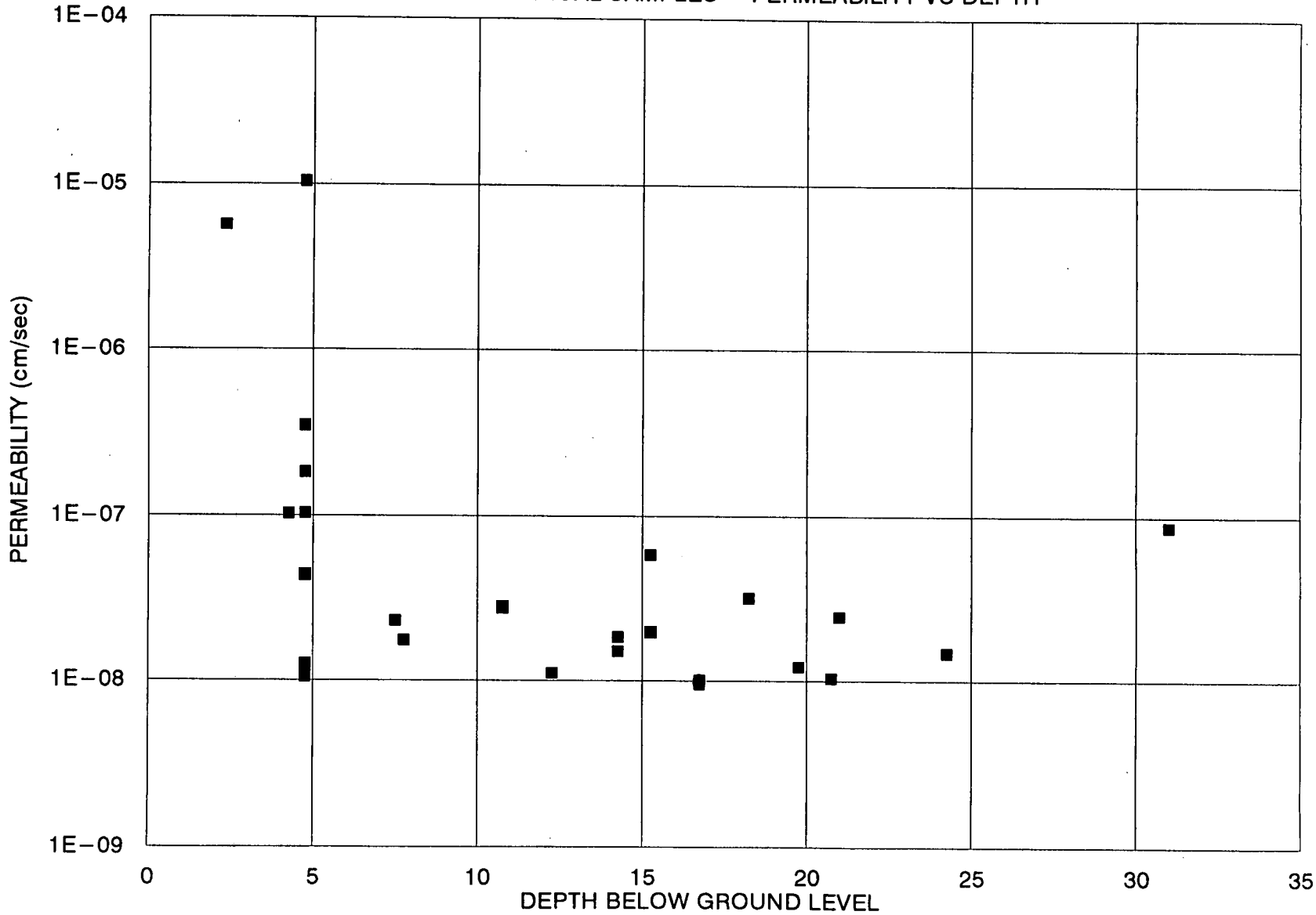

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TABLE 2-7

LYSIMETER WATER RESULTS FOR TOTAL URANIUM, ISOTOPIC URANIUM, AND TRITIUM

FINAL ROUND

Lysimeter #	Ground Surface above MSL (feet)	Lysimeter Depth (feet) BGL	Total U (ug/L)	U 238 (pCi/L)	U 235/236 (pCi/L)	U 234 (pCi/L)	Tritium (tu)
11482	610.68	5.0	22.0	6.70	0.38	15.0	NA
11483	611.07	34.5	0.52	0.14	0.0063	0.45	4.49
11484	598.86	37.5	2.90	0.82	0.044	1.3	TBR
11486	602.31	36.5	TBR	TBR	TBR	TBR	TBR
11488	579.84	7.0	1.88 -	0.731 J	0.05 J	1.16 J	9.8
11557	598.89	6.6	10.8 -	2.95 J	0.165 -	3.26 -	12.7
11558	580.22	33.5	TBR	TBR	TBR	TBR	NA
11559	579.99	45.5	23.62 -	6.03 J	0.393 -	15.2 J	10.0
11130	592.80	22.5	2.13 -	0.718 J	0.036 U	0.838 J	5.23
11131*	592.80	36.0	7.40 NV	NA	NA	NA	NA
11132	591.50	26.0	4.20	0.99	0.032	2.10	NA
11133*	591.50	48.0	9.60 NV	NA	NA	NA	NA
11234*	566.66	14.0	3.80 NV	NA	NA	NA	NA

MSL = Mean Sea Level
BGL = Below Ground Level
NA = Not Analyzed
TBR = To Be received
* = Most recent sample collected during the OU5 Ground Water Sampling of the 8 existing lysimeters project.

TABLE 2-8

RADIONUCLIDE RESULTS FOR SOIL FROM LYSIMETER BORINGS

Lysimeter #	Surface Elevation above MSL (feet)	Sample Interval (feet) BGL	Total U (mg/kg)	U 238 (pCi/g)	U 235/236 (pCi/g)	U 234 (pCi/g)	TCLP Total U (ug/L)	TCLP U 238 (pCi/L)	TCLP U 235/236 (pCi/L)	TCLP U 234 (pCi/L)
LOCATION I										
11482	610.68	6.5 - 7.0	2.02	0.893 -	-0.011 U	0.803 -	4.23 J	2.43 J	0.079 J	3.21 J
11483	611.07	39.5	2.04 -	1.06 -	0.011 UJ	0.914 -	4.42 J	3.2	0.067 J	5.08 J
LOCATION II										
11484	598.86	36.0 - 37.0	2.32 -	0.829 -	0.021 U	0.925 -	7.01 J	4.09 J	0.205 J	5.44 J
11485	598.9	7.0 - 8.0	2.17 -	1.22 -	0.071 J	1.10 -	1.26 J	1.08 J	0.049 J	1.03 J
11557	598.89	NA	NA	NA	NA	NA	NA	NA	NA	NA
LOCATION III										
11486	602.31	36.5 - 37.0	2.33 -	0.948 -	0.010 U	0.718 -	4.36 J	5.56 J	0.216 J	6.68 J
LOCATION IV										
11487	584.99	26.0 - 26.5	2.01 -	0.900 -	0.015 U	0.665 -	4.94 J	3.48 J	0.137 J	5.90 J

See footnotes at end of table

FER\CRU2\PREDESIGN\TDO\TAB2-8\July 11, 1995 (9:40am)

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TABLE 2-8
(Continued)

Lysimeter #	Surface Elevation above MSL (feet)	Sample Interval (feet) BGL	Total U (mg/kg)	U 238 (pCi/g)	U 235/236 (pCi/g)	U 234 (pCi/g)	TCLP Total U (ug/L)	TCLP U 238 (pCi/L)	TCLP U 235/236 (pCi/L)	TCLP U 234 (pCi/L)
LOCATION V										
11488	579.84	6.5 - 7.0	2.03 -	1.08 -	0.035 U	0.882 -	4.76 J	2.96 J	0.127 J	3.14 J
11489	579.87	36.0 - 36.5	2.15 -	0.897 -	0.0725 -	0.764 -	9.91 J	5.09 J	0.15 J	5.59 J
11490	579.92	46.5 - 47.0	1.46 -	0.684 -	0.010 U	0.642 -	5.94 J	3.579 J	0.088 J	3.224 J
11558	580.22	NA	NA	NA	NA	NA	NA	NA	NA	NA
11559	579.99	NA	NA	NA	NA	NA	NA	NA	NA	NA

Note:

(1) Lysimeters 11557, 11558, and 11559 are replacement lysimeters for 11485, 11489, and 11490 respectively. No environmental soil samples were taken from the replacement borings.

MSL = Mean Sea Level
BGL = Below Ground Level
NA = Not Applicable

TABLE 2-9

SUMMARY OF SOIL CLASSIFICATIONS AND SIZE DISTRIBUTIONS BASED ON GEOTECHNICAL TESTING

Geotech Boring	Depth B.G.L. (ft)	Br/Gr Interface B.G.L. (ft)	USCS Soil Classification	Liquid Limit %	Plastic Limit %	Plastic Index %	Spec. Grav.	Moist. Cont. % Dry Wt.	Gravel %	Sand %	Silt & Clay %	Silt %	Clay %
11468	2.0- 4.5	13.5	Lean Clay W/Sand (CL)	47.2	17.9	29.3	2.72	17.5	3.7	18.9	77.4	35.8	41.6
11468	4.5- 6.0	13.5	Sandy Lean Clay (CL)	31.9	16.1	15.8	2.70	14.0	6.5	27.6	65.9	36.8	29.1
11468	9.0-11.5	13.5	Sandy Lean Clay (CL)	25.5	14.7	10.8	2.74	14.1	2.7	41	56.3	34.9	21.4
11468	15.0-17.5	13.5	Sandy Lean Clay (CL)	28.0	14.7	13.3	2.73	14.0	10.3	24.2	65.5	36.9	28.6
11468	19.5-22.0	13.5	Sandy Lean Clay (CL)	24.1	14.2	9.9	2.76	12.4	13	25.9	61.1	37.2	23.9
11468	25.0-26.5	13.5	Sandy Lean Clay (Cl)	25.3	13.6	11.7	2.70	15.5	6.2	27.8	66.0	38.9	27.1
11469	1.5- 3.0	12.0	Lean Clay (Cl)	45.1	21.1	24.0	2.67	27.7	0	3.9	96.1	58.2	37.9
11469	3.0- 5.5	12.0	Lean Clay W/Sand (CL)	37.1	14.9	22.2	2.70	17.2	2.5	18	79.5	46.9	32.6
11469	9.0-10.5	12.0	Sandy Lean Clay (Cl)	25.8	14.3	11.5	2.69	13.1	7.6	24.8	67.6	41.3	26.3
11469	15.5-18.0	12.0	Lean Clay W/Sand (CL)	25.2	13.7	11.5	2.73	14.2	4.1	18.9	77.0	45.3	31.7
11469	20.0-21.5	12.0	Sandy Lean Clay (Cl)	25.3	14.6	10.7	2.72	12.8	7.2	26.5	66.3	38.0	28.3
11469	24.0-25.5	12.0	Sandy Lean Clay (Cl)	21.6	13.6	8.0	2.73	15.2	10.4	32.1	57.5	33.3	24.2
11469	30.0-31.5	12.0	Sandy Lean Clay (Cl)	24.5	14.3	10.2	2.68	14.4	12.2	27.9	59.9	37.6	22.3
11470B	1.5- 3.0	9.3	Silty Clayey Sand (SC-SM)	19.8	14.3	5.5	2.71	19.4	12.2	43.6	44.2	33.5	10.7
11470B	3.5- 6.0	9.3	Silty Sand (SM)	NP[a]	NP	NP	2.70	14.4	7	43.6	49.4	40.9	8.5
11470B	8.0-10.5	9.3	Sandy Silt (ML)	16.0	15.2	0.8	2.72	13.7	1.2	36.1	62.7	47.9	14.8
11470B	13.5-15.0	9.3	Lean Clay W/Sand (CL)	26.5	14.8	11.7	2.69	15.7	3.2	25.5	71.3	38.8	32.5
11470B	18.0-19.5	9.3	Lean Clay W/Sand (CL)	23.7	13.9	9.8	2.75	15.9	8.3	17.9	73.8	49.3	24.5
11470B	23.5-25.0	9.3	Sandy Lean Clay (Cl)	22.5	12.3	10.2	2.75	13.6	9.5	31.1	59.4	38.1	21.3
11470B	30.0-32.0	9.3	Sandy Lean Clay WGrav (CL)	27.5	14.8	12.7	2.73	20.6	15.7	32.9	51.4	32.8	18.6
11471	1.5- 3.0	11.5	Lean Clay (CL)	51.9	28.0	23.9	2.67	24.4	0	5.9	94.1	60.4	33.7
11471	3.5- 6.0	11.5	Fat Clay (CH)	50.5	18.4	32.1	2.72	24.9	0	3.8	96.2	55.4	40.8
11471	10.5-11.5	11.5	Well Graded Sand (SW)	NP	NP	NP	2.70	24.0	2.4	59.7	37.9	26.8	11.1
11471	15.0-16.5	11.5	Silt (ML)	22.5	19.3	3.2	2.73	17.2	0	3.9	96.1	78.4	17.7

See footnotes at end of table

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TABLE 2-9
(Continued)

Geotech Boring	Depth B.G.L. (ft)	Br/Gr Interface B.G.L. (ft)	USCS Soil Classification	Liquid Limit %	Plastic Limit %	Plastic Index %	Spec. Grav.	Moist. Cont. % Dry Wt.	Gravel %	Sand %	Silt & Clay %	Silt %	Clay %
11471	17.0-19.5	11.5	Sandy Lean Clay (Cl)	21.0	12.4	8.6	2.77	9.4	10.7	36	53.3	34.3	19.0
11471	27.5-29.0	11.5	Sandy Lean Clay (Cl)	25.9	14.7	11.2	2.69	13.0	11.8	27.2	61.0	36.4	24.6
11472	1.5- 3.0	16.5	Lean Clay (CL)	49.1	20.8	28.3	2.65	26.1	0	3.2	96.8	49.3	47.5
11472	3.5- 6.0	16.5	Lean Clay W/Sand (CL)	29.4	15.8	13.6	2.74	15.7	2.7	21.4	75.9	41.0	34.9
11472	9.5-11.5	16.5	Clayey Sand W/Grav (SC)	24.5	13.1	11.4	2.69	10.5	25.8	29.3	44.9	24.9	20.0
11472	18.5-19.5	16.5	Clayey Sand W/Grav (SC)	19.4	11.2	8.2	2.74	9.5	24.2	54.2	21.6	13.8	7.8
11472	23.0-25.5	16.5	Sandy Lean Clay (Cl)	25.0	13.1	11.9	2.69	12.7	7.1	28.4	64.5	38.8	25.7
11473	3.5- 6.0	13.5	Lean Clay W/Sand (CL)	31.1	17.3	13.8	2.70	14.9	5.6	17.2	77.2	44.3	32.9
11473	6.5- 8.5	13.5	Lean Clay W/Sand (CL)	29.3	15.6	13.7	2.74	13.2	7.3	20.8	71.9	37.0	34.9
11473	9.0-10.5	13.5	Sandy Lean Clay (Cl)	25.0	15.1	9.9	2.70	13.4	5.9	29.2	64.9	37.5	27.4
11473	15.5-18.0	13.5	Sandy Lean Clay (Cl)	27.3	14.3	13.0	2.77	12.8	8.9	24.8	66.3	35.6	30.7
11473	20.0-22.0	13.5	Sandy Lean Clay (Cl)	30.9	14.7	16.2	2.71	14.1	5.5	24.9	69.6	35.5	34.1
11473	23.5-25.0	13.5	Sandy Lean Clay (Cl)	24.2	14.9	9.3	2.70	11.5	6.9	28.6	64.5	35.1	29.4
11474	1.5- 3.0	11.3	Lean Clay (CL)	44.2	18.1	26.1	2.63	29.5	7.7	8.5	83.8	46.4	37.4
11474	3.5- 6.0	11.3	Lean Clay W/Sand (CL)	27.9	19.2	8.7	2.79	16.5	0.8	16.6	82.6	56.1	26.5
11474	9.0-10.5	11.3	Sandy Lean Clay (CL)	25.1	13.5	11.6	2.76	12.6	5.1	26.1	68.8	41.2	27.6
11474	14.0-16.5	11.3	Sandy Lean Clay (CL)	24.2	13.6	10.6	2.75	13.0	10.8	27.5	61.7	36.1	25.6
11474	18.5-21.0	11.3	Sandy Lean Clay (CL)	27.9	14.2	13.7	2.70	13.7	8.4	24.9	66.7	35.3	31.4
11474	23.5-25.0	11.3	Sandy Lean Clay (CL)	25.4	13.4	12.0	2.70	13.1	8.5	24.4	67.1	41.1	26.0
11475	2.0- 4.5	16.5	Lean Clay (Cl)	48.5	16.2	32.3	2.62	23.2	0.8	9.7	89.5	43.4	46.1
11475	6.5- 9.0	16.5	Lean Clay (Cl)	49.2	26.0	23.2	2.66	23.1	1.6	11.5	86.9	43.7	43.2
11475	11.0-13.5	16.5	Lean Clay W/Sand (CL)	33.3	17.4	15.9	2.74	14.1	1.8	25.6	72.6	38.3	34.3
11475	15.5-18.0	16.5	Sandy Lean Clay (CL)	26.9	12.9	14.0	2.71	13.2	6.9	25.3	67.8	37.3	30.5
11475	19.5-21.0	16.5	Sandy Lean Clay (CL)	26.7	14.3	12.4	2.72	15.0	14.5	23.4	62.1	34.6	27.5
11476	1.5- 3.0	10.0	Lean Clay W/Sand (CL)	40.7	17.8	22.9	2.70	21.9	11.5	16.4	72.1	37.1	35.0
11476	3.5- 6.0	10.0	Lean Clay W/Sand (CL)	30.5	15.9	14.6	2.64	14.8	2.1	13.2	84.7	43.6	41.1
11476	9.5-12.0	10.0	Sandy Silty Clay (CL-ML)	18.8	14.2	4.6	2.77	12.9	0.1	30.5	69.4	48.2	21.2
11476	14.0-16.5	10.0	Silty Clayey Sand (SC-SM)	18.1	12.3	5.8	2.75	11.1	10.3	41.7	48.0	34.1	13.9

See footnotes at end of table

TABLE 2-9
(Continued)

Geotech Boring	Depth B.G.L. (ft)	Br/Gr Interface B.G.L. (ft)	USCS Soil Classification	Liquid Limit %	Plastic Limit %	Plastic Index %	Spec. Grav.	Moist. Cont. % Dry Wt.	Gravel %	Sand %	Silt & Clay %	Silt %	Clay %
11476	18.5-21.0	10.0	Lean Clay W/Sand (CL)	20.2	12.5	7.7	2.70	14.4	2.3	26.6	71.1	44.6	26.5
11476	24.0-25.5	10.0	Sandy Lean Clay (CL)	25.1	14.2	10.9	2.68	15.0	5.2	25	69.8	38.5	31.3
11477	1.5- 3.0	11.5	Lean Clay (Cl)	37.8	20.0	17.8	2.72	22.8	0	6.9	93.1	56.7	36.4
11477	3.5- 6.0	11.5	Lean Clay W/Sand (CL)	30.4	15.0	15.4	2.73	19.4	1.4	26.9	71.7	42.6	29.1
11477	8.0- 9.0	11.5	Silty Sand (Sm)	NP	NP	NP	2.75	21.3	6.6	53.8	39.6	35.2	4.4
11477	14.0-16.5	11.5	Sandy Lean Clay (Cl)	25.1	13.1	12.0	2.72	15.1	5.2	27.8	67.0	40.6	26.4
11477	22.0-22.5	11.5	Sandy Lean Clay (Cl)	21.9	13.0	8.9	2.70	13.9	4.2	34.8	61.0	36.4	24.6
11477	22.5-23.5	11.5	Silty Sand (Sm)	NP	NP	NP	2.75	13.6	6.5	53.2	40.3	33.2	7.1
11477	34.0-35.5	11.5	Sandy Lean Clay (Cl)	25.1	13.3	11.8	2.73	12.1	10	26.2	63.8	39.2	24.6
SUMMARY OF RESULTS FROM STANDARD PROCTOR TESTS													
11468	2.0- 6.5	13.5	Lean Clay W/Sand (CL)	45.3	16.2	29.1			38.1	38.1	2.3	4.5	7.5
11468	9.0-13.0	13.5	Lean Clay W/Sand (CL)	30.8	14.1	16.7			41.5	29.2	3.1	11.8	14.4
11469	3.0- 7.5	12.0	Lean Clay W/Sand (CL)	36.1	15.1	21.0			38.7	34.1	2.8	7.6	11.2
11469	7.5-12.0	12.0	Lean Clay W/Sand (CL)	29.4	13.0	16.4			39.5	32.1	3.4	8.3	13.1
11470B	3.5- 7.5	9.3	Sandy Silt (ML)	17.7	15.7	2.0			44.8	11.1	3.1	12.5	21.6
11470B	7.5-12.0	9.3	Sandy Silt (ML)	17.3	16.7	0.6			53.7	12.3	3.3	6.3	22.9
11471	3.0- 7.5	11.5	Fat Clay (CH)	50.5	19.3	31.2			55.9	40.2	0.0	1.3	2.6
11471	7.5-10.5	11.5	Lean Clay (CL)	43.0	21.8	21.2			63.2	32.8	0.0	0.6	3.4
11472	3.5- 7.5	16.5	Lean Clay W/Sand (CL)	30.9	14.0	16.9			39.4	37.4	2.3	6.5	11.3
11472	9.0-12.0	16.5	Sandy Lean Clay (CL)	28.7	13.8	14.9			31.0	29.6	7.9	13.7	12.0
11473	3.0- 7.5	13.5	Lean Clay W/Sand (CL)	35.4	15.8	19.6			45.3	37.6	1.6	6.5	8.1
11473	7.5-12.0	13.5	Lean Clay W/Sand (CL)	31.0	14.8	16.2			38.5	38.4	2.7	6.5	11.8
11474	3.0- 7.5	11.3	Lean Clay W/Sand (CL)	28.1	16.2	11.9			52.2	29.3	1.5	4.8	11.1
11474	7.5-12.0	11.3	Lean Clay W/Sand (CL)	26.2	13.8	12.4			47.2	29.0	2.3	5.9	13.2
11475	4.5- 8.5	16.5	Lean Clay W/Sand (CL)	42.8	15.8	27.0			46.3	38.2	0.9	5.1	9.1
11476	3.5- 7.5	10.0	Lean Clay W/Sand (CL)	33.0	14.8	18.2			39.2	38.2	2.2	6.3	9.1

See footnotes at end of table

TABLE 2-9
(Continued)

Geotech Boring	Depth B.G.L. (ft)	Br/Gr Interface B.G.L. (ft)	USCS Soil Classification	Liquid Limit %	Plastic Limit %	Plastic Index %	Spec. Grav.	Moist. Cont. % Dry Wt.	Gravel %	Sand %	Silt & Clay %	Silt %	Clay %
11476	12.0-15.0	10.0	Lean Clay W/Sand (CL)	20.7	12.7	8.0			44.7	28.3	0.9	7.7	18.1
11477	3.5- 7.5	11.5	Lean Clay W/Sand (CL)	42.2	16.6	25.6			40.4	39.9	0.7	4.3	14.3
11477	14.0-18.0	11.5	Sandy Lean Clay (CL)	22.7	14.5	8.2			40.0	18.3	7.7	12.2	19.1
11478	3.5- 7.5	16.0	Lean Clay W/Sand (CL)	35.3	16.6	18.7			37.9	36.5	3.3	7.1	11.7
11478	7.5-10.0	16.0	Sandy Lean Clay (CL)	26.6	14.8	11.8			38.6	30.1	4.0	10.4	13.3
11479	3.5- 7.5	10.0	Sandy Lean Clay (CL)	28.8	14.1	14.7			36.1	27.9	3.8	11.6	17.4
11479	7.5-10.5	10.0	Sandy Lean Clay (CL)	25.2	14.9	10.3			35.7	28.5	6.0	9.1	13.6
11480	3.0- 7.5	12.5	Lean Clay W/Sand (CL)	38.5	15.8	22.7			42.4	40.4	1.6	5.1	9.0
11480	7.5-12.0	12.5	Lean Clay W/Sand (CL)	27.2	14.4	12.8			47.7	31.1	1.3	6.2	13.2
11481	3.5- 7.5	12.5	Sandy Lean Clay (CL)	30.7	14.5	16.2			32.8	29.0	2.2	7.5	11.9
11481	13.5-18.5	12.5	Lean Clay W/Sand (CL)	24.9	12.8	12.1			41.0	29.6	3.0	0.1	25.0
11478	1.5- 3.0	16.0	Fat Clay (CH:)	51.0	20.6	30.4	2.69	24.3	0	5.1	94.9	51.0	43.9
11478	3.5- 6.0	16.0	Lean Clay W/Sand (CL)	37.5	16.5	21.0	2.71	20.3	3.4	17.7	78.9	39.8	39.1
11478	10.5-12.0	16.0	Lean Clay W/Sand (CL)	28.0	16.2	11.8	2.71	14.1	4.5	25	70.5	38.6	31.9
11478	21.5-23.0	16.0	Sandy Lean Clay (Cl)	24.3	13.9	10.4	2.67	10.8	7.3	32.1	60.6	35.7	24.9
11478	24.5-26.0	16.0	Sandy Silty Clay (Cl-Ml)	18.6	12.7	5.9	2.72	11.1	3.9	41.3	54.8	36.7	18.1
11478	30.5-32.0	16.0	Silty Sand (Sm)	NP	NP	NP	2.70	12.0	0	57.4	42.6	22.1	20.5
11478	33.5-35.0	16.0	Silty Clayey Sand (SC-SM)	23.2	16.5	6.7	2.72	16.1	0	55.2	44.8	26.1	18.7
11479	1.5- 3.0	10.0	Fat Clay (CH:)	53.5	16.8	36.7	2.67	25.0	0.6	13.1	86.3	39.3	47.0
11479	3.5- 6.0	10.0	Sandy Lean Clay (Cl)	21.3	14.1	7.2	2.74	12.5	3.9	42.8	53.3	34.4	18.9
11479	16.5-17.5	10.0	Silty Sand(SM)	NP	NP	NP	2.71	14.6	14.2	64.7	21.1	12.9	8.2
11479	18.5-21.0	10.0	Sandy Lean Clay (Cl)	25.2	14.2	11.0	2.69	12.5	6.8	28.4	64.8	39.8	25.0
11479	23.0-25.5	10.0	Sandy Lean Clay (Cl)	24.5	13.9	10.6	2.70	13.9	2	28.3	69.7	41.2	28.5
11479	31.5-33.0	10.0	Silty,Clayey Sand W/Gravel (SC)	19.6	12.4	7.2	2.70	17.1	17.2	38.7	44.1	30.4	13.7
11479	34.5-36.0	10.0	Sandy Lean Clay (Cl)	24.1	14.2	9.9	2.71	13.0	8.6	31	60.4	36.7	23.7
11480	0.5- 3.0	12.5	Lean Clay (CL)	49.6	17.8	31.8	2.71	22.5	2.9	10.2	86.9	41.2	45.7
11480	5.0- 7.5	12.5	Lean Clay (CL)	39.7	18.6	21.1	2.78	20.6	1	11.2	87.8	51.2	36.6
11480	9.5-12.0	12.5	Lean Clay W/Sand (CL)	32.0	18.0	14.0	2.76	14.8	0.4	20	79.6	44.8	34.8
11480	14.0-16.5	12.5	Lean Clay W/Sand (CL)	23.1	13.6	9.5	2.73	13.0	4.7	24.2	71.1	44.8	26.3
11480	18.0-20.0	12.5	Sandy Lean Clay (Cl)	25.1	13.9	11.2	2.69	13.8	4.9	25.5	69.6	40.6	29.0

