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Department of Energy

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JUL 1 6 1997

DOE-1204-97

Mr. James A. Saric, Remedial Project Manager
U.S. Environmental Protection Agency
Region 5 - SRF-5J
77 West Jackson Boulevard
Chicago, Illinois 60604-3590

Mr. Thomas Schneider, Project Manager
Ohio Environmental Protection Agency
401 East 5th Street
Dayton, Ohio 45402-2911

Dear Mr. Saric and Mr. Schneider:

TRANSMITTAL OF FINAL TEST PAD PROGRAM FINAL REPORT FOR THE ON-SITE DISPOSAL FACILITY

This letter transmits the *Final Test Pad Program Final Report for the On-Site Disposal Facility* (Revision 0). Approval of this report was received from the U.S. Environmental Protection Agency (U.S. EPA) on May 27, 1997, and from the Ohio Environmental Protection Agency (OEPA) on June 18, 1997. This report incorporates all changes as a result of comments from the U.S. EPA and OEPA.

Please contact Rod Warner at (513) 648-3156 if there are any questions regarding this transmittal.

Sincerely,

Johnny W. Reising
Fernald Remedial Action
Project Manager

FEMP:Warner

Enclosure: As Stated

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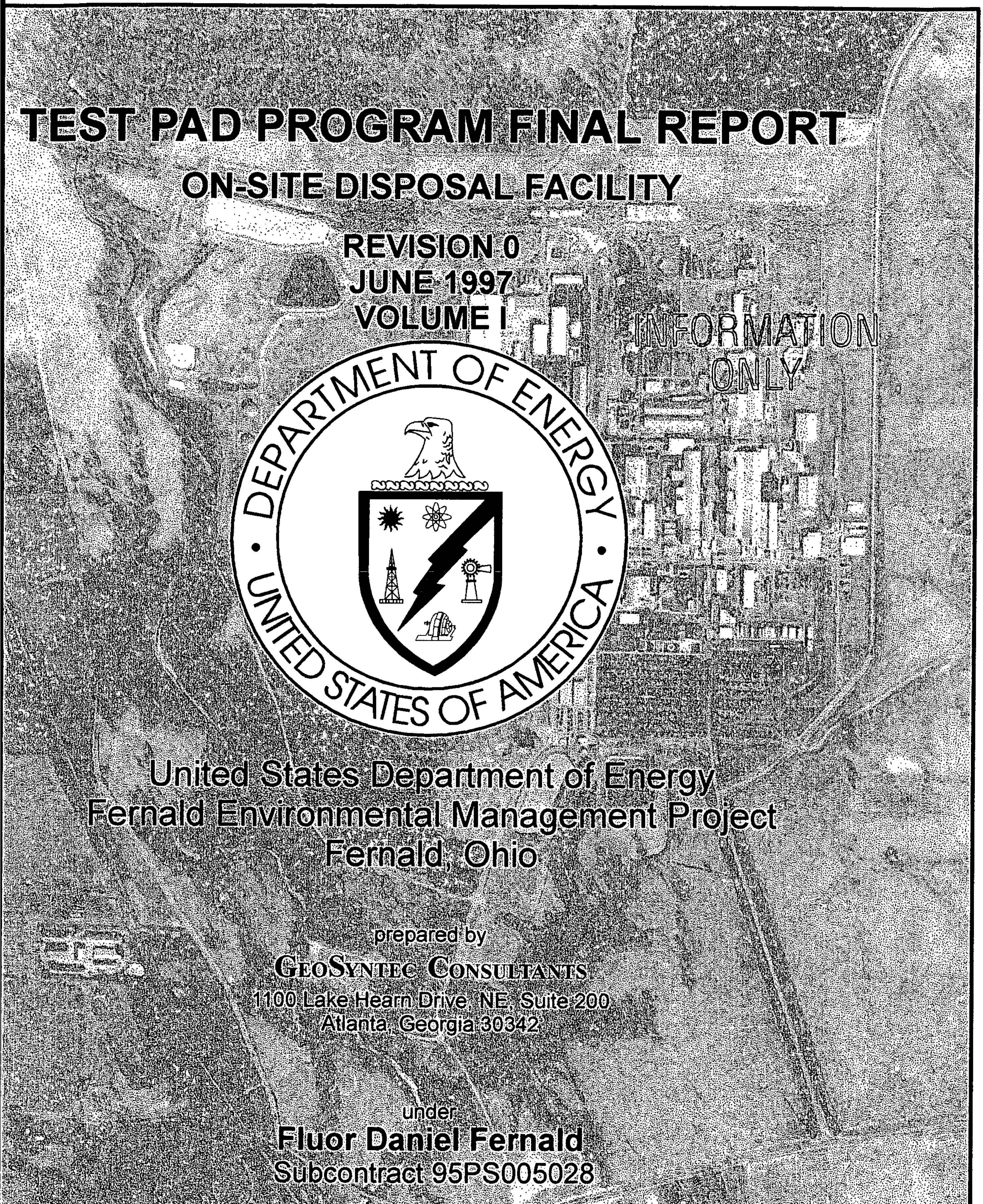

TEST PAD PROGRAM FINAL REPORT

ON-SITE DISPOSAL FACILITY

REVISION 0
JUNE 1997
VOLUME I

INFORMATION ONLY

United States Department of Energy
Fernald Environmental Management Project
Fernald, Ohio

prepared by
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under
Fluor Daniel Fernald
Subcontract 95PS005028

No. 22

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SECTION 1

1. INTRODUCTION

1.1 Background and Purpose

The Fernald Environmental Management Project (FEMP), located in Fernald, Ohio, is undergoing remediation pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Remediation at the FEMP is being addressed as five interrelated sets of activities, with each set identified as an "operable unit" (OU).

As described in the *Final Record of Decision* (ROD) *for Remedial Actions at Operable Unit 2* (OU2) [DOE, 1995c], the selected remedy for OU2 involves construction of an on-site disposal facility (OSDF) for permanent disposal of impacted material, including soil, flyash, lime sludge, and solid waste excavated as part of the OU2 remedial action. The conceptual design of the OSDF was developed as an alternative in the *Final Feasibility Study* (FS) *Report for Operable Unit 2* [DOE, 1995b] and identified as the selected remedial alternative in the OU2 ROD.

On-site disposal of impacted material is also the preferred alternative for Operable Unit 3 and Operable Unit 5 at the FEMP. The final Records of Decision for these operable units are dated May 1995 and August 1995, respectively. In addition, the material sent to the OSDF by OU3 may include contributions from OU1 and OU4. All material destined for OSDF disposal must meet the OSDF waste acceptance criteria (WAC). The OU2 ROD has established an initial WAC for the OSDF for 346 picoCuries/gram (pCi/g) of uranium-238 (U-238) or 1030 parts per million (ppm) total uranium.

DOE intends to build only one on-site disposal facility. Therefore, the OSDF will be designed to accommodate all or any portion of the total volume of impacted material meeting the WAC that results from remediation of the operable units. The total volume of material from all operable units is estimated to be 2.5 million bank/unbulked (i.e., in-place prior to excavation) cubic yards (1.9 million bank/unbulked cubic meters). The engineered features of the OSDF will include a liner system and final cover system (Figure 1-1), both of which contain layers of compacted low-permeability clay.

The OU2 ROD contains applicable or relevant and appropriate requirements (ARARs) that must be satisfied in the OU2 remedial design/remedial action (RD/RA). The ARARs for OU2 present detailed requirements for a soil liner test pad program to evaluate the suitability of the low-permeability clay materials proposed for use in the OSDF liner and final cover systems. The test pad program is the subject of this Test Pad Program Final Report (TPPFR). Details of the ARARs relevant to the test pad program are described in Section 2 of this report.

1.2 Program Requirements

The Fernald Environmental Restoration Management Corporation (FERMCO) established procedural requirements for the test pad program. These procedural requirements are:

- submit draft Test Pad Work Plan (TPWP) for review by DOE, USEPA, and Ohio EPA;
- incorporate comments on the TPWP;
- issue the final TPWP prior to completion of the intermediate OSDF design package;
- perform field and laboratory testing prior to, and during construction of the test pad, and evaluate the test pad results; and
- prepare and submit a TPPFR prior to completion of the OSDF final design package.

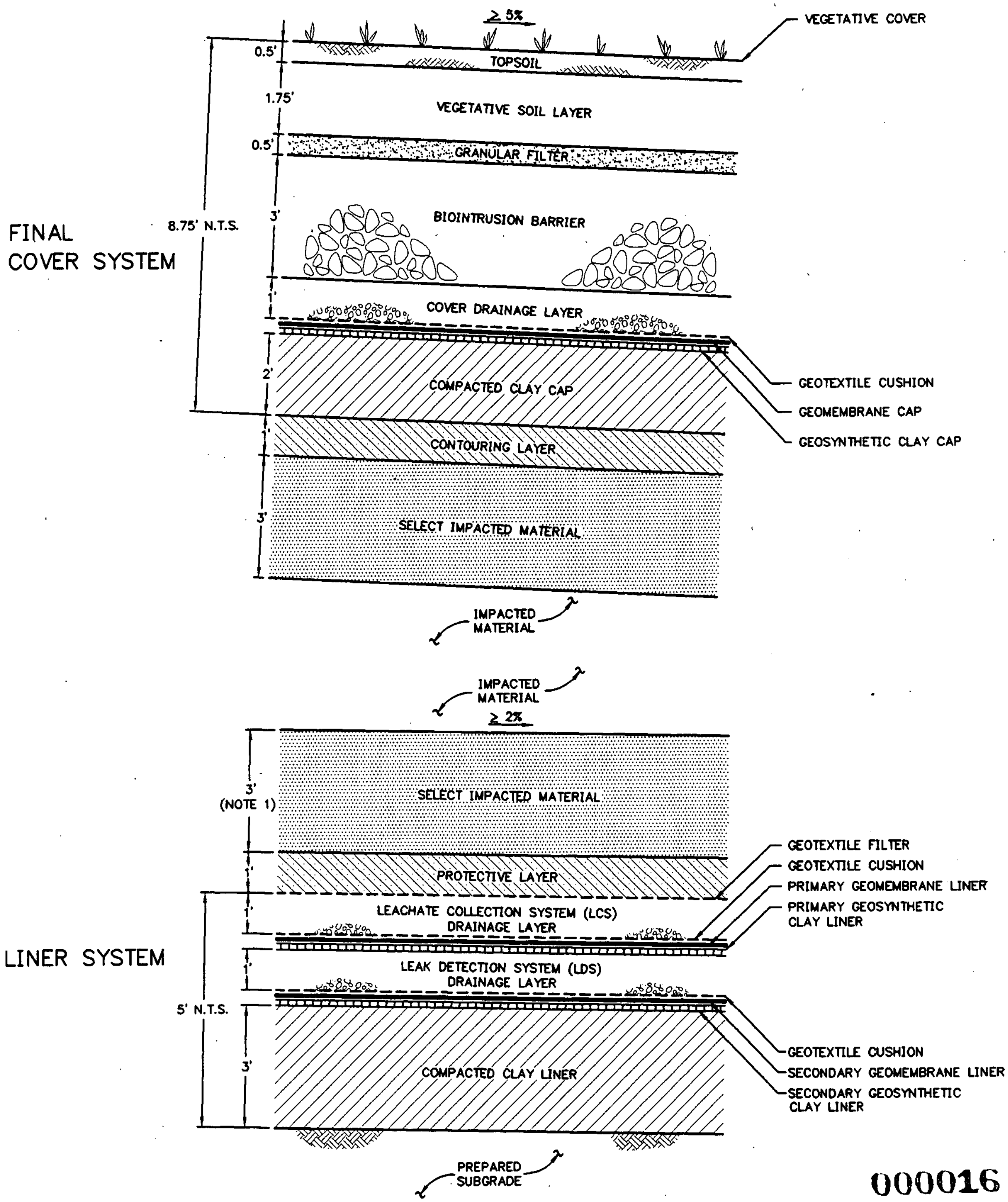
This TPPFR has been prepared pursuant to the requirements identified above. In particular, the test pad program was performed, and this TPPFR was prepared, in accordance with the approved TPWP, titled "Test Pad Work Plan, On-Site Disposal Facility, Revision 0" [GeoSyntec, 1996].

1.3 Organization of TPPFR

The TPPFR is organized as follows:

- an overview of the test pad program is presented in Section 2;
- information on the clay borrow soils that were used in the test pad program is presented in Section 3;
- the laboratory testing program conducted prior to test pad construction is described in Section 4;
- the layout and civil design of the test pads is presented in Section 5;
- a summary of the test pad construction activities is presented in Section 6;
- construction quality assurance (CQA) field monitoring and testing for the test pad program are described in Section 7;
- field permeability testing of the test pads is presented in Section 8; and
- recommendations developed from the test pad program with respect to OSDF compacted clay liner and cap construction are presented in Section 9.

LINER AND COVER SYSTEM DESIGN ON-SITE DISPOSAL FACILTY



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NOTE:

1. SELECT IMPACTED MATERIAL THICKNESS ABOVE LINER SYSTEM MAY BE DECREASED TO 2 FEET IF THE FIRST LIFT OF MATERIAL TO BE PLACED OVER THE SELECT IMPACTED MATERIAL CONSISTS OF SOIL OR RELATIVELY SMALL SIZE DEBRIS THAT CAN BE PLACED IN CONTROLLED LIFTS.

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FIGURE NO.	1-1
PROJECT NO.	GE3900-5.4
DOCUMENT NO.	F9630212.CDO
FILE NO.	39000019.DWG

relationship between compacted dry density, moisture content, and hydraulic conductivity [Othman and Luettich, 1994], a delineation was made in the TPWP between an upper horizon and a lower horizon brown till. Two test pads were constructed, one using upper horizon brown clay and the other using lower horizon brown clay.

As indicated in the preceding paragraph, the focus of the TPWP was on the brown till. A gray till layer underlies the brown till, and it, too, has properties that make it a candidate material for compacted clay liner and cap construction. It is anticipated that the clay used in OSDF construction will be brown till, not gray till. However, should the OSDF design at some point call for the use of gray till, a separate test pad program will be undertaken to evaluate this material. If a gray till test pad program is needed, it will be designed to satisfy the same criteria as used to develop the brown till test pad program. Gray till will only be used for OSDF construction if it is found that an inadequate supply of brown till exists on site. The need for gray till will be identified (through monitoring of the progress of brown till borrow area development) at least two years prior to exhausting the brown till borrow source, thereby providing adequate time to perform a test pad program using the gray till.

2.2 Objectives of the Test Pad Program

As described in the TPWP, the purpose of the test pad program is to provide information regarding the hydraulic conductivity and compaction characteristics of the soils (upper horizon brown till and lower horizon brown till) that will be used for construction of the OSDF compacted clay liner and cap. The information obtained during the test pad program is used in this report to qualify the upper horizon brown till and lower horizon brown till borrow sources (i.e., OSDF area and East Field borrow area) and establish procedures for construction using these materials.

The primary objective of the test pad program is to demonstrate that the brown till can meet the following criteria for compacted clay liner and cap materials:

- the brown till can be compacted using field construction procedures to a hydraulic conductivity of no greater than 1 x 10^{-7} cm/s for the compacted clay liner and compacted clay cap; and

- the brown till meets the other criteria for compacted clay liner and cap materials prescribed in the Ohio Solid Waste Disposal Regulations, Ohio Administrative Code (OAC) 3745-27-08(C)(1), or alternatively, where criteria are not met, that the materials and techniques proposed for compacted clay liner and cap construction satisfy the alternative demonstration requirement of OAC 3745-27-08(C).

2.3 Methodology of Test Pad Program

2.3.1 Introduction

The test pad program consisted of the following phases of work:

- preparation of TPWP;

- laboratory testing prior to test pad construction (hereafter referred to as the pre-construction laboratory testing program);

- test pad construction;

- field permeability testing; and

- development of recommendations for compacted clay liner and cap materials and construction procedures.

Brief descriptions of the four phases of work are provided in the following subsections. First, however, roles and responsibilities of the project participants are described.

2.3.2 Roles and Responsibilities

An earthwork contractor (i.e., the Test Pad Contractor) was procured by FERMCO (i.e., the Construction Manager) to construct the test pads. The Test Pad Contractor was Wise Construction Company, Cincinnati, Ohio (Wise). The Test Pad Contractor's work activities are described in Section 6 of this TPPFR.

GeoSyntec Consultants, Atlanta, Georgia (GeoSyntec) was the architect/engineer (A/E) that designed the test pad program and also served as the CQA Engineer for implementation of the program. The CQA Engineer provided laboratory testing and CQA services during construction of the test pads, conducted the field permeability tests, developed the construction specifications and CQA plan for test pad construction, and prepared the test pad program final report. The A/E also provided resident engineering services during test pad construction. The qualifications of the A/E CQA personnel involved in the project and the scope of CQA activities are presented in Section 7 of this TPPFR.

The Construction Manager, FERMCO, prepared a health and safety plan (H&S plan) for implementation of the test pad program. A copy of the H&S plan was provided by the Construction Manager to project participants. The Construction Manager oversaw implementation of the H&S plan during test pad program field activities, conducted surveying, procured material and equipment, and supervised Wise.

2.3.3 Pre-Construction Laboratory Testing

Pre-construction laboratory testing was conducted on bulk samples of upper and lower horizon brown till. The purpose of the pre-construction laboratory testing program was to establish preliminary acceptable permeability zones (APZs) for each till material. The APZ is defined as those combinations of compaction conditions (i.e., compaction moisture content and dry unit weight) which produce a compacted clay liner and cap having a hydraulic conductivity not greater than 1×10^{-7} cm/s. The APZ concept is shown in Figure 2-2. The preliminary APZ is established during the pre-construction laboratory testing program and is used to establish compaction requirements for the test pad. The final APZ is established after the test pad program results become available. The recommended final APZ for the brown till is given in this TPPFR. The APZ is a function of soil type, soil preprocessing technique, and type of compaction.

Details of the pre-construction and laboratory testing program are presented in Section 4 of this TPPFR.

2.3.4 Test Pad Construction

Two test pads were constructed in an area located within the proposed OSDF footprint. The test pad location is shown in Figure 2-1. Each test pad consisted of six compacted lifts and had a nominal final thickness of 3 ft (0.9 m). A 3-ft (0.9-m) thick test pad was constructed (even though the ARARs allow a minimum thickness of 2 ft (0.6 m)) because: (i) it is the same thickness as the OSDF compacted clay liner; and (ii) it may potentially provide more reliable results than a thinner test pad because it reduces the potential for interfering effects of the natural ground in the test results. Furthermore, USEPA guidance [USEPA, 1993] indicates the following: "*The thickness of the test pad is usually not less than the thickness of the soil liner proposed for a facility but may be as little as 0.6 to 0.9 m (2 to 3 feet) if thicker liners are to be employed at full scale.*"

Each test pad contained three lanes with target compaction conditions as summarized below.

- Lane 1 had target conditions selected to fall within the "lower" portion of the preliminary APZ established as indicated in Section 2.3.2 (i.e., using the results of the pre-construction laboratory testing program).

- Lane 2 had target compaction conditions selected to fall within the "midrange" portion of the preliminary APZ.

- Lane 3 had target compaction conditions selected to fall within the "upper" portion of the preliminary APZ.

The three target compaction conditions described above are illustrated in Figure 2-3. The actual target compaction criteria developed using the results of the pre-construction laboratory testing program are presented in Section 4 of this TPPFR.