TABLE 2-9
(Continued)

Geotech Boring	Depth B.G.L. (ft)	Br/Gr Interface B.G.L. (ft)	USCS Soil Classification	Liquid Limit %	Plastic Limit %	Plastic Index %	Spec. Grav.	Moist. Cont. % Dry Wt.	Gravel %	Sand %	Silt & Clay %	Silt %	Clay %
11480	24.5-27.0	12.5	Sandy Lean Clay (Cl)	26.2	13.9	12.3	2.71	12.5	8.8	27.9	63.3	36.7	26.6
11480	29.0-31.5	12.5	Sandy Lean Clay (Cl)	25.9	14.5	11.4	2.72	14.4	7.1	26.7	66.2	36.9	29.3
11481	3.5- 6.0	12.5	Sandy Lean Clay (Cl)	31.0	15.5	15.5	2.74	14.7	8.9	24.9	66.2	36.5	29.7
11481	6.5- 9.0	12.5	Sandy Lean Clay (Cl)	26.6	15.4	11.2	2.72	14.3	5.7	25.7	68.6	39.7	28.9
11481	15.5-18.0	12.5	Sandy Lean Clay (Cl)	23.7	13.0	10.7	2.73	11.8	6.5	29.8	63.7	37.8	25.9
11481	20.0-22.0	12.5	Sandy Lean Clay (Cl)	22.6	13.0	9.6	2.73	13.2	7.7	28.2	64.1	38.4	25.7
11481	26.5-28.0	12.5	Sandy Silty Clay (CL-ML)	17.6	13.2	4.4	2.67	16.2	7.2	27.4	65.4	44.2	21.2
11481	32.5-34.0	12.5	Lean Clay W/Sand (CL)	26.0	14.5	11.5	2.73	14.9	5.5	23.7	70.8	40.1	30.7
11481	37.0-38.5	12.5	Sandy Lean Clay (Cl)	26.1	13.7	12.4	2.73	13.1	13.1	26.3	60.6	35.4	25.2

[a]NP = Nonplastic

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below ground level is almost constant. Samples below 30 feet show an increase in sand and gravel (Figure 2-14). This analysis is consistent with the lithologic soil descriptions which show that the lithology in the gray till grades from lean clays to sandy lean clays with depth.

Water content as a percentage of dry weight was calculated for undisturbed soil samples and was plotted versus depth, as shown in Figure 2-15. Pore space was calculated and plotted as shown in Figure 2-16. The two graphs correlate and indicate that there is significantly more pore space and less water in the soils between 0 and 5 feet below the surface. This factor may be related to the vertical permeability, shown as a plot in Figure 2-17. Hydraulic conductivity results range from 1×10^{-5} cm/sec to 1×10^{-8} cm/sec in samples from zero to five feet deep, but ranged from 1×10^{-8} cm/sec to 7×10^{-9} cm/sec below five feet deep. This suggests that the permeability of the gray clay is consistently lower than in the brown clay even though the sand percentage increases with depth. This reduction in permeability may be due to the reduced pore space with depth.

In addition to geotechnical samples, soil samples were collected for total and isotopic uranium analysis from seven of the geotechnical borings, one from the brown clay and one from the gray clay from each boring, for a total of 14 samples. These data assisted in defining the vertical and horizontal distribution of uranium in the soil of the study area. Total uranium concentrations were from 1.7 mg/kg to 3.4 mg/kg (Table 2-10), which is consistent with the established background of 3.4 mg/kg (the established FEMP 95th percentile background level.)

2.6 GROUNDWATER ELEVATION AND PRECIPITATION MEASUREMENTS

2.6.1 Objectives

Groundwater levels in monitoring wells and daily precipitation measurements were collected to construct hydrographs to determine hydraulic gradients in the till, and to provide input data for inverse modeling that predicted horizontal hydraulic conductivities. The hydraulic gradients are important in calculating the vertical flow rates of water, using Darcy's Law, through the till. The horizontal hydraulic conductivity is important in determining the horizontal component of flow through the till. Establishing the flow rates will help determine how protective the selected location is of human health and the environment. This is discussed in detail in Section 4.0.

TABLE 2-10

RADIONUCLIDE RESULTS FOR SOILS FROM GEOTECHNICAL BORINGS

Boring #	Surface Elevation above MSL (feet)	Sample Interval (feet) BGL	Total U (mg/kg)	U 238 (pCi/g)	U 235/236 (pCi/g)	U 234 (pCi/g)
11468	610.04	4.5 - 6.0	2.77 -	0.767 -	0.049 -	0.726 -
		22.0 - 23.5	3.04 -	1.314 J	0.031 U	0.969 -
11470	606.96	6.0 - 7.5	2.0 -	0.686 -	0.033 J	0.0575 -
		20.5 - 22.0	2.2 -	0.857 -	0.031 J	1.056 -
11472	584.63	6.0 - 7.5	1.83 -	1.036 -	0.018 U	0.771 -
		12.0 - 13.5	2.04 -	1.019 -	0.060 J	0.83 -
11474	591.94	1.5 - 3.0	1.90 -	1.145 -	0.053 U	1.03 -
		12.0 - 13.5	2.01 -	0.809 -	0.027 J	0.765 -
11476	594.12	6.0 - 7.5	1.98 -	0.945 -	0.017 U	0.842 -
		16.5 - 18.0	1.72 -	0.714 -	0.041 J	0.609 -
11478	601.35	6.0 - 7.5	1.79 J	1.07 J	0.031 U	0.924 -
		20.0 - 21.5	2.36 J	0.858 J	0.1 J	1.06 -
11480	606.28	3.0 - 4.5	3.44 J	2.67 J	0.107 J	2.37 -
		12.0 - 13.5	2.09 J	0.901 J	0.031 J	1.03 -

MSL = Mean Sea Level
BGL = Below Ground Level

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2.6.2 Procedures and Field Activities

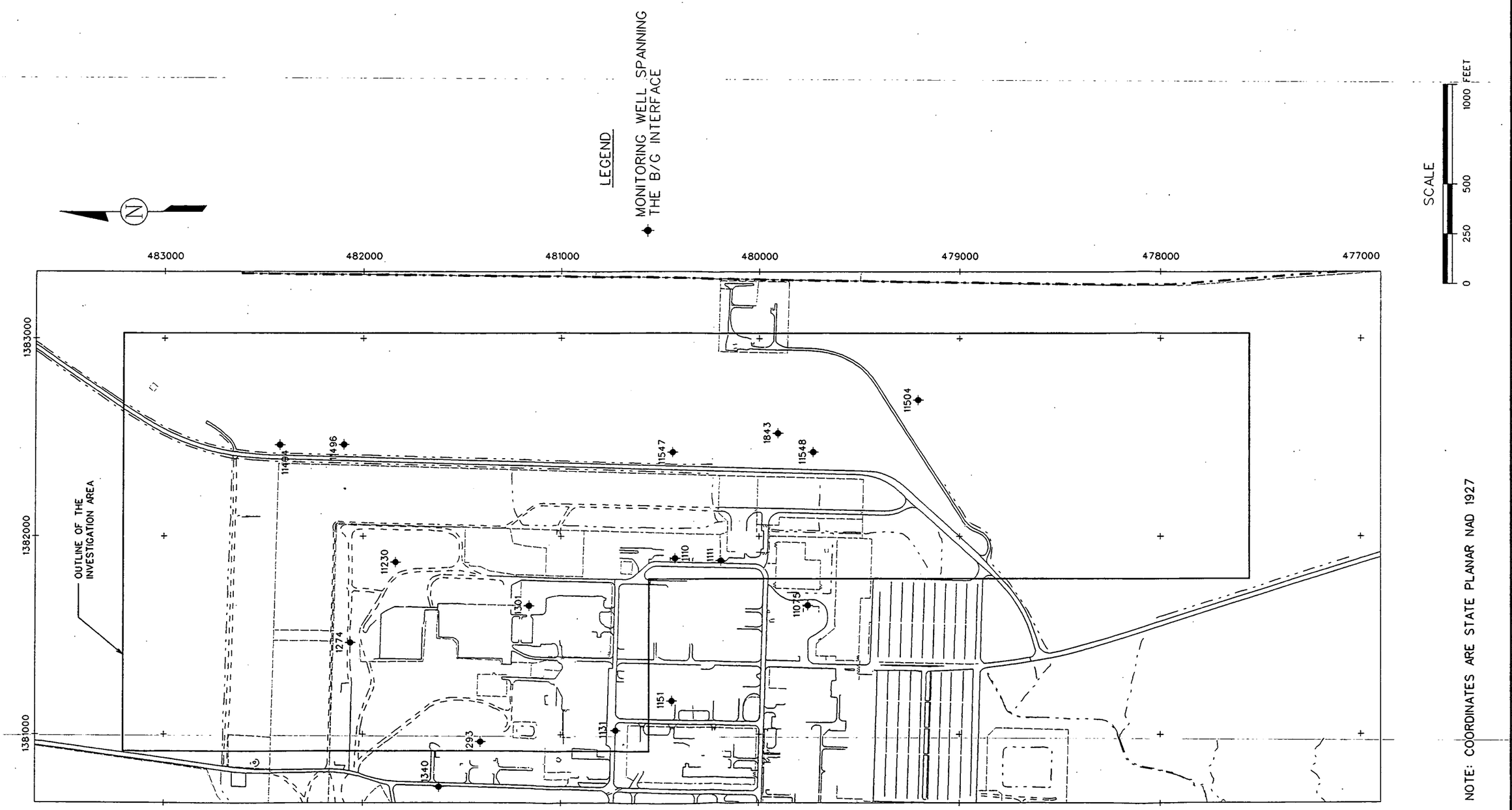
An inverse model was proposed that used measured rainfall data and the corresponding response in selected wells to estimate the horizontal hydraulic conductivity of the till. This is called inverse modeling because traditional modeling uses measured values of hydraulic conductivity to predict water level changes. (See Section 3.0 for a detailed description of the inverse modeling.)

To complete the proposed inverse modeling, groundwater elevation data was required from numerous wells within the study area for a relatively long period of time. The following wells that were considered to have potentially rapid responses to precipitation recharge were monitored with transducers and data loggers: 1110, 1112, 1151, 1152, 1274, 1278, 1293, 1418, and 11230. Data loggers collected water levels every hour for a two-month period. Other wells were manually monitored on a regular basis. One manual measurement per week was made, with an additional measurement made one day after rainfall events which exceeded 0.5 inches. These manually monitored wells include the following: 1064, 1124, 1144, 1149, 1152, 1160, 1167, 1276, 1274, 1293, 1299, 1301, 1340, 1733, 1887, 1843, 1866, 1905, 11067, 11074, 11075, 11491, 11492, 11493, 11494, 11495, 11496, 11497, 11498, 11499, 11500, 11501, 11546, 11547, and 11548. (See Figure 2-19).

Groundwater level measurements from wells for each round were collected within a 24-hour period of consistent weather conditions to minimize atmospheric and precipitation effects on groundwater levels. Water level measurements were collected in accordance with the SCQ. All measurements were recorded to the nearest 0.01 feet. All wells were surveyed and their coordinates added to the SED. The water level measurements and precipitation measurements were combined to develop hydrographs for all of the wells. These hydrographs are shown in Appendix C. These hydrographs were used to determine whether the wells respond quickly to precipitation events and if they were at equilibrium.

2.6.3 Results

The water level measurements for the new wells (shown on Tables 2-11 and 2-12) demonstrate high vertical hydraulic gradients between adjacent wells (nests) screened at different intervals. The deep wells show consistently lower water level elevations than the shallow wells indicating that a vertical hydraulic gradient exists. Also, water level measurements indicated that the uppermost limit of the perched groundwater has been identified from the wells screened across the brown/gray till interface (Figure 2-19). The contours for the uppermost water level is presented on Figure 2-20. The data are consistent with the concept that the uppermost perched groundwater surface generally conforms to the contours of



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MONIORING WELLS SPANNING THE B/G INTERFACE

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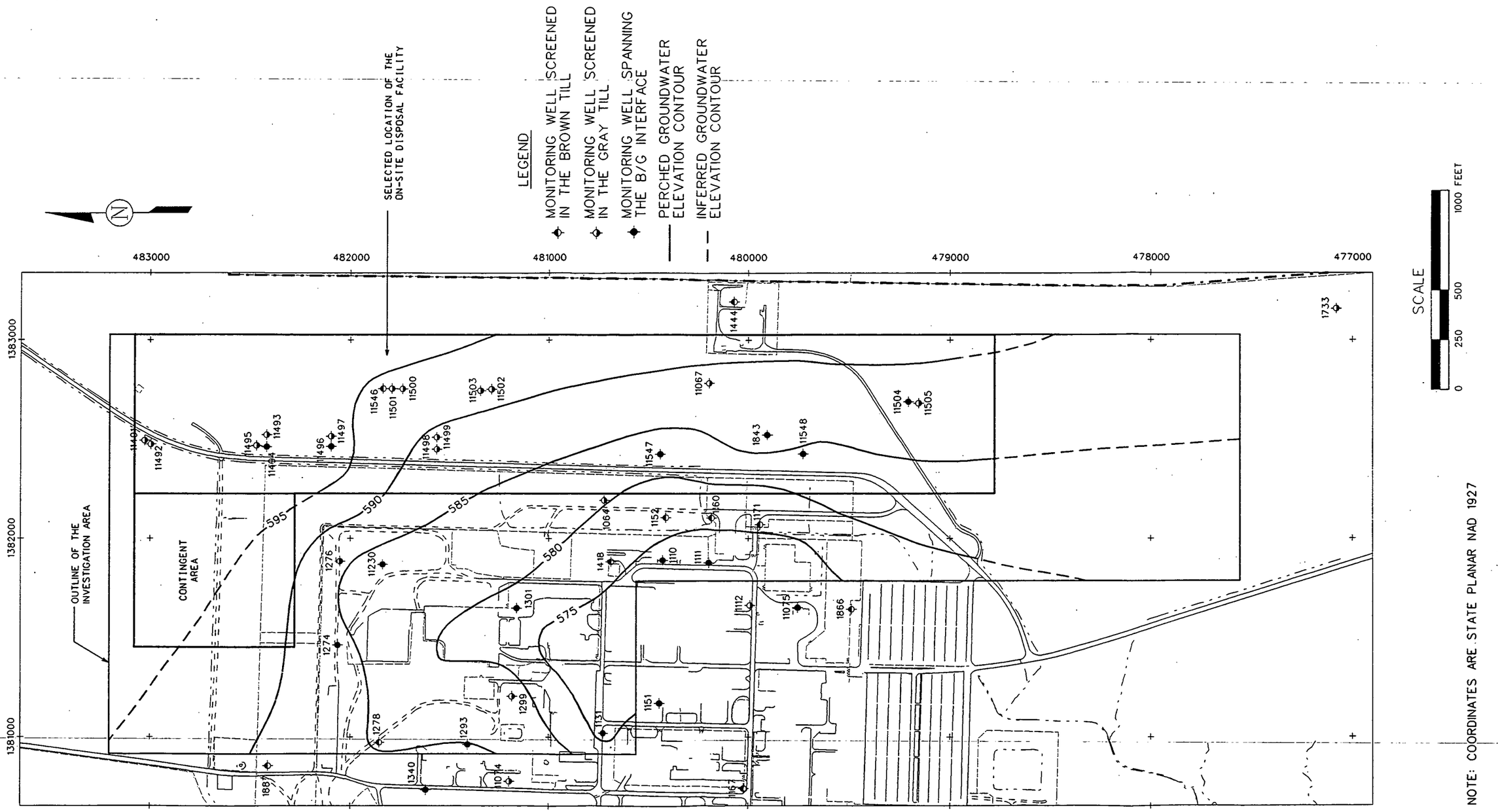
DATE 3-20-95
DRAWN R. WILLIAMS

FIGURE 2-19

FILE NAME: /2ccs1/dgn/map/hor/dpth/ph20028.dgn



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U.S. DEPARTMENT OF ENERGY

PERCHED GROUNDWATER CONTOURS FOR WELLS SCREENED ACROSS THE BROWN/GRAY INTERFACE

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FIGURE 2-20

FILE NAME: /2ccs1/dgn/map/hor/dpth/ph20037.dgn

the brown/gray till interface. The results show that the perched groundwater has a potential for movement southwest at a gradient ranging from about 0.011 to 0.025.

The water level data are consistent with geotechnical tests (ASTMD D2216) that measured 100% volumetric soil saturation on samples collected from five feet or deeper. Soil samples from zero to five feet deep had water contents that ranged from 93% to 100% saturation. Water content versus depth is presented in Figure 2-15.

Six new wells were installed at the brown-gray interface. Hydrographs for these wells are provided in Appendix C. Table 2-11 summarizes data concerning these water levels. Seven well pairs were installed to measure vertical hydraulic gradients in the till. Hydrographs of these wells are provided in Appendix

TABLE 2-11

SUMMARY OF WATER LEVEL DATA, BROWN/GRAY TILL INTERFACE WELLS MARCH 29, 1995

Well No.	Depth to Perched Water (feet below surface)	Elevation of Perched Water (feet above brown/gray interface)	Comment
11494	5.77	7	stabilized water level
11496	5.00	6	stabilized water level
11504	7.41	4	declining trend
11546	8.54	5	slow recovery trend
11547	7.60	9	slow recovery trend
11548	5.78	9	slow recovery trend

C, and a summary of vertical gradients is provided in Table 2-12. Water level and precipitation data are in Appendix B. Vertical gradients were calculated to range from 0.26 to 2.43 (Table 2-12). A discussion on how these vertical gradients impact the flow rates is discussed in Section 4.0.

TABLE 2-12

SUMMARY OF WATER LEVEL DATA FROM PAIRED WELLS COMPLETED IN THE TILL

Well No.	Ground Elevation (ft) M.S.L.[b]	Screened Interval (ft) B.G.L.[c]	Brown/Gray Clay Interface (ft) B.G.L.	Center of Screened Interval Depth (ft) M.S.L.	Water Level[a] (ft) M.S.L.	Calculated Gradient (vertical downward)
11492	610.53	15.0 - 22.0	8.5	592.03	596.01	0.26
11491	611.13	25.0 - 29.5	12.5	583.88	593.93	
11494	603.51	8.0 - 16.5	10.5	591.26	599.63	1.10
11493	603.38	18.0 - 24.5	13.5	582.13	589.61	
11496	602.65	9.0 - 17.0	9.5	589.65	600.12	1.25
11497	602.34	28.0 - 32.0	9.0	572.34	578.56	
11499	594.68	15.0 - 22.0	9.0	576.18	590.58	1.77
11498	594.60	27.0 - 33.0	7.0	564.6	570.08	
11500	598.93	19.0 - 25.5	12.0	576.68	594.29	0.45
11501	598.97	33.0 - 37.0	10.5	563.97	588.6	
11502	593.79	18.0 - 22.0	13.5	573.79	588.37	2.43
11503	593.47	24.0 - 28.0	12.0	567.47	572.99	
11504	590.02	14.0 - 18.0	14.8[d]	574.02	586.06	1.13
11505	590.08	23.0 - 27.0	9.8	565.08	575.93	

[a]Water levels measured March 20, 1995

[b]M.S.L. = Mean Sea Level

[c]B.G.L. = Below Ground Level

[d]Brown/gray contact not clearly defined in Rotasonic core sample.

2.7 URANIUM DISTRIBUTION COEFFICIENT (K_d) TESTING

The K_d study was performed to determine how natural species of uranium in groundwater and soil partition between phases. This information is important in the analysis and evaluation of the retardation of uranium and the potential contaminant transport through the geology. Uranium was the focus of this study because it is the principal contaminant at the FEMP that has the potential to impact groundwater within the 1,000 year design life of the on-site disposal facility.

To obtain the most representative results, natural materials were used. This included natural soils from the area of the investigation, natural perched groundwater contaminated with uranium, and natural perched groundwater without contamination.

2.7.1 Procedures and Completed Activities

The batch testing was performed according to ASTMD 4319. A detailed discussion of the procedures and completed activities is included in Appendix L.

2.7.2 Results

The results of the K_d study are listed in Table 2-13. This table indicates the initial and equilibrium soil and solute concentrations and the resulting K_d values. When a population of K_d values is available, the geometric mean is the standard calculation for determining a representative value for the population. The geometric mean is listed in Table 2-13. The lowest K_d measured for the brown till was 8.5 L/kg, and the highest K_d measured for the brown till was 18.8 L/kg. The geometric mean of brown till K_d values is 12.4 L/kg. The lowest K_d measured for the gray till was 8.0 L/kg, and the highest K_d measured for the gray till was 27.1 L/kg. The geometric mean of gray till K_d values is 10.8 L/kg. How this K_d value impacts the time of travel and the protectiveness of human health and the environment is discussed in Section 4.0.

2.8 PREDESIGN INVESTIGATION DATA SUMMARY

2.8.1 CPT Data Results Summary

CPT data identified CGM which included gravel, sand and silt. The potential granular material identified by the CPT data constitute approximately five percent of the CPT profiles in lithologic sections considered to be above the GMA. Some of these data may represent encounters with large gravel or cobble size particles in a clay matrix rather than interbedded CGMs. Sixteen visual field classifications

TABLE 2-13

K_d TEST RESULTS

Till Type	BROWN	GRAY	BROWN	GRAY	BROWN	GRAY	BROWN	GRAY
Boring # (sample #)	B11491 (1)	B11491 (2)	B11493 (3)	B11493 (4)	B11496 (5)	B11496 (6)	B11498 (7)	B11498 (8)
Co (ug/l)	3293.20	3293.20	3293.20	3293.20	3293.20	3293.20	3293.20	3293.20
Cw1 (ug/l)	1161.60	1406.50	1588.70	1627.50	1314.80	804.80	1661.80	1523.00
W (g)	400.00	400.00	400.00	400.00	400.00	400.00	400.00	400.00
V (l)	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50
Cstar (mg/kg)	18.70	16.50	14.90	14.60	17.30	21.80	14.30	15.50
C (mg/l)	1.20	1.40	1.60	1.60	1.30	0.80	1.70	1.50
Kd (l/kg)	16.10	11.70	9.40	9.00	13.20	27.10	8.60	10.20

Till Type	BROWN	GRAY	BROWN	GRAY	BROWN	GRAY
Boring # (sample #)	B11500 (9)	B11500 (10)	B11502 (11)	B11502 (12)	B11504 (13)	B11504 (14)
Co (ug/l)	3293.20	3293.20	3293.20	3293.20	3293.20	3293.20
Cw1 (ug/l)	1126.10	1596.66	1669.30	1715.30	1044.20	1712.20
W (g)	400.00	400.00	400.00	400.00	400.00	400.00
V (l)	3.50	3.50	3.50	3.50	3.50	3.50
Cstar (mg/kg)	19.00	14.80	14.20	13.80	19.70	13.80
C (mg/l)	1.10	1.60	1.70	1.70	1.00	1.70
Kd (l/kg)	16.80	9.30	8.50	8.00	18.80	8.10

Brown Geometric Mean Kd	12.40
Gray Geometric Mean Kd	10.80

of Rotasonic™ and geotechnical hollow stem auger borings strongly support this assessment. The CPT data were added to the solid block modeling for an enhanced lithologic interpretation. CPT data were also significant in demonstrating heterogeneity of the till; i.e., the CGMs are localized making the potential for interconnectability low.

2.8.2 Perched Groundwater and Vadose Water Radionuclide Results Summary

Detections for total uranium concentrations in the perched groundwater in the area of the proposed disposal facility range from 1.4 μg/L to 198.91 μg/L. The range of concentrations detected for isotopic uranium varied from 0.077 pCi/L to 56.6 pCi/L for U-238; from none detected to 2.50 pCi/L for U-235/236; and from 0.54 pCi/L to 62.3 pCi/L for U-234. The range of detections for total and isotopic uranium are heavily influenced by two wells, 11547 and 11548. These wells are screened across the brown/gray till interface and exhibit total uranium concentrations of 198.91 μg/L and 59.91 μg/L, respectively. The wells were resampled and analyzed at the on-site radiological laboratory, the concentrations of total uranium had dropped from 198.91 μg/L to 75 μg/L for 11547 and from 59.91 μg/L to 17 μg/L for 11548. Copies of the Predesign Investigation data are included in Appendix B. A sampling program is being considered to investigate the nature and extent of groundwater contamination in the areas around wells 11547 and 11548.

Detections for total uranium concentrations in the vadose zone of the glacial till in the area of the proposed disposal facility range from 0.4 μg/L to 22.0 μg/L. The range of concentrations detected for isotopic uranium in the glacial till vadose water varied from 0.14 pCi/L to 6.70 pCi/L for U-238; from none detected to 0.38 pCi/L for U-235/236; and from 0.45 pCi/L to 15.0 pCi/L for U-234. Samples with higher concentrations were collected from shallow lysimeters, and lower concentrations were measured in lysimeters in the deeper portion of the gray till. The two total uranium samples in this report from the vadose zone of the GMA were collected from lysimeters 11131 and 11133 during the most recent sampling round of the Ground Water Sampling of the Existing 8 Lysimeters. The results for these samples were 7.40 μg/L for 11131 and 9.60 μg/L for 11133. The FEMP does not have an established background concentration for water collected from the vadose zone.

The range of tritium concentrations detected in the perched groundwater in the area of the proposed disposal facility varied from 1.33 TU to 21.8 TU. A background concentration has not been established for tritium in groundwater at the FEMP. The tritium concentrations detected in the vadose zone of the glacial till ranged from 4.49 TU to 12.7 TU. The results were inconclusive when used as an aid in the

determination of ground water travel time through the till. However, due to the variation of the concentrations vertically and laterally, the heterogeneous nature of the till was supported.

When the results from the Predesign Investigation are compared to the established background concentrations (RI Report March 1995), the data indicates that the perched groundwater has a higher than background concentration. Except for the two high values for total uranium from 11547 and 11548, the average total uranium concentration detected in the area of the proposed disposal facility is 5.09 μg/L. The 95th percentile background for total uranium in perched groundwater was statistically established in the RI Report as 4.0 μg/L.

2.8.3 Perched Groundwater Chemical Results Summary

Chemical analyses were conducted to determine the chemical characteristics of the perched ground water and vadose zone water.

The range of general water quality parameter concentrations in the perched groundwater varied from none detected to 2,820 μg/L for bromide; chloride varied from 3.44 mg/L to 231 mg/L. The range of sulfate concentrations varied from 56 mg/L to 1,100 mg/L; alkalinity concentrations ranged from 347 mg/L to 4200 mg/L; nitrate/nitrite ranged from 0.2 mg/L to 4.02 mg/L; and total phosphates ranged from 121 μg/L to 518 μg/L. Magnesium concentrations varied from 39,800 μg/L to 290,000 μg/L.

Background values for chloride, sulfate, magnesium, nitrate, and phosphate have been investigated at the FEMP. Background values for bromide and alkalinity have not been established at the FEMP. The established perched groundwater background values for chloride, sulfate, nitrate and total phosphorus are: 120 mg/L, 352.992 mg/L, 10.0 mg/L, and 679 μg/L respectively (Operable Unit 2 RI Report March 1995). The established perched groundwater background for magnesium at the FEMP is 48,546 μg/L (Operable Unit 2 RI Report March 1995).

General water quality and magnesium results in perched groundwater that the ranges from the Predesign Investigation for sulfate, nitrate, and total phosphorus concentrations were below the ranges reported for FEMP background. Chloride and magnesium were detected at concentrations higher than the established background levels. The presence of these chemicals in excess concentrations in water samples may be attributed to impacts from past agricultural activities.

The vadose water in the area of the proposed disposal facility was also sampled for the same water quality parameters. The chemical analyses were conducted in an effort to determine when the installation water was purged. These data should not be compared to other water quality results because the installation water has not been fully purged from the lysimeter.

2.8.4 Soil Uranium Results Summary

The soil sampling results for radionuclides collected during the field activities indicate that the concentrations of radionuclides in soil in the area of the proposed on-site disposal facility are consistent with the established background concentrations. The range of positive detections for total uranium from well, lysimeter, and geotechnical borings are: 1.77 mg/kg to 3.71 mg/kg; 2.01 mg/kg to 2.33 mg/kg; and 1.72 mg/kg to 3.44 mg/kg respectively, which is within the background of 3.4 mg/kg established for the FEMP (CERCLA/RCRA Background Soil Study, 1993).

The range of positive detections for isotopic uranium in soil for U-238 ranged from 0.605 pCi/g to 2.67 pCi/L in well borings, lysimeter borings, and in geotechnical borings. U-235/236 ranged from none detected to 0.107 pCi/g in well borings, lysimeter borings, and geotechnical borings. U-234 ranged from 0.0575 pCi/g to 2.37 pCi/g in well borings, lysimeter borings, and geotechnical borings. The background for U-238, U-235/236, and U-234 in soils are; 1.12 pCi/g, 0.15 pCi/g; and 1.12, respectively (Operable Unit 2 RI, March 1995).

The concentration of TCLP total uranium detected in soil from well and lysimeter borings ranged from 2.40 μg/L to 27.53 μg/L; and from 1.26 μg/L to 7.01 μg/L, respectively. The TCLP concentration of U-238 detected in soil samples from well borings ranged from 1.95 pCi/L to 10.5 pCi/L; and lysimeter in soil from lysimeter borings, from 1.08 pCi/L to 5.56 pCi/L. TCLP U-235/236 concentrations ranged from 0.0156 pCi/L to 0.725 pCi/L in soil from well borings; and from 0.049 pCi/L to 0.216 pCi/L from soil in lysimeter borings. TCLP U-234 concentrations ranged from 2.39 pCi/L to 13.30 pCi/L in soil from well borings; and from 1.03 pCi/L to 6.68 pCi/L in soil from lysimeter borings.

The concentrations of analytes did vary slightly with depth. Detections for total uranium samples collected at or above the brown/gray till interface ranged from 1.77 mg/kg to 3.71 mg/kg in all Predesign Investigation soil borings in the area of the proposed disposal facility. The average total uranium concentration for soil samples collected at or above the brown/gray till interface was 2.57 mg/kg. Total

uranium concentrations ranged from 1.59 mg/kg to 3.04 mg/kg for samples collected below the interface. The average total uranium concentration for soil samples collected below the interface was 2.09 mg/kg.

The Predesign Investigation uranium in soils results exhibit that the soils in the area of the proposed disposal facility are not contaminated with uranium, and are within the established background values for uranium in soils.

2.8.5 Geotechnical Testing Summary

The geotechnical sampling conducted during the Predesign Investigation included: Atterberg Limits; grain size distribution measurements; water content measurements; and permeability tests.

Results from the grain size distribution and Atterberg Limits indicate that soils in the area are classified primarily as Sandy Lean Clays. Soil samples were poorly-sorted mixtures of clay and silt with variable percentages of sand and gravel. Particle size distribution data were combined into the silt and clay, and sand and gravel percentages. These calculated 'silt plus clay' and 'sand plus gravel,' data indicate that the upper portion of the brown till (0-10 feet deep) contained significantly less sand and gravel than the gray till. The average grain size distribution for samples collected from 10 to 30 feet below ground level is almost constant. Samples below 30 feet show an increase in sand and gravel. These results are consistent with the general trend of the lithologic soil descriptions which indicate that the area lithology grades from lean clays to sandy lean clays with depth.

Sample results from water content tests indicate a volumetric soil saturation of 100% on samples collected from five feet or deeper. Soil samples from zero to five feet deep had water contents that ranged from 93% to 100% saturation. The water content and pore space data correlate and indicate that there is significantly more pore space and less water in the soils between 0 and 5 feet below the surface. This factor may be related to the vertical permeability since results range from 1×10^{-5} cm/sec to 1×10^{-8} cm/sec in samples from above five feet deep. Soil samples collected below a depth of five feet range from 1×10^{-8} cm/sec to 7×10^{-9} cm/sec. This suggests that the permeability of the gray clay, which is lower in the deeper samples, is related to decreasing pore space in the clay.

2.8.6 Water Level Data Summary

Water level data results derived from wells screened deep in the gray till show consistently lower water level elevations than the shallow wells. This indicates that a vertical hydraulic gradient exists within the

glacial till. Hydrographs generated from the groundwater levels in monitoring wells and daily precipitation measurements collected during the Predesign Investigation were used to determine well response to precipitation events. Water levels from wells screened across the brown/gray interface indicate a potential perched groundwater flow toward the southwest with a gradient ranging from about 0.011 to 0.025 in the investigation area for the upper limit of the perched groundwater.

Water level data results were also used in the Inverse Modeling of the perched ground water in the area of the proposed disposal facility to estimate hydraulic conductiveness. The results are discussed in detail in Section 3.0.

3.0 MODELING

This section discusses inverse groundwater modeling that estimated hydraulic conductivity in the Predesign Investigation study area by using existing water level measurements. Also discussed is three-dimensional solid block modeling that identified the potential presence of extensive vertical and horizontal coarse granular materials and determined the thickness of the brown till, the thickness of the gray till, the surface for the brown/gray till interface, and the surface of the GMA.

3.1 INVERSE GROUNDWATER MODELING

The term inverse modeling is used to distinguish this modeling methodology from normal groundwater flow modeling. In groundwater flow modeling, estimates of model parameters such as infiltration rate and hydraulic conductivity are used to produce estimates of aquifer hydraulic head. In contrast, the objective of inverse modeling is to estimate the value of one or more model parameters based on historical groundwater elevation data. Therefore, inverse modeling is a parameter estimation procedure. Details of the inverse modeling are provided in Appendix I. This section includes a brief summary of the objectives of inverse modeling, methodology, conceptual model, technical approach, and inverse modeling results and conclusions.

3.1.1 Objectives Of Inverse Modeling

Inverse modeling was conducted to obtain a set of estimated values of hydraulic conductivity in the Predesign Investigation Study Area based on the measured water levels in monitoring wells collected over a period of time. The resulting estimates of hydraulic conductivity were used to test assumptions concerning the physical structure of the site geology, to assist in determining the appropriateness of conceptual models of the site hydrogeology, and to provide qualitative indications of the degree of connectivity in the till hydrogeology and the ability of the soils to transmit water horizontally.

3.1.2 Methodology

The model MODINV, developed at the James Cook University (Doherty, 1990), was used to estimate hydraulic conductivities based on observed water level measurements in monitoring wells. MODINV uses the U.S. Geological Survey (USGS) modular three-dimensional finite difference groundwater flow model, MODFLOW (McDonald and Harbaugh, 1988), as its forward processor. The Hydrologic Evaluation of Landfill Performance (HELP) model (EPA, 1984) was used to estimate the infiltration rates needed for MODFLOW.

3.1.2.1 Conceptual Model

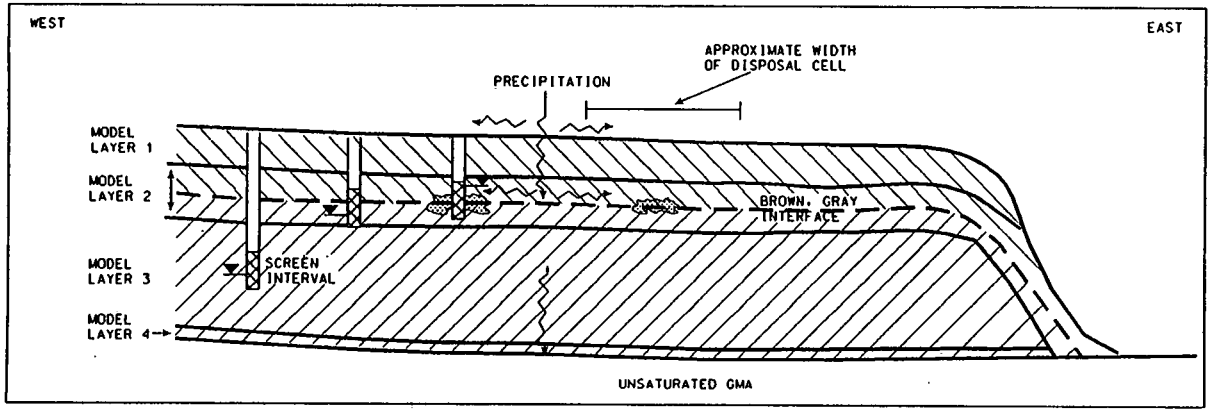
The hydraulic conductivity of the till in the perched groundwater zone was estimated with inverse modeling by developing a conceptual model; as depicted on Figure 3-1 by using geological information from the Site-Wide Environmental Database. For the conceptual model, the till was divided into four layers. Layer 1 is the top-most layer entirely within the brown till that extends from the ground surface to approximately five (5) feet above the brown/gray till interface. Layer 2 of the model is partly in the brown till and partly in the gray till. This layer was assumed to consist of fine-granular till deposits (brown and gray) with interstitial sand and gravel. This layer extends from the bottom of Layer 1 to 5 feet below the brown/gray till interface. Layer 2 is conceptualized as where the majority of the perched water zones were assumed to occur. Layer 3 is conceptualized to consist of all remaining gray clay except for the bottom one foot. Layer 4 is a one-foot thick gray clay layer resting on top of the unsaturated GMA. Layer 4 is confined and is held at atmospheric pressure to simulate its contact with the unsaturated GMA.

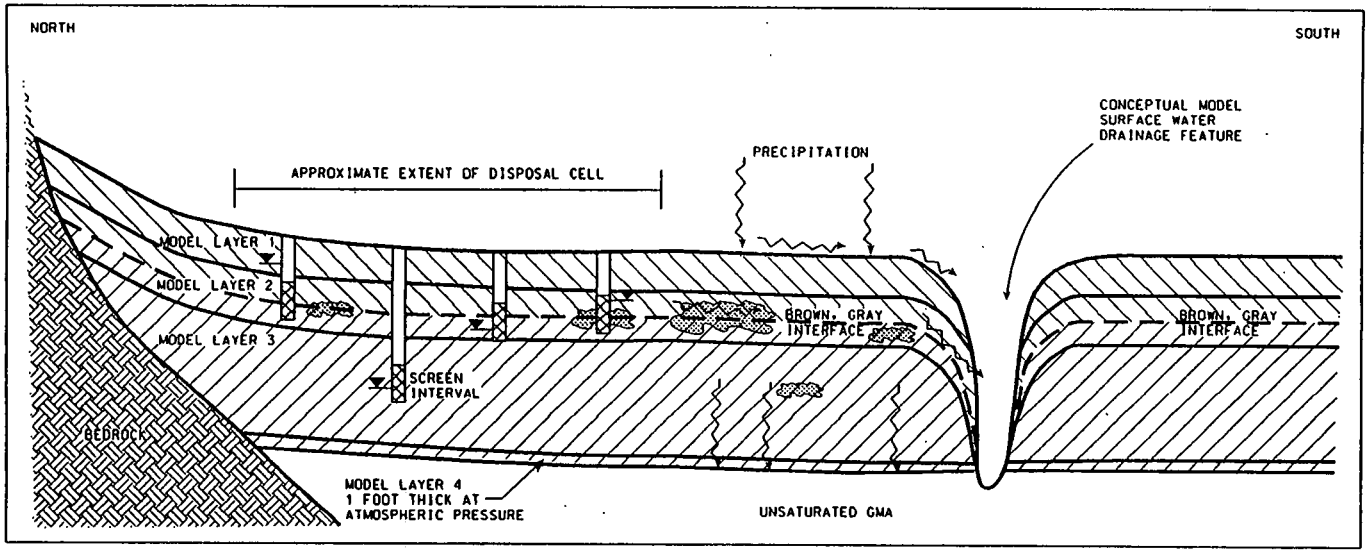
Hydraulic stresses to the modeled area included pumping at the Plant 6 area, well bailing activity, infiltration, vertical flow to the GMA, and seepage to a local drainage channel. In the northern portions of the modeled area, bedrock rises sharply terminating all layers and provides a no-flow boundary. In the southern portion of the modeled area, the conceptual model incorporated a drainage channel feature to allow seepage.

3.1.2.2 Technical Approach

A normal grid spacing of 100 feet was selected for the disposal facility area. Modeled boundaries were extended 1,000 feet beyond the area under consideration for the disposal facility to minimize the effects of boundary conditions on the final results. Grid spacing in this area ranged from 200 to 300 feet. Boundaries of the modeled area were treated as no-flow boundaries.

MODINV was used to estimate the hydraulic conductivity of Layer 2 using daily precipitation data and water level measurements taken at the site from October 4, 1994 to February 22, 1995 from wells screened in the till. Inverse modeling or parameter estimation was completed in two phases so that the field data collection program could be optimized and water level measurements from newly installed monitoring wells in the investigation area could be incorporated into the modeling. During the first phase, modeling used water level and daily precipitation data from October 4, 1994 to November 30, 1994; the second phase used remaining data to February 22, 1995.





LEGEND:

- BROWN TILL
- GRAY TILL
- BEDROCK
- COARSE GRAINED MATERIAL
- OBSERVED WATER LEVEL

NOT TO SCALE

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CONCEPTUAL MODEL FOR INVERSE MODELING

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FIGURE 3-1

FILE NAME: /USR/ERMA5/2CCS1/DGN/MAP/HDR/DPTH/PH20036.DGN

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MODFLOW was run in the steady state mode to verify that the average annual infiltration and specified vertical hydraulic conductivities were compatible with the observed water levels.

In order to develop a manageable modeling scenario, 1,885 cells for conceptual model Layer 2 were organized into 431 groups having the same value of hydraulic conductivity and optimization was performed on a subregion basis. A total of six subregions were created. Iterative parameter optimization was performed on a subregion by subregion basis using the latest available values of hydraulic conductivities from all previous runs.

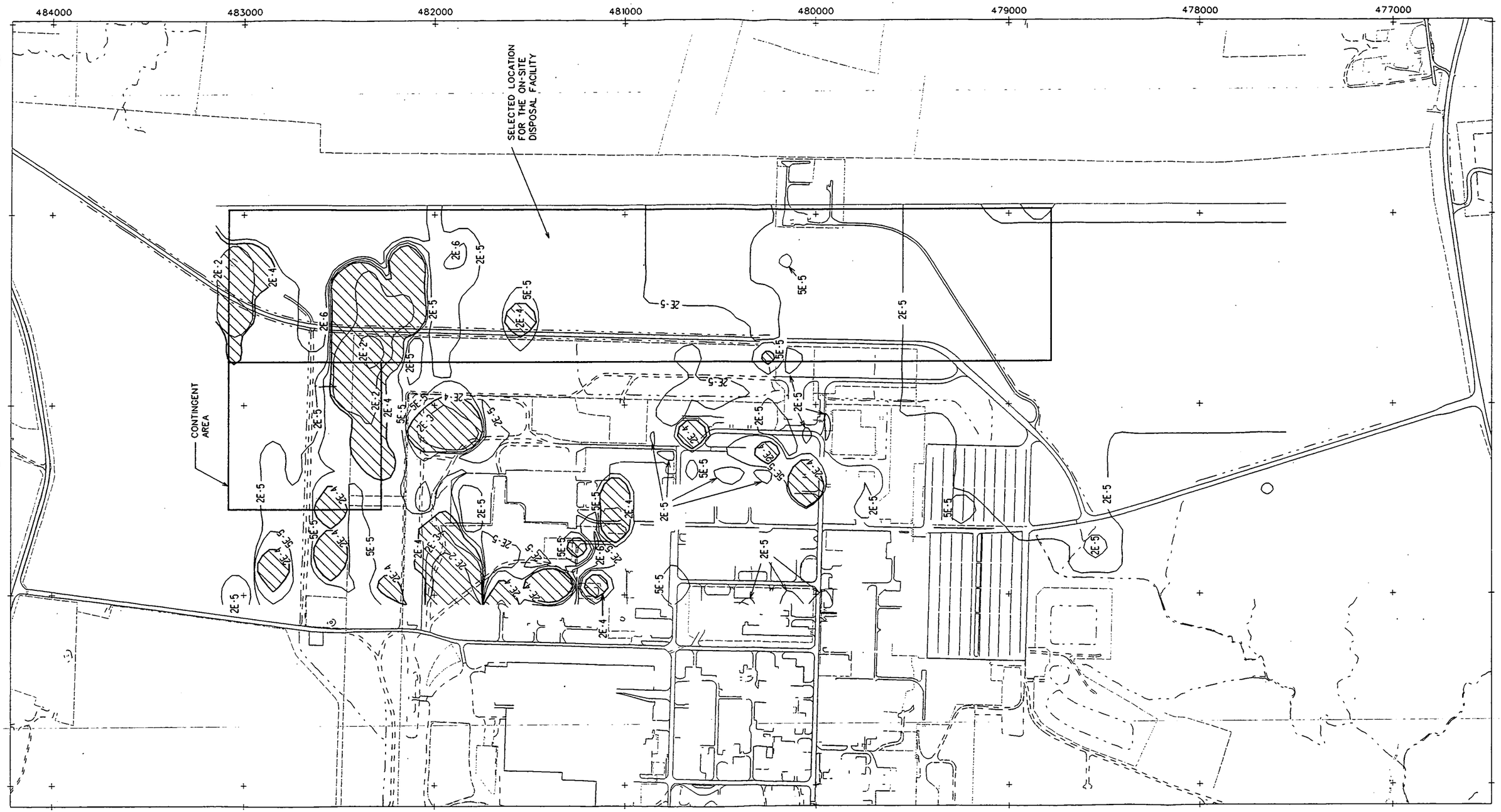
3.1.3 Inverse Modeling Results And Conclusions

Inverse modeling should be considered an attempt to estimate gross characteristics of the till and prevent potential flaws in the disposal facility design. The following conclusions can be drawn from the inverse modeling results:

- Average vertical hydraulic conductivity of the gray till was estimated by the model to be approximately 4 x 10^{-7} cm/sec. Geotechnical investigations, which provided substantial horizontal and vertical coverage of the investigation area, indicated that the vertical hydraulic conductivity of the gray till ranges from 7 x 10^{-9} to 9.2 x 10^{-8} cm/sec. The FS models for Operable Unit 2 used 1.9 x 10^{-6} cm/sec as a vertical hydraulic conductivity value. The value used in FS modeling allowed for more water infiltration than the inverse modeling and the actual field conditions. Therefore, both the inverse modeling and actual field results have demonstrated that the actual vertical permeabilities are more protective of human health and the environment than the values used in the FS modeling.

- Inverse modeling predicted the horizontal hydraulic conductivity at the brown and gray clay interface to be approximately 2 x 10^{-5} cm/sec for the area being considered for the disposal facility location (Figure 3-2). This is within the range of typical hydraulic conductivities for till and silty soils (Freeze and Cherry, 1979) and an order of magnitude higher than the geometric mean value of slug tests (1.9 x 10^{-6} cm/sec) conducted as part of other investigations at the FEMP outside the Predesign Investigation Study Area. These slug test results indicate that the existing geology is more protective of human health and the environment than predicted by the modeling.

- The results of inverse modeling indicate that within the proposed disposal facility area there are two subareas with potentially higher horizontal hydraulic conductivity at the brown/gray till interface. The estimated conductivities range from 2 x 10^{-4} to 2 x 10^{-2} and the areas are approximately 200 x 500 feet and 500 x 1,100 feet in areal extent (Figure 3-2). (Note that smallest model grid spacing is 100 feet and only conductivity at the brown/gray till interface was estimated.) These actual conductivities will be confirmed by slug tests



LEGEND

ESTIMATED HORIZONTAL HYDRAULIC CONDUCTIVITY CONTOUR (cm/sec)

AREAS HAVING ESTIMATED HORIZONTAL HYDRAULIC CONDUCTIVITY GREATER THAN 2E-4 cm/sec

SCALE

0 250 500 1000 FEET

NOTE: COORDINATES ARE STATE PLANAR NAD 1927

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INVERSE MODELING RESULTS HORIZONTAL HYDRAULIC CONDUCTIVITY FOR BROWN/GRAY INTERFACE LAYER

DATE 4-28-95
DRAWN R. WILLIAMS

FIGURE 3-2

FILE NAME: /2ccs1/dcn/map/hor/dpth/ph20035.dgn

conducted in upcoming work programs. These areas offer enhanced protection of the GMA since they are underlain by 30 to 40 feet of gray till, which has vertical hydraulic conductivities ranging from 7 x 10^{-7} to 9.2 x 10^{-8} cm/sec.

- The inverse modeling also predicted that outside the area under consideration for the disposal facility (under the former Production Area), there are several zones of potentially higher horizontal hydraulic conductivity at the brown/gray till interface. This finding may support not locating the disposal facility within the former Production Area.