2.3.5 Field Permeability Testing

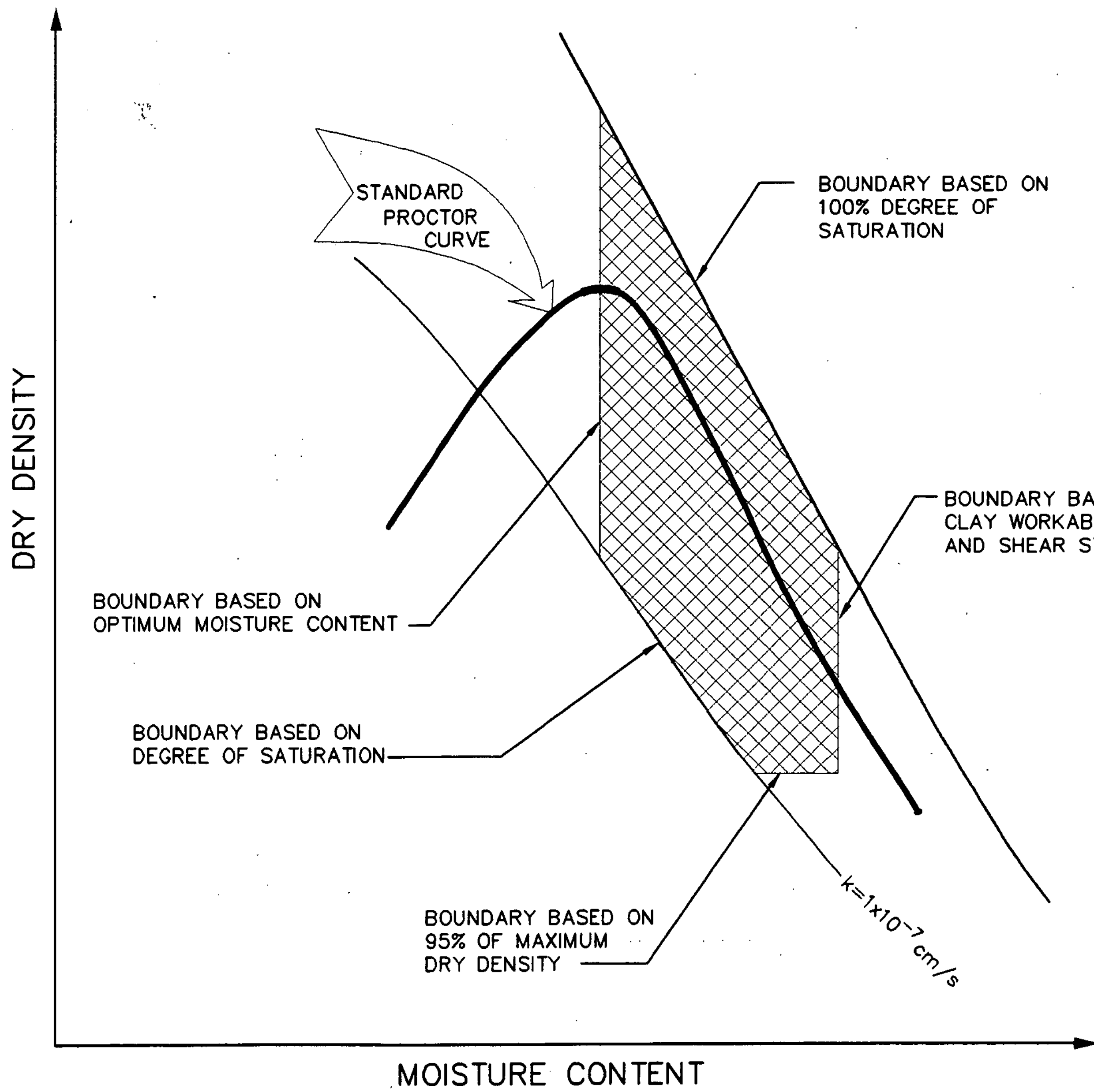
After construction of the test pads, field permeability tests were performed on Lanes 1 and 2 of each test pad. The field tests were performed using sealed double-ring infiltrometers (SDRIs). The measured hydraulic conductivities of these first SDRI tests met the requirements for the compacted clay liner and cap (i.e., hydraulic conductivity less than or equal to 1×10^{-7} cm/s). Therefore, in accordance with criteria established in the TPWP, field testing of Lane 3 was not needed. If, however, unanticipated results had been obtained for either Lanes 1 or 2, then SDRI testing of Lane 3 would have been performed.

Details of the field permeability testing program are presented in Section 8 of this TPPFR.

2.3.6 Development of Recommendations

Based on the findings of the test pad program, recommendations for compacted clay liner and cap materials and construction procedures were developed. These recommendations are presented in Section 9 of this TPPFR.

ACCEPTABLE PERMEABILITY ZONE (APZ) CONCEPT



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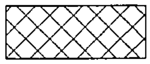

ACCEPTABLE PERMEABILITY ZONE

NOTE: FIGURE ADAPTED FROM DANIEL [1990].

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FIGURE NO.	2-2
PROJECT NO.	GE3900-5.4
DOCUMENT NO.	F9630212.CDO
FILE NO.	39000002.DWG

TARGET COMPACTION CONDITION CONCEPT

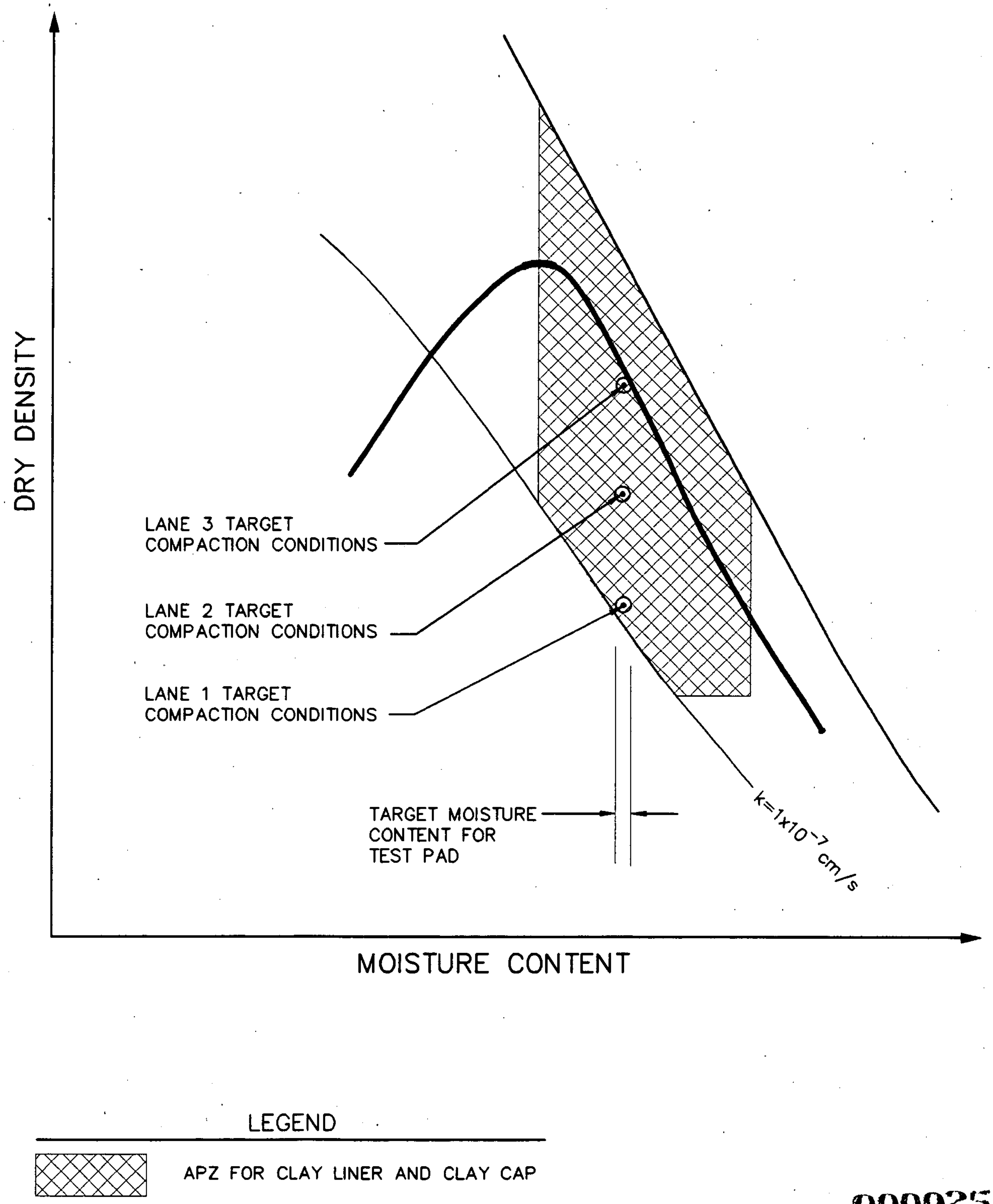

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FIGURE NO.	2–3
PROJECT NO.	GE3900–5.4
DOCUMENT NO.	F9630212.CDO
FILE NO.	39000001

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SECTION 3

3. EXISTING INFORMATION ON THE BROWN TILL

3.1 Introduction

The source of the compacted clay liner and cap material considered in the TPWP is the on-site brown till located in the upper 10 to 15 ft (3.0 to 4.5 m) of the OSDF area and East Field borrow area. A geologic cross section through the OSDF area showing the relative location of the brown till in the soil stratigraphy is presented in Figure 3-1. Geotechnical investigations have previously been conducted on the brown till in the OSDF area and borrow area. The existing information is summarized in this section and an evaluation is presented to: (i) document that the brown till from the OSDF area and borrow area has properties satisfying the OU2 ARARs; and (ii) analyze the variability of the brown till with respect to sample depth and lateral location.

The remainder of this section is organized as follows:

- a review of the clay material properties required by the ARARs is presented in Section 3.2;
- a summary of previous geotechnical investigations providing test results for the brown till is presented in Section 3.3;
- a summary and analysis of currently available geotechnical laboratory test results on the brown till is presented in Section 3.4; and
- conclusions regarding the use of the brown till for the test pads is presented in Section 3.5.

3.2 Clay Material Criteria

OU2 ARARs pertaining to the compacted clay liner and cap are from OAC 3745-27-08(C). These applicable requirements, obtained from the OU2 ROD [DOE, 1995c], are summarized in Table 3-1. The requirements pertaining specifically to the clay material properties are:

- 100 percent of the particles shall have a maximum dimension not greater than 2 in. (50 mm);
- not more than 10 percent of the particles, by weight, shall have a dimension greater than 0.75 in. (19 mm);
- at least 50 percent of the particles, by weight, shall pass through a U.S. No. 200 standard sieve;
- at least 25 percent of the particles, by weight, shall have a maximum dimension not greater than 0.002 mm; and
- the compacted material shall have a hydraulic conductivity of not greater than 1×10^{-7} cm/s for the compacted clay liner system and compacted clay cap.

3.3 Summary of Previous Geotechnical Investigations

A number of geotechnical investigations have been performed from 1991 to 1995 for purposes of evaluating geotechnical subsurface conditions at the FEMP property (and particularly in the OSDF area and on-site borrow area), and to obtain samples of brown and gray clay for geotechnical laboratory testing. Information from the following reports is summarized and analyzed in this section.

- "*On-Site Disposal Cell Pre-Design Activities Engineering Report*" [Parsons, 1994]. This report contains stratigraphic information obtained from 10 borings located within the on-site borrow area; the report also contains laboratory test results for soil samples obtained from the borings.
- "*Disposal Facility Pre-Design Geotechnical Investigation Soil Investigation Data Report Summary Document*" [Parsons, 1995a]. This report contains

TABLE 3-1

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARS) FOR COMPACTED CLAY LINER AND CAP MATERIALS [DOE, 1995C] FEMP ON-SITE DISPOSAL FACILITY[1]

CITATION	REQUIREMENT Recompacted Soil Liner
Ohio Solid Waste Disposal Regulations OAC 3745-27-08 (C)(1)	The recompacted soil liner shall be: • constructed using loose lifts 8 in. thick with a maximum permeability of 1 x 10^{-7} cm/s. • constructed of a soil with a maximum clod size of 3 in. or half the lift thickness, whichever is less. • constructed of soil with: - 100% of the particles having a maximum dimension not greater than 2 in. - not more than 10% of the particles, by weight, having a dimension greater than .75 in. - not less than 50% of the particles, by weight, passing through the 200-mesh sieve. - not less than 25% of the particles, by weight, having a maximum dimension not greater than 0.002 millimeters. • compacted to at least 95% of the maximum standard Proctor dry density using ASTM D 698 or at least 90% of the maximum modified Proctor dry density using ASTM D 1557. • compacted at a moisture content at or wet of optimum. Alternatives for the above requirements may be used if it is demonstrated to the satisfaction of the Director that the materials and techniques will result in each lift having a maximum permeability of 1 x 10^{-7} cm/s. Additionally, the recompacted soil liner shall: • not be comprised of solid waste. • be constructed using the same number of passes and lift thickness, and the same or similar type and weight of compaction equipment established through a test pad program. • placed on the bottom and exterior sides of the landfill and have a minimum bottom slope of two percent and a maximum slope based on: - compaction equipment limitations; - slope stability; - maximum friction angle between any soil-geosynthetic interface and between any geosynthetic-geosynthetic interface; and - resistance of geosynthetics and geosynthetic seams to tensile forces. • constructed on a prepared surface that shall: - be free of debris, foreign material, and deleterious material; - be able to bear the weight of the landfill and its construction operations without causing or allowing a failure of the liner to occur through settling; and - not have any abrupt changes in grade that may result in damage to geosynthetics.

TABLE 3-1 (continued)

CITATION	REQUIREMENT Recompacted Soil Liner
Ohio Solid Waste Disposal Regulations OAC 3745-27-08 (C)(15)	**Cap System Recompacted Soil Barrier Layer(2)** The recompacted soil barrier layer of the cap shall be: • a minimum of 18 inches thick and constructed in accordance with the specifications outlined above for construction of the recompacted soil liner for a landfill facility ((C)(1)(a) to (C)(1)(g) and (C)(1)(m) to (C)(1)(o) of OAC 3745-27-08) with the exception that the maximum permeability of the recompacted soil barrier shall be 1 x 10^{-6} cm/s; • be constructed of a soil with 100% of the particles having a maximum dimension not greater than 2 inches and with not more than 10% of the particles, by weight, having a dimension greater than 0.75 inches. • be compacted to at least 95% of the maximum "Standard Proctor Density" using ASTM D 698 or at least 90% of the maximum "Modified Proctor Density" using ASTM D 1557.

Notes: 1. In this TPPFR, the following terminology is used: compacted clay liner = recompacted soil liner in Ohio Solid Waste Disposal Regulations; and compacted clay cap = cap system recompacted soil barrier layer of the Ohio regulations.

2. More stringent criteria for clay cap thickness (24 inches) and maximum permeability (1 x 10^{-7} cm/s) have been adopted in the actual OSDF design.

stratigraphic information obtained from 14 borings located within the OSDF area; this report also contains laboratory test results for soil samples obtained from the borings.

- "*Geotechnical Investigation Report On-Site Disposal Facility*" [Parsons, 1995]. This report contains stratigraphic information obtained from 36 borings located within the OSDF area; this report also contains laboratory test results for soil samples obtained from the borings.

The reports listed above present findings from a total of 50 soil borings in the OSDF area and 10 soil borings in the borrow area. The information contained in the three reports listed above specifically related to the brown till is summarized in Table 3-2 and includes:

- boring location in terms of northing coordinate;
- sample depth;
- natural moisture content test results (ASTM D 2216);
- index test results, including Atterberg limits (ASTM D 4318), particle size distribution (ASTM D 422), and soil classification (ASTM D 2487);
- results of standard Proctor compaction tests (ASTM D 698).

3.4 Analysis of Existing Geotechnical Data

Examination of the data in Table 3-2 reveals that the brown till will meet material property criteria presented in Section 3.2, with two exceptions. The first exception is the requirement that at least 25 percent of the particles, by weight, must have a maximum dimension not greater than 0.002 mm. The second exception, which occurs in only a very few cases, is the requirement that at least 50 percent of the particles by weight, must pass through a U.S. No. 200 standard sieve. This latter exception is not significant because: (i) the Section 02225 of the OSDF Construction Specifications requires that granular lenses and other nonconforming soils not be used as compacted clay liner or cap material; and (ii) even if small amounts of nonconforming soil were used, the natural mixing and blending that will occur during the excavation, transportation, placement, processing, and compaction of the material will result in a blended material with at least 50 percent of the particles, by weight, passing through a U.S. No. 200 standard sieve.

Alternative requirements for the percentage of particles having a maximum dimension not greater than 0.002 mm were previously proposed by DOE in accordance with OAC 3745-27-08(C). As explained in the 13 December 1995 DOE document entitled "*Alternative to OAC Prescriptive Specifications for Compacted Soil Liners*," an alternative is proposed wherein the average fraction of clay-size particles of the brown till need only exceed 15 percent. Verification of the suitability of the brown till, and hence, the proposed alternative requirement, is provided by the results of the test pad program.

An analysis of the data summarized in Table 3-2 was performed to evaluate the trends of variability of material characteristics with respect to boring location and sample depth. Compaction and index characteristics that may affect hydraulic conductivity were investigated because a change in these characteristics would indicate the need to delineate separate clay sources for the test pad program and potentially for construction of the OSDF compacted clay liner and cap components. These characteristics include:

- percent of particles smaller than 0.005 mm (percent clay);
- percent of particles passing the U.S. No. 200 standard sieve;
- plasticity index (PI); and
- optimum moisture content (OMC) and maximum dry density from the standard Proctor compaction test (ASTM D 698).

The analysis of the data in Table 3-2 reveals that the percentage of particles smaller than 0.005 mm, the percentage of particles passing the No. 200 sieve, and the

TABLE 3-2

SUMMARY OF GEOTECHNICAL DATA ON BROWN TILL FEMP ON-SITE DISPOSAL FACILITY

Boring Number	Sample Number	Borehole Northing[2]	Borehole Easting[2]	Sample Depth	Particle Size[3]			Atterberg Limits[4]			Standard Proctor Compaction[5]	
					Percentage Coarser than No. 200 Sieve	Percentage Passing No. 200 Sieve	Percentage Smaller than 0.005 mm	LL	PL	PI	Optimum Moisture Content (%)	Maximum Dry Density (pcf)
11468	403071	483039.84	1351018.65	2.0-4.5	22.6	77.4	40.0	47.2	17.9	29.3		
11468	403103	483039.84	1351018.65	2.0-6.5	23.8	76.2	37.0	45.3	16.2	29.1	16.7	110.5
11468	403074	483039.84	1351018.65	4.5-6.0	34.1	65.9	28.0	31.9	16.1	15.8		
11468	403077	483039.84	1351018.65	9.0-11.5	43.7	56.3	22.0	25.5	14.7	10.8		
11468	403104	483039.84	1351018.65	9.0-13.0	29.3	70.7	29.0	30.8	14.1	16.7	11.6	125.0
11469	402820	482830.31	1351298.75	1.5-3.0	3.9	96.1	37.0	45.1	21.1	24		
11469	402821	482830.31	1351298.75	3.0-5.5	20.5	79.5	32.0	37.1	14.9	22.2		
11469	402824	482830.31	1351298.75	3.0-7.5	27.2	72.8	35.0	36.1	15.1	21	13.9	118.5
11469	402826	482830.31	1351298.75	9.0-10.5	32.4	67.6	27.0	25.8	14.3	11.5		
11469	402828	482830.31	1351298.75	7.5-12.0	28.4	71.6	32.0	29.4	13	16.4	11.3	123.7
11471	402962	481282.81	1350976.29	1.5-3.0	5.9	94.1	34.0	51.9	28	23.9		
11471	402963	481282.81	1350976.29	3.5-6.0	3.8	96.2	41.0	50.5	18.4	32.1		
11471	402966	481282.81	1350976.29	3.0-7.5	3.9	96.1	39.0	50.5	19.3	31.2	19.3	105.7
11471	402978	481282.81	1350976.29	7.5-10.5	4.0	96.0	32.0	43.0	21.8	21.2	17.4	110.6
11471	402969	481282.81	1350976.29	10.5-	62.1	37.9	12.0	NP	NP	NP		
11472	402939	479765.76	1350939.74	11.5	3.2	96.8	48.0	49.1	20.8	28.3		
11472	402940	479765.76	1350939.74	1.5-3.0	24.1	75.9	35.0	29.4	15.8	13.6		
11472	402958	479765.76	1350939.74	3.5-6.0	23.2	76.8	37.0	30.9	14	16.9	14.4	119.0
11472	402945	479765.76	1350939.74	3.5-7.5	55.1	44.9	18.0	24.5	13.1	11.4		
11472	402959	479765.76	1350939.74	9.5-11.5	39.4	60.6	29.0	28.7	13.8	14.9	12	124.9
11473	402918	480196.20	1350949.67	9.0-12.0	22.8	77.2	33.0	31.1	17.3	13.8		
11473	402923	480196.20	1350949.67	3.5-6.0	17.1	82.9	37.0	35.4	15.8	19.6	15.1	116.7
11473	402920	480196.20	1350949.67	3.0-7.5	28.1	71.9	35.0	29.3	15.6	13.7		
11473	402925	480196.20	1350949.67	6.5-8.5	23.1	76.9	38.0	31.0	14.8	16.2	13.7	120.6
11473	402922	480196.20	1350949.67	7.5-12.0	35.1	64.9	27.0	25.0	15.1	9.9		
11474	402891	480720.45	1351255.61	9.0-10.6	16.2	83.8	38.0	44.2	18.1	26.1		
11474	402892	480720.45	1351255.61	1.5-3.0	17.4	82.6	27.0	27.9	19.2	8.7		
11474	402896	480720.45	1351255.61	3.5-6.0	18.5	81.5	28.0	28.1	16.2	11.9	13.7	119.2
11474	402901	480720.45	1351255.61	3.0-7.5	23.8	76.2	29.0	26.2	13.8	12.4	12.8	122.6
11474	402898	480720.45	1351255.61	7.5-12.0	31.2	68.8	28.0	25.1	13.5	11.6		
				9.0-10.5								