3.2 SOLID BLOCK MODELING OF LITHOLOGY AND COARSE GRAINED MATERIALS

3.2.1 Objectives

Solid block modeling techniques were used in the Predesign Investigation to classify the till within the study area. The objective of the model was to quantify two aspects of this classification:

i) definition of the thickness of the gray clay, and

ii) estimation of potential location, extent, and volume of CGM within the gray clay layer. (See Section 3.2.3 for a definition of CGM).

In addition, the distribution data provided by the geostatistical methods were used to estimate uncertainty from existing data coverage. These results were then used in the Project Specific Plan (PSP) of the Operable Unit 2 Predesign Field Investigation to assist in defining effective locations for cone penetrometers, soil borings, and lysimeters. All information collected from CPTs, soil borings, and lysimeters was entered into the database and the model was updated and finalized for this report. There were 9,858 data points from the SED, Phase I and II of the Predesign Investigation, and the Design Geotechnical Investigation (Phase III) CPTS.

3.2.2 Methodology

Geostatistical techniques were used to estimate potential locations of CGM. The estimation variable used was a zero/one indicator derived from the classification of the input data points as CGM (1's) or not CGM (0's). This technique is called "indicator kriging".

Variogram models are developed to estimate variability in the input data by direction and distance. By examining the variability in several directions, anisotropic conditions can be estimated. The variogram models were the primary controls for the kriging process. Kriging provides two important parameters for every block in the model:

- a kriged estimate, or expected value, for the estimation variable, and
- a kriging variance, which can be used to describe a distribution for the estimation variable.

By combining the two parameters, confidence estimates can be made for model locations. This approach was used in the Predesign Investigation to define locations of greatest uncertainty in the models.

All geostatistical analyses and displays developed in this study were performed using software developed by Intergraph Corporation of Huntsville, Alabama.

3.2.3 Data Collection and Analysis

Digital terrain models were developed from observed (boreholes, wells) or interpreted (cone penetrometer) contacts between the brown and gray clay layers and between the gray clay and the top of the GMA. The X,Y,Z coordinates of geologic contacts were combined with some manual interpretation of contours and processed by a Delaunay triangulation algorithm to obtain the final terrain models (Intergraph Corporation, MGE Terrain Modeling, Version 5.05). A digital terrain model of the ground surface was developed from contours of the site taken from the 1992 flyover.

Sample intervals were coded according to their lithological type. There were two types of material considered: (1) "CGM", which included sand, gravel, sandy gravel, gravely sand, silty sandy, clayey sand, silty sandy gravel, silty gravely sand, clayey sandy gravel, and clayey gravely sand, and (2) "clay", which included sandy silty clay, silty sandy clay, sandy clay, gravely clay, silt, and clay. Samples grouped into the "CGM" category were assigned a value of one. Other samples were assigned a value of zero.

One of the requirements for effective application of geostatistical techniques is the need for consistent "support" among the input data points. To achieve this for the data being used in this study, it was necessary to remove the variability in the size of the sample interval. This was done by splitting all sample intervals into one foot increments, with X,Y,Z coordinates assigned as the center of each one-foot interval. Intervals of less than 6 inches or sample fragments less than 6 inches were removed. For example a sample interval of 3.1 feet would be split into three one-foot intervals.

The projected surface of the top of the GMA was considered the bottom of the model. This was done to avoid the inclusion of the predominantly sandy samples from the GMA in the statistical analyses of the samples in the glacial overburden layer. Samples which were denoted as "No Recovery" were also excluded from the data set.

A block model was defined to cover the entire study area with an additional buffer of about 500 feet in all four directions. The larger size ensured that data outside of the study area, yet still close enough to have an impact on the modeling, were included in the analysis. The model location (NAD 1927) is as follows:

X (East)	:	1,380,650	to	1,383,300
Y (North)	:	477,300	to	483,450
Z (Elevation)	:	549 MSL	to	610 MSL

A grid spacing of 50 feet horizontal and one-foot vertical was used, resulting in a model of just over 415,000 blocks.

Horizontal variograms were run with a 25-foot lag out to a distance of 500 feet at azimuths of 0, 30, 60, 90, 120 and 150 degrees. A vertical variogram was also run with a one-foot lag, to a distance of 20 feet. Experimental variogram models were developed based on the results, and indicated an anisotropic axis aligned at roughly 109 degrees azimuth (E19S). The model ranges were estimated as 260 feet along the major anisotropic axis and as 90 feet along the minor axis. Along the major axis, material is more continuous; whereas, moving along the minor axis, and away from the major axis, continuity decreases. The vertical range was estimated as 2.5 feet.

Indicator kriging was run against the input data over the portion of the block model covering the study area. A first kriging run was made using search radii equal to the variogram ranges. A second kriging run was made using double the variogram ranges as the search radii. Results from the first kriging run were used wherever possible. In areas of the model where the first run was unable to estimate a value (based on distance from model point to input data), the results from the second kriging run were inserted. Locations where the second run results were used were marked in the model for later analysis or display.

Blocks within the model were denoted as air, brown clay, gray clay, or GMA according to their location relative to the terrain models described above. Kriging results then were assigned only for blocks denoted as gray clay.

3.2.4 Results

Based on the digital terrain models (DTM) of the brown/gray till interface and the top of the GMA, a third DTM was generated representing the thickness of the gray clay. Contour maps of the brown/gray till interface surface and the gray clay thickness were created from these DTMs (Figures 3-3 and 3-4).

Kriged estimates were used to classify each model location as CGM or non-CGM. The indicator kriging methodology is described in Section 3.2.2. The resulting kriging estimate is a continuous parameter that ranges from zero to one, with zero representing non-CGM and one representing CGM. The parameter is an estimate of the probability that the material at each location is non-CGM or CGM. For example, if the estimate at a particular location is 0.9, then the material is likely to be CGM. Likewise, if the estimate at a particular location is 0.1, then the material is likely to be non-CGM. A cutoff value was chosen in order to classify all of the locations in the model grid as either non-CGM or CGM. The cutoff value used to make this determination was 0.4. Model locations with a kriged estimate less than 0.4 were classified as non-CGM; locations with a kriged estimate equal to or greater than 0.4 were classified as CGM. The choice of 0.4 as the cutoff value represents a conservative choice in that it includes more material as CGM in the classification of the lithology. The results of the kriging classification are summarized by five cross-sections through the study area (Figures 3-5 through 3-10).

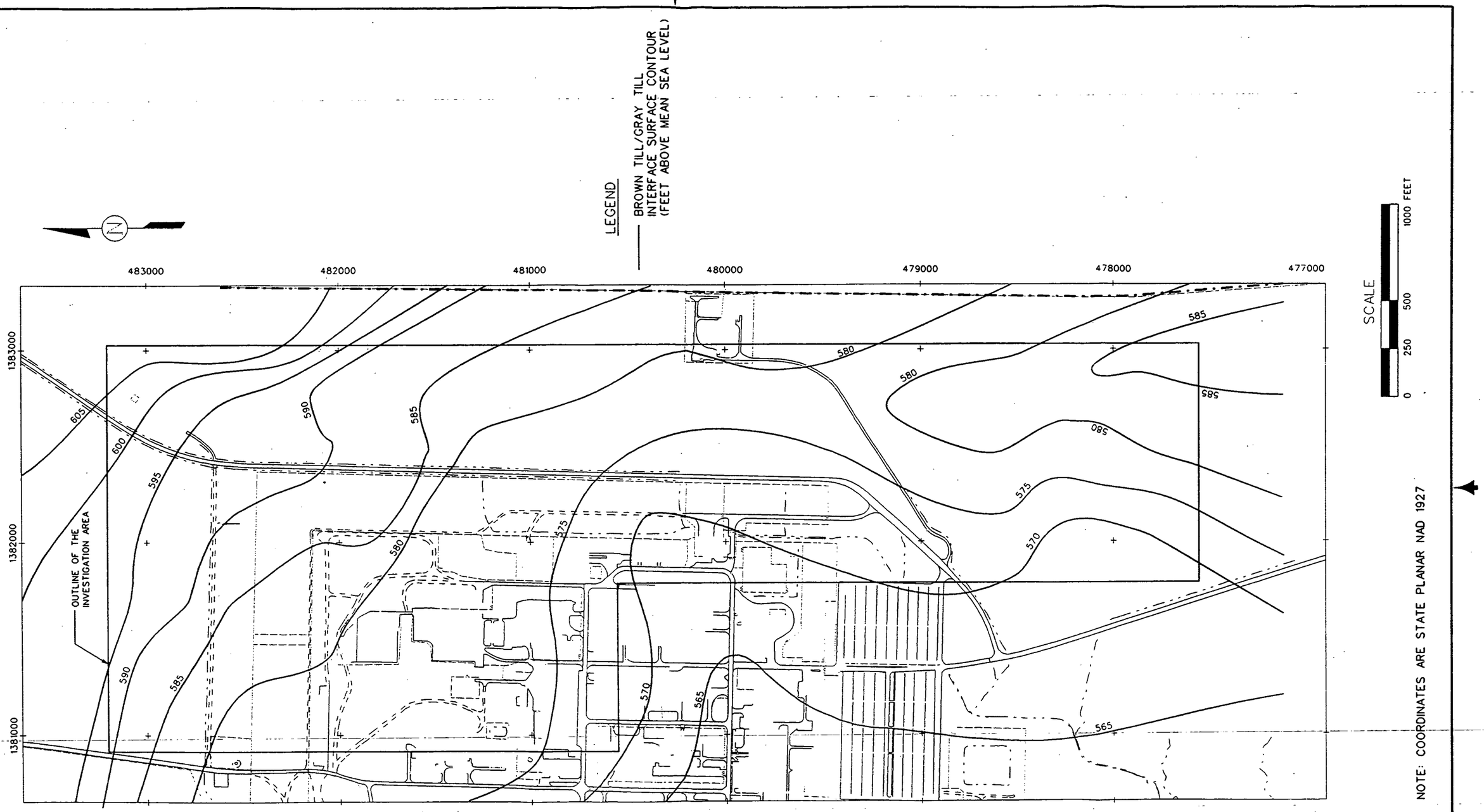
Based on the statistical results from the kriging process, a new parameter was developed at each model location which reflected the probability that the "true" value for the location is greater than 0.4. For example, a model location with a kriged estimate of 0.2 and a kriged variance of 0.1 would be assigned a probability estimate of about 2.5 percent, derived from the one-sided probability that a normally distributed random variable exceeds the mean by more than two standard deviations.

Two factors contribute to the calculation of the probability estimates:

i) the value of the kriged estimate, as determined by the distribution of data points with zeroes (non-CGM) and ones (CGM) around the model location. As the kriged estimate increases closer to the 0.4 cutoff value, the probability value increases.

ii) the value of the kriging variance, as determined by the quantity and proximity of data points surrounding the model location. As data points become more distant from the modeling location, or less numerous, the kriging variance increases, the "spread" in the estimated kriging distribution increases, and the area under the normal curve above 0.4 (the probability value) increases.

Figures 3-11 through 3-14 illustrate iso-probability contours for planes parallel to the brown clay/gray clay interface at a depth of 1, 5, 10 and 15 feet within the gray clay. Contours marked as 50 percent enclose areas where the model has estimated CGM (as indicated on Figures 3-6 through 3-10). Contours labelled 25 and 40 percent represent areas which were classified as non-CGM, yet suggest with higher probability (relative to areas outside the contour lines) that CGM may be located in these areas.



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000090

BROWN TILL / GRAY TILL INTERFACE SURFACE

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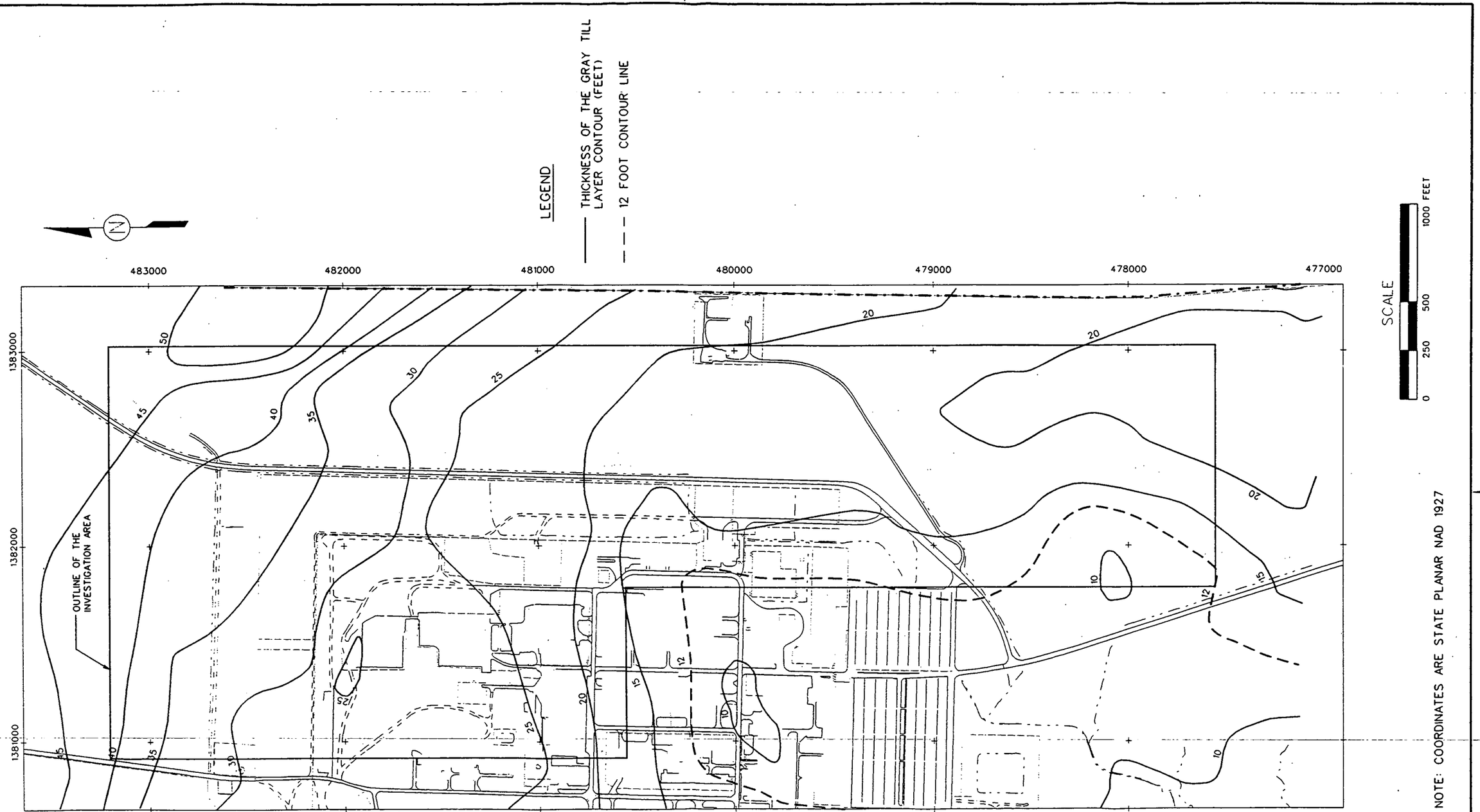
FIGURE 3-3

FILE NAME: /2ccs1/dgn/map/hor/dpth/ph20014.dgn



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THICKNESS OF THE GRAY TILL

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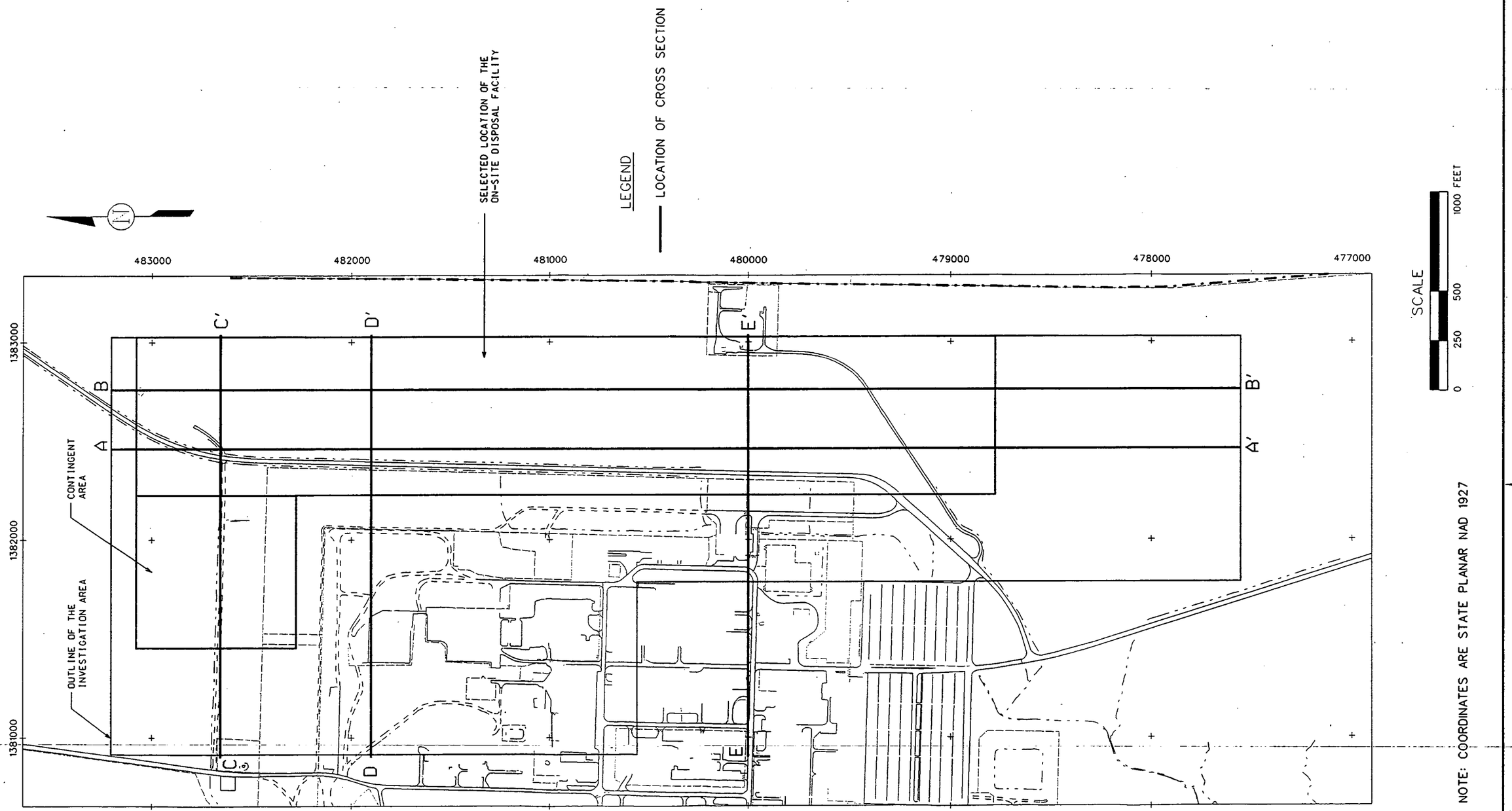
FIGURE 3-4

FILE NAME: /2ccs1/dgn/map/hor/dpth/ph20017.dgn



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CROSS-SECTION LOCATION MAP 000032

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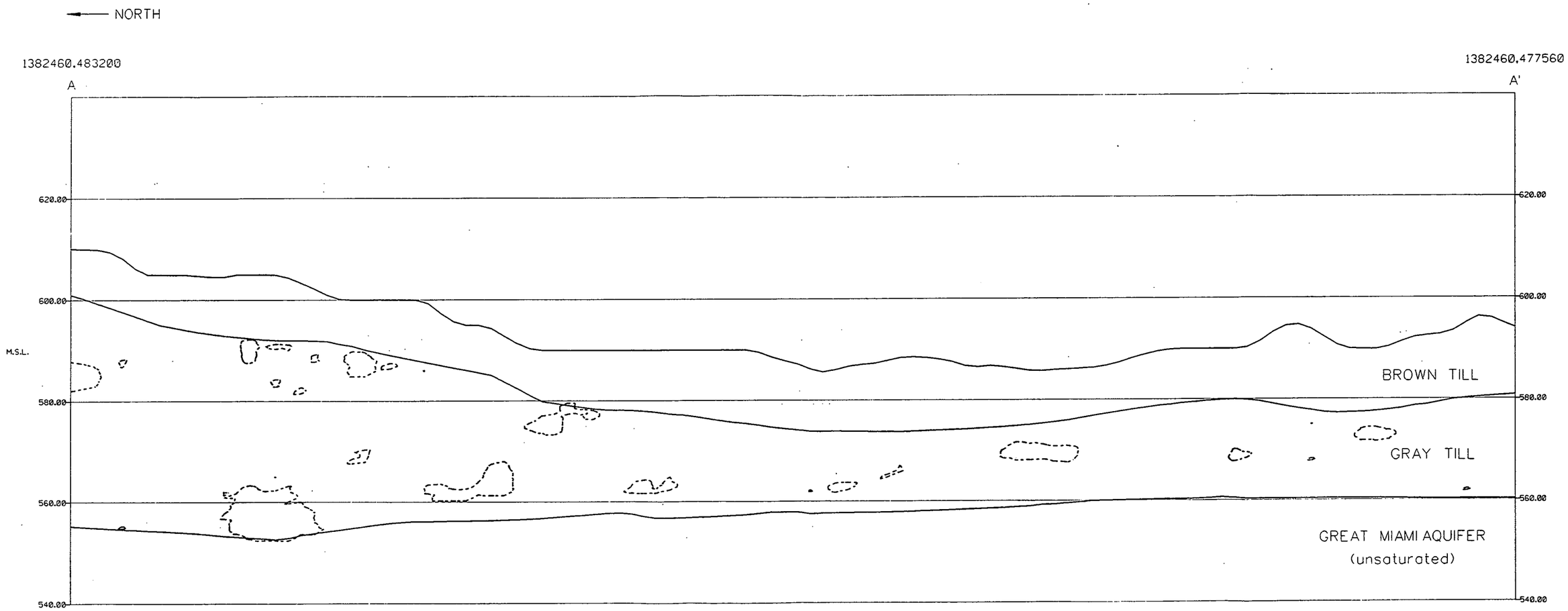
FIGURE 3-5

FILE NAME: /2ccs1/dgn/map/hor/dpth/ph20041.dgn



LEGEND

MODELED LOCATIONS OF COARSE GRAINED MATERIAL IN GRAY TILL
(Based on Indicator Value = 0.4)

HORIZONTAL SCALE: 0 200' 400' 800'
VERTICAL 0 10' 20' 40'

NOTE:

COORDINATES ARE STATE PLANAR NAD 1927

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MODELED LOCATIONS OF COARSE GRAINED MATERIALS SECTION A-A'

000093

DATE 05/04/95
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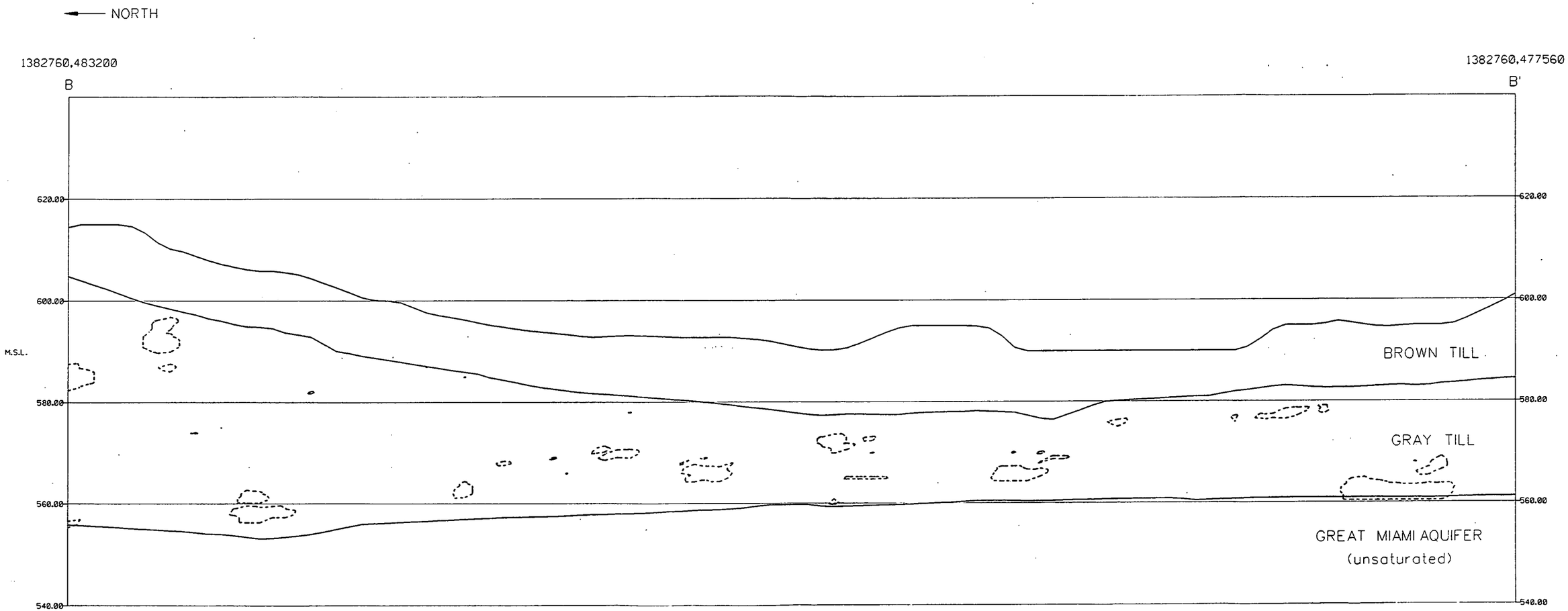
FIGURE 3-6

FILE NAME: /usr/ermc5/2ccs1/dgn/sec/geo/dpth/krig_a.dgn



LEGEND

MODELED LOCATIONS OF COARSE GRAINED MATERIAL IN GRAY TILL
(Based on Indicator Value = 0.4)

HORIZONTAL SCALE: 0 200' 400' 800'
VERTICAL 0 10' 20' 40'

NOTE:

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MODELED LOCATIONS OF COARSE GRAINED MATERIALS SECTION B-B'

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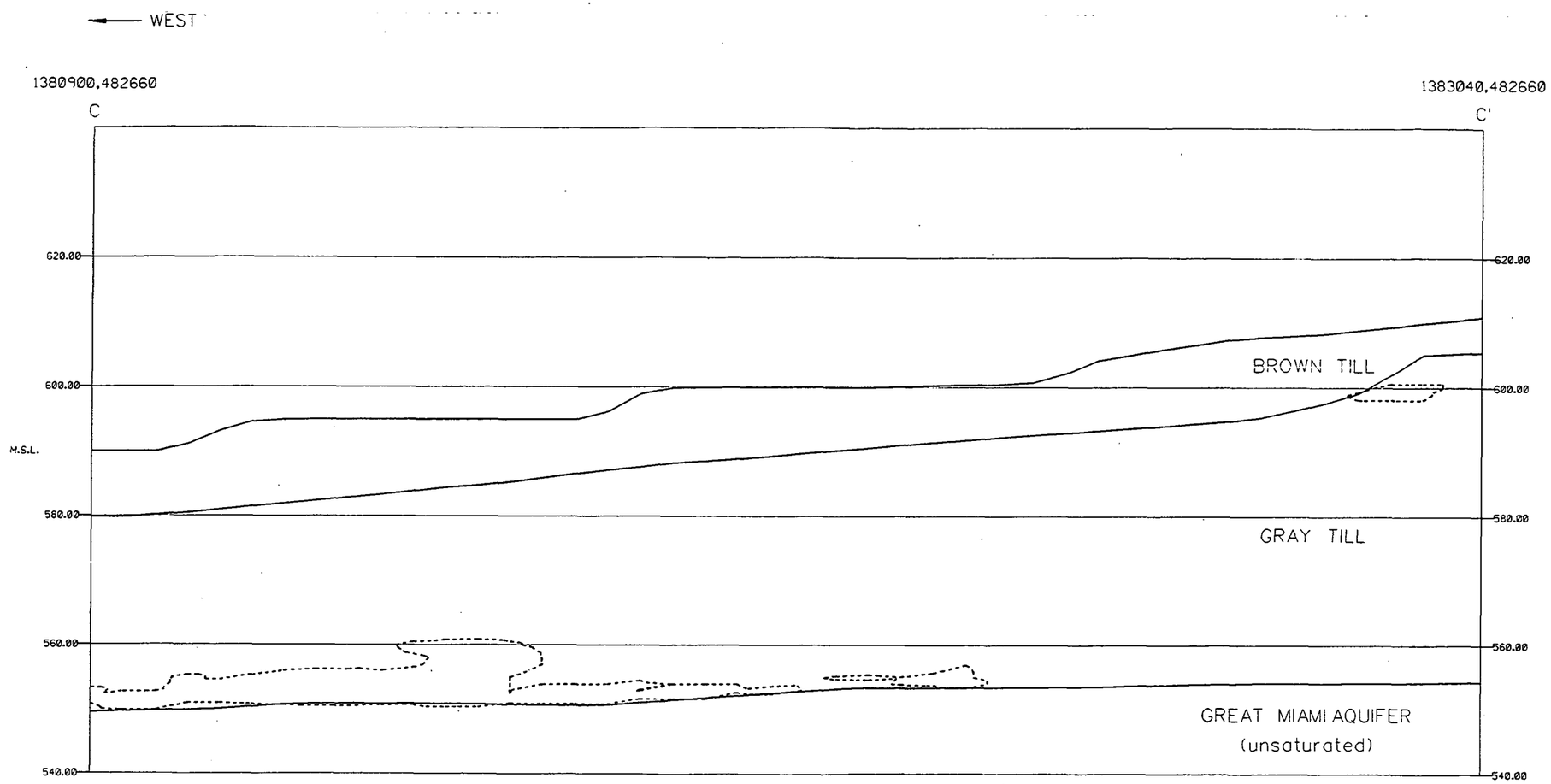
FIGURE 3-7

FILE NAME: /usr/ermo5/2ccs1/dgn/sec/geo/dpth/krig_b.dgn



LEGEND

MODELED LOCATIONS OF COARSE GRAINED MATERIAL IN GRAY TILL (Based on Indicator Value = 0.4)

HORIZONTAL SCALE: 0 100' 200' 400'
VERTICAL 0 10' 20' 40'

NOTE:

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MODELED LOCATIONS OF COARSE GRAINED MATERIALS SECTION C-C'

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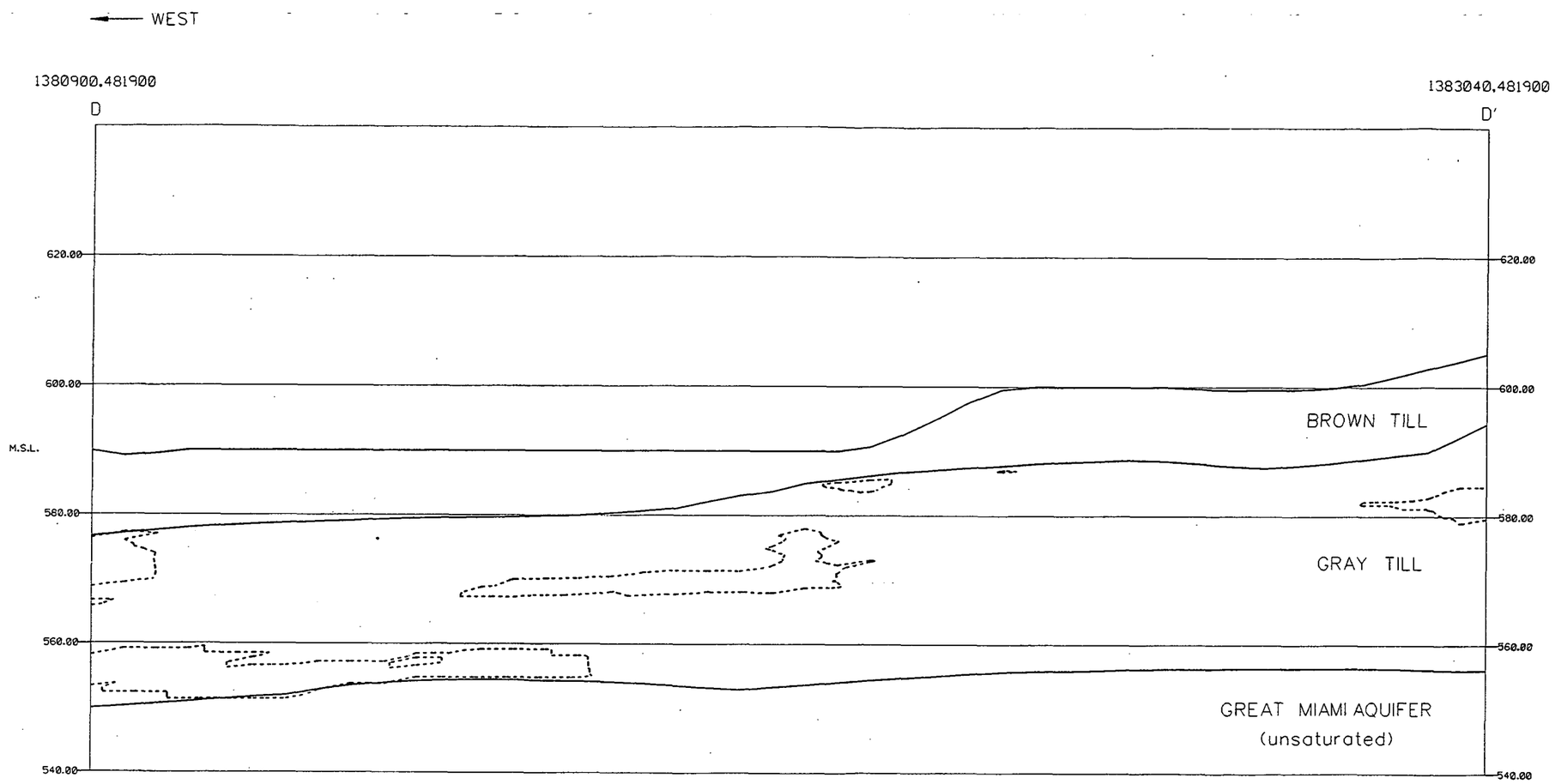
FIGURE 3-8

FILE NAME: /usr/ermo5/2ccs1/dgn/sec/geo/dpth/krig_c.dgn



LEGEND

MODELED LOCATIONS OF COARSE GRAINED MATERIAL IN GRAY TILL
(Based on Indicator Value = 0.4)

HORIZONTAL SCALE: 0 100' 200' 400'
VERTICAL 0 10' 20' 40'

NOTE:

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MODELED LOCATIONS OF COARSE GRAINED MATERIALS SECTION D-D'

000096

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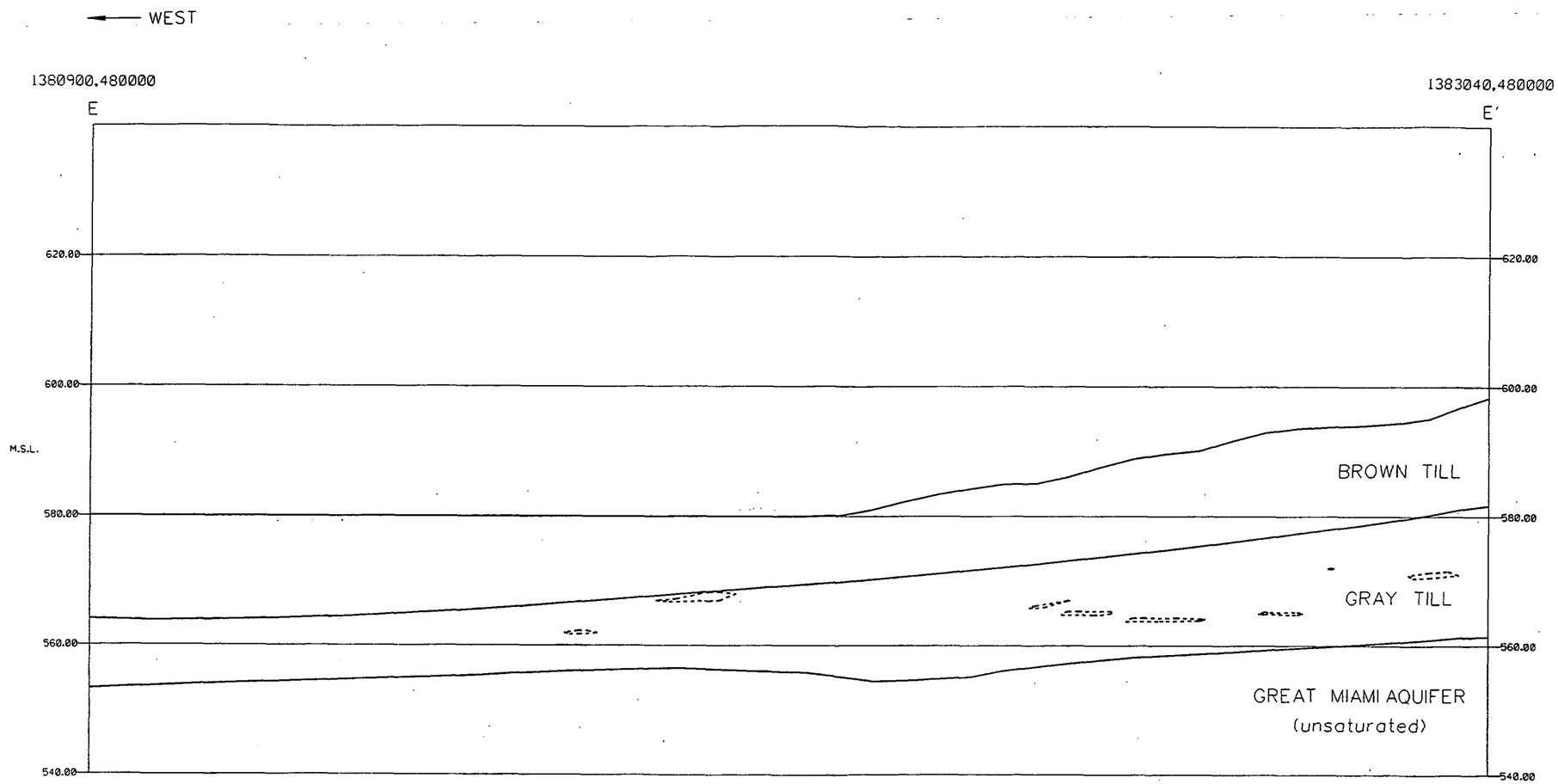
FIGURE 3-9

FILE NAME: /usr/erma5/2ccs1/dgn/sec/geo/dpth/krig_d.dgn



LEGEND

MODELED LOCATIONS OF COARSE GRAINED MATERIAL IN GRAY TILL
(Based on Indicator Value = 0.4)

HORIZONTAL SCALE: 0 100' 200' 400'
VERTICAL 0 10' 20' 40'

NOTE:

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MODELED LOCATIONS OF COARSE GRAINED MATERIALS SECTION E-E'

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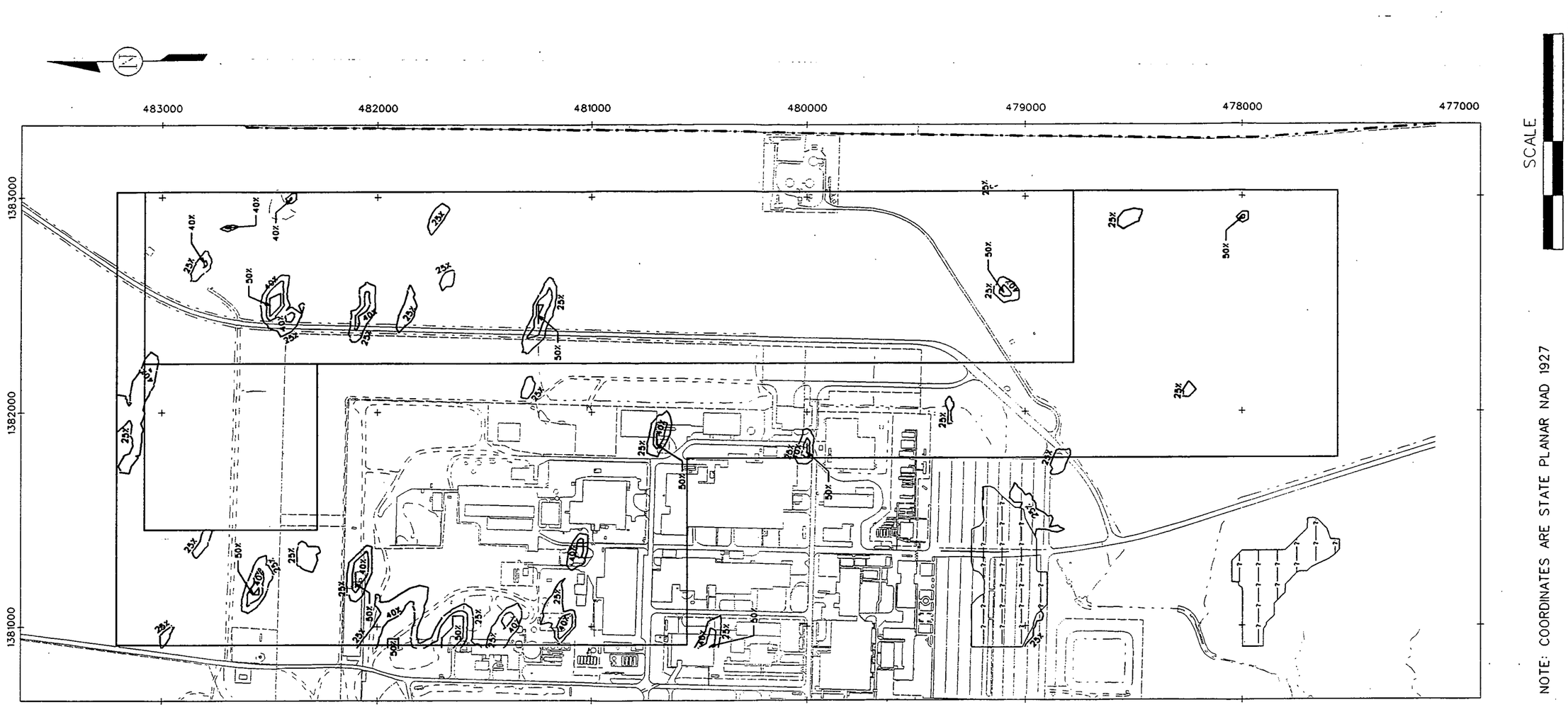
FIGURE 3-10

FILE NAME: /usr/erma5/2ccs1/dgn/sec/geo/dpth/krig_e.dgn



LEGEND

UNKNOWN AREAS (NO DATA)

ISO-PROBABILITY CURVES (at 25%, 40%, 50%)

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PROBABILITIES OF MISCLASSIFIED NON-COARSE GRAINED MATERIAL

1' BELOW BROWN/GRAY INTERFACE

000038

DATE 06/07/95

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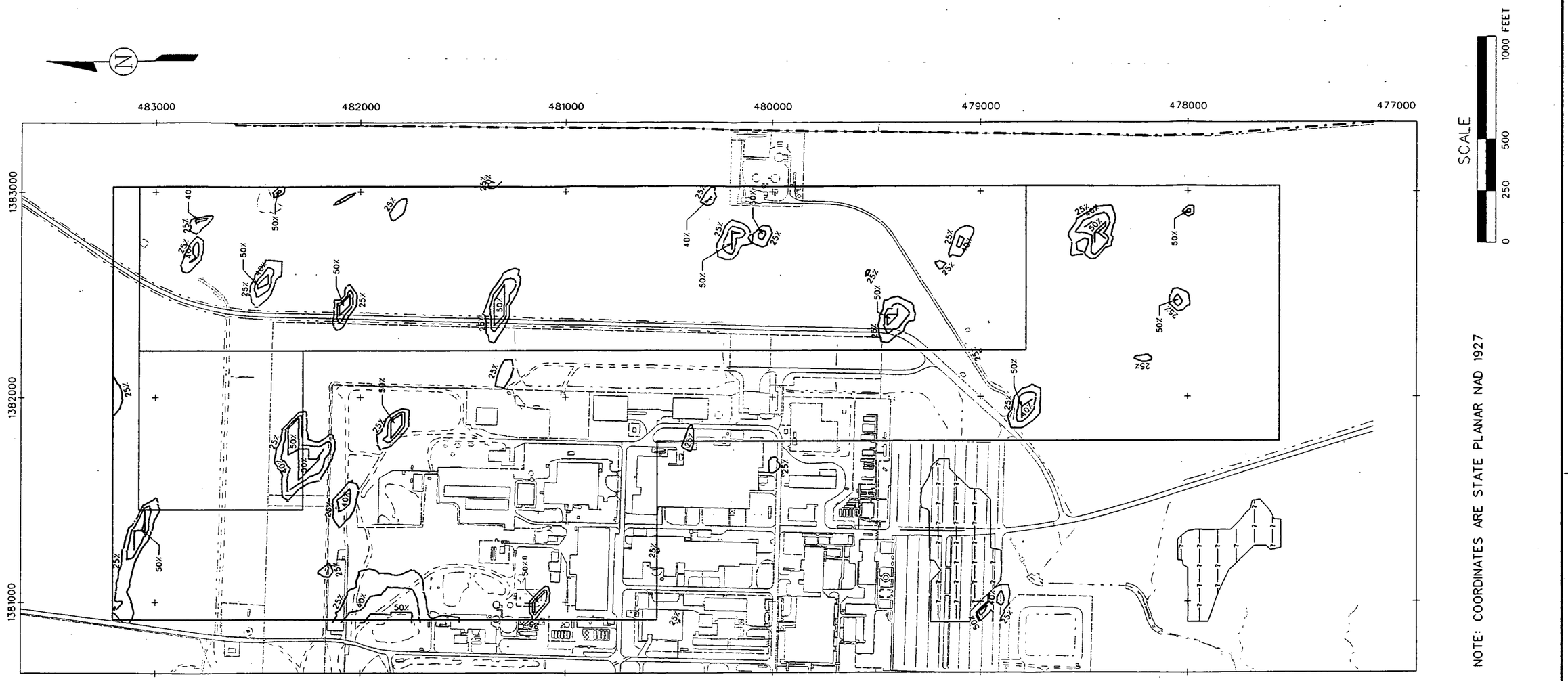
FIGURE 3-11

FILE NAME: /2ccs1/mgvo/sgm3/



LEGEND

UNKNOWN AREAS (NO DATA)

ISO-PROBABILITY CURVES (at 25%, 40%, 50%)

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PROBABILITIES OF MISCLASSIFIED NON-COARSE GRAINED MATERIAL

5' BELOW BROWN/GRAY INTERFACE

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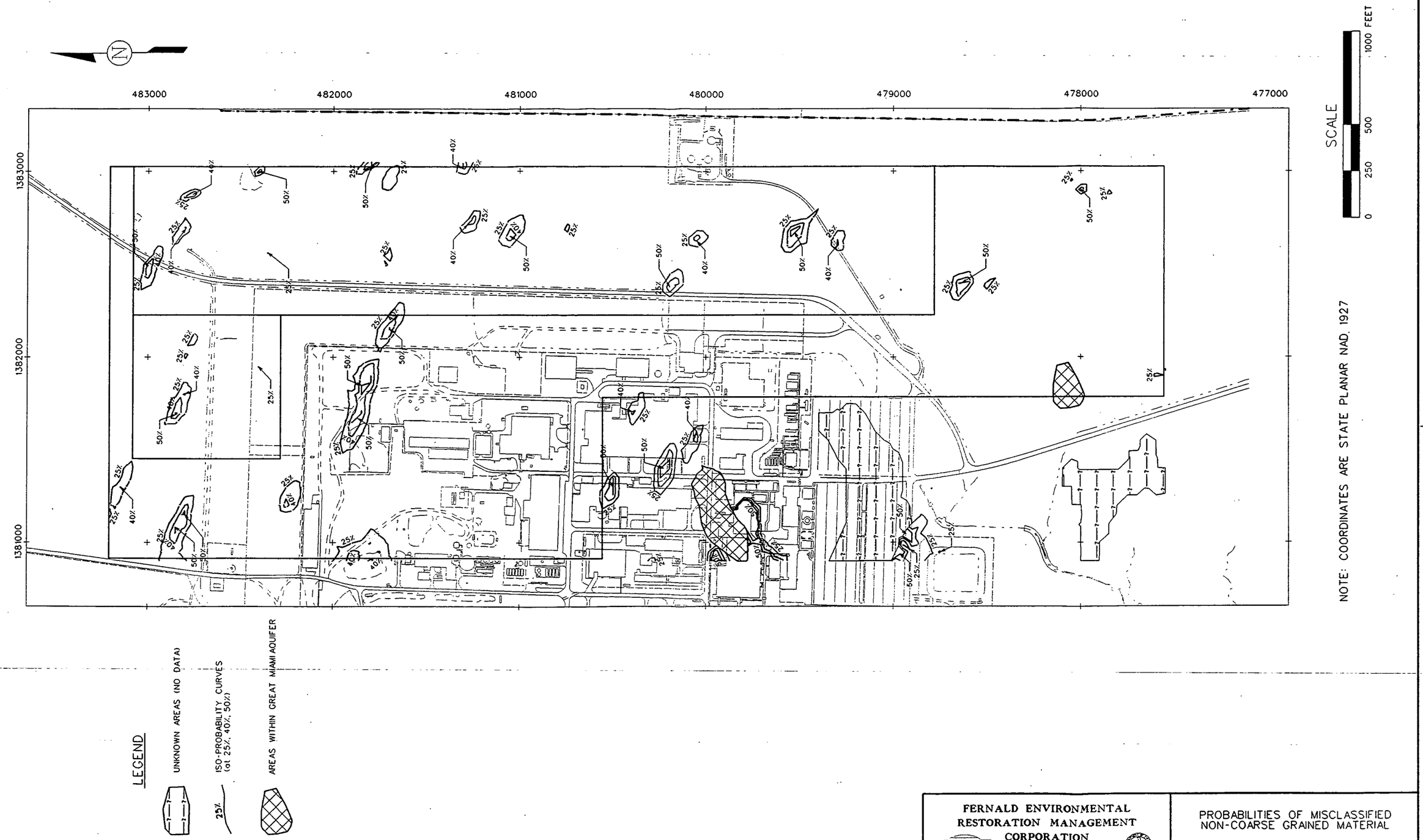
FIGURE 3-12