Notes:
1. Data Compiled from Parsons [1994, 1995a, 1995b].
2. North American Datum 1983
3. ASTM D 422
4. ASTM D 4318 (LL = liquid limit; PL = plastic limit; and PI = plasticity index).
5. ASTM D 698

TABLE 3-2 (continued)

Boring Number	Sample Number	Borehole Northing[2]	Borehole Easting[2]	Sample Depth	Particle Size[3]: Percentage Coarser than No. 200 Sieve	Particle Size[3]: Percentage Passing No. 200 Sieve	Particle Size[3]: Percentage Smaller than 0.005 mm	Atterberg Limits[4]: LL	Atterberg Limits[4]: PL	Atterberg Limits[4]: PI	Standard Proctor Compaction[5]: Optimum Moisture Content (%)	Standard Proctor Compaction[5]: Maximum Dry Density (pcf)
11475	403251	479656.68	1351231.57	2.0-4.5	10.5	89.5	45.0	48.5	16.2	32.3		
11475	403264	479656.68	1351231.57	4.5-8.5	15.5	84.5	38.0	42.8	15.8	27	18.1	108.3
11475	403254	479656.68	1351231.57	6.5-9.0	13.2	86.8	44.0	49.2	26	23.2		
11475	403258	479656.68	1351231.57	11.0-13.5	27.2	72.8	35.0	33.3	17.4	15.9		
11476	402988	481586.18	1350980.71	1.5-3.0	27.9	72.1	34.0	40.7	17.8	22.9		
11476	402989	481586.18	1350980.71	3.5-6.0	15.3	84.7	40.0	30.5	15.9	14.6		
11476	402993	481586.18	1350980.71	3.5-7.5	22.6	77.4	37.0	33.0	14.8	18.2	15.2	113.3
11476	403010	481586.18	1350980.71	12.0-15.0	27.0	73.0	30.0	20.7	12.7	8	10.5	127.3
11477	402863	481831.18	1351279.71	1.5-3.0	6.9	93.1	37.0	37.8	20	17.8		
11477	402864	481831.18	1351279.71	3.5-6.0	28.3	71.7	28.0	30.4	15	15.4		
11477	402866	481831.18	1351279.71	3.5-7.5	19.7	80.3	39.0	42.2	16.6	25.6	14.6	116.0
11477	402868	481831.18	1351279.71	8.0-9.0	60.4	39.6	4.0	NP	NP	NP		
11477	402874	481831.18	1351279.71	14.0-18.0	41.7	58.3	18.0	22.7	14.5	8.2	10.5	128.4
11478	402790	482133.05	1351291.73	1.5-3.0	5.1	94.9	44.0	51.0	20.6	30.4		
11478	402792	482133.05	1351291.73	3.5-6.0	21.1	78.9	39.0	37.5	16.5	21		
11478	402796	482133.05	1351291.73	3.5-7.5	25.6	74.4	35.0	35.3	16.6	18.7	14.7	116.5
11478	402813	482133.05	1351291.73	7.5-10.0	31.3	68.7	30.0	26.6	14.8	11.8	12.7	122.6
11478	402798	482133.05	1351291.73	10.5-12.0	29.5	70.5	30.0	28.0	16.2	11.8		
11479	403021	482120.19	1350995.94	1.5-3.0	13.7	86.3	48.0	53.5	16.8	36.7		
11479	403022	482120.19	1350995.94	3.5-6.0	46.7	53.3	18.0	21.3	14.1	7.2		
11479	403048	482120.19	1350995.94	3.5-7.5	36.0	64.0	27.0	28.8	14.1	14.7	11.8	123.3
11479	403049	482120.19	1350995.94	7.5-10.5	35.8	64.2	28.0	25.2	14.9	10.3	13	119.5
11480	402768	482448.04	1351297.95	0.5-3.0	13.1	86.9	45.0	49.6	17.8	31.8		
11480	402771	482448.04	1351297.95	3.0-7.5	17.2	82.8	39.0	38.5	15.8	22.7	15.2	113.8
11480	402770	482448.04	1351297.95	5.0-7.5	10.2	89.8	38.0	39.7	18.6	21.1		
11480	402774	482448.04	1351297.95	7.5-12.0	21.2	78.8	30.0	27.2	14.4	12.8	12.5	123.5
11480	402773	482448.04	1351297.95	9.5-12.0	20.4	79.6	35.0	32.0	18	14		
11481	403202	482660.50	1350405.12	3.5-6.0	33.8	66.2	28.0	31.0	15.5	15.5		
11481	403230	482660.50	1350405.12	3.0-7.5	38.2	61.8	28.0	30.7	14.5	16.2	13.4	120.2
11481	403204	482660.50	1350405.12	6.5-9.0	43.9	56.1	23.0	26.6	15.4	11.2		
11481	403231	482660.50	1350405.12	13.5-18.5	29.4	70.6	30.0	24.9	12.8	12.1	12.5	122.2
11470B	403131-1	482790.71	1351042.41	1.5-3.0	55.8	44.2	12.0	19.8	14.3	5.5		
11470B	403132-1	482790.71	1351042.41	3.5-6.0	50.6	49.4	8.0	NP	NP	NP		
11470B	403169-1	482790.71	1351042.41	3.5-7.5	44.1	55.9	10.0	17.7	15.7	2	11.1	125.0
11470B	403137-1	482790.71	1351042.41	8.0-10.5	37.3	62.7	15.0	16.0	15.2	0.8		
11470B	403170-1	482790.71	1351042.41	7.5-12.0	34.0	66.0	12.0	17.3	16.7	0.6	11.4	124.0
G2-120	405124	478800	1351164.79	5.0-7.0	33.3	66.7	34.0	30.7	15.7	15		
G2-121	404812	479000	1351314.11	10-11.7	34.0	66.0	28.0	26.9	15	11.9		
G2-121	404814	479000	1351314.11	12.5-14.5	38.8	61.2	26.0	26.4	14.4	12		

Notes:
1. Data Compiled from Parsons [1994, 1995a, 1995b].
2. North American Datum 1983
3. ASTM D 422
4. ASTM D 4318 (LL = liquid limit; PL = plastic limit; and PI = plasticity index).
5. ASTM D 698

TABLE 3-2 (continued)

Boring Number	Sample Number	Borehole Northing[2]	Borehole Easting[2]	Sample Depth	Particle Size[3]: Percentage Coarser than No. 200 Sieve	Particle Size[3]: Percentage Passing No. 200 Sieve	Particle Size[3]: Percentage Smaller than 0.005 mm	Atterberg Limits[4]: LL	Atterberg Limits[4]: PL	Atterberg Limits[4]: PI	Standard Proctor Compaction[5]: Optimum Moisture Content (%)	Standard Proctor Compaction[5]: Maximum Dry Density (pcf)
G2-122	404821	479000	1350915.67	5.0-7.0	3.4	96.6	37.0	30.7	17.2	13.5		
G2-122	404824	479000	1350915.67	10.0-12.0	30.0	70.0	33.0	28.6	14.9	13.7		
G2-123	404797	480000	1351312.37	7.5-9.5	33.6	66.4	29.0	26.6	15.2	11.4		
G2-123	404800	480000	1351312.37	12.5-14.5	31.7	68.3	31.0	28.0	14.4	13.6		
G2-124	405002	480000	1350695.40	5.0-7.0	3.8	96.2	47.0	56.3	18.9	37.4		
G2-124	405004	480000	1350695.40	10.0-12.0	13.8	86.2	43.0	41.6	18.8	22.8		
G2-125	405023	480600	1350663	2.5-4.5	9.0	91.0	36.0	37.5	18.8	18.7	18.2	111.6
G2-125	405026	480600	1350663	7.5-9.5	34.4	65.6	24.0	22.4	13.9	8.5		
G2-125	405029	480600	1350663	12.5-14.5	39.5	60.5	18.0	16.3	12.4	3.9		
G2-126	404768	481300	1351533.64	7.5-9.5	32.6	67.4	24.0	22.6	14.7	7.9		
G2-126	404771	481300	1351533.64	12.5-14.5	35.9	64.1	25.0	23.8	13.7	10.1	11.3	125.0
G2-127	404751	481300	1351293.21	7.5-9.5	24.7	75.3	33.0	28.3	14.8	13.5		
G2-128	405040	481200	1350644.79	2.5-4.5	20.0	80.0	42.0	39.4	17.3	22.1		
G2-128	405043	481400	1350644.79	7.5-9.5	41.4	58.6	28.0	27.8	15.5	12.3	12.6	123.0
G2-128	405046	481400	1350644.79	12.5-14.5	51.3	48.7	22.0	28.3	15.5	12.8		
G2-129	404729	482000	1351546.03	5.0-7.5	1.5	98.5	40.0	32.9	18.6	14.3		
G2-129	404732	482000	1351546.03	10.0-12.5	40.7	59.3	24.0	24.3	14.9	9.4		
G2-130	405075	482000	1350648.72	5.0-7.0	27.5	72.5	25.0	23.8	13.7	10.1		
G2-130	405077	482000	1350648.72	10.0-12.0	23.1	76.9	30.0	25.2	14.1	11.1		
G2-131	404704	482800	1351543.57	7.5-9.5	29.8	70.2	34.0	27.1	15.1	12		
G2-132	405102	483000	1350414.49	5.0-7.0	7.1	92.9	46.0	48.2	20.6	27.6	14.5	118.0
G2-132	405105	483000	1350414.49	10.0-12.0	25.2	74.8	27.0	25.1	14.8	10.3		
G2-133	405053	482600	1349813.50	2.5-4.5	2.2	97.8	41.0	47.3	16.8	30.5	15.8	98.5
G2-133	405055	482500	1349813.50	7.5-9.5	31.8	68.2	25.0	26.9	15.3	11.6		
G2-134	405140	478,800	1351504.25	12.0-14.0	38.4	61.6	23.0	24.6	13.5	11.1		
G2-201	2	478479.25	1350255.01	2.5-4.5	3.0	97.0	48.8	49.0	18	31		
G2-201	4	478479.25	1350255.01	7.5-9.5	12.0	88.0	42.0	30.0	17	13		
G2-202	1	478676.08	1350881.05	0.0-2.0								
G2-202	3	478676.08	1350881.05	5.0-7.0	39.0	61.0	18.0	20.0	14	6		
G2-202	4	478676.08	1350881.05	7.5-9.5	35.0	65.0	27.0	27.0	15	12		
G2-202	5	478676.08	1350881.05	10.0-12.0	31.0	69.0	27.0	25.0	14	11		
G2-203	5	478264.29	1350667.59	10.0-12.0	59.0	41.0	15.0	21.0	13	8		
G2-204	1	478463.15	1351295.60	0.0-2.0								
G2-204	4	478463.15	1351295.60	7.5-9.5	32.0	68.0	29.0	27.0	15	12		
G2-204	6	478463.15	1351295.60	12.5-14.5	29.0	71.0	27.0	24.0	14	10		
G2-205	2	477852.36	1350454.88	2.5-4.5	13.0	87.0	36.0	41.0	23	18		
G2-205	3	477852.36	1350454.88	5.0-7.0	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.		
G2-205	5	477852.36	1350454.88	10.0-12.0	35.0	65.0	27.0	28.0	16	12		
G2-206	1	478048.67	1351081.50	0.0-2.0								
G2-206	2	478048.67	1351081.50	2.5-4.5	24.0	76.0	35.0	35.0	17	18		

Notes:
1. Data Compiled from Parsons [1994, 1995a, 1995b].
2. North American Datum 1983
3. ASTM D 422
4. ASTM D 4318 (LL = liquid limit; PL = plastic limit; and PI = plasticity index).
5. ASTM D 698

TABLE 3-2 (continued)

Boring Number	Sample Number	Borehole Northing[2]	Borehole Easting[2]	Sample Depth	Particle Size[3]			Atterberg Limits[4]			Standard Proctor Compaction[5]	
					Percentage Coarser than No. 200 Sieve	Percentage Passing No. 200 Sieve	Percentage Smaller than 0.005 mm	LL	PL	PI	Optimum Moisture Content (%)	Maximum Dry Density (pcf)
G2-206	3	478048.67	1351081.50	5.0-7.0	28.0	72.0	37.0	N.A.	N.A.	N.A.		
G2-206	4	478048.67	1351081.50	7.5-9.5	32.0	68.0	30.0	28.0	15	13		
G2-206	5	478048.67	1351081.50	10.0-12.0	36.0	64.0	26.0	26.0	15	11		
G2-206	6	478048.67	1351081.50	12.4-14.5	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.		
G2-207	1	477646.51	1350879.51	0.0-2.0								
G2-207	5	477646.51	1350879.51	10.0-12.0	33.0	67.0	27.0	26.0	16	10		
G2-208	2	477838.17	1351493.02	2.5-4.5	2.0	98.0	35.0	44.0	20	24		
G2-208	3	477838.17	1351493.02	5.0-7.0	30.0	70.0	31.0	40.0	17	23		
G2-208	4	477838.17	1351493.02	7.5-9.5	31.0	69.0	27.0	31.0	15	16		
G2-208	5	477838.17	1351493.02	10.0-12.0	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.		
G2-209	BULK	478155.04	1351394.37	0.0-25.0	30.0	70.0	30.0	28.0	13	15		
G2-210	BULK	478161.69	1350355.36	0.0-25.0	25.0	75.0	31.0	28.0	14	14		
G2-SB-1	404608	479000	1351423.85	1.5-5.0	7.9	92.1	42.0	48.9	18.6	30.3	17.5	104.8
G2-SB-10	404637	482500	1351425.69	1.5-5.0	15.4	84.6	42.0	46.5	17.2	29.3	17.1	109.9
G2-SB-11	404642	482500	1350774.40	1.5-5.0	22.4	77.6	30.0	29.1	16.3	12.8	14.3	119.0
G2-SB-12	404599	482800	1351118.36	1.5-4.2	10.8	89.2	47.0	50.4	19.1	31.3	18.1	106.1
G2-SB-13	404583	482700	1350113.43	1.5-5.0	13.4	86.6	42.0	46.0	17.2	28.8	16.6	112.1
G2-SB-14	404578	482600	1350142.05	1.5-5.0	11.7	88.3	44.0	51.5	18.2	33.3	18.7	107.1
G2-SB-15	404649	479600	1347147.30	1.0-2.0							21.4	101.0
G2-SB-16	404650	480000	1347691.12	1.0-2.0							20.9	103.9
G2-SB-17	405366	480900	1348112.13	1.0-2.0							19.3	109.1
G2-SB-2	404603	478900	1350798.64	1.5-5.0	7.8	92.2	38.0	41.0	18.1	22.9	17	107.5
G2-SB-2,3,4,6	404617	479850		0.0-1.5							17.7	105.6
G2-SB-3	404591	479500	1351115.51	1.5-5.0	4.4	95.6	38.0	46.1	17.6	28.5	17.8	105.8
G2-SB-4	404615	479850	1351428.92	1.5-5.0	15.8	84.2	40.0	47.6	17.8	29.8	17.2	107.5
G2-SB-5	404627	479850	1350780.18	1.5-5.0	10.1	89.9	42.0	49.7	18.8	30.9	18.2	106.8
G2-SB-6	404595	480600	1351101.05	1.5-5.0	6.8	93.2	32.0	36.5	19.6	16.9	17.3	106.3
G2-SB-7	404632	481400	1351404.44	1.5-5.0	12.0	88.0	41.0	45.1	17.6	27.5	18.5	109.6
G2-SB-8	404621	481400	1350742.84	1.5-5.0	9.7	90.3	40.0	42.0	17.1	24.9	17.5	109.7
G2-SB-	404644	482500		0.0-1.5							19.3	105.3
8,9,10,11	404587	481900	1351110.22	1.5-5.0	8.5	91.5	42.0	48.4	18.6	29.8	19.2	107.2
G2-SB-9												
				Number of Data Points	128	128	128	124	124	124	51	51
				Average	29.8	74.1	31.2	32.8	16.1	16.7	15.9	113.1
				Std. Dev. σ	23.0	14.2	9.7	10.2	2.1	8.7	3.0	8.2

Notes:
1. Data Compiled from Parsons [1994, 1995a, 1995b].
2. North American Datum 1983
3. ASTM D 422
4. ASTM D 4318 (LL = liquid limit; PL = plastic limit; and PI = plasticity index).
5. ASTM D 698

plasticity index (PI), decrease with increasing depth, and the standard Proctor optimum moisture content decreases while the maximum dry density increases with increasing depth. Inspection of the grain size distribution curves for the brown till indicates that these variations in material properties correlate to the amount of sand in the till, which increases with increasing depth. The trend of increasing sand content is gradual and not indicative of a distinct stratigraphic unconformity in the brown till. However, this trend is likely to affect the compaction characteristics of the brown till and therefore will likely cause a shift in the APZ. This phenomenon is consistent with that described by Othman and Luettich [1994]. In an effort to evaluate whether a shift in APZ is significant, the brown till is delineated into two horizons, as follows:

- the upper horizon is defined as the brown till (excluding topsoil) extending from the ground surface to a depth of approximately 5 ft (1.5 m); and
- the lower horizon is defined as the brown till located below a depth of approximately 5 ft (1.5 m).

In order to evaluate whether the compaction and index properties of the brown till vary consistently with respect to lateral location, the data from Table 3-2 was grouped according to horizon and graphed with respect to the northing coordinate of the boring. The northing coordinate is used as the indicator of sample (lateral) location since the OSDF area and on-site borrow area are relatively long in the north-south direction but narrow in the east-west direction (see Figure 2-1). The data was then plotted on the following graphs:

- Figure 3-2 shows the percentage of particles smaller than 0.005 mm as a function of northing coordinate;
- Figure 3-3 shows the percentage of particles passing the No. 200 sieve as a function of northing coordinate;
- Figure 3-4 shows the PI as a function of northing coordinate;
- Figure 3-5 shows the standard Proctor optimum moisture content as a function of northing coordinate; and

- Figure 3-6 shows the standard Proctor maximum dry density as a function of northing coordinate.

Visual inspection of the data shown in Figures 3-2 through 3-6 reveals no apparent trends relative to the sample northing coordinate. Visual examination of these figures also reveals that the material properties of the brown till from the OSDF area are not significantly different than the material properties of the brown till from the borrow area. Figures 3-2 through 3-6 clearly demonstrate the differences in soil properties and characteristics between the two brown till horizons. For each property or characteristic of interest, the upper horizon clearly has a different average value than the lower horizon. The average value and standard deviation of each property or characteristic for each horizon is summarized in Table 3-3. In general, the upper horizon is more plastic, has a higher percentage of fines, has a higher standard Proctor OMC, and a lower standard Proctor maximum dry density than the lower horizon.

3.5 Findings

Based on the analyses presented in this section of this TPPFR, it is found that:

- with the exception of percentage of clay-size particles (i.e., particles with a maximum dimension not greater than 0.002 mm), both horizons of the brown till meet the remaining material property criteria of the OU2 ARARs;
- soil samples from a few of the borings had less than a 50 percent fraction passing the 200 mesh sieve; soils not meeting this requirement will not be used for construction of clay liners; and
- within each horizon, there are not significant differences in material properties between the OSDF area and the borrow area.