FILE NAME: /2ccs1/mgva/sampling/ph20004.sep



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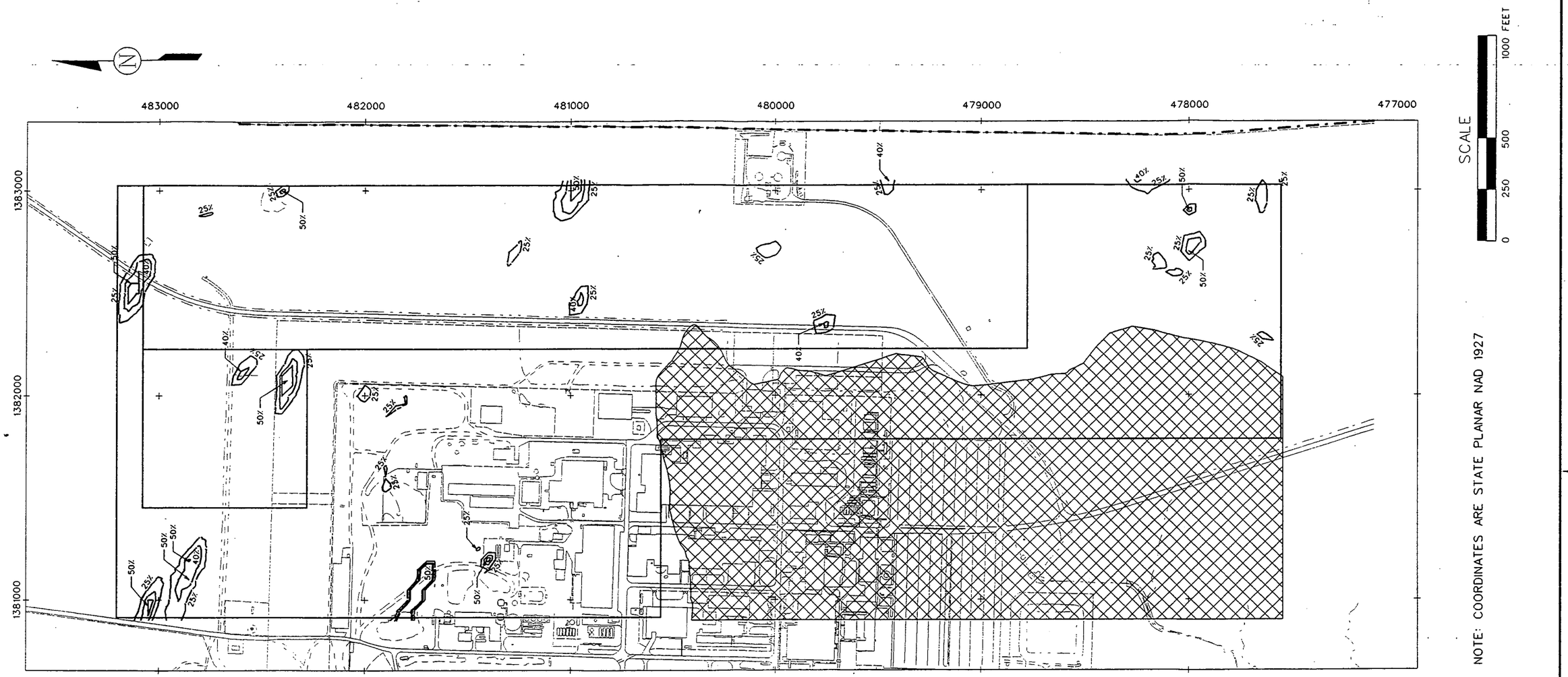
PROBABILITIES OF MISCLASSIFIED NON-COARSE GRAINED MATERIAL
10' BELOW BROWN/GRAY INTERFACE

DATE 06/07/95
DRAWN JCF

FIGURE 3-13

FILE NAME: /2ccs1/mgvo/sgm5/ph



LEGEND

25% ISO-PROBABILITY CURVES (at 25%, 40%, 50%)

AREAS WITHIN GREAT MIAMI AQUIFER

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PROBABILITIES OF MISCLASSIFIED NON-CGM MATERIAL
15' BELOW BROWN/GRAY INTERFACE

DATE 06/07/95
DRAWN JCF

FIGURE 3-14

FILE NAME: /2ccs1/mgva/sgm5/[illegible]

4.0

4.0 CONCLUSIONS

4.1 INTRODUCTION

Based on planning meetings between the U.S. Department of Energy (DOE), Fernald Environmental Restoration Management Corporation (FERMCO), U.S. Environmental Protection Agency (EPA), and Ohio Environmental Protection Agency (OEPA), the Predesign Investigation included three objectives. Objective 1 was to identify the most suitable hydrogeology in the investigation area on the east side of the FEMP. The field components involved verification of the gray clay thickness and the identification of interbedded granular material. Objective 2 was the verification of the protection of human health and the environment. The field components included measurements of existing vertical and horizontal uranium contamination; solubility of uranium present; retardation of uranium; lateral and vertical hydraulic gradients within the perched groundwater; and background concentrations of uranium in the perched groundwater. Objective 3 was to develop field information for the design of the disposal facility. The field components included identifying initial geotechnical properties of the soil in the footprint of the disposal facility.

This section presents the conclusions associated with the above objectives. Objective 1 resulted in a recommended location for the disposal facility. Objective 2 served to verify the protectiveness of the area in comparison to the modeling parameters used in the FS modeling of the disposal facility. Objective 3 was not intended to directly result in conclusions for this report and is not discussed in this section. However, the preliminary geotechnical information gathered in this investigation will be used in the preliminary design of the disposal facility.

4.2 OBJECTIVE 1 - IDENTIFY THE MOST SUITABLE HYDROGEOLOGY IN THE INVESTIGATION AREA

As was noted in Section 1.0, an overall goal of the Predesign Investigation was the determination of the most suitable location for the on-site disposal facility. This goal was based on the objective of demonstrating the most suitable hydrogeologic location within the investigation area.

The most suitable hydrogeology in the investigation area is a location which:

- has the highest overall average gray till thickness
- excludes thinner gray till regions within the investigation area
- contains the least amount of interbedded coarse granular material (CGM)

After Phases I and II of the Predesign Investigation were completed, a location with these characteristics was selected (Figure 4-1). The following subsections discuss the overall logic for establishing that location for the disposal facility.

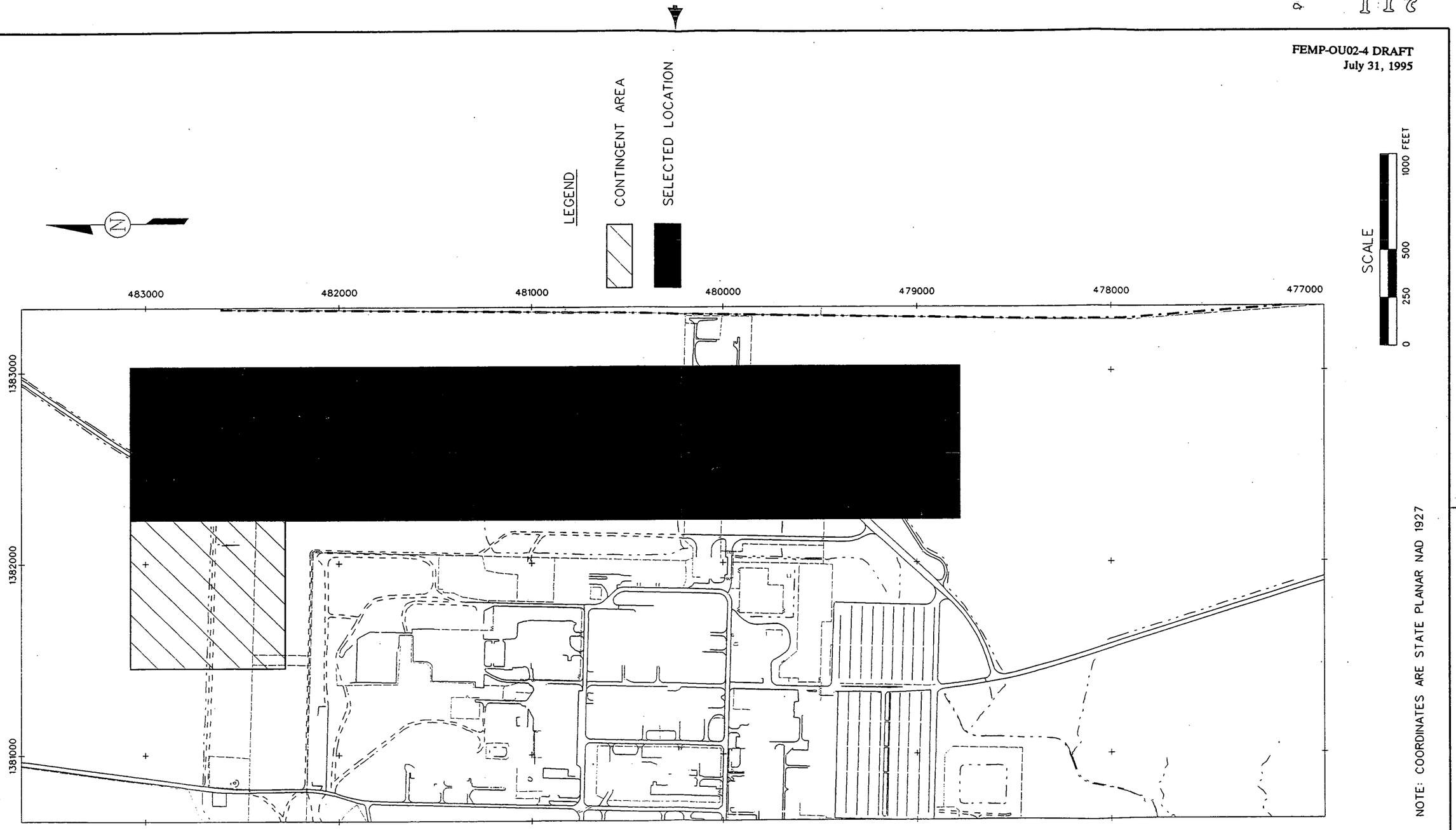
4.2.1 Verification Of Gray Till Thickness

The gray till thickness was verified visually from boring log descriptions of well installations, boring installations, and lysimeter installations. The boring logs contained continuous descriptions of the lithology from the surface to the bottom of the bore hole. All available boring logs were used including those from activities prior to the Predesign Investigation. The descriptions helped to identify the top of the gray till, which was determined to be the brown/gray till interface, and the bottom of the gray till, which was at the gray till/GMA interface. Also, sixteen CPT soundings from Phase III penetrated deep enough to be used for refinement of the location of the bottom of the gray till. The CPT soundings could not be used to identify the brown/gray till interface because the variation of the grain size distribution at the interface from the brown till to the gray till was too small to be measured by the CPT probe.

The visual determinations of top of gray till and bottom of gray till were made for use in kriging the surfaces for the solid block modeling. The kriging results were used to determine the thickness of the gray till for the entire modeled area (Figures 3-4 and 4-2). At the southwestern edge of the investigation area, gray till with thicknesses of less than 12 feet was encountered. The 12-foot thickness is a critical parameter to meet since this is the minimum thickness of gray till used in the Operable Unit 2 Feasibility Study (FS) modeling to demonstrate protectiveness of human health and the environment.

If the disposal facility were to be located toward the southern end of the investigation area, the average thickness of the gray till beneath the facility would be approximately 20 feet. Placement toward the northern end would increase the average gray till thickness to approximately 30 feet. Maintaining the maximum average thickness is important in increasing the protection of human health and the environment.

The thickness of the gray till by itself is not sufficient for selecting a location. The effectiveness of the gray till thickness for protecting human health and the environment is dependent upon the volume and interconnection of interbedded CGM. The lower the volume and interconnection of CGM the



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SELECTED LOCATION FOR THE PROPOSED ON-SITE DISPOSAL FACILITY

DATE 5-2-95
DRAWN R. WILLIAMS

FIGURE 4-1

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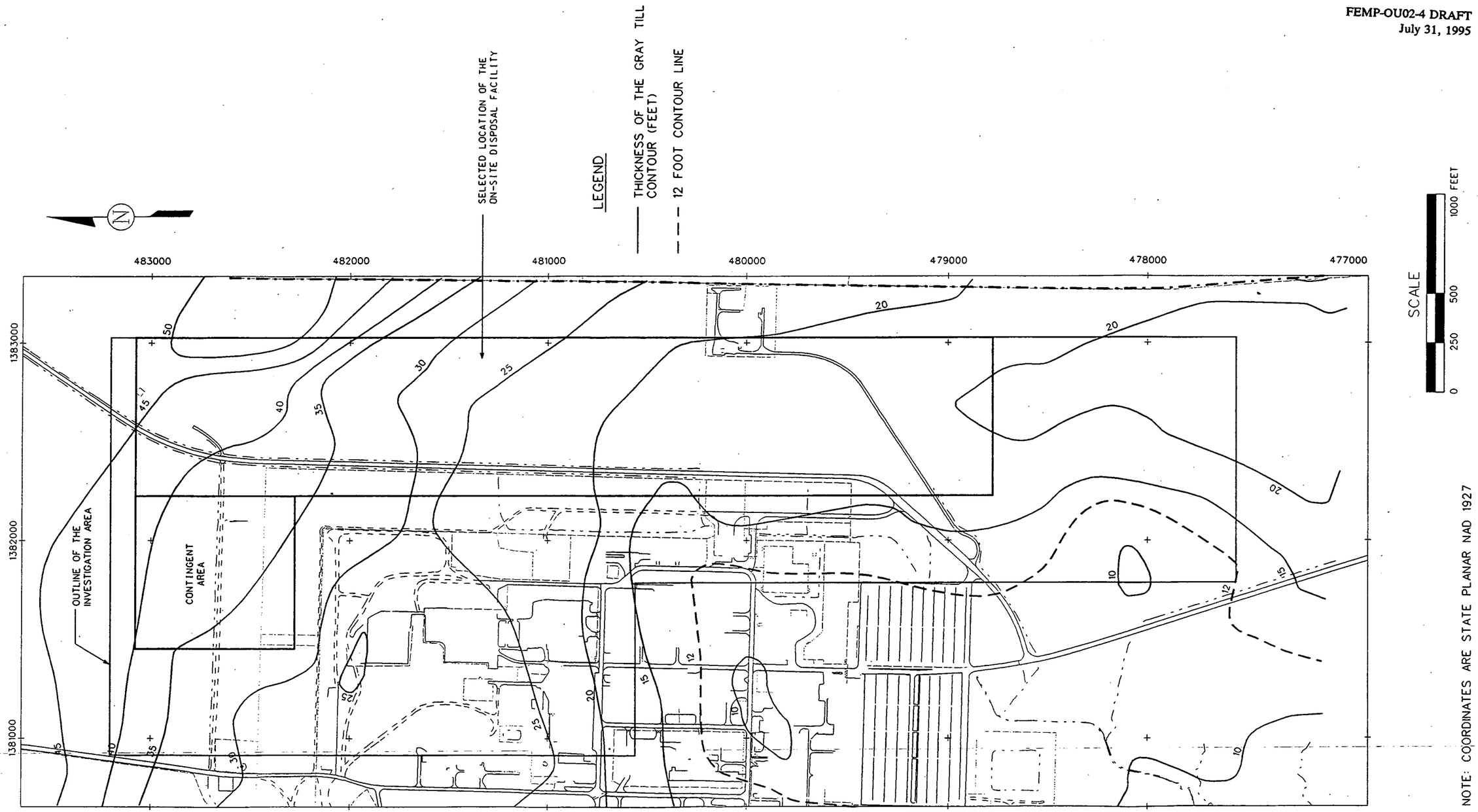

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THICKNESS OF THE GRAY TILL

DATE 5-4-95
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FIGURE 4-2

FILE NAME: /2ccs1/dgn/mgp/hor/dpth/ph20017.dgn

greater the protectiveness because the CGM will transmit perched groundwater at a higher rate than the other till material.

4.2.2 Identification Of Interbedded Coarse Granular Material (CGM)

Interbedded coarse granular material was identified visually from the boring logs from well installations, boring installations, and lysimeter installations. Also, CPT logs were used in the granular material identification. The tops and bottoms of interbedded coarse granular material, from all of the well, boring, and lysimeter installations and CPTs, were used in the 3-Dimensional Solid Block Modeling to determine the potential vertical and horizontal extent of the interbedded coarse granular material in the gray till. Cross sectional views of the modeling are provided in Figures 3-5 through 3-10. The bodies of interbedded coarse granular material, shown by these cross sections, are localized and not interconnected. However, the sizes of these bodies become larger westward and northward (Figures 3-6 and 3-9). This coarse granular material is expected to have a higher vertical and horizontal hydraulic conductivity than the surrounding gray till, thus perched groundwater will move faster through these areas. Consequently, selecting a location for the disposal facility that has a minimal amount of interbedded CGM in the gray till and the smallest bodies of CGM is more protective of human health and the environment.

4.2.3 Selected Location For The Disposal Facility

The selected location and configuration for the disposal facility, as presented in Figure 4-1, achieved Objective 1 as follows:

- The average thickness of the gray till would be approximately 30 feet.
- The minimum thickness of the gray till would be approximately 15 feet.
- The location has a minimal amount of CGM and that CGM is in small bodies.

A minimum thickness for the gray till of 12 feet is met throughout most of the investigation area. Therefore, the selection of the location becomes dependent upon the volume of interbedded coarse granular material within the gray till. Selecting a location with the lowest volume of CGM will reduce the potential of interconnection between interbedded CGM; thereby, reducing the potential for vertical flow paths.

Figure 4-3 shows the proposed location from the Operable Unit 5 Feasibility Study and Figure 4-4 shows the preliminary location proposed after Phase I of the Predesign Investigation. The sizes of the

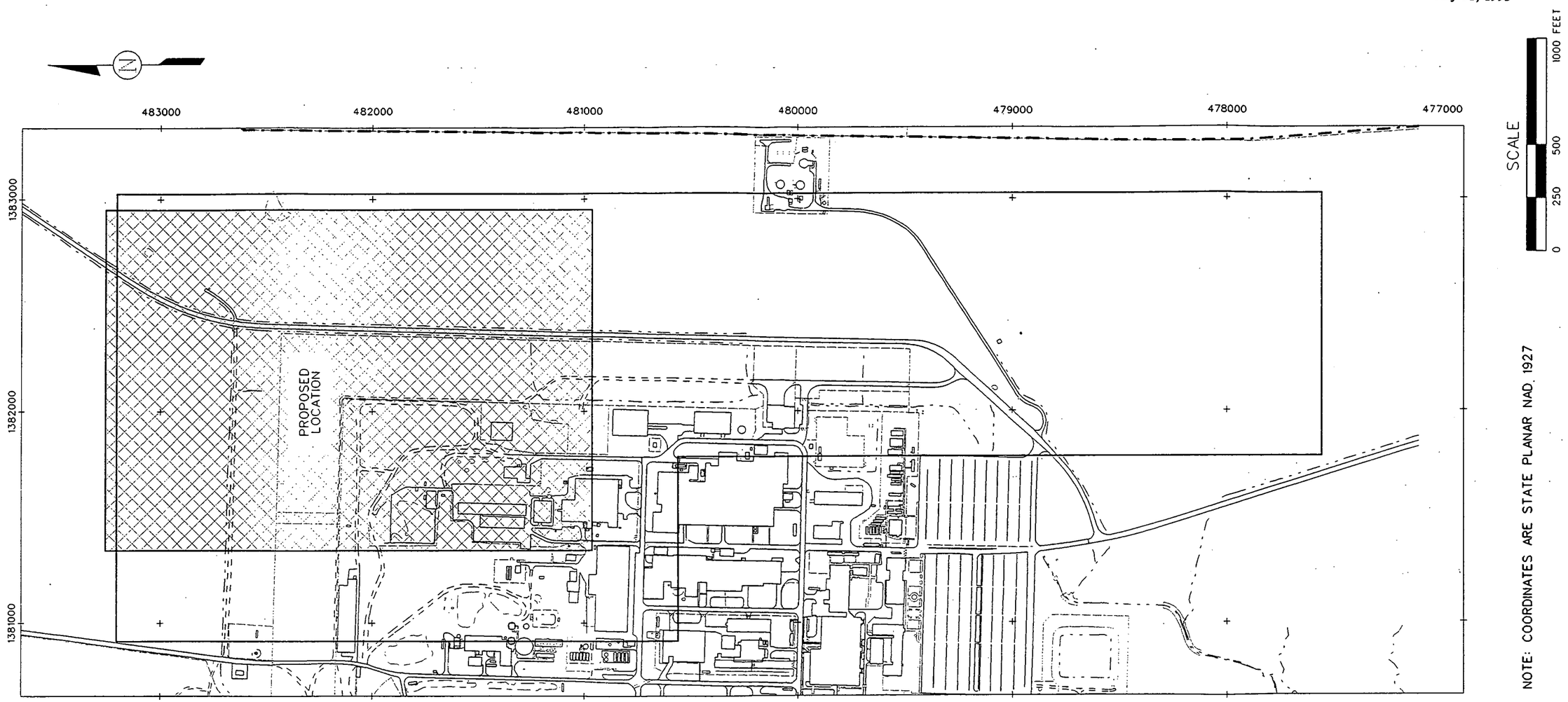
configurations considered for the location of the disposal facility were determined using estimated volumes of materials for disposal, the width of the berms, and the thickness and slope of the cap. Solid block modeling was used to determine the volumes for the gray till and the interbedded CGM within the investigation area, the selected location, Operable Unit 5 proposed location, and the Phase I Predesign Proposed Location as follows.

LOCATION	GRAY CLAY VOLUME (CUBIC YARDS)	COARSE GRANULAR MATERIAL VOLUME (CUBIC YARDS)	PERCENTAGE OF COARSE GRANULAR MATERIAL
Investigation Area	9,876,200	548,900	5.6
Proposed OU5	4,356,200	312,400	7.1
Phase I Predesign	3,635,400	222,900	6.4
Selected Location	3,321,600	145,600	4.4

As indicated in the table, the selected location has the lowest volume and percentage of interbedded coarse granular material of the proposed locations; thereby, making the selected location the best location at the FEMP for the on-site disposal facility. Also, the selected location has a minimum gray till thickness of 15 feet, with an average thickness of 30 feet, making the selected location more protective of human health and the environment than the minimum required thickness for the gray till of 12 feet. Furthermore, the selected location satisfies the engineering considerations presented in the following paragraphs.

Moving the location and configuration further north may be acceptable, but is less desirable since the percentage of silt in the gray till is increased and the percentage of clay in the gray till is decreased, thus reducing the protectiveness of the gray till. Moving the location northward would also place the disposal facility closer to steep slopes which have increased runoff due to precipitation, thereby increasing runon at the disposal facility with associated erosional potential.

In the western portion of the investigation area, the gray till will be subjected to deep construction excavation during remediation in the Production Area (as presented in the Operable Unit 5 Feasibility Study Report). Avoidance of the deep construction excavations is important from an engineering standpoint since constructing a facility over these areas after they have been backfilled would make



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PROPOSED LOCATION FOR DISPOSAL FACILITY FROM OU5 FS

DATE 06/28/95
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FIGURE 4-3

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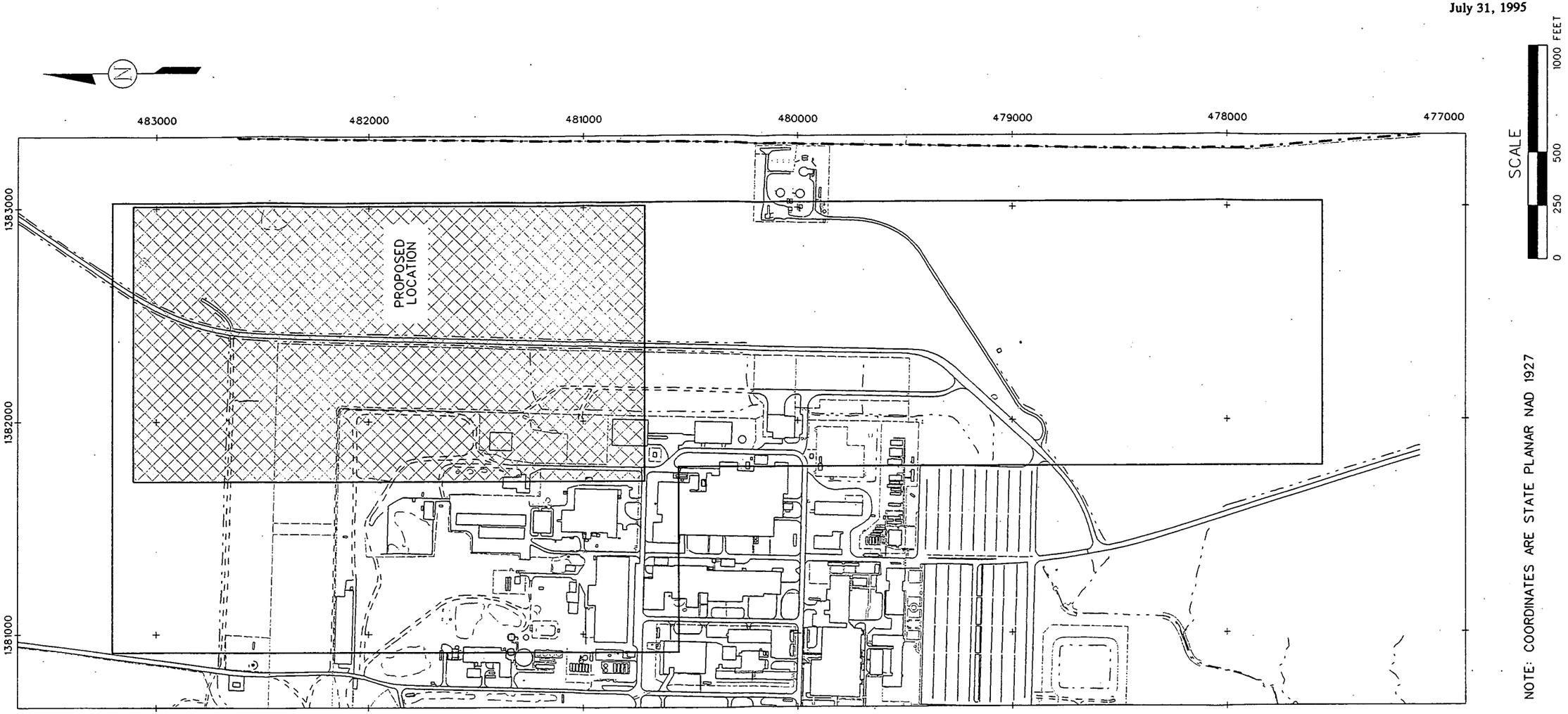

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PROPOSED LOCATION FOR DISPOSAL FACILITY FROM PHASE 1 OF PDI STUDY

DATE 06/28/95
DRAWN JCF

FIGURE 4-4

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the disposal facility susceptible to potential differential settlement, therefore jeopardizing the integrity of the disposal facility liner.