TABLE 3-3

STATISTICAL COMPARISON OF BROWN TILL GEOTECHNICAL PROPERTIES
FEMP ON-SITE DISPOSAL FACILITY

Geotechnical Property	Brown Till Population		Upper Horizon Brown Till		Lower Horizon Brown Till	
	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
Percentage Smaller Than 0.005 mm	31.9	9.0	36.9	8.5	29.3	8.0
Percentage Passing No. 200 Sieve	75.1	13.9	83.9	12.3	70.4	12.3
Plasticity Index (PI)	17.4	8.2	23.7	7.7	14.0	6.2
Standard Proctor Optimum Moisture Content (%)	15.4	2.9	17.7	1.4	13.5	2.2
Standard Proctor Maximum Dry Density (pcf)	114.5	7.9	107.6	4.2	119.9	5.6

VARIABILITY OF CLAY CONTENT
BROWN TILL

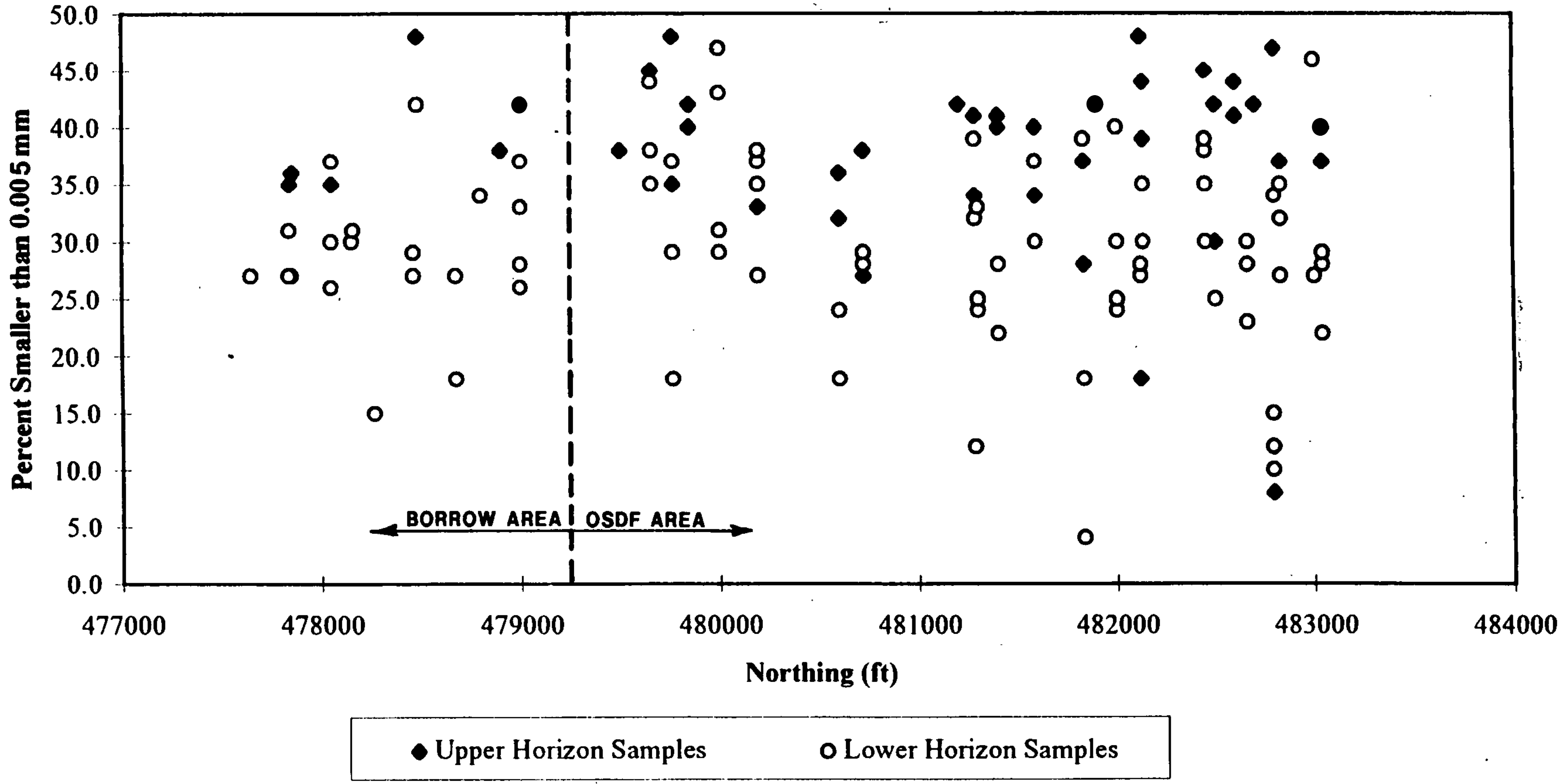

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FIGURE NO. 3-2
PROJECT NO. GE3900-5.4
DOCUMENT NO. F9630212.CDO
FILE NO. DF

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VARIABILITY OF FINES CONTENT
BROWN TILL

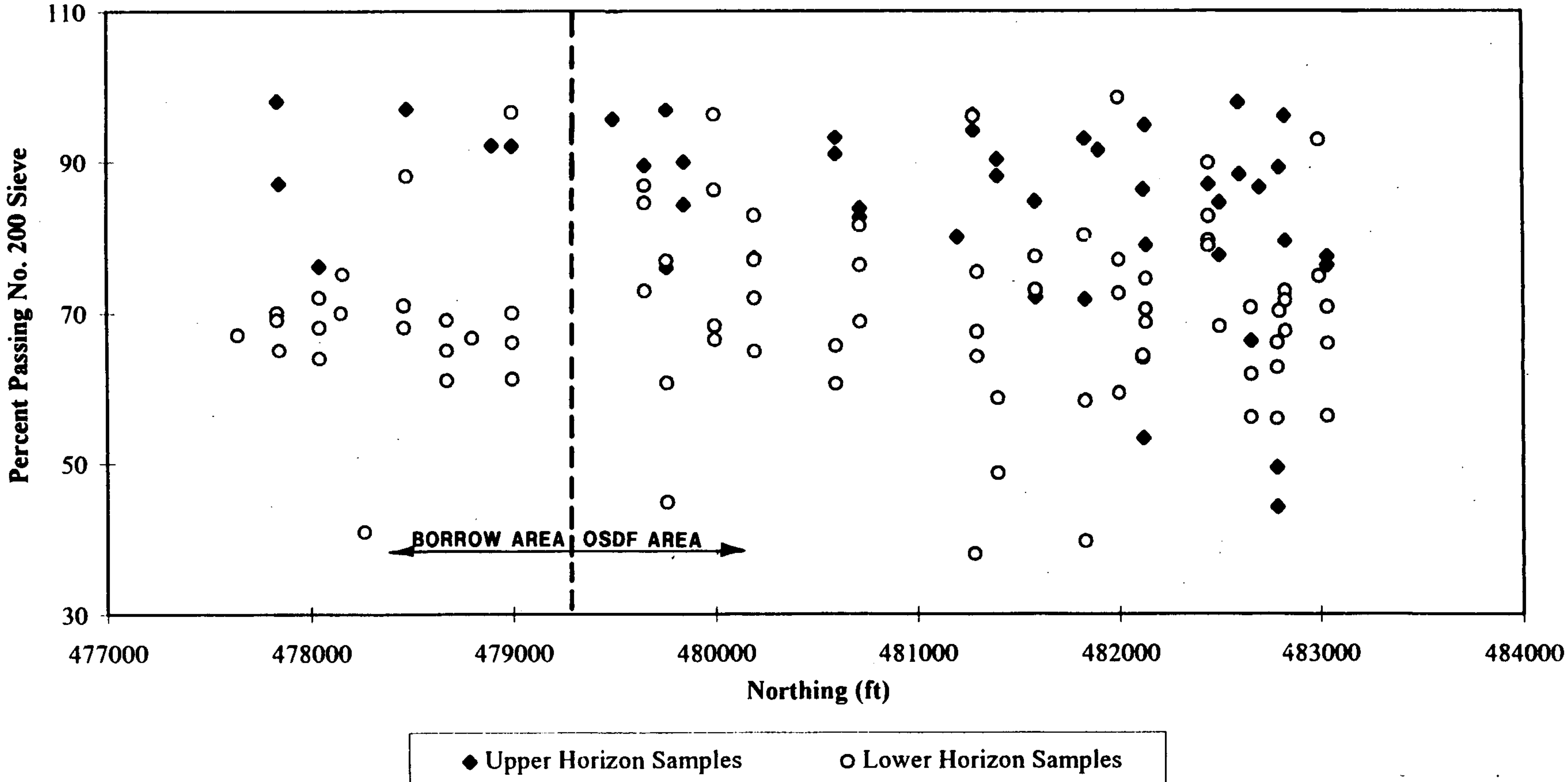

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FIGURE NO.	3-3
PROJECT NO.	GE3900-5.4
DOCUMENT NO.	F9630212.CDO
FILE NO.	DF

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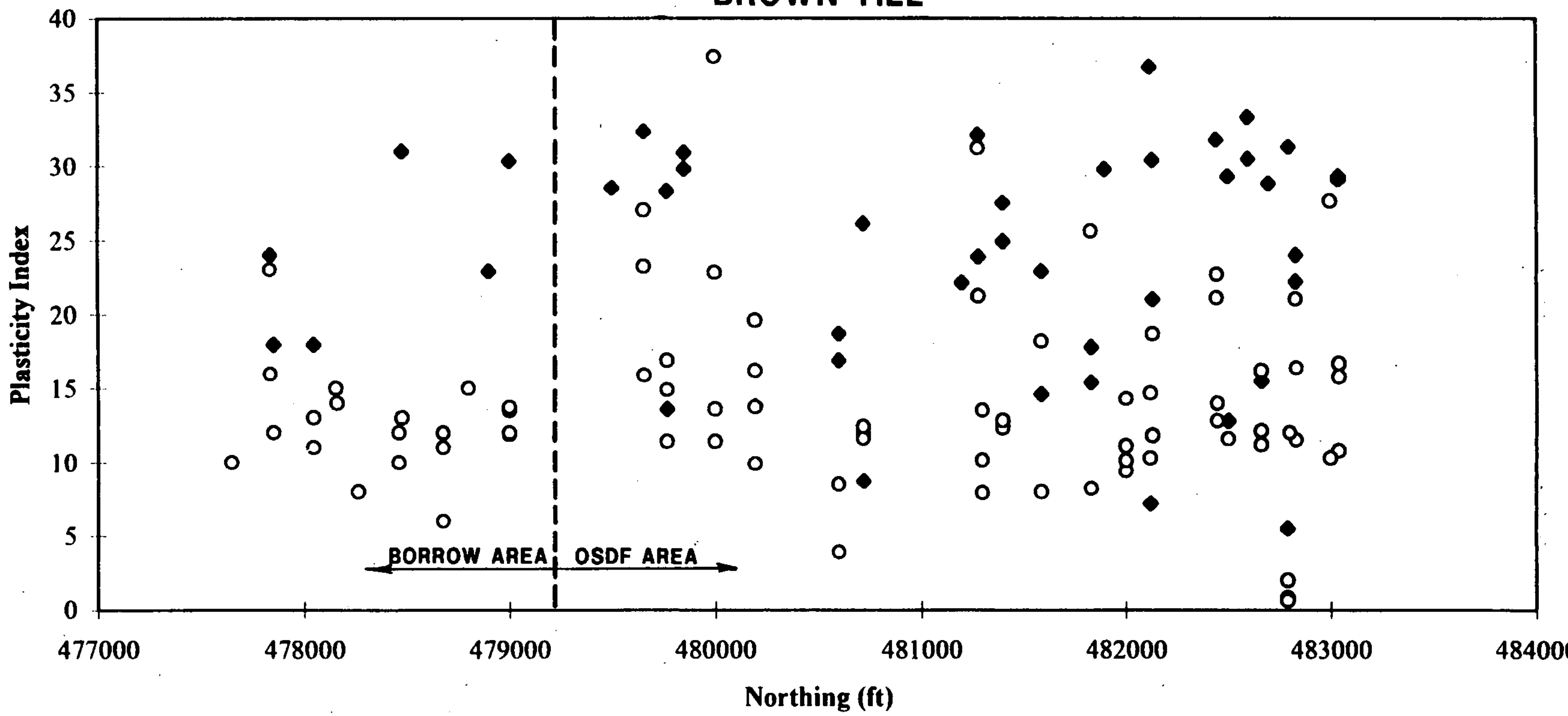
VARIABILITY OF PLASTICITY INDEX
BROWN TILL



◆ Upper Horizon Samples ○ Lower Horizon Samples

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FIGURE NO.	3-4
PROJECT NO.	GE3900-5.4
DOCUMENT NO.	F9630212.CDO
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VARIABILITY OF STANDARD PROCTOR OPTIMUM MOISTURE CONTENT

BROWN TILL

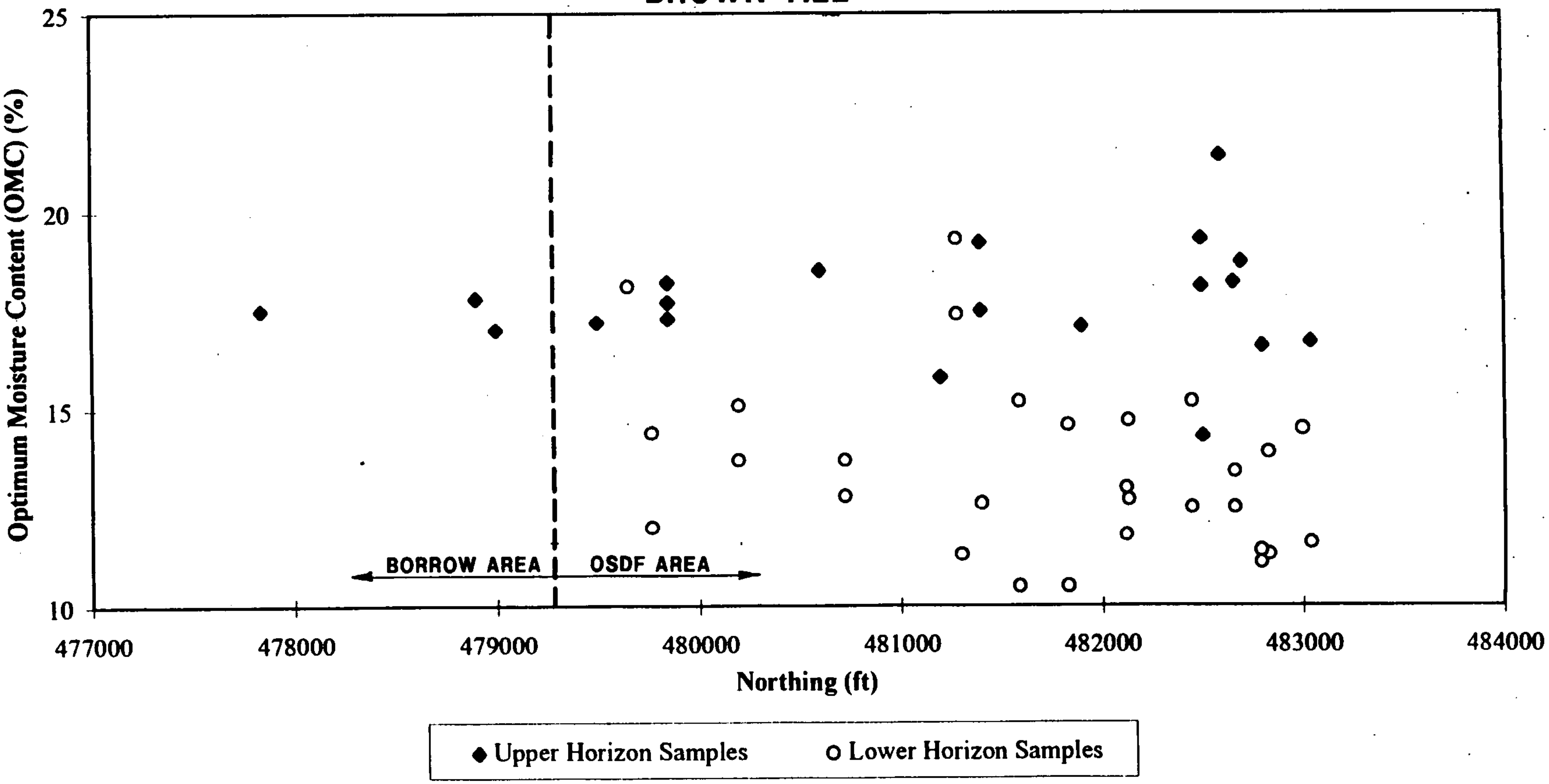

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FIGURE NO. 3-5

PROJECT NO. GE3900-5.4

DOCUMENT NO. F9630212.CDO

FILE NO. DF

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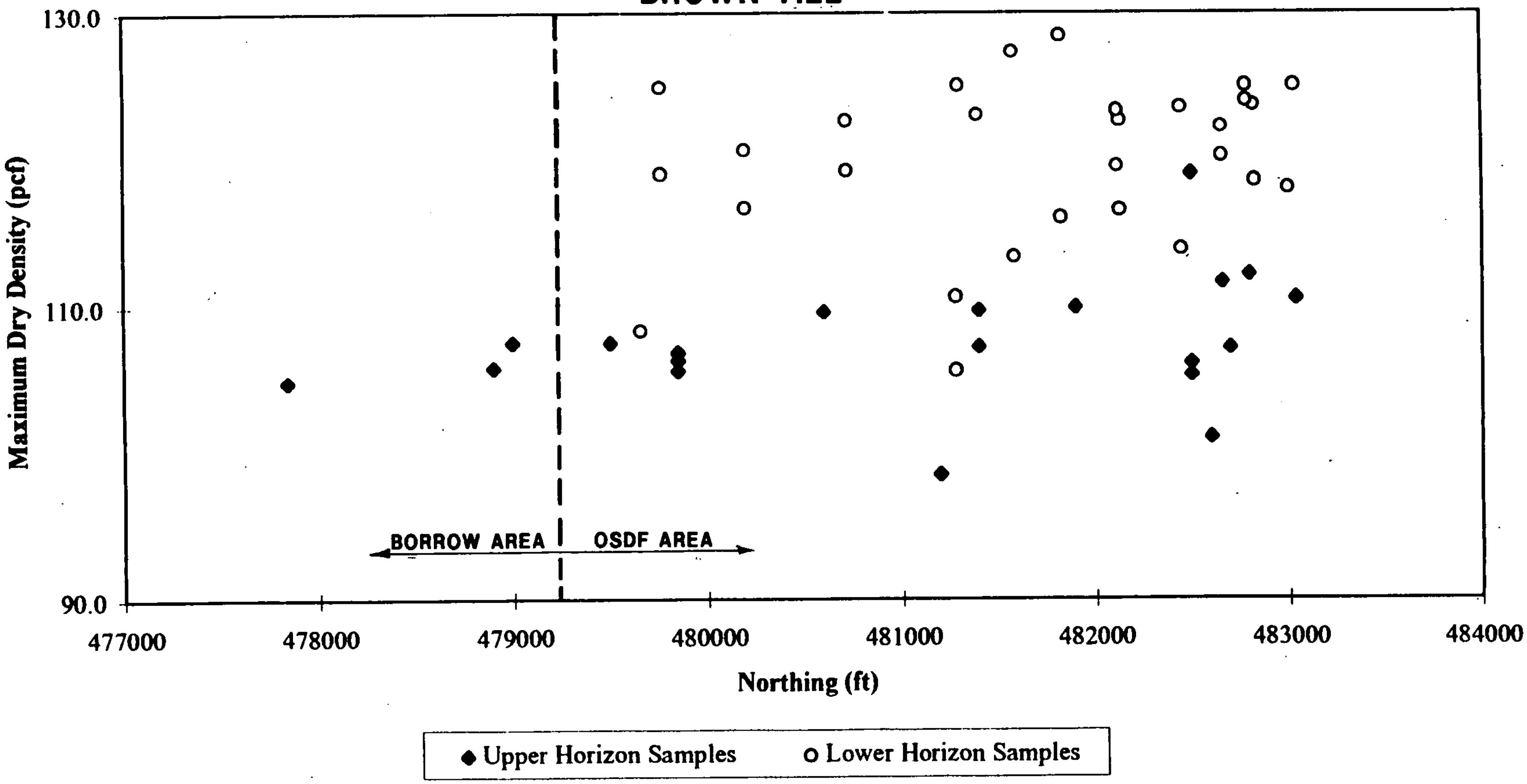
VARIABILITY OF STANDARD PROCTOR MAXIMUM DRY DENSITY
BROWN TILL



GEOSYNTEC CONSULTANTS
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FIGURE NO. 3-6
PROJECT NO. GE3900-5.4
DOCUMENT NO. F9630212.CDO
FILE NO. DF

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SECTION 4

4. PRE-CONSTRUCTION LABORATORY TESTING PROGRAM

4.1 Introduction

The purpose of the pre-construction laboratory testing program was to: (i) establish APZs for the upper and lower horizon brown till materials; and (ii) select the range of target compaction conditions to be evaluated during the test pad program. Pre-construction testing was used to evaluate soil index properties, compaction characteristics, and hydraulic conductivity characteristics. The program was formulated following the general guidelines provided by Daniel [1990]. The program included three phases of work: (i) sampling and laboratory testing; (ii) defining the APZ; and (iii) selecting compaction conditions for the test pads.

4.2 Sampling and Laboratory Testing

As part of the program, two bulk samples of each brown till horizon were obtained on 7 February 1996 from the test pad borrow excavation shown in Figure 4-1. Each sample consisted of approximately 75 lbs (34 kg) of soil taken from the mid-elevation of the horizon. Samples were placed in 5-gal (19-l) plastic buckets which were sealed with tape. In addition to the bulk samples, natural moisture content samples were obtained at 1-ft (0.3-m) vertical intervals throughout each horizon. Each natural moisture content sample consisted of approximately 2 lbs (900 g) of soil placed in sealed air-tight glass sample jars. All samples were carefully packaged and shipped via courier to GeoSyntec's Geomechanics and Environmental Laboratory (GEL) in Atlanta, Georgia, for index, compaction, and permeability testing as summarized in Table 4-1 and described below.

Index testing (i.e., particle-size distribution, Atterberg limits, soil classification, and moisture content tests) was conducted on each bulk sample and on a composite sample formed by blending the two individual samples from each horizon. The purpose of the index tests was to verify that the source of upper horizon brown till and lower horizon brown till used in constructing the test pads met the material-property criteria

TABLE 4-1

SUMMARY OF PRE-CONSTRUCTION LABORATORY TESTS FOR TEST PAD PROGRAM FEMP ON-SITE DISPOSAL FACILITY

Sample No.	Particle-Size Distribution (ASTM D 422)	Atterberg Limits (ASTM D 4318)	Moisture Content (ASTM D 2216)	Soil Classification (ASTM D 2487)	Standard Proctor (ASTM D 698)	Modified Proctor (ASTM D 1557)	Hydraulic Conductivity (ASTM D 5084)
Upper Horizon Sample No. UH1	1	1	3	1	1	0	0
Upper Horizon Sample No. UH2	1	1	3	1	1	0	0
Composite Sample No. UH3	1	1	3	1	1	1	10
Lower Horizon Sample No. LH1	1	1	3	1	1	0	0
Lower Horizon Sample No. LH2	1	1	3	1	1	0	0
Composite Sample No. LH3	1	1	3	1	1	1	10

Note: Particle-size distribution test results will report fraction of particles finer than 0.002 mm.

set forth by the ARARs and to ensure general consistency of index properties with previous geotechnical test results on the brown till (i.e., Figures 3-2 through 3-6).

Standard Proctor compaction testing (i.e., ASTM D 698) was conducted on each bulk sample and on the composite bulk sample from each horizon. The purpose of the compaction tests was to establish the compaction characteristics of each soil as well as the consistency of the compaction characteristics between sample locations. One modified Proctor compaction test (i.e., ASTM D 1557) was performed on the composite bulk sample from each horizon to assist in defining the APZ. The purpose of the modified Proctor test was to establish the line of optimums for the upper and lower horizon brown tills. The reasons for establishing the line of optimum are two-fold: (i) to assist in establishing contours of degree of saturation and hydraulic conductivity because these contours are usually more or less parallel to the line of optimums; and (ii) the line of optimums is useful in establishing effective construction quality assurance (CQA) procedures for soil liners since research and experience have shown that the larger the fraction of compaction points (i.e., combinations of compaction moisture content and dry density) of a clay liner or cap falling above the line of optimums, the better the overall quality of construction. (See page 51 of EPA/600/R-93/182 "*Technical Guidance Document - Quality Assurance and Quality Control for Waste Containment Facilities.*")

Hydraulic conductivity testing was conducted on specimens of remolded soil obtained from the composite bulk samples. The laboratory hydraulic conductivity tests were performed in accordance with ASTM D 5084 "*Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter.*" The GEL formed remolded specimens to target moisture/density points and conducted the hydraulic conductivity testing; ten target moisture/density points were used to establish an APZ for each till horizon. Each specimen was tested at three effective confining stresses, 2 psi (13.8 kPa), 5 psi (34.5 kPa), and 10 psi (68.9 kPa). The specimens were tested at a hydraulic gradient not exceeding 30 and using tap water as the permeant.

The pre-construction laboratory test results are presented in Appendix A of this TPPFR. A summary of the test results is presented in Tables 4-2, 4-3, and 4-4. A review of the data in these tables confirms that the source of upper horizon brown till

TABLE 4-2

SUMMARY OF PRE-CONSTRUCTION PHASE LABORATORY INDEX TEST RESULTS

Site Sample ID	Lab Sample No.	As-Received Moisture Content ASTM D 1140 (%)	Grain Size: Percent Passing #200 Sieve ASTM D 1140 (%)	Grain Size: ASTM D 422		Atterberg Limits ASTM D 4318			Soil Classification ASTM D 2487	Compaction ASTM D 698			Compaction ASTM D 1557			Specific Gravity ASTM D 854 (-)	Hydraulic Conductivity ASTM D 5084 Table No.
				Sieve Figure No.(3)	Hydrom. Figure No.(3)	LL (%)	PL (%)	PI (-)		Max. Dry Unit Weight (pcf)	Optimum Moisture Content (%)	Fig. No.(3)	Max. Dry Unit Weight (pcf)	Optimum Moisture Content (%)	Fig. No.		
411980	96B71	25.5															
411981	96B72	26.8															
411982	96B73	22.1															
411983	96B74	19.2	73.5	1	1	43	19	24	CL - Lean Clay with Sand	111.6	17.2	2					
411984	96B75	18.8	74.8	3	3	43	20	23	CL - Lean Clay with Sand	111.8	16.7	4					
411985	96B76	14.5															
411986	96B77	15.9															
411987	96B78	15.8															
411988	96B79	14.1															
411989	96B80	13.9	67.1	5	5	25	16	9	CL - Sandy Lean Clay	124.3	12.3	6					
411990	96B81	13.2	55.2	7	7	24	15	9	CL - Sandy Lean Clay with Gravel	124.8	11.8	8					
411991	96B82	13.3															
411992	96B83	10.6															
411993	96B84	12.4															
411983 & 411984	96B100(1)									113.0	16.3	9	124.9	11.9	10	2.72	4-3
411989 & 411990	96B101(2)									126.0	11.7	11	135.0	8.3	12	2.71	4-4

Notes:
1. Laboratory samples 96B74 and 96B75 were combined.
2. Laboratory samples 96B80 and 96B81 were combined.
3. Referenced figures are included with detailed pre-construction laboratory results presented in Appendix A.

TABLE 4-3

SUMMARY OF PRE-CONSTRUCTION PHASE LABORATORY HYDRAULIC CONDUCTIVITY TEST RESULTS (UPPER HORIZON SOIL)

Site Sample ID	Lab Sample No.[1]	Hydraulic Conductivity ASTM D 5084			
		Test Specimen Initial Conditions		Consolidation Pressure (psi)	Hydraulic Conductivity (cm/s)
		Dry Unit Weight (pcf)	Moisture Content (%)		
411983 & 411984 Combined	96B100.01	106.3	16.7	2	5.2E-5
				5	2.8E-5
				10	2.0E-6
	96B100.02	110.9	17.0	2	6.4E-7
				5	1.8E-7
				10	2.5E-8
	96B100.03	108.3	18.4	2	8.4E-8
				5	2.7E-8
				10	2.3E-8
	96B100.04	110.2	18.6	2	4.8E-8
				5	1.1E-8
				10	6.7E-9
	96B100.05	106.3	20.7	2	1.1E-8
				5	6.8E-9
				10	5.2E-9
	96B100.06	107.1	18.5	2	1.2E-6
				5	6.5E-7
				10	1.0E-7
	96B100.07	108.3	17.3	2	6.7E-6
				5	2.4E-6
				10	9.0E-7
	96B100.08	119.3	12.4	2	1.4E-7
				5	1.2E-7
				10	4.8E-8
	96B100.09	112.8	17.2	2	2.1E-8
				5	1.3E-8
				10	9.2E-9
	96B100.10	106.4	19.2	2	5.5E-8
				5	2.8E-8
				10	2.1E-8

Note: 1. Laboratory samples 96B74 (site sample 411983) and 96B75 (site sample 411984) were combined to produce Sample 96B100.

TABLE 4-4

SUMMARY OF PRE-CONSTRUCTION PHASE LABORATORY HYDRAULIC CONDUCTIVITY TEST RESULTS (LOWER HORIZON SOIL)

Site Sample ID	Lab Sample No.[1]	Hydraulic Conductivity ASTM D 5084			
		Test Specimen Initial Conditions		Consolidation Pressure (psi)	Hydraulic Conductivity (cm/s)
		Dry Unit Weight (pcf)	Moisture Content (%)		
411989 & 411990 Combined	96B101.01	118.7	11.9	2	1.5E-5
				5	1.3E-5
				10	8.9E-6
	96B101.02	124.7	11.7	2	5.3E-6
				5	5.4E-6
				10	1.7E-6
	96B101.03	121.5	13.6	2	3.0E-8
				5	2.3E-8
				10	1.7E-8
	96B101.04	123.4	14.0	2	2.8E-8
				5	1.6E-8
				10	1.1E-8
	96B101.05	118.4	15.7	2	2.8E-8
				5	2.3E-8
				10	2.0E-8
	96B101.06	118.3	13.7	2	5.6E-8
				5	3.8E-8
				10	2.3E-8
	96B101.07	128.3	9.8	2	6.8E-7
				5	3.1E-7
				10	1.5E-7
	96B101.08	125.1	11.9	2	1.2E-7
				5	3.6E-8
				10	2.3E-8
	96B101.09	126.8	12.3	2	9.1E-8
				5	2.3E-8
				10	1.9E-8
	96B101.10	120.1	13.1	2	9.0E-8
				5	3.6E-8
				10	2.4E-8

Note: 1. Laboratory samples 96B80 (site sample 411989) and 96B80 (site sample 411990) were combined to produce Sample 96B101.

and lower horizon brown till used in constructing the test pads met the material-property criteria set forth in the ARARs and the index properties are generally consistent with previous geotechnical test results on the brown till. The results from the pre-construction laboratory testing program were used to develop the APZ and target compaction conditions as described in Sections 4.3 and 4.4 which follow.

4.3 Laboratory Acceptable Permeability Zone

Results of the hydraulic conductivity tests on the remolded samples from each horizon were superimposed on a graph of dry density versus moisture content to establish contours of equal hydraulic conductivity and the limits of the APZs. The APZ concept was illustrated in Figure 2-2 of this TPPFR. The APZs developed following pre-construction laboratory testing are presented in Figures 4-2 and 4-3 for the upper and lower horizons, respectively. The boundaries of each APZ were as follows:

- the left boundary is the standard Proctor OMC;
- the right boundary is the moisture content at four percentage points wet of the standard Proctor OMC based on clay shear strength and workability considerations; and
- the lower boundary is defined by two requirements:
    - a contour of maximum acceptable hydraulic conductivity (1×10^{-7} cm/s); and
    - the dry density at 95 percent of the standard Proctor maximum dry density.

4.4 Selection of Target Compaction Conditions

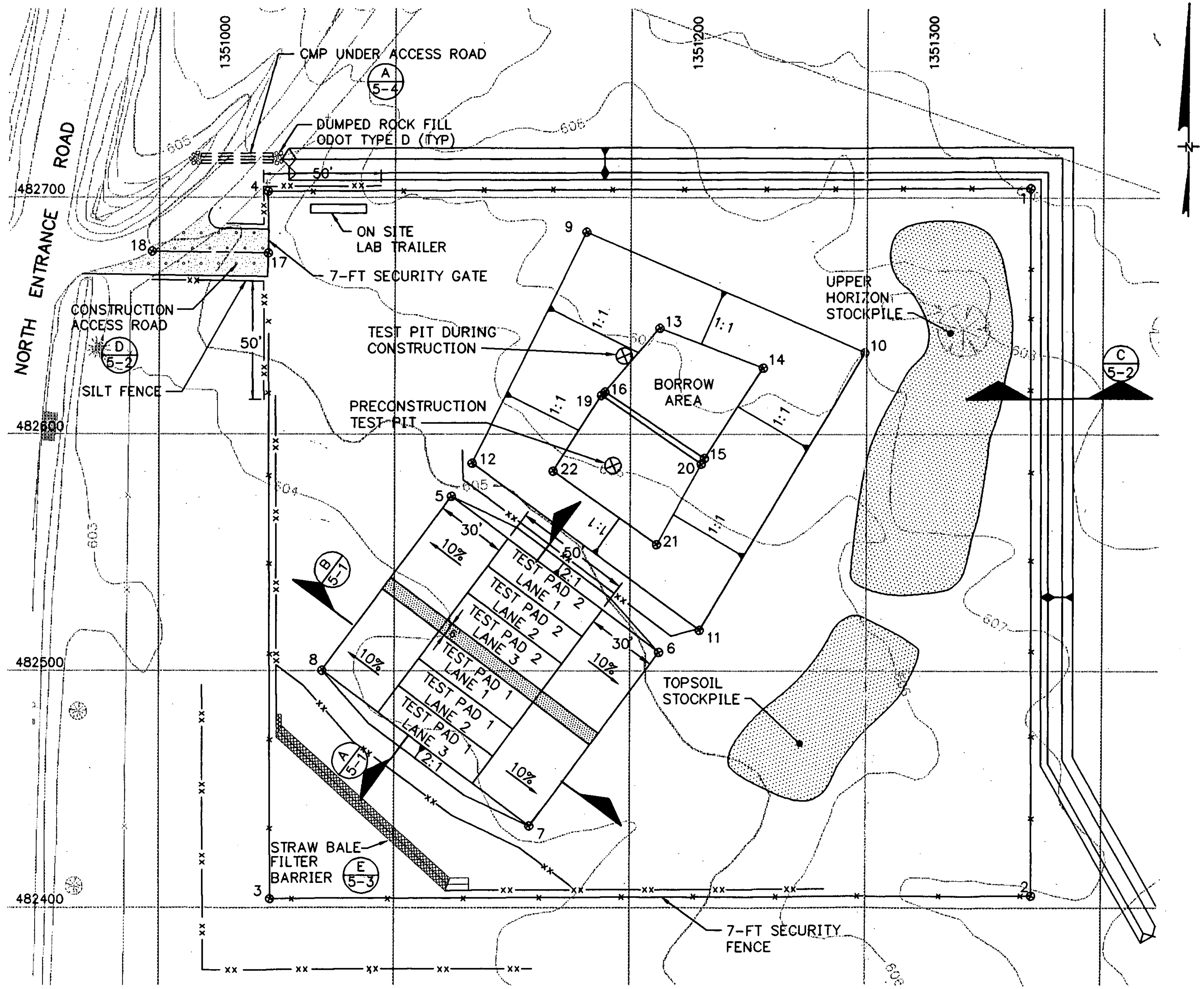
As previously described in Section 2.3.3 of the TPPFR, two test pads were constructed, one using the upper horizon brown till and the other using the lower horizon brown till. Each test pad consisted of three lanes with the target compaction conditions summarized below, as illustrated in Figure 2-3.

- Lane 1 has target conditions selected to fall within the "lower" portion of the APZ.

- Lane 2 has target compaction conditions selected to fall within the "midrange" portion of the APZ.

- Lane 3 has target compaction conditions selected to fall within "upper" portion of the APZ.

The APZs presented in Figures 4-2 and 4-3 were used to establish target compaction conditions for construction of each test pad. A target moisture content range was established for each test pad and a target dry density was established for each lane. These target compaction conditions are shown in Figures 4-4 and 4-5. The targeted moisture content was selected to be 2 percentage points wet of standard Proctor optimum with an allowable range of ± 1 percentage point (i.e., from 1 to 3 points wet of standard Proctor optimum). The targeted dry densities were selected to be approximately 95, 97, and 98 to 99 percents of standard Proctor maximum dry density for Lanes 1, 2, and 3, respectively. These target compaction conditions were used for test pad construction.



CONTROL POINTS		
POINT	NORTHING	EASTING
1	482703.8	1351369.0
2	482404.7	1351370.3
3	482403.7	1351047.2
4	482702.7	1351045.9
5	482573.9	1351124.0
6	482508.0	1351212.2
7	482434.5	1351157.2
8	482500.3	1351069.1
9	482685.6	1351181.1

CONTROL POINTS		
POINT	NORTHING	EASTING
10	482634.9	1351299.1
11	482517.4	1351229.2
12	482587.9	1351132.6
13	482645.0	1351212.2
14	482628.2	1351255.8
15	482590.0	1351231.1
16	482618.0	1351188.9
17	482676.7	1351045.9
18	482677.4	1350996.7

CONTROL POINTS		
POINT	NORTHING	EASTING
19	482616.6	1351187.4
20	482587.5	1351229.9
21	482553.5	1351211.1
22	482584.6	1351167.0

NOTES:

1. TOPOGRAPHIC BASE MAP TAKEN FROM FIGURE 2-1.
2. TEST PAD 1 WAS CONSTRUCTED OF UPPER HORIZON BROWN TILL (i.e. THE UPPER 5 FT OF BROWN TILL). TEST PAD 2 WAS CONSTRUCTED OF LOWER HORIZON BROWN TILL (i.e. FROM 5 TO 11 FT DEPTH).