Moving the location of the disposal facility east beyond the FEMP property boundaries would place the facility close to a slope that trends into an erosional terrace and into an area where the gray clay thickness rapidly reduces. This slope would then be an engineering concern since it could potentially impact the stability of the facility.

4.3 OBJECTIVE 2 - VERIFICATION OF PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

The field components completed for the Predesign Investigation were compared to the Operable Unit 2 Feasibility Study modeling assumptions to verify existing local conditions and protection of human health and the environment. The assumptions from the Feasibility Study were used to determine the time of travel for the contamination to the Great Miami Aquifer. The following is a list of Feasibility Study modeling assumptions and the associated Predesign Investigation field verification components:

(1) Existing Water and Soil Contamination. The FS assumed that no significant contamination existed in these media.

Field Components

- Verify the existing vertical and horizontal uranium concentrations for soil and perched groundwater.
- Determine the solubility of the uranium existing in the soil.
- Determine the concentration of uranium in water in the vadose zone.

(2) Hydraulic Parameters. The vertical gradient varied seasonally in the model, but averaged approximately 1.0; the model assumed that there was no horizontal flow. This assumption, that all flow moved vertically, conservatively minimized the vertical time of travel. The vertical hydraulic conductivity of the gray till used in the FS modeling was 1.9×10^{-6} cm/sec. The calculated infiltration rate through the proposed cap of the disposal facility was 1.22 in/yr.

Field Component

- Identify the vertical and lateral perched groundwater gradients. These gradients will be used in conjunction with the vertical hydraulic gradients measured during the geotechnical activities of the Predesign Investigation to calculate the existing infiltration rates and vertical seepage velocity.

(3) Retardation of Uranium. The K_d for the gray till was 3.1 mL/g, which was a value derived from calibrating the model with lysimeter data.

Field Components

- Determine the K_d value through direct testing.
- Determine the K_d from uranium concentrations in lysimeter samples.

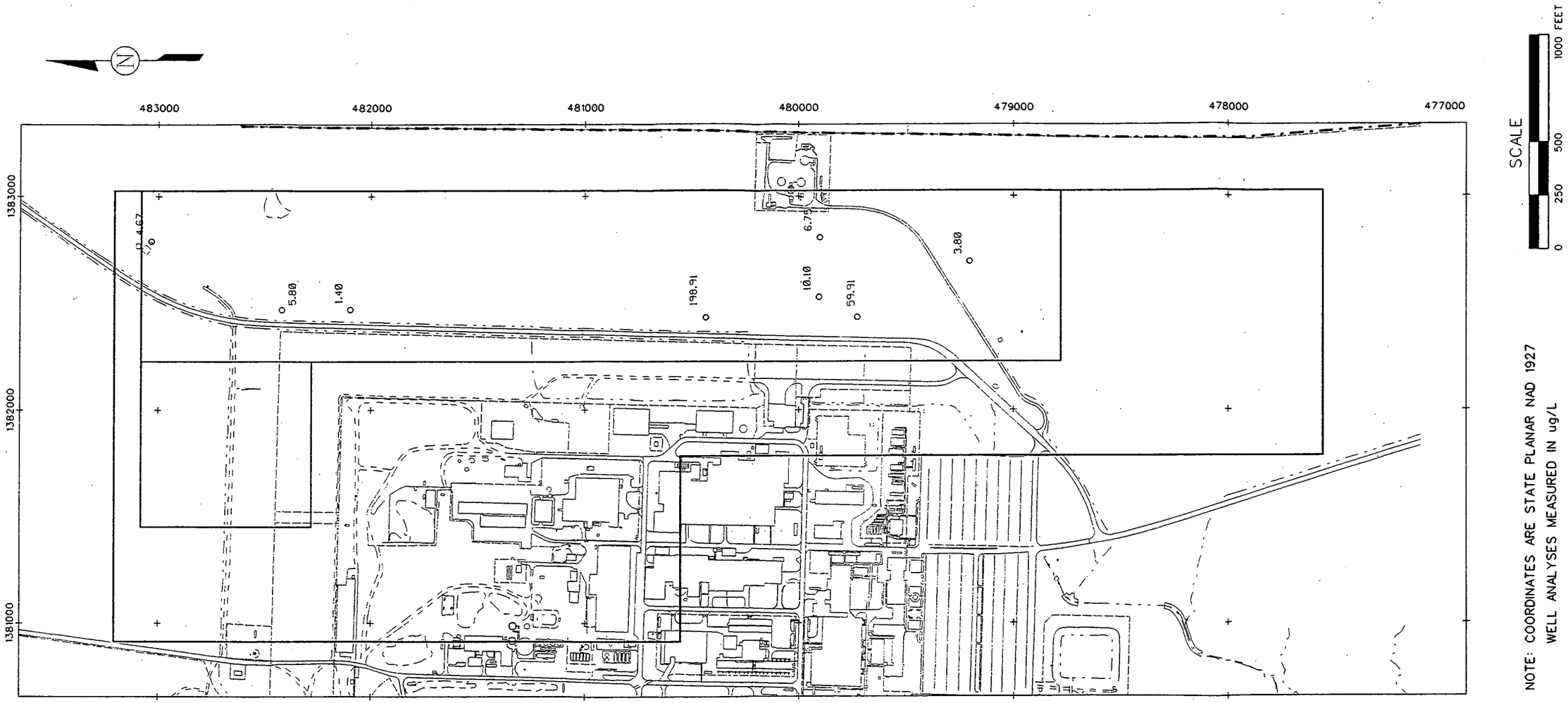
The following subsections discuss the Predesign Investigation field components and how they compare to the Operable Unit 2 Feasibility Study assumptions to verify protection of human health and the environment.

4.3.1 Existing Water and Soil Contamination

4.3.1.1 Verification of Existing Vertical and Horizontal Uranium Concentrations

The Operable Unit 2 FS modeling assumed that the perched groundwater had no uranium under the disposal facility location. Total uranium concentrations from all of the wells installed during the Predesign Investigation in the gray till and within the investigation area are presented in Figures 4-5 and 4-6. Total uranium concentrations measured in the perched groundwater ranged from non-detects in Wells 11492 and 11501, to 198.61 μg/L in Well 11547. However, total uranium concentration in Well 11547 was 75 μg/L when resampled. Well 11548 had a total uranium concentration of 59.91 μg/L. Except for Wells 11547 and 11548, the maximum total uranium concentration measured for the other 16 Predesign Investigation wells was 14.4 μg/L.

Once uranium from the glacial overburden reaches the Great Miami Aquifer, concentrations are reduced by a factor of approximately 20 due to mixing. (Dilution factors are even higher when source areas are localized, such as near Well 11547.) Therefore, 14.4 μg/L uranium results in an increase in the Great Miami Aquifer concentration by 0.72 μg/L. Furthermore, uranium present in



NOTE: COORDINATES ARE STATE PLANAR NAD 1927
WELL ANALYSES MEASURED IN ug/L

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U-TOTAL IN PERCHED GROUNDWATER
SCREENED ACROSS BROWN TILL/ GRAY TILL INTERFACE

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FIGURE 4-5

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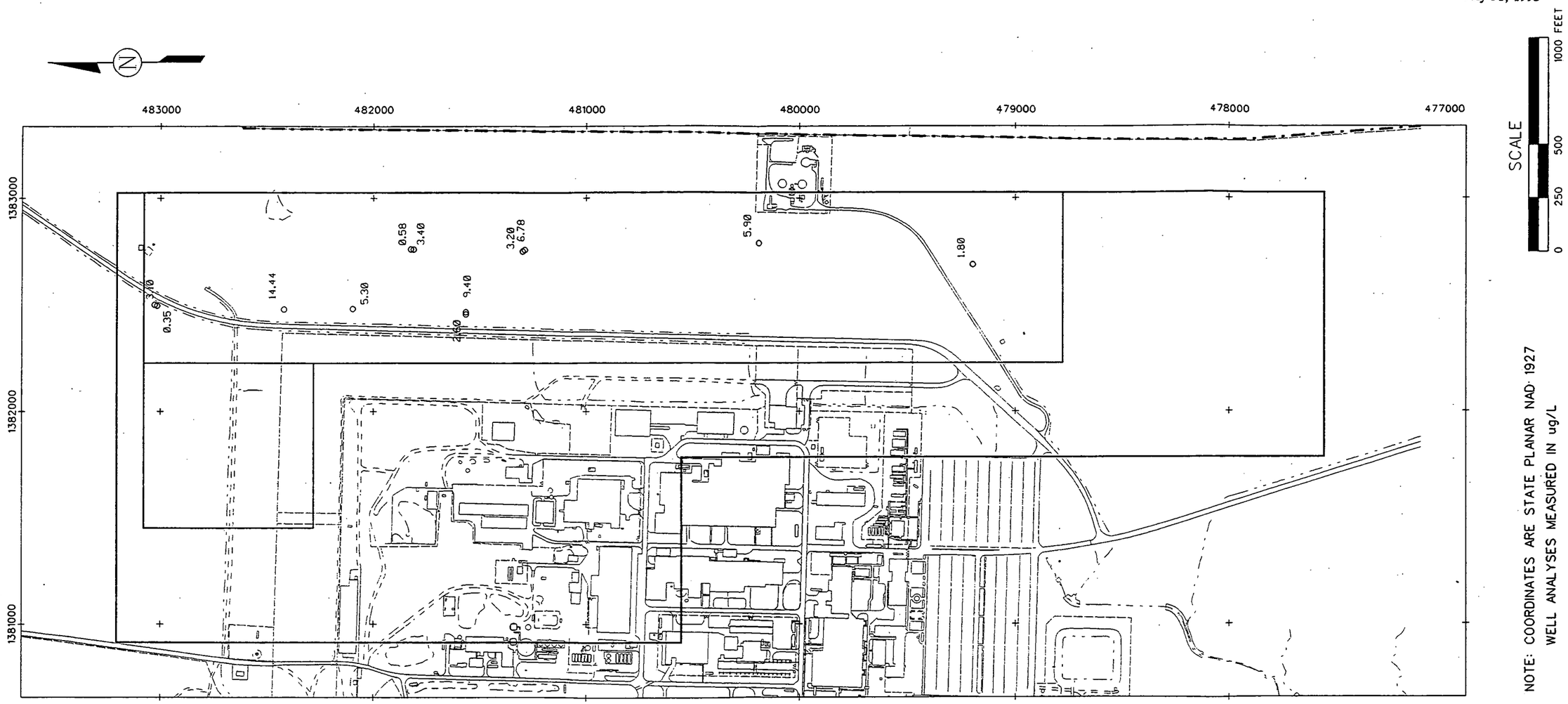

NOTE: COORDINATES ARE STATE PLANAR NAD 1927
WELL ANALYSES MEASURED IN ug/L

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U-TOTAL IN PERCHED GROUNDWATER SCREENED WITHIN GRAY TILL

DATE 07/27/95
DRAWN JCF

FIGURE 4-6

FILE NAME: /2ccs1/mgva/utotal/ph20202.dgn

glacial overburden would arrive in the GMA much earlier than the uranium from the disposal facility due to the reduced infiltration through the cap and will not result in an additive effect. Consequently, the 14.4 μg/L uranium in the vadose zone groundwater does not change the protectiveness of the disposal facility as modeled in the Operable Unit 2 FS.

In contrast to the other perched groundwater results, the uranium concentration in Wells 11547 and 11548 ranged between 59.91 to 198.6 μg/L. When diluted by a factor of 20, those concentrations would result in GMA levels of 3 to 10 μg/L. These concentrations are significant and indicate that Wells 11547 and 11548 need further investigation to identify the source and the extent of the contamination. The extent of this contamination will be investigated in the future, and mitigative measures will be developed if needed. Section 6.0, the Path Forward, discusses this further.

Total uranium concentrations in 52 soil samples ranged from 1.77 mg/kg (Well 11494) to 3.71 mg/kg (Well 11504). The 95th percentile for these concentrations is 3.32 mg/kg. Since the 95th percentile background concentration for soil at the FEMP has been established at 3.4 mg/kg for total uranium, the aforementioned concentration range can be considered uncontaminated. This demonstrates that the soil in the selected location is consistent with the assumption made in the FS model that no significant contamination exists in the soil.

4.3.1.2 Concentrations of Uranium in Water in the Vadose Zone

Background lysimeters were installed in a single nest northwest of the FEMP to determine the range of background uranium concentrations in vadose zone groundwater. Also, new lysimeters were installed in the investigation area and were sampled along with the existing lysimeters. The existing lysimeters were installed prior to the Predesign Investigation.

The results of Predesign Investigation lysimeter sampling are presented in Table 2-7. The results from the background lysimeters are 32.0 μg/L in the gray till and 23.62 μg/L in the GMA. The results from the new lysimeters in the investigation area varied from 0.52 μg/L to 22 μg/L. In evaluating the results from the lysimeters installed as part of the Predesign Investigation, it is important to consider that the uranium concentration in existing lysimeters has generally declined since the beginning of sampling two years ago (see Figures 4-7 and 4-8). The initial results from those existing lysimeters ranged from 2.5 to 8 μg/L in the glacial till and 11 to 52 μg/L in the GMA.

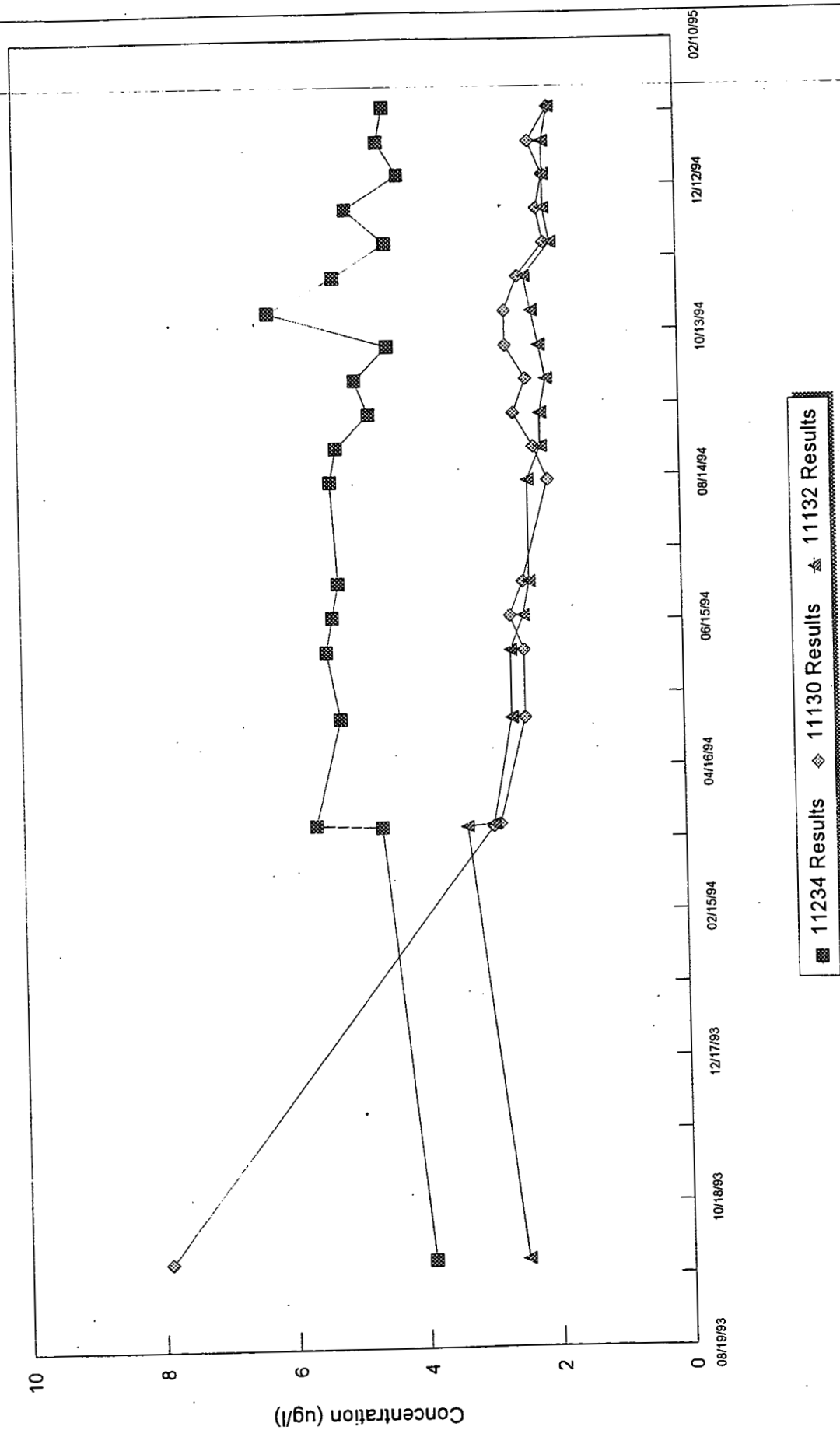

Figure 4-7 Till Lysimeters 11234, 11130, and 11132
Uranium Concentrations

000115

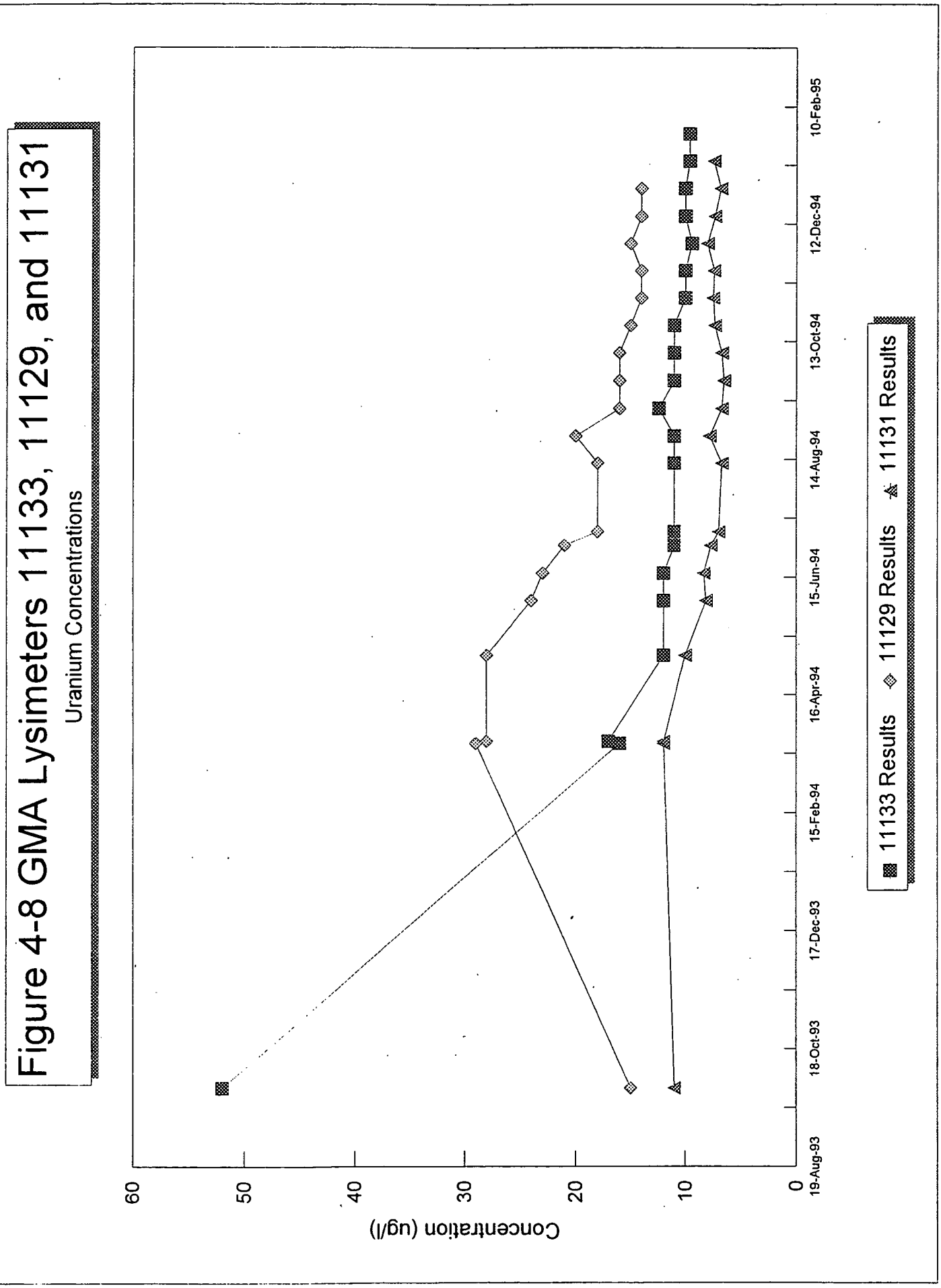
Figure 4-8 GMA Lysimeters 11133, 11129, and 11131
Uranium Concentrations
Concentration (ug/l)
60
50
40
30
20
10
0
19-Aug-93
18-Oct-93
17-Dec-93
15-Feb-94
16-Apr-94
15-Jun-94
14-Aug-94
13-Oct-94
12-Dec-94
10-Feb-95
11133 Results
11129 Results
11131 Results

The variation over time appears to concur with the ASTM procedure for installation of lysimeters (D4696) which states that a lysimeter should be installed a year prior to sampling so that the lysimeter has time to equilibrate with the environment. Therefore, the newly installed lysimeters also need to be sampled for a longer period of time to determine the equilibrated concentrations.

4.3.1.3 Solubility (Leachability) of Existing Uranium

Toxicity characteristic leaching procedure (TCLP) extraction was completed on 31 soil samples collected during the Predesign Field Investigation. Total and isotopic uranium were analyzed on the extract. The TCLP was performed in conjunction with standard soil uranium analyses for each soil sample. The results of the TCLP and soil uranium analysis are listed in Table 2-8. The TCLP tests were completed to determine the nature of potential uranium contamination in the area. Since soil sampling indicated that the uranium present in the soil was at background levels, the TCLP data should be considered characteristic of soil containing background concentrations of uranium.

The leachability of background uranium in soils can be defined as the concentration of uranium that enters solution in micrograms per liter (μg/L) at equilibrium under natural or laboratory conditions. Based on the data presented in Table 2-8, the leachability (TCLP) of background uranium ranged from 2.4 to 27.53 μg/L in soil samples that contained from 1.77 mg/kg to 3.71 mg/kg total uranium. This range of TCLP results can be compared to vadose zone and perched groundwater concentrations, although it should be noted that TCLP is an acidic leaching procedure that will elevate leachability above the normal environmental leachability. In comparison, the lysimeter total uranium concentrations in the existing lysimeters in the disposal facility area ranged from 2.13 μg/L to 9.60 μg/L in samples taken during the Predesign Investigation. The total uranium concentrations detected in groundwater monitoring wells located in the disposal facility area ranged from 0.35 μg/L to 14.44 μg/L (excluding well 11547 and 11548 results). It was generally found that the range of groundwater concentrations is less than the TCLP results, supporting the conclusion that the total uranium concentrations at the selected location are most likely in the range of background.

4.3.2 Hydrogeologic Parameters

4.3.2.1 Vertical and Lateral Perched Groundwater Gradients

Potential vertical infiltration (flow) rates were calculated by the following equation:

$$q = Ki \quad (1)$$

where

q = infiltration rate,

K = vertical hydraulic conductivity, and

i = vertical gradient

Vertical perched groundwater gradients were calculated for each nest of wells (see Table 4.1). The gradients were calculated by taking the ratio of water level changes to the distance between the mid-points of the screens. The calculated vertical gradients ranged from 0.26 to 2.43 (Table 4.1). This wide range of vertical hydraulic gradient indicates that the gray till is not well connected hydraulically. The vertical gradients in the Operable Unit 2 FS were calculated by the HELP model based on the change in response to precipitation and subsequent infiltration. No horizontal gradient was used since all of the flow was considered vertical. This is conservative because assuming all flow as vertical minimizes the time and distance for travel to the Great Miami Aquifer.

The vertical hydraulic conductivities measured during the Predesign Investigation ranged from 9.53×10^{-9} cm/sec to 5.83×10^{-8} cm/sec. These permeabilities are 2 to 3 orders of magnitude lower than that assumed for the FS modeling (i.e., 1.9×10^{-6}). The FS modeling assumption was conservative because a higher permeability will reduce the time of travel to the GMA.

The vertical infiltration rates ranged from 0.03 in/yr to 0.96 in/yr (see Table 4.1). The highest calculated infiltration rate of 0.96 in/yr is lower than the infiltration rate of 1.22 in/yr that was derived from the HELP model in the Operable Unit 2 FS report based on the construction of the disposal facility.