0 50
SCALE IN FEET

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PROJECT NO. GE3900-5.4	FIGURE NO. 4-1
DOCUMENT NO. F9630212	FILE NO. 39000020.DWG

ACCEPTABLE PERMEABILITY ZONE (APZ) UPPER HORIZON SOIL

BASED ON PRE-CONSTRUCTION TESTING

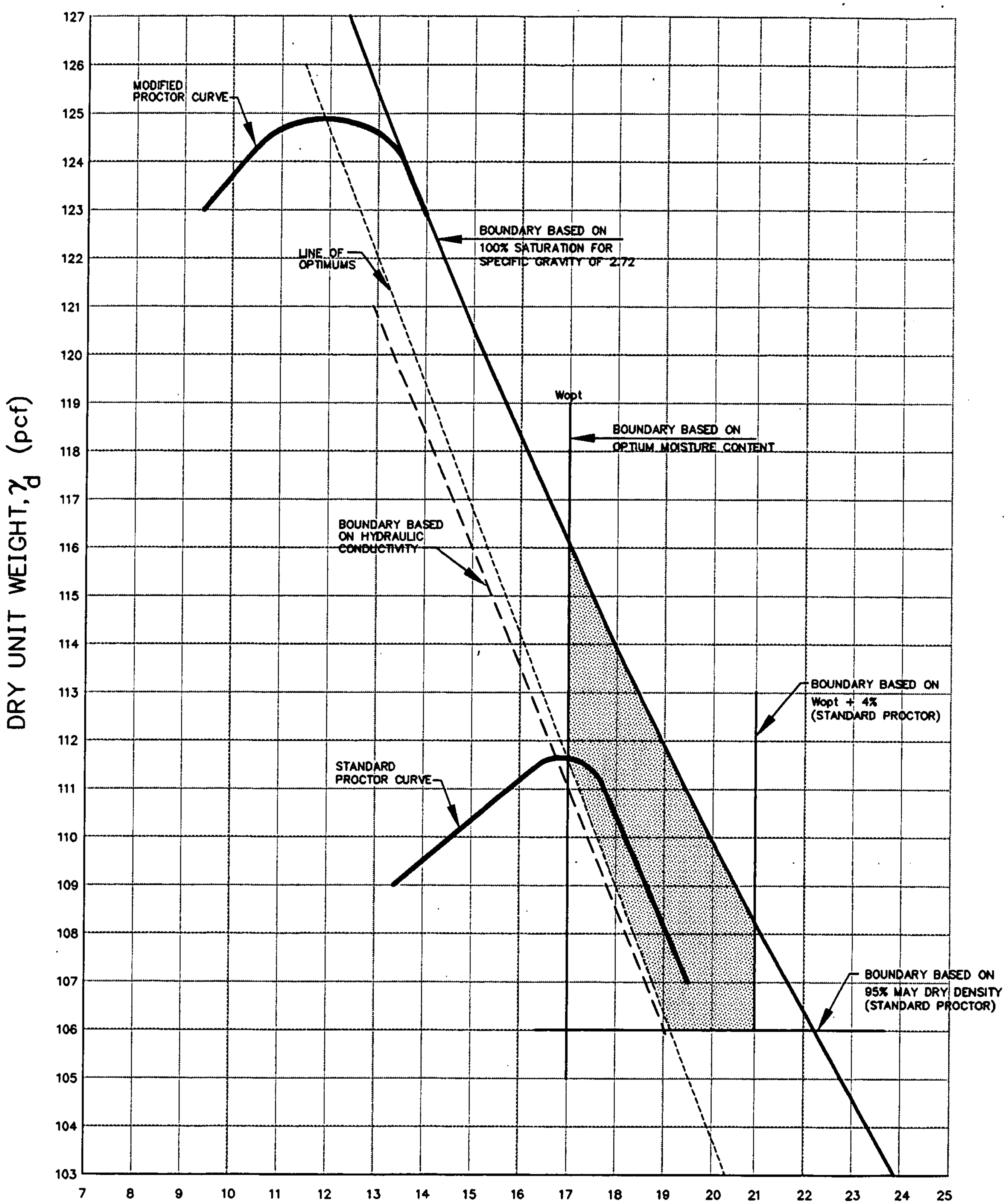

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FIGURE NO.	4–2
PROJECT NO.	GE3900–05.4
DOCUMENT NO.	F9630212.CDO
FILE NO.	3900F003.DWG

ACCEPTABLE PERMEABILITY ZONE (APZ)
LOWER HORIZON BROWN TILL

BASED ON PRE-CONSTRUCTION LABORATORY TESTING

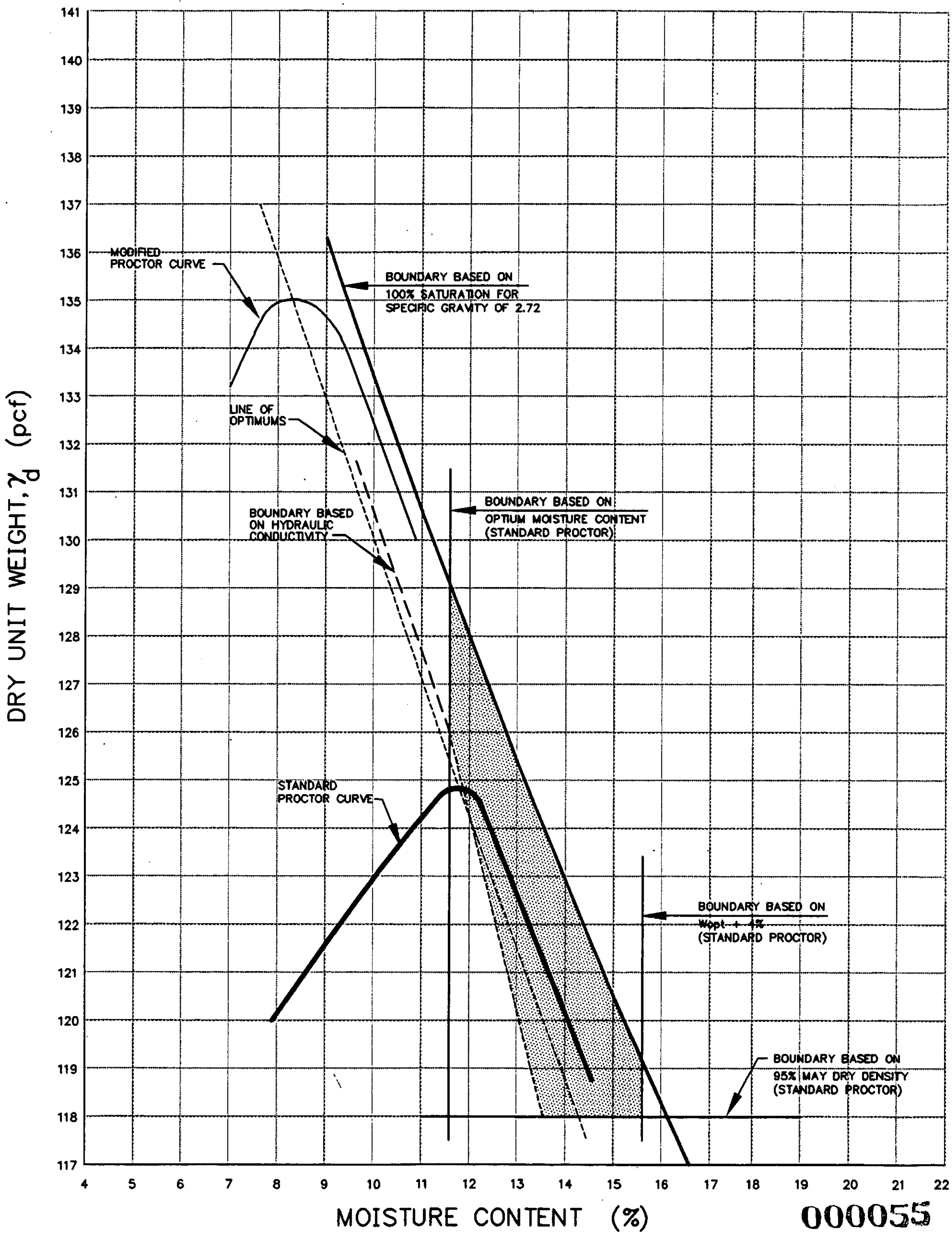

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FIGURE NO.	4–3
PROJECT NO.	GE3900–05.4
DOCUMENT NO.	F9630212.CDO
FILE NO.	3900F005.DWG

TARGET MOISTURE CONTENT AND DRY DENSITY FOR UPPER HORIZON SOIL

BASED ON PRE-CONSTRUCTION TESTING

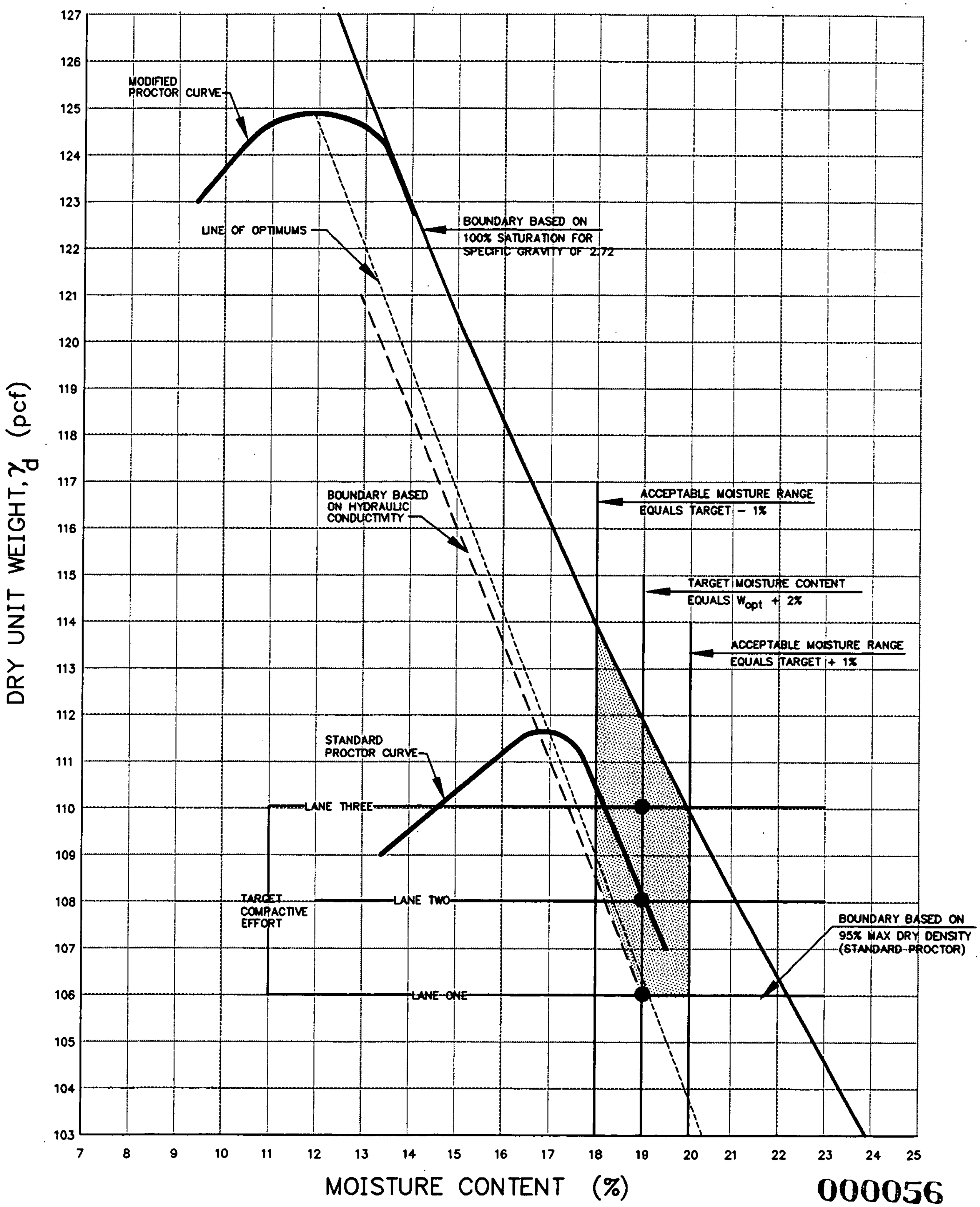

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FIGURE NO.	4-4
PROJECT NO.	GE3900-05.4
DOCUMENT NO.	F9630212.CDO
FILE NO.	3900F004.DWG

TARGET MOISTURE CONTENT AND DRY DENSITY FOR LOWER HORIZON SOIL

BASED ON PRE-CONSTRUCTION TESTING

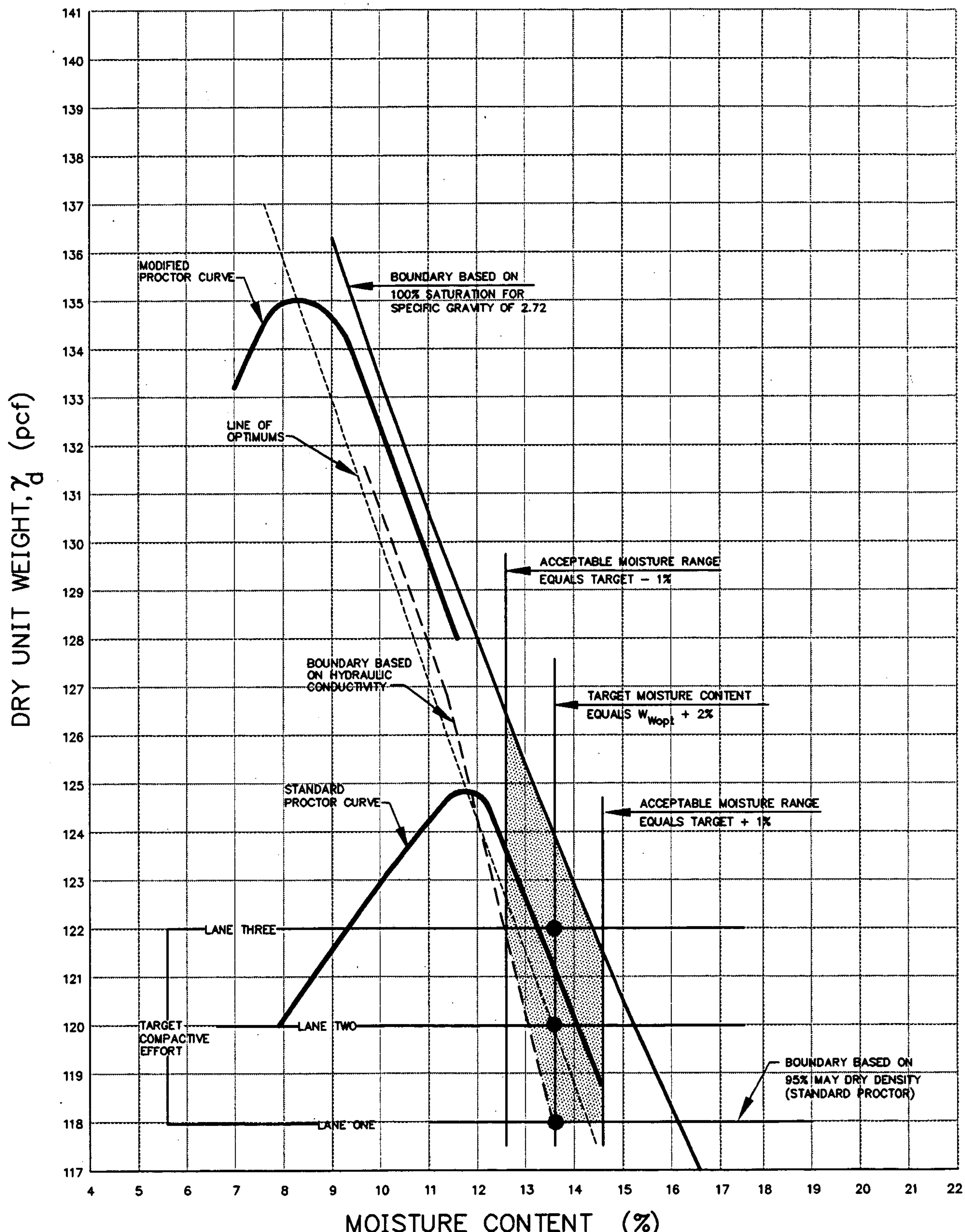

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FIGURE NO.	4-5
PROJECT NO.	GE3900-05.4
DOCUMENT NO.	F9630212.CDO
FILE NO.	3900F006.DWG

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SECTION 5

5. TEST PAD DESIGN

5.1 Test Pad Layout

Test pad design criteria include OU2 ARARs for test pad layout and construction (Table 5-1). The layout of the test pads is influenced by the following requirements (OAC 3745-27-08(C)(1)(m)):

- the test pad must have a minimum width three times the width of the compaction equipment and a minimum length two times the length of the compaction equipment;
- the test pad must be comprised of at least four lifts; and
- a new test pad must be constructed when there is a significant change in soil material properties.

The design layout of the test pad is illustrated in Figures 4-1 and 5-1. Other design features are shown, as built, in Figures 5-2, 5-3, and 5-4. This layout satisfies the requirements presented above. Each test pad was designed to be 42.9 ft (13.1 m) wide to allow for construction of three separate lanes, all with similar moisture contents (although with slight moisture variations between lanes likely due to the limitations of construction), but each with a different compactive effort (as illustrated in Figures 4-4 and 4-5). The design width of each lane is equal to the "full pass" width of a Caterpillar 815 compactor, 14.3 ft (4.4 m). The total width of each test pad is four times the width of a Caterpillar 815 compactor ((i.e., compactor width equal to 10.7 ft (3.2 m) and test pad width equal to 42.9 ft (13.2 m)). The design length of the top of each test pad is 50 ft (15.2 m) which is twice the length of the compactor. The end slopes and side slopes of the test pad were designed to allow construction equipment to achieve speeds comparable to those achieved during actual construction and to provide full coverage during compaction.

As previously discussed in Section 2.3.4 of this TPPFR, the test pads were designed to include six lifts with a nominal total thickness of 3 ft (0.9 m). The

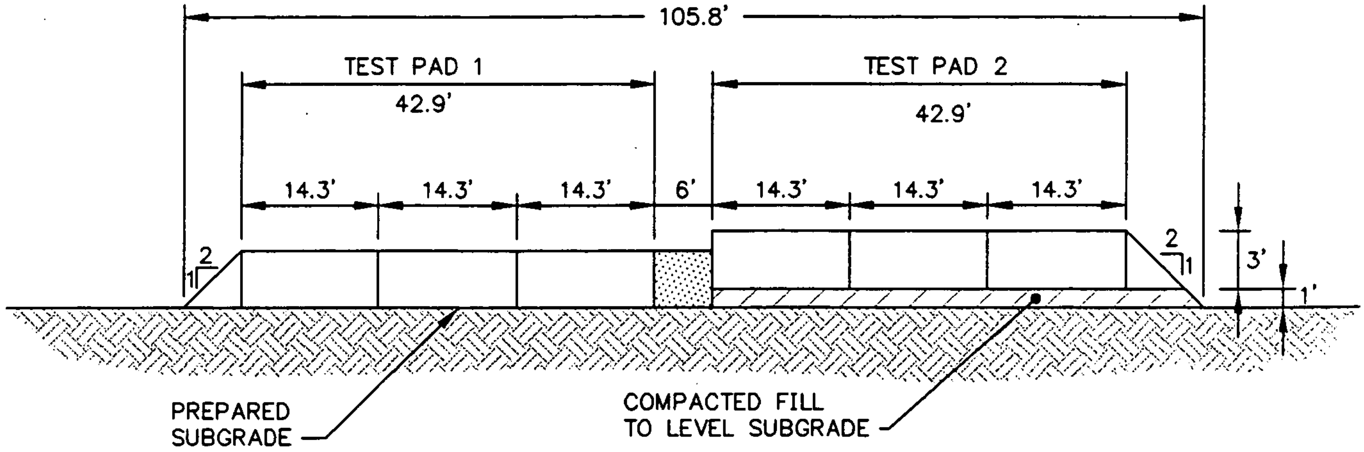
TABLE 5-1

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARS) FOR TEST PAD PROGRAM [DOE, 1995C] FEMP ON-SITE DISPOSAL FACILITY

CITATION	REQUIREMENT Test Pads
Ohio Solid Waste Disposal Regulations OAC 3745-27-08 (C)(1)(m)	The recompacted soil liner and the recompacted soil barrier layer in the cap system shall be modeled by the construction of test pads. The test pads shall: • be designed such that the proposed tests are appropriate and their results are valid. • be constructed to establish the construction details which are necessary to obtain sufficient compaction to satisfy the permeability requirement. The construction details include: - lift thickness; - water content necessary to achieve the desired compaction; and - type, weight, and number of passes of construction equipment. • be constructed prior to the construction of the sanitary landfill component which the test pad will model. • be constructed whenever there is a significant change in soil material properties. • have a minimum width three times the width of the compaction equipment, and a minimum length two times the length of compaction equipment, including power equipment and any attachments. • be comprised of at least four lifts. • be tested for field permeability, following the completion of test pad construction. For each lift a minimum of 3 tests for moisture content and density shall be performed. • be reconstructed as many times as necessary to meet the permeability requirement. Any amended construction details shall be noted. An alternative to test pads may be used if it is demonstrated to the satisfaction of the Director that the alternative meets the requirements.

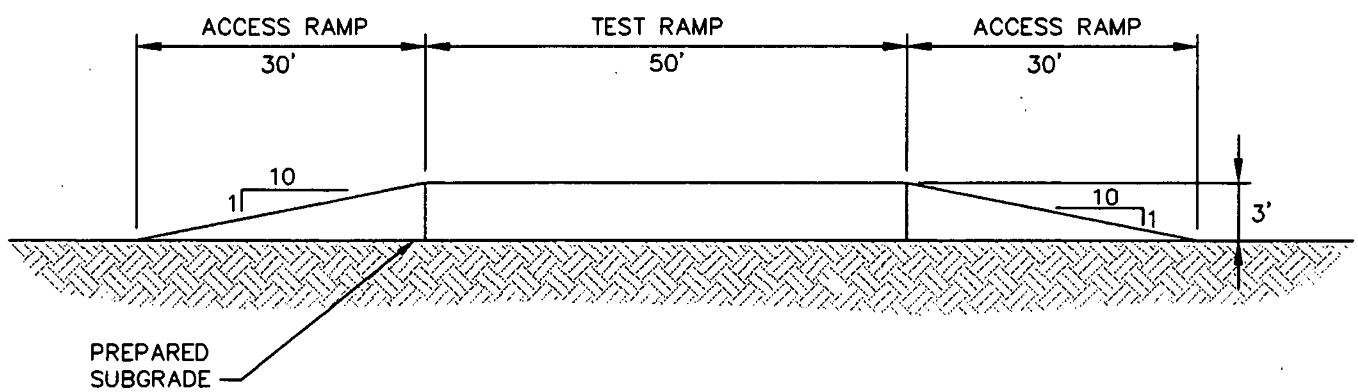
Note: In this TPPFR the following terminology is used: compacted clay liner = recompacted soil liner in Ohio Solid Waste Disposal Regulations; and compacted clay cap = cap system recompacted soil barrier layer of the Ohio regulations.

TEST PAD DETAILS



A SECTION
4-1 TEST PADS 1 AND 2

HORIZONTAL SCALE: 1" = 20'
VERTICAL SCALE: 1" = 10'



B SECTION (TYPICAL)
4-1 TEST PAD

HORIZONTAL SCALE: 1" = 20'
VERTICAL SCALE: 1" = 10'

000061

NOTE:
SUBGRADE PREPARATION SHALL CONSIST OF TOPSOIL REMOVAL, GRADING TO REQUIRED ELEVATIONS, PROOFROLLING, AND BACKFILLING IN ACCORDANCE WITH SECTION 02220 OF THE TEST PAD CONSTRUCTION SPECIFICATIONS.

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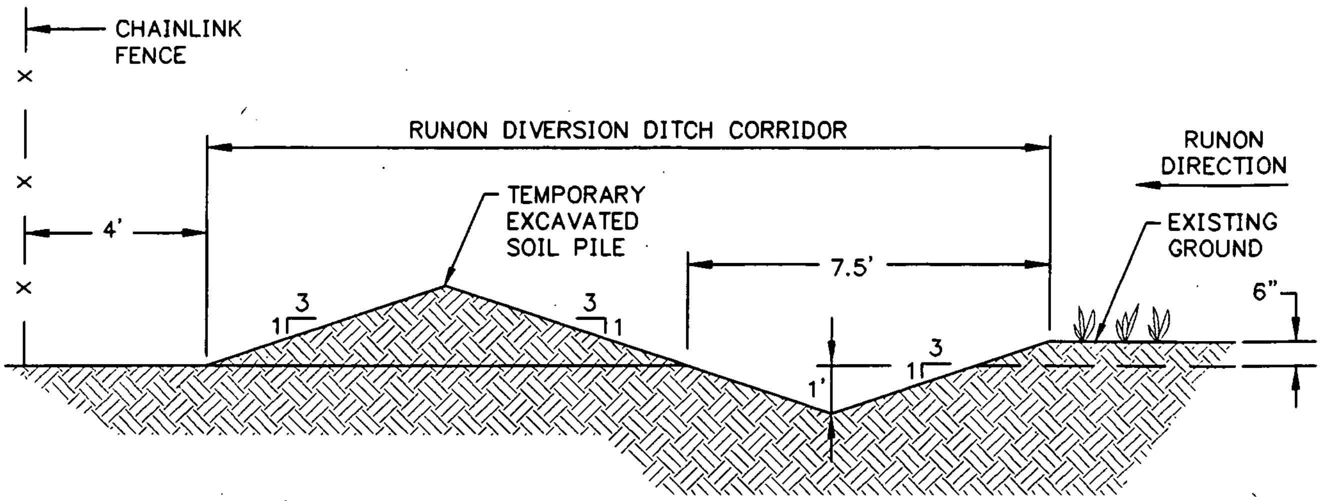
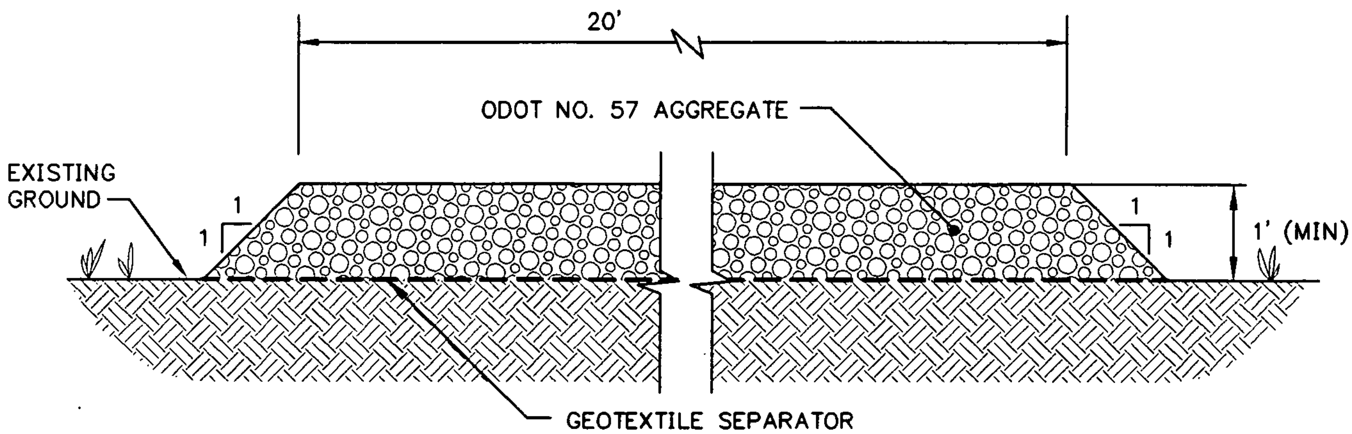
FIGURE NO.	5-1
PROJECT NO.	G3900-5.4
DOCUMENT NO.	F9630212.CDO
FILE NO.	39000014.DWG

TEST PAD CONSTRUCTION SITE DETAILS



C / 4-1 SECTION
RUNON DIVERSION DITCH
SCALE: NTS

NOTE: TOPSOIL SHALL BE REMOVED TO A DEPTH OF 6 INCHES FROM THE RUNON DIVERSION DITHC CORRIDOR PRIOR TO EXCAVATION OF THE RUNON DIVERSION DITCH.



D / 4-1 DETAIL (TYPICAL)
CONSTRUCTION ACCESS ROAD
SCALE: NTS

000062

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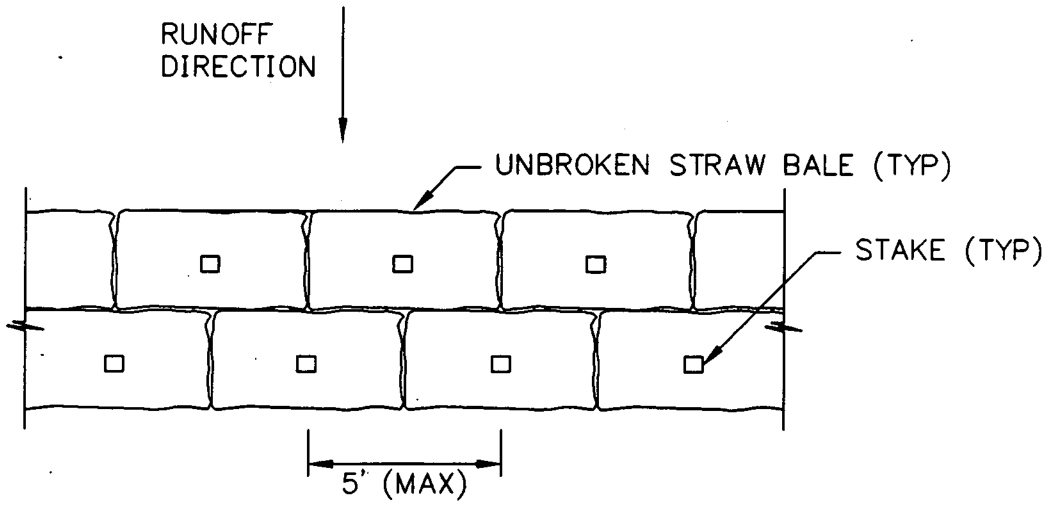
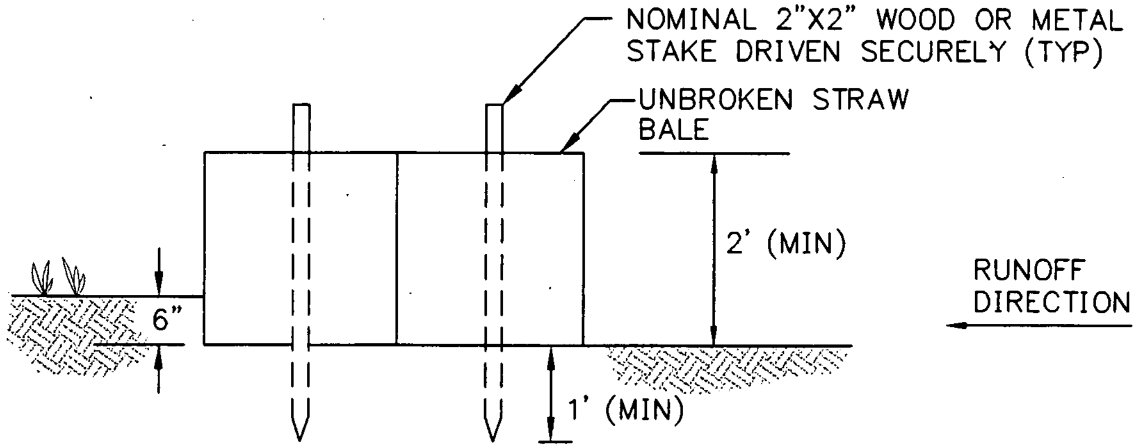
FIGURE NO.	5-2
PROJECT NO.	GE3900-5.4
DOCUMENT NO.	F9630212.CDO
FILE NO.	39000013.DWG

EROSION AND SEDIMENT CONTROL DETAILS



PLAN (TYP)



SECTION (TYP)

E / 4-1 DETAIL
STRAW BALE FILTER BARRIER

000063

SCALE: NTS

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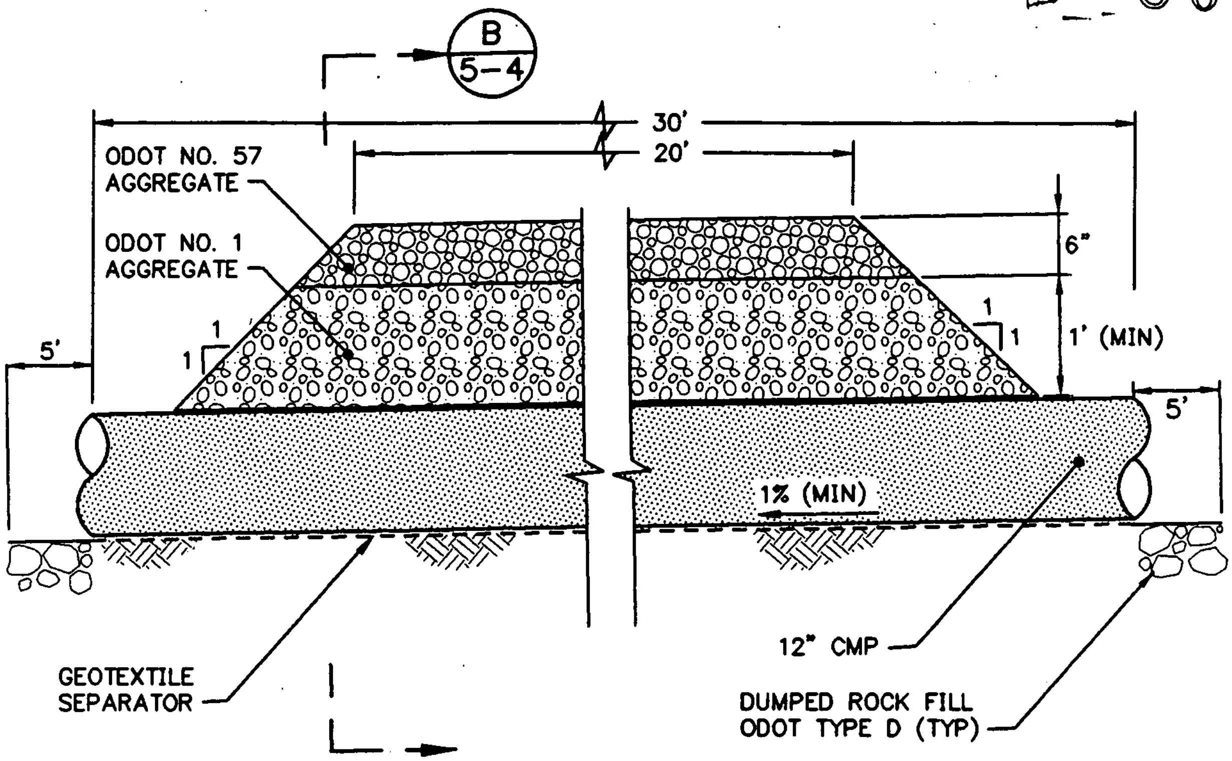
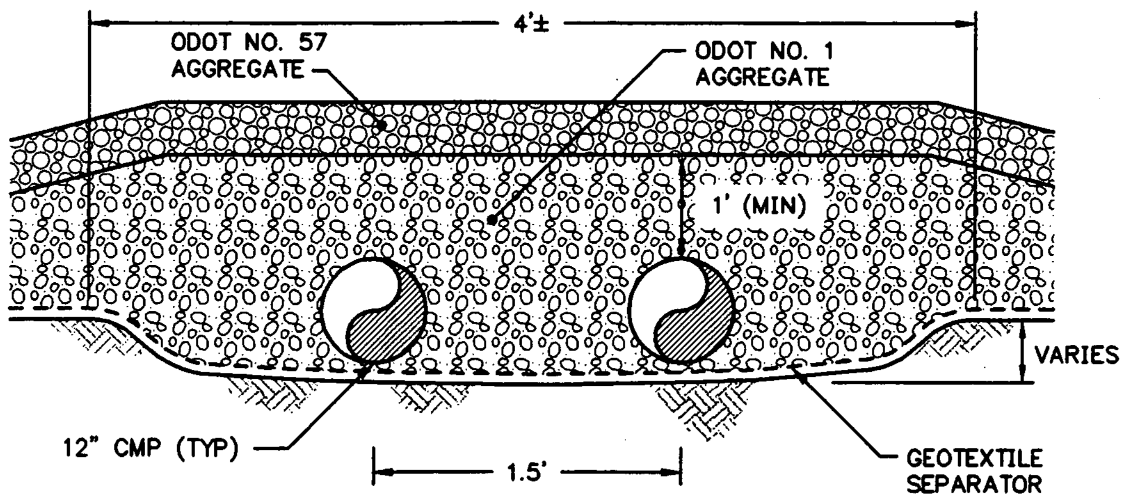
FIGURE NO.	5-3
PROJECT NO.	GE3900-5.4
DOCUMENT NO.	F9630212.CDO
FILE NO.	39000015.DWG

CULVERT DETAILS

867



A
4-1
SECTION
CMP UNDER EXISTING ACCESS ROAD
SCALE: NTS



B
5-4
SECTION
CMP UNDER EXISTING ACCESS ROAD
SCALE: NTS

000064

NOTE: CONTRACTOR SHALL ESTABLISH GRADES OF CMP IN THE FIELD TO MATCH THE ELEVATION OF THE BOTTOM OF THE DIVERSION DITCH ON THE UPGRADIENT SIDE.

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ATLANTA, GEORGIA

FIGURE NO.	5-4
PROJECT NO.	GE3900-5.4
DOCUMENT NO.	F9630212.CDO
FILE NO.	3900A012.DWG

SECTION 6

6. TEST PAD CONSTRUCTION

6.1 Introduction

The purpose of this section of the TPPFR is to describe the general sequence of construction activities, and summarize the methods that were used to construct the test pads.

The Test Pad Contractor was responsible for performing the work in accordance with the TPWP and the Construction Specifications presented in Appendix C of the TPWP. The remainder of this section describes the test pad construction operations including: (i) pre-construction meeting; (ii) site preparation; (iii) borrow material preparation; (iv) placement and compaction of lifts; and (v) surveying. Where appropriate, references are made to sections of the Construction Specifications which are specifically relevant to these operations. A list of the Construction Specifications presented in Appendix C of the TPWP is provided below.

- Division 1: General
  - Section 01000, *General Requirements*
  - Section 01050, *Surveying*
  - Section 01600, *Materials and Equipment*

- Division 2: Site Work
  - Section 02110, *Clearing, Grubbing, and Stripping*
  - Section 02200, *General Earthwork*
  - Section 02220, *Compacted Clay Test Pads*
  - Section 02270, *Erosion and Sediment Control*
  - Section 02950, *Site Restoration*

Photographs documenting test pad construction, quality control testing, and field permeability testing are presented in Appendix C of this TPPFR.

6.2 Pre-construction Meeting

A pre-construction meeting was held on 7 May 1996 in the conference room of Trailer T-58 at the FEMP. The meeting was attended by the Test Pad Contractor superintendent, CQA Engineer site manager, Construction Manager, other FERMCO representatives, and DOE representatives. The agenda and minutes for this meeting are presented in Appendix B of this TPPFR. The actual test pad construction schedule is presented in Figure 6-1.

6.3 Site Preparation

The first phase of test pad construction involved site preparation which included: (i) site layout and access; (ii) stripping; (iii) establishing erosion and sediment control; and (iv) establishing temporary facilities. Sections of the TPWP Construction Specifications specifically relevant to these activities include 01050, 02110, 02200, and 02270. The Test Pad Contractor performed site preparation on 30-31 May 1996.

The general sequence of site preparation followed by the Test Pad Contractor were:

- install security fencing as shown on Figure 4-1;
- construct the construction access road and temporary culverts as shown on Figures 4-1, 5-2, and 5-4;
- install the silt fence and straw bale filter check dam as shown on Figures 4-1 and 5-3;
- remove topsoil and vegetation from the test pad area and borrow excavation area, and constructed the runon diversion ditch (see Figures 4-1 and 5-2); and
- mobilize temporary construction facilities (e.g., trailers, sanitary facilities, etc.) to the test pad construction site.

The surveyor established and marked the construction access road and limits of the test pad construction site prior to the Test Pad Contractor beginning work. Additionally, the Surveyor surveyed and marked the location of the borrow excavation and test pads.

6.4 Borrow Material Preparation

The test pads were constructed using the upper horizon brown till and lower horizon brown till obtained from the borrow excavation area shown in Figure 4-1. The contractor processed the borrow materials after placing them on the test pads. Processing consisted of mechanical mixing and moisture conditioning to reduce clod size and to distribute moisture evenly through the soil. Processing also involved removal of oversized particles visually observed by one or more spotters. Visual spotting was initially thought to be adequate for oversized particle removal because it was anticipated that the number of such particles would be small. However, as discussed in Section 6.5 below, the volume of such particles was found to be significant and visual spotting was not adequate to remove all oversized particles.

As an initial part of the test pad program, borrow material processing techniques were evaluated. The initially preferred method of soil processing was discing, as this has proven to be cost effective on previous projects. Discing refers to making multiple passes over the soil with a heavy-duty construction disc (harrow) pulled by a farm tractor or bulldozer. Processing material by discing was evaluated on 5-6 June 1996 and was found to be inadequate in breaking down brown till clods during this test pad program. Therefore, the Construction Manager mobilized a transverse rotary mixer (RACO 250) to the site for soil processing on 13 June 1996. The transverse rotary mixer proved to be more effective than discing in reducing clod size and distributing moisture.

During evaluation of the soil processing methods, a distinction between clods and remolded clumps of soil was made. At the moisture conditions which will be targeted during compacted clay layer construction, remolded clumps of flexible and properly moisture-conditioned soil form easily. These clumps are acceptable because they are homogeneous and are easily incorporated into the lift of compacted clay. Remolded clumps can be easily broken apart by hand. Clods, on the other hand, are defined as large particles of clay with a hard core of soil not homogeneous with respect to the overall material being processed. The core of a large clod may be drier than the target moisture content of the material being processed and may retain the in-situ structure of the till. Large clods are not acceptable for incorporation in the lift.

After the preferred method of soil processing was selected, the Test Pad Contractor processed material from each horizon of the brown till to uniformly distribute the moisture and reduce the clod size to no larger than 3 in. (75 mm). The Test Pad Contractor processed the soil to achieve uniform moisture content within ± 1.0 percentage point of the target moisture content in the compacted lift.