Vertical seepage velocities can be determined by using the following equation:

$$v = q/P_e \quad (2)$$

where

v = vertical seepage velocity

q = infiltration rate (see Equation 1)

P_e = effective porosity

TABLE 4-1

CALCULATION OF POTENTIAL VERTICAL GROUNDWATER FLOW IN NESTED WELLS

Well No.	Screen Interval	Vertical Gradient	Nearest Geotechnical Boring	Lab Vertical Permeability (cm/sec)	Potential Infiltration Rate (in/yr)	Vertical Seepage Rate (in/yr)
11492	15-22 (gray till)	0.26	11468	1.03×10^{-8}	0.03	.19
11491	25-29.5 (gray till)					
11494	8-16.5 (brown till)	1.10	11480	2.77×10^{-8}	0.38	2.39
11493	18-24.5 (gray till)					
11496	9-17 (brown till)	1.25	11479	1.21×10^{-8}	0.19	1.19
11497	28-32 (gray till)					
11499	15-22 (brown till)	1.77	11477	1.96×10^{-8}	0.43	2.70
11498	27-33 (gray till)					
11500	19-25 (gray till)	0.45	11477	5.83×10^{-8}	0.33	2.08
11501	33-37 (gray till)					
11502	18-22 (gray till)	2.43	11471	3.18×10^{-8}	0.96	6.04
11503	24-28 (gray till)					
11504	14-18 (brown till)	1.13	11475	9.53×10^{-9}	0.13	0.82
11505	23-27 (gray till)					

Notes:

(1) Vertical gradients calculated between mid-point of screens.
(2) Vertical infiltration rate, q, calculated by $q = Ki$, where K is vertical hydraulic conductivity, and i is the vertical gradient in cm/sec. Conversion to in/yr from cm/sec is made by multiplying by 1.24×10^7.
(3) Since all wells have not reached equilibrium, gradients may vary by less than an order of magnitude.
(4) Vertical seepage rate, v, calculated by $v = q/P_e$, where q is infiltration rate and P_e is effective porosity. Effective porosity is assumed to be 15.9 percent in this table.

Time of travel of water through the gray till can then be calculated as

$$T = \frac{D}{V} \qquad (3)$$

where

T = time of travel

V = vertical seepage velocity

D = till thickness

For the infiltration rates presented in the FS (1.22 in/yr) and in this investigation (0.03 - 0.96 in/yr), estimated times of travel through the gray till are presented in Table 4-2.

TABLE 4-2

TIME OF TRAVEL FOR WATER
(Gray Till Only)

Infiltration Rates (in/yr)	Effective Porosity* P_e	Vertical Seepage Rate (in/yr) V	Time of Travel through 15 ft of till (yrs) T
1.22	0.04	30.5	5.9
1.22	0.10	12.2	14.7
1.22	0.159	7.67	23.5
0.03-0.96	0.04	0.75 - 24.0	240 - 7.5
0.03-0.96	0.10	0.3 - 9.6	600 - 18.7
0.03-0.96	0.159	.19 - 6.04	947.4 - 29.8

*Sources: 0.159 - Operable Unit 2 Feasibility Study
0.04 to 0.10 is the normal expected range of effective porosity for till. (HELP Model, Vol. 3 OSWER Guide, Version 2)

The following points should be noted:

- These are travel times for water and not for contaminants
- These are travel times through only the gray till and do not include the unsaturated GMA

The time of travel for the contaminants will be impacted by the retardation of uranium due to adsorption (K_d) by the soil. The time of travel for the contaminants will be discussed in the Retardation of Uranium section.

Horizontal gradients can be calculated from the potentiometric surface map (Figure 2-20). Assuming that the potentiometric surface map closely resembles the potentiometric surface of the brown/gray till in shape and slope, horizontal gradients can be estimated in the range of 0.01 to 0.03 (see Section 2). These horizontal gradients are lower than the vertical gradients calculated from well nests (Table 4.1). The lower horizontal gradients would apparently indicate that most of the groundwater flow is in the vertical direction. However, the actual impact of the horizontal flow component on perched groundwater flow can only be determined when the horizontal conductivity is measured, which will determine the horizontal flow rate. The activities that will be performed to measure the horizontal conductivity and flow rates are discussed in Section 6, Path Forward. Determining the horizontal flow component is important because it may increase the vertical travel time of water and the contaminants that may come from the proposed disposal facility.

In summary, this analysis shows that the existing vertical flow conditions at the selected site are more protective of human health and the environment than the assumptions used in Operable Unit 2 FS modeling in two ways:

(1) Permeability is lower than that used in the Operable Unit 2 FS modeling for the gray till layer.

(2) The range of vertical infiltration calculated for natural conditions based on Predesign Investigation data are actually lower than the 1.22 in/yr calculated in FS modeling under post-disposal facility conditions.

4.3.3 Retardation of Uranium

4.3.3.1 Uranium Distribution Coefficient (K_d) Testing

The adsorption of uranium on soil retards the migration of uranium and increases the time of travel for uranium. The retardation of uranium is determined by measuring the uranium distribution coefficient (K_d).

The gray till uranium distribution coefficient (K_d) used in the Operable Unit 2 FS disposal facility vertical transport model was 3.1 L/kg. This value was the calibrated result using lysimeter uranium concentrations data. In the Predesign Investigation, the gray clay was batch sampled to be representative of the entire investigation area with the resulting uranium K_d measured in batch testing to be 10.8 L/kg (Section 2.6). A K_d of 10.8 L/kg would result in more retardation of uranium than the K_d of 3.1 used in the Operable Unit 2 FS, and thus the selected area would be more protective of human health and the environment than predicted in the Operable Unit 2 FS.

The retardation of uranium as it is transported by groundwater can be calculated by the following equation:

$$R = 1 + \left(\frac{\rho_b K_d}{\theta_e}\right)$$

R = retardation factor (the number of times slower that uranium moves in relation to water)
ρ_b = bulk density of the soil
K_d = distribution coefficient
θ_e = effective soil moisture content (effective porosity for the gray till)

Multiplying the retardation factor by the time of travel for water will determine the uranium time of travel.

The bulk density, effective porosity, and distribution coefficient used in the Operable Unit 2 FS modeling were 1.85 g/cm^3, 15.9 percent, and 3.1 mL/g respectively. Using these values in the equation above, the retardation factor for uranium can be calculated to be 37. The seepage velocity of groundwater through the glacial till used in the Operable Unit 2 FS was 7.67 inches/yr (0.64 ft/yr) based on an infiltration rate of 1.22 inches/yr. With a 15 foot gray till thickness, groundwater would take 23.5 years to travel to the top of the unsaturated GMA. Uranium would take 870 years to travel to the top of the unsaturated GMA through 15 feet of till due to the retardation factor of 37 (Table 4-3).

Table 4-3 presents the time of travel for uranium for varying K_d, infiltration rate, and effective porosity. It can be seen in the table that, for a given combination of K_d and infiltration rate, effective porosity has almost no effect on uranium time of travel (though it has significant effect on the time of travel of water). In contrast, both the infiltration rate and the K_d have important impacts on the uranium time of travel. The Predesign Investigation results verify a more protective travel time for uranium than that assumed in the Operable Unit 2 FS report. The combination of lower infiltration rate and higher K_d increases the travel time of uranium through the gray till by a factor of approximately 4.3 as indicated by the 3776 years calculated for the Predesign results and the 870 years for the FS modeling results.

TABLE 4-3

RETARDATION AND TIME OF TRAVEL
(Gray Till Only)

K_d mL/g	Infiltration Rate (in/yr)	Effective Porosity P_e	Water Time of Travel (Years)	Retardation R	Uranium Time of Travel (Years)
3.1	1.22	0.159	23.5	37	870
3.1	1.22	0.10	14.7	58.4	858
3.1	1.22	0.04	5.9	144	850
3.1	0.96	0.159	29.8	37	1102
3.1	0.96	0.10	18.7	58.4	1092
3.1	0.96	0.04	7.5	144	1080
10.8	1.22	0.159	23.5	126.6	2975
10.8	1.22	0.10	14.7	206.8	2951
10.8	1.22	0.04	5.9	500	2953
10.8	0.96	0.159	29.8	126.6	3776
10.8	0.96	0.10	18.7	200.8	3755
10.8	0.96	0.04	7.5	500.5	3754

4.3.3.2 Lysimeter Results

Vadose zone uranium concentrations were used in the Operable Unit 2 and Operable Unit 5 FSs for the purpose of calibrating uranium transport. The FS modeling calculated the K_d of 3.1 L/kg by calibrating the vertical transport model to lysimeter data existing at the time of the FS and assuming that background soil and groundwater (in gray till) uranium concentrations were zero. In the Operable Unit 2 and Operable Unit 5 FSs, the on-site lysimeter results were conservatively assumed to

represent a front of contamination that was propagating through the zone sampled by the lysimeters, and the decrease in concentration over time was assumed to be the result of the contamination migrating out of the lysimeter sampling range. The results from the PDI do not weaken the conservatism of those assumptions. In fact, the background lysimeter results may indicate that the decreasing concentrations are a result of the lysimeter reaching equilibrium with the environment and not from contaminant transport; however, further sampling of the background lysimeters is needed to confirm this. Using the results from sampling of the existing lysimeters during the Predesign Investigation (15 months after their installation), a new calibrated K_d of 3.41 mL/g was obtained. This value is more protective of human health and the environment than the 3.1 mL/g.

4.4 SUMMARY

The selected location (Figure 4-1) met the established objectives for the on-site disposal facility: (1) the most suitable location in the investigation area and (2) verification of protection of human health and the environment.

The selection of the most suitable hydrogeology was achieved by locating the site in an area with the best combination of gray till thickness and minimization of interbedded granular material. The selected location for the on-site disposal facility enhances protectiveness of human health and the environment in the following ways:

- Both the measured K_d value of 10.8 L/kg and the recalibrated value of 3.4 L/kg are more protective than the 3.1 L/kg used in the Operable Unit 2 Feasibility Study modeling.
- Because of the measured gradients and hydraulic conductivity, the vertical infiltration rate ranged from 0.03 in/yr to 0.96 in/yr, which is lower than the 1.22 in/yr developed during the FS modeling; and
- the selected location has gray till thickness ranging from 15 to 50 feet, which is more protective than the 12 foot value used for the Operable Unit 2 FS modeling.

5.0

5.0 SUBSTANTIVE REQUIREMENTS

Some of the activities involved in the remedial action for Operable Unit 2 would require various Federal and State permits. However, section 121(d) of CERCLA states that "no Federal, State, or local permit shall be required for the portion of any removal or remedial action conducted entirely onsite...." Although permits are not required, the Operable Unit 2 remediation must comply with the substantive requirements of the permits that would have been required. Because the on-site disposal facility will contain waste from Operable Units 2, 3, and 5, the substantive requirements identified in the ARARs for each operable unit must be considered. Examples of the permits that would have been required include those for air emissions, wetlands impacts, hazardous waste disposal, and the Ohio solid waste permit to install (PTI). The substantive requirements of the Ohio PTI are the only standards that are directly related to this Predesign Investigation. The substantive requirements for the other permits will be discussed in a permitting cross-walk that will be prepared as part of the remedial design process.

Under the Ohio Solid Waste Disposal Regulations, a permit to install (PTI) is required before constructing a new solid waste disposal facility [Ohio Administrative Code (OAC) 3745-27-06]. Although a PTI from the State of Ohio is not required, the on-site disposal facility must comply with the substantive requirements of the permit requirements. This section will discuss how a significant portion of the substantive requirements of the Ohio solid waste disposal facility PTI application have been met by this Predesign Investigation Report, the Operable Unit 2 RI Report, and the Operable Unit 2 FS Report.

In addition to the substantive requirements of the PTI application, the on-site disposal facility will meet, or justify a waiver from, the solid waste disposal facility siting criteria [OAC 3745-27-07(H)]. The criteria with the greatest impact on the location of the facility are the following:

- The limits of solid waste placement cannot be located within 300 feet of the property line.
- The limits of solid waste placement cannot be located within 1,000 feet of an existing water supply well or developed spring.
- A solid waste landfill cannot be located above an aquifer declared by the federal government under the Safe Drinking Water Act to be a sole source aquifer.

- A solid waste landfill cannot be located above an unconsolidated aquifer capable of sustaining a yield of 100 gallons per minute for a 24-hour period to an existing or future water supply well located within 1,000 feet of the limits of solid waste placement.

The study area in this Predesign Investigation, which had been previously identified as the best area for the location of the disposal facility, will meet the first two criteria. However, because the GMA is a sole-source aquifer and underlies the entire FEMP, a CERCLA waiver was granted by EPA to allow construction of an on-site disposal facility over a sole-source, high-yield aquifer. The waiver was granted based on the protective combination of existing hydrogeology (at least 12 feet of gray clay) and engineering controls that will be provided by the disposal facility. As stated earlier in this report, the actual hydrogeologic conditions exceed the 12-foot gray clay requirement, thus providing added safety over that modeled in the Operable Unit 2 FS.

The Resource, Conservation, and Recovery Act (RCRA), which is an ARAR for the Operable Unit 5 remediation, also includes location standards which prohibit the construction of a disposal facility near a fault which has had recent displacement and require an enhanced design if the facility is located in a 100-year floodplain [40 CFR 264.18(a) and (b)]. Neither of these standards impact the siting or construction of the on-site disposal facility at the FEMP.

The substantive requirements of the Ohio solid waste PTI which have not been addressed by this report will be met through future studies, investigations, and activities, and the engineering design of the disposal facility. The future studies, including geotechnical investigations and additional field work, are discussed in Section 6.0 of this report. The following is a list of the substantive requirements and a brief discussion of how these requirements have been met.

SUBSTANTIVE REQUIREMENTS

1. Identify geologic stratigraphy and significant zones of saturation corresponding to site-boring information.

   This and the following two requirements were satisfied by installing wells and lysimeters in zones of significant saturation and collecting geotechnical samples from significant intervals for geotechnical testing. Also, these borings were installed with continuous sampling for lithological descriptions to determine the geologic stratigraphy. These requirements are satisfied by the discussion in Section 2.3, Well Installation and Sampling; Section 2.4, Lysimeter Installation and Sampling; Section 2.5, Geotechnical Boring Installation and Sampling; Section 2.6, Groundwater Elevation and Precipitation Measurements; Section 3.2, Solid Block Modeling of Lithology and Course Grained Materials; Section 4.2, Identify the

Most Suitable Hydrogeology in the Investigation Area; and Section 4.3, Verification of Protection of Human Health and the Environment. The groundwater flow patterns are presented in Section 1.5.2.3 of the Operable Unit 2 FS Report.

2. Identify the uppermost aquifer and all saturated strata above the uppermost aquifer.

   See discussion under Substantive Requirement No. 1.

3. Identify groundwater flow patterns for the uppermost aquifer and all significant zones of saturation above the uppermost aquifer.

   See discussion under Substantive Requirement No. 1.

4. All well logs of the borings intercepted by the cross-section.

   This requirement is satisfied by Appendix F of this Predesign Investigation Report, which contains all of the boring logs.

5. Provide sufficient hydrogeologic information to allow the Director to:

   A. Determine the suitability of the site for solid waste disposal.

      Sections 2.0 and 3.0 of this Predesign Investigation Report provide the hydrogeologic information and Section 4.0 discusses the suitability of the selected location using the information presented in Sections 2.0 and 3.0.

   B. Identify and characterize the hydrogeology of the uppermost aquifer system and all geologic strata that exist above the uppermost aquifer system.

      New wells, lysimeters, and geotechnical borings were installed during the Predesign Investigation. Continuous lithologic descriptions were performed to identify the strata for all of these activities. Water level measurements, chemical analysis on the water and soil, and geotechnical soil analysis were performed to characterize the strata (till) above the uppermost aquifer system. These are identified in Section 2.6, Groundwater Elevation and Precipitation Measurements; Section 3.1, Inverse Groundwater Modeling; Section 4.2, Identify the Most Suitable Hydrogeology; and Section 4.3, Verification of the Protection of Human Health and the Environment.

   C. Sufficiently characterize the site geology to allow for the evaluation of the proposed design of the facility and to ensure that it will be in compliance with the requirements.

      Geotechnical samples were collected and analyzed to determine the mechanical properties of the soil to determine the suitability of the selected location for design requirements. This requirement is satisfied by Section 2.5, Geotechnical Boring Installation and Sampling; Section 3.2, Solid Block Modeling of Lithology and Coarse Grained Materials; and Section 4.2, Identify the Most Suitable Hydrogeology.

6. Provide a description, based on publicly available information, of the regional hydrogeology of the proposed facility which shall include:

A. The direction of the groundwater flow in the regional aquifer.
B. The identification of recharge and discharge areas of the regional aquifer.

These two requirements are discussed and identified in Section 1.5.2.3 of the Operable Unit 2 FS Report.

C. Regional stratigraphy.
D. The structural geology, including a description of local and regional structural features.
E. A description of the regional geomorphology, including the location of surface water bodies, floodways, and an analysis of any topographic features that may influence the groundwater flow system.

These three requirements are discussed in Section 3.0 of the Operable Unit 2 RI Report.

7. Provide a detailed description of the hydrogeology under the proposed landfill facility which shall be based on data collected from boreholes, piezometers, and test pits and shall include:

A. A description of the consolidated and unconsolidated stratigraphic units from the ground surface down to the base of the uppermost aquifer system.

This description is included in Section 2.2, Cone Penetrometer Testing; Section 2.3, Well Installation and Sampling; Section 2.4, Lysimeter Installation and Sampling; Section 3.2, Solid Block Modeling of Lithology and Course Grained Materials; Section 4.2, Identify the Most Suitable Hydrogeology in the Investigation Area; and Section 4.3, Verification of Protection of Human Health and the Environment. These descriptions include sedimentary composition, textural classification (Unified Soil Classification System), Atterberg limits, gain size distribution, hydraulic conductivity, thickness of the lithologic units, and the lateral extent of the lithologic units.

B. A description of the uppermost aquifer system and all significant zones of saturation above the uppermost aquifer system. This description shall include the depth to, and lateral and vertical extent of, the uppermost aquifer system and all significant zones of saturation above the uppermost aquifer system.

This requirement is met by the discussions in Section 2.6, Groundwater Elevation and Precipitation Measurements; Section 3.1, Inverse Groundwater Modeling; Section 4.2, Verification of Protection of Human Health and the Environment; Appendix B, Water Level Data and Precipitation Data; and Appendix C, Hydrographs.

8. A detailed description of the drilling and soil sampling methods used in characterizing the soil and hydrogeologic properties of the proposed facility, and the analytical procedures and methodology used to characterize the soil and rock materials obtained from test pits and borings.

Section 2 presents a detailed description of all the field and laboratory procedures and methods used during the Predesign Investigation, which satisfies this requirement.

9. A detailed description of the methodology, equipment, and procedures used to define the uppermost aquifer system and all significant zones of saturation above the uppermost aquifer

system including the well and piezometer construction specifications, and water level measurement procedures.

This requirement is satisfied by discussions in Section 2.3, Well Installation and Sampling; Section 2.4, Lysimeter Installation and Sampling; and Section 2.6, Groundwater Elevation and Precipitation Measurements of this Predesign Investigation Report and Sections 7.0 and 8.0 of the Project Specific Plan.

10. The methodology, equipment, and procedures used to determine the groundwater quality in the uppermost aquifer system and any significant zones of saturation above the uppermost aquifer system including:

    A. Collection of groundwater samples, including well evacuation, sample withdrawal, sample containers and handling and sample preservation.

    This requirement is satisfied by the discussion in Section 2.3, Well Installation and Sampling and Section 2.4, Lysimeter Installation and Sampling. Also, this requirement is discussed in detail in Sections 7.0 and 8.0 of the "Project Specific Plan for Phases I and II of the Operable Unit 2 Predesign Field Investigation" and Section 6.0 of the SCQ.

    B. Performance of field analysis including procedures and forms for recording data and the location, time, and facility specific considerations associated with the data acquisition and calibration of field devices.

    This requirement is satisfied by Sections 7.0 and 8.0 and Attachment IV of the Project Specific Plan.

    C. Decontamination of equipment.

    This requirement is satisfied by Sections 7.0 and 8.4.4 of the Project Specific Plan and Appendix K of the SCQ.

    D. Chain of custody control including standardized field tracking reporting forms to record sample custody in the field prior to and during shipment and preprepared sample labels containing all information necessary for effective sample tracking.

    This requirement is satisfied by Section 8.0 and Attachment IV of the Project Specific Plan.

    E. Field and laboratory quality assurance and quality control including collection of replicate samples, submission of field bias blanks, and potential interferences.

    This requirement is satisfied by Sections 6.0, 7.0, and 8.0 of the Project Specific Plan.

    F. Analysis of groundwater samples.

    This requirement is satisfied by discussions in Section 2.3, Well Installation and Sampling and Section 2.4, Lysimeter Installation and Sampling of this Predesign Investigation Report and by Sections 7.0 and 8.0 of the Project Specific Plan.

11. All boring logs, test pit logs, groundwater quality data, soil analytical data, and any other data generated while preparing the report.

    The appendices included as part of this Predesign Investigation Report satisfy this requirement.

6.0

6.0 PATH FORWARD

This section discusses future activities that will serve to further clarify the hydrogeology of the disposal facility footprint. Those activities can be divided into these areas - substantive requirements, perched groundwater sampling, and lysimeter sampling.

6.1 SUBSTANTIVE REQUIREMENTS

Section 5.0 discussed the substantive hydrogeologic/geotechnical requirements of the Ohio Solid Waste Disposal Regulations (OAC 3745-27-06). Certain requirements need additional action; the list below discusses those requirements and how they will be addressed with future activities.

1. An interpretation of the groundwater flow system, including rate of flow, direction of flow, vertical and lateral components of flow, interconnections between and within the uppermost aquifer system, and any significant zones of saturation above the uppermost aquifer system.

   An interpretation of the groundwater flow system has been completed and is discussed in the Predesign report in Section 2.6, Groundwater Elevation and Precipitation Measurements; Section 3.1, Inverse Groundwater Modeling; Section 4.3.2.1, Lateral and Vertical Gradient; and Section 4.3.3, Travel Time of Groundwater Through the Vadose Zone. These sections discuss flow rates, the vertical and lateral components of flow, and the interconnections between and within the uppermost aquifer system. However, some of the values were obtained using calculations with inferred values (i.e., Section 3.1 assumes a hydraulic conductivity value that was derived from groundwater elevation measurements). Also, the general flow direction and rate has been determined by contouring water level measurements of wells screened across the brown/gray till interface, which has been determined to be the uppermost zone in the perched groundwater system. Therefore, it will be necessary to obtain actual hydraulic conductivities, and actual flow directions and rates that will be included as part of the design of the disposal facility. This information will be gathered in the future by conducting the following activities:

   Slug Tests. Slug tests will be performed on the wells installed during the Predesign Investigation to determine actual horizontal hydraulic conductivities. The results will be compared to the hydraulic conductivities derived from the Inverse Modeling. Any issues associated with horizontal hydraulic conductivities will be addressed in the detailed engineering design of the disposal facility. This will be determined after the slug tests have been completed and analyzed.

Flow Meter Readings. High vertical groundwater gradients were identified, which may demonstrate a potential for localized preferential flow. Flow meter readings will be used to estimate the flow direction and velocity in each newly installed well. This will refine the understanding of the perched groundwater system and will be used to determine if requirements are needed for potential groundwater control.

2. A quantification of the vertical and horizontal hydraulic conductivity of the uppermost aquifer system and all strata within the zone of saturation above the uppermost aquifer system.

   The horizontal hydraulic conductivities for the uppermost aquifer system need to be determined by conducting slug tests. The vertical hydraulic conductivities for the strata within the zone of saturation above the uppermost aquifer system, the brown and gray till, were determined by conducting vertical permeability tests during the geotechnical portion of the Predesign Investigation.

3. Identification and characterization of recharge and discharge areas within the boundaries of the proposed facility.

   While the Predesign Investigation field activities were being conducted, drain tiles were identified at various erosional features in the study area, which may have an effect on the recharge of the perched groundwater system. The use of Ground Penetrating Radar (GPR) will assist in determining the location and depth of the drainage tile system. Our current understanding is that the drainage tile system is located approximately 4 to 5 feet below grade. The current preliminary construction plans include the removal of several feet of the upper till for site preparation and initial construction activities. The GPR investigation will assist in the design optimization of this initial site preparation activity.

6.2 PERCHED GROUNDWATER SAMPLING

Besides the requirements discussed above, an additional future activity has been identified due to perched groundwater samples collected from wells 11547 and 11548 that had uranium concentrations of 198.61 μg/L and 59.91 μg/L respectively. Additional water samples and soil samples will be collected to determine the nature and extent of this contamination.

6.3 LYSIMETER SAMPLING

Sampling of the lysimeters installed during the Predesign Investigation will continue to be sampled until they have reached equilibrium.

6.4 SUMMARY

In summary, the additional activities that will address the aforementioned requirements and other design issues are as follows:

Slug Tests:	Evaluate horizontal conductivity and determine if engineered flow barriers are required.
Perched Water Flow Rates:	Using flow meters, determine if localized preferential flow exists and if localized engineered flow barriers are required.
GPR:	Determine the location and depth of the drain tiles and address potential flow issues in the disposal facility design and construction planning.
Groundwater and Soil Sampling:	Characterize the nature and extent of contamination found in Wells 11547 and 11548.
Lysimeter Sampling	Continue sampling of the new lysimeters until equalibrium has been reached.

References

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