6.5 Removal of Oversize Particles

Visual spotting at the level carried out during the test pad program was found to be insufficient to remove all oversized particles. The method used for visual spotting included removal of oversized particles observed in the borrow area prior to transportation to the test pad. In addition, two full time spotters with occasional help from up to three others were used to identify and remove oversized particles on the test pad during placement and processing of soil. The area of the test pad surface was approximately 50 ft (15 m) by 50 ft (15 m). Oversized particles were removed by spotters as soil was being placed and again as the soil was processed with the HAMM RACO 250 transverse rotary mixer. Each time the transverse rotary mixer passed through a lift more oversized particles were removed. In some cases, the soil was processed as many as three or four times. Trenching for the infiltrometer rings subsequently confirmed that all oversize particles were not removed by this method. However, hydraulic conductivities significantly lower than 1×10^{-7} cm/sec were successfully achieved as further discussed in Section 8.

6.6 Placement and Compaction of Lifts

The general sequence of activities, used during construction, for placement and compaction of each lift of borrow material on the test pads is listed below

(Section 02220 of the TPWP Construction Specifications is specifically relevant to these activities):

- the surface of the subgrade was moisture-conditioned and scarified prior to placing the first lift of material; for each test pad, a given lift was constructed across all three lanes at the same time;

- the thickness of each lift of material was measured to the bottom of the indentation of the pad-foot;

- the clay was spread using a Caterpillar D-5 bulldozer to a loose lift thickness of approximately 8 in. (200 mm); due to the nature of the material and the moisture content targeted, pad-foot indentations of 3 to 5 in. (75 to 250 mm) remained after compaction; to achieve a 6 in. (300 mm) compacted lift thickness the loose lift thickness measured to the bottom of the pad-foot indentation was approximately 10 in (500 mm);

- the material was processed using one to three passes of the transverse rotary mixer; processing was to a depth of 1 in. (25 mm) below the bottom of the pad-foot print of the previous lift;

- the lift was compacted using the specified number of passes of the Caterpillar 815 in each lane; the specified number of passes for a given lane was selected considering the target compaction conditions for that lane; and

- locations for moisture/density testing of the compacted clay were prepared by the Test Pad Contractor by smoothing the compacted clay surface using the blade of the dozer; as indicated in Section 7.4.3 of this TPPFR, CQA personnel evaluated moisture content and dry density using the nuclear gauge at not less than three locations per lift per lane.

If the CQA Site Manager indicated that the moisture content was not within the target range, the Test Pad Contractor was instructed to further process the material (e.g., to dry back, or blend additional water into the soil, as appropriate) until an acceptable uniform moisture content was obtained. Alternatively, the Test Pad Contractor was directed to remove the lift and replace it with more suitable material.

The procedure used for moisture conditioning included:

- the clay was spread to the appropriate loose lift thickness and pulverized with the transverse rotary mixer to reduce clods and provide uniform moisture content;
- CQA personnel evaluated the moisture content using the microwave method on 2 to 3 locations dispersed over the area of the lift;
- if moisture content was in the specified range of plus 2 percentage points above the standard Proctor optimum moisture content ± 1 percentage point, then the material was compacted with the Caterpillar 815; and
- if moisture content was determined to be dry of the specified moisture range an appropriately calculated volume of water was added using the hand held hose of a trailer mounted, 900 gallon (3,300 liter), hydroseeder; CQA personnel retested to confirm the moisture content was within the specified range and the material was compacted with the Caterpillar 815.

The method of adding water with a hand-held hose proved to be inadequate in achieving a uniform distribution of added moisture (see discussion in Section 7.4.3).

The number of passes (i.e., one "full coverage" pass across the test fill) of the Caterpillar 815 was specified by the CQA Engineer. A minimum of 4 passes in Lane 1, 7 passes in Lane 2, and 10 passes in Lane 3 were specified for Test Pad Number 1. A minimum of 4 passes in Lane 1, 6 passes in Lane 2, and 8 passes in Lane 3 were specified for Test Pad Number 2. Experience with the brown till in both horizons revealed that the dry density achieved was more dependent on moisture content than compactive effort beyond 4 passes. Although additional passes continue the kneading effect, significant changes in dry density were not observed in all cases. Based on the experience with Test Pad Number 1 and lift one of the Test Pad

Number 2, the number of passes were reduced in lanes 2 and 3 of Test Pad Number 2 from 7 and 10 to 6 and 8, respectively.

The final lift (Lift No. 6) was graded with a bulldozer after compaction and lightly compacted with a smooth drum roller until smooth. To protect SDRI test locations, the Test Pad Contractor covered each test pad with flexible plastic sheeting (e.g., visqueen) that was at least 8 mils (0.2 mm) thick. The plastic sheeting on each test pad was anchored at the edges using sandbags.

6.7 Excavation Dewatering

The Test Pad Contractor was responsible for managing perched ground-water that entered the borrow area excavation. Overall, the rate of perched ground-water flow into the excavation was insignificant. Essentially, no water flow was detected during excavation of material for placement on the test pads. Minor flow (one to two gallons per hour maximum) was observed in sampling holes in the borrow area.

6.8 Surveying

An appropriately trained and qualified Surveyor provided surveying equipment and personnel for construction layout and monitoring. The Surveyor was a member of the Construction Manager's organization. Section 01050 of the TPWP Construction Specifications is specifically relevant to these activities. Surveying activities, prior to and during the test pad construction phase, included:

- establishing at least three control points located at convenient locations in close proximity to the test pads and borrow area that are referenced to the site coordinate system and National Geodetic Vertical Datum (NGVD);

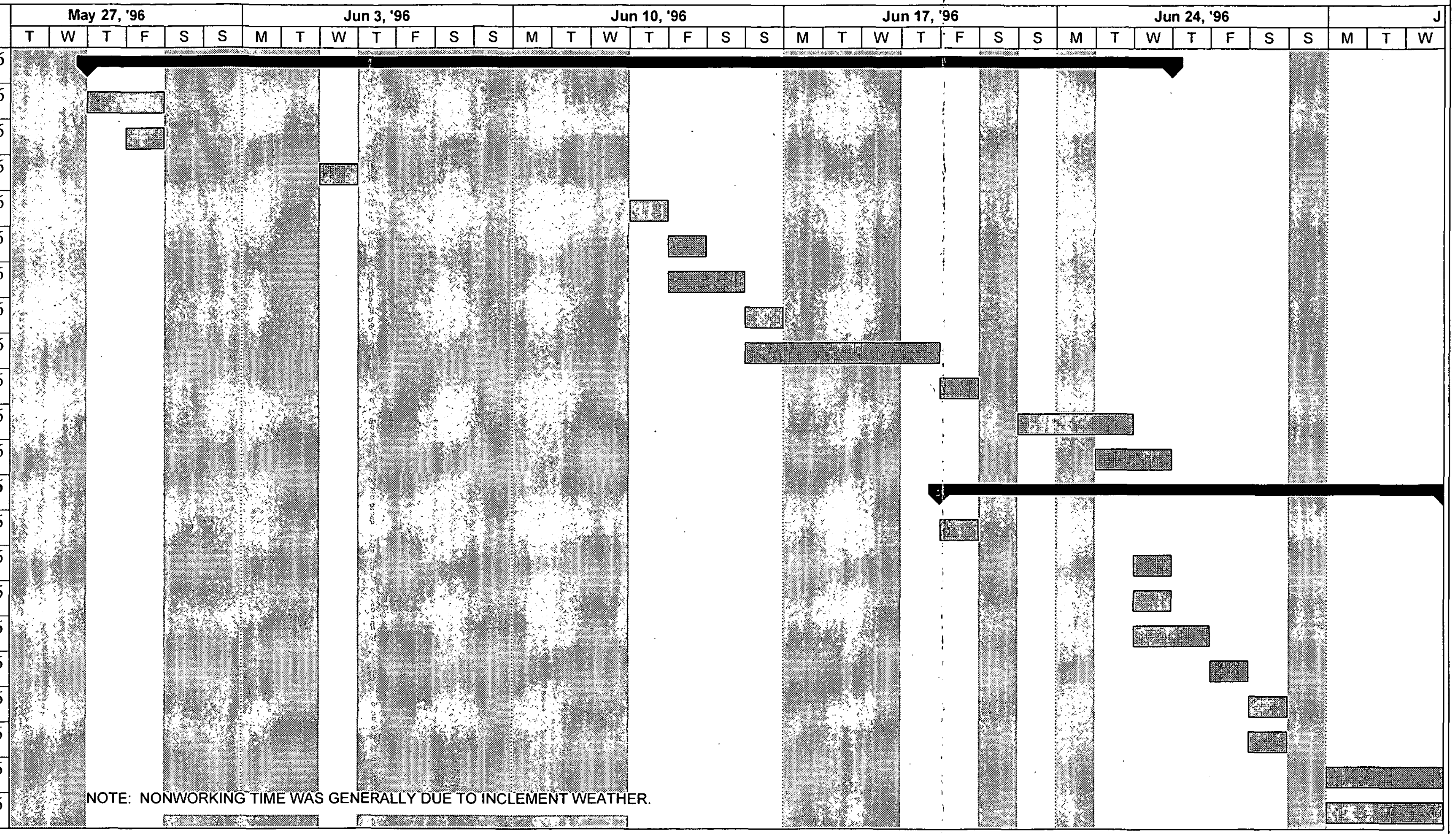
- staking the locations for the construction access road, security fence, silt fence, diversion berms, test pads, and borrow excavation; and

- staking toe and crest lines of the test pads as needed during construction to control the work.

During test pad construction, the CQA Site Manager provided assistance to the Surveyor for monitoring compacted lift thickness. For each lane, the elevation of the top of the compacted lift (measured at the bottom of compactor cleat marks) was measured using a survey level. The same locations were surveyed for every lift so accurate thicknesses could be measured.

FIGURE 6-1
OSDF TEST PAD PROGRAM, ACTUAL CONSTRUCTION SCHEDULE 1996

ID	Task Name	Duration	Start	Finish
1	**TEST PAD #1**	**12d**	**May 30 '96**	**Jun 26 '96**
2	STRIPPING TOPSOIL	2d	May 30 '96	May 31 '96
3	PREPARE BORROW PIT	1d	May 31 '96	May 31 '96
4	EVALUATE SOIL PROCESSING	1d	Jun 5 '96	Jun 5 '96
5	CONSTRUCT LIFT #1	1d	Jun 13 '96	Jun 13 '96
6	CONSTRUCT LIFT #2	1d	Jun 14 '96	Jun 14 '96
7	CONSTRUCT LIFT #3	2d	Jun 14 '96	Jun 15 '96
8	CONSTRUCT LIFT #4	1d	Jun 16 '96	Jun 16 '96
9	CONSTRUCT LIFT #5	2d	Jun 16 '96	Jun 20 '96
10	CONSTRUCT LIFT #6	1d	Jun 21 '96	Jun 21 '96
11	SDRI 1-1	2d	Jun 23 '96	Jun 25 '96
12	SDRI 1-2	2d	Jun 25 '96	Jun 26 '96
13	**TEST PAD #2**	**10d**	**Jun 21 '96**	**Jul 3 '96**
14	PREPARE BORROW PIT	1d	Jun 21 '96	Jun 21 '96
15	CONSTRUCT LIFT #1	1d	Jun 26 '96	Jun 26 '96
16	CONSTRUCT LIFT #2	1d	Jun 26 '96	Jun 26 '96
17	CONSTRUCT LIFT #3	2d	Jun 26 '96	Jun 27 '96
18	CONSTRUCT LIFT #4	1d	Jun 28 '96	Jun 28 '96
19	CONSTRUCT LIFT #5	1d	Jun 29 '96	Jun 29 '96
20	CONSTRUCT LIFT #6	1d	Jun 29 '96	Jun 29 '96
21	SDRI 2-1	3d	Jul 1 '96	Jul 3 '96
22	SDRI 2-2	3d	Jul 1 '96	Jul 3 '96



Project:
Date: Jun 30 '97

Task		Milestone	●	Rolled Up Task		Rolled Up Progress	
Progress		Summary		Rolled Up Milestone	◇	Nonworking Time	

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SECTION 7

7. TEST PAD CQA

7.1 Overview

The CQA monitoring, testing, and documentation program was implemented as part of the test pad program. The CQA program was designed to verify that construction materials, equipment, and procedures used in the test pad program were in conformance with the TPWP. The CQA plan addressed:

- CQA personnel requirements;
- CQA field, office, and laboratory activities; and
- CQA documentation.

7.2 Quality Assurance Standards

The information generated from the test pad program is essential in establishing the requirements of OSDF Construction Specifications for materials and methods required for construction of the compacted clay liner and cap. Data Quality Objectives (DQOs) for the test pad program were established in Appendix F of the TPWP. These DQOs satisfy requirements of the Sitewide CERCLA Quality Assurance Project Plan (SCQ) for the FEMP. Quality assurance observations, verifications, testing, and documentation described in the following paragraphs are in compliance with objectives and standards set forth in the TPWP CQA Plan.

7.3 CQA Personnel Requirements

During test pad construction, the CQA Engineer provided a CQA Site Manager and one CQA technician on-site on a full-time basis. Additional technicians were mobilized to the site, as required, to meet work load requirements. During peak activity (i.e., construction of Test Pad Number 2 and installation of SDRIs on Test Pad

Number 1) as many as four technicians were on site. The CQA Site Manager directed the activities of the CQA Technician(s). These individuals were responsible for providing technical direction to the Test Pad Contractor, performing field CQA activities, and installing the SDRIs.

7.4 CQA Activities

7.4.1 Laboratory Testing Program

A qualified member of the CQA organization monitored the sampling activities for the pre-construction laboratory testing program described in Section 4 of the TPWP. The CQA Site Manager monitored and documented the following activities:

- surveying and staking of locations for the test pit prior to the start of test pit excavation activities;
- test pit excavation and collection of samples; and
- shipping samples to the CQA geotechnical testing laboratory.

7.4.2 Site and Subgrade Preparation

During the site and subgrade preparation phase, CQA personnel monitored and documented the Test Pad Contractor's activities to ensure that the requirements set forth in the TPWP Construction Specifications were satisfied. The CQA personnel monitored, verified, and documented the following construction activities:

- site surveying and layout;
- installation of silt fence;
- topsoil removal;

- installation of runon control berms; and

- subgrade preparation and proofrolling.

CQA personnel confirmed that the Test Pad Contractor established the erosion and sediment control system before surface vegetation and topsoil was removed. The CQA Site Manager visually evaluated the suitability of the subgrade and borrow area surface before clay processing commenced.

7.4.3 Test Pad Construction

During construction of the test pads, CQA personnel monitored and documented that the Test Pad Contractor's activities satisfied the requirements set forth in the TPWP Construction Specifications. Any identified deficiencies were resolved. Prior to commencing test pad construction, the CQA personnel calibrated the nuclear moisture/density gauge to sand cone density and oven moisture content tests. The results of these calibrations are presented in Appendices E, F, and G of this TPPFR.

CQA personnel monitored processing and placement of the clay in the test pads. The following monitoring activities were performed for each test pad:

- evaluation of the adequacy of the pulverizing operations to blend the material and to reduce the maximum clod size to not more than 3 in. (75 mm) in largest dimension or half the lift thickness, whichever was less;

- verification that spotters identified and removed particles larger than 2 in. (50 mm) in largest dimension;

- verification that adjustment of moisture content to within $\pm$ 1.0 percentage point of the test pad target moisture content was completed prior to compaction; to facilitate this process, CQA personnel performed nuclear moisture tests (ASTM D 3017) in the borrow area and microwave moisture tests on the loose lift placement (see discussion in Section 6.5 and field data in Appendix E and G);

- verification of a loose lift thickness to produce a 6 in. (150 mm) compacted lift thickness; this generally required a loose lift thickness of 10 in. (500 mm) measured to the bottom of the previous pad-foot indentation;

- verification of the total test pad thickness of 3 ft (0.9 m) $\pm$ 2 in. (50 mm);

- verification of the correct approximate speed of compaction equipment;

- verification that each lift was scarified prior to placement of the next lift;

- verification of uniform coverage of each lift by the compactor; and

- verification that the specified number of passes were made by the compactor.

After the specified number of passes of the compactor, the CQA personnel performed the monitoring activities listed below for each lift of each test pad:

- CQA personnel assisted the Surveyor in surveying the elevation of the lift at the specified locations and documented the compacted thickness of each lift, measured to the bottom of the pad-foot indentation.

- CQA personnel evaluated the moisture content and the dry density of the compacted clay at three locations per lift per lane using the nuclear gauge (ASTM D 2922 and 3017). Summaries of moisture/density results are presented in Table 7-1 and Table 7-2 for Test Pad Numbers 1 and 2 respectively. A discussion of results is included in Section 7.5. During compaction of the first lift, CQA personnel specified the number of passes required in each lane to produce the desired range of dry densities. The minimum acceptable number of passes was four. CQA personnel documented that all other lifts were compacted using the same number of passes in each lane as was used in the first lift (i.e., each lane had the same compactive effort in each lift).

- CQA personnel evaluated bonding between lifts by hand excavating a test hole approximately 1.5 ft (0.4 m) by 1 ft (0.3 m) wide and 0.8 ft (0.2 m)

TABLE 7-1

SUMMARY OF CONSTRUCTION PHASE MOISTURE DENSITY TEST RESULTS TEST PAD 1

Lift Number	Lane Number	Number of Passes	Target Moisture (Percent)	Actual Moisture (Percent)	In Range (Y or N)	STD Proctor Max Dry Unit Weight (PCF)	Actual Dry Unit Weight (PCF)	Percent Compaction	Dry Density (Pass/Fail)	
1	1	4	23.8-25.8	24.5	Y	99.2	99.0	100	P	
1	1	4	23.8-25.8	24.0	Y	99.2	99.8	101	P	
1	1	4	23.8-25.8	25.1	Y	99.2	99.4	100	P	
1	1	4	23.8-25.8	24.5	Y	99.2	99.4	100	P	AVG.
1	2	7	23.8-25.8	21.6	N	99.2	104.6	106	P	
1	2	7	23.8-25.8	23.2	N	99.2	100.7	102	P	
1	2	7	23.8-25.8	25.1	Y	99.2	97.6	98	P	
1	2	7	23.8-25.8	23.5	N	99.2	101.0	102	P	AVG.
1	3	10	23.8-25.8	24.9	Y	99.2	98.5	99	P	
1	3	10	23.8-25.8	21.3	N	99.2	104.7	106	P	
1	3	10	23.8-25.8	20.7	N	99.2	105.0	106	P	
1	3	10	23.8-25.8	22.3	N	99.2	102.7	104	P	AVG.
2	1	4	21.5-23.5	23.0	Y	106.8	100.8	94	F	
2	1	4	21.5-23.5	20.9	N	106.8	104.3	98	P	
2	1	4	21.5-23.5	22.4	Y	106.8	102.5	96	P	
2	1	4	21.5-23.5	22.1	Y	106.8	102.5	96	P	AVG.
2	2	7	21.5-23.5	22.3	Y	106.8	101.4	95	P	
2	2	7	21.5-23.5	22.4	Y	106.8	101.2	95	P	
2	2	7	21.5-23.5	21.5	Y	106.8	102.7	96	P	
2	2	7	21.5-23.5	22.1	Y	106.8	101.7	95	P	AVG.
2	3	10	21.5-23.5	23.4	Y	106.8	100.7	94	F	
2	3	10	21.5-23.5	23.2	Y	106.8	100.7	94	F	
2	3	10	21.5-23.5	21.8	Y	106.8	101.5	95	P	
2	3	10	21.5-23.5	22.8	Y	106.8	101.0	95	P	AVG.

TABLE 7-1 (continued)

Lift Number	Lane Number	Number of Passes	Target Moisture (Percent)	Actual Moisture (Percent)	In Range (Y or N)	STD Proctor Max Dry Unit Weight (PCF)	Actual Dry Unit Weight (PCF)	Percent Compaction	Dry Density (Pass/Fail)	
3	1	4	19.0-21.0	20.8	Y	110.3	104.7	95	P	
3	1	4	19.0-21.0	21.4	N	110.3	103.0	93	F	
3	1	4	19.0-21.0	19.5	Y	110.3	106.5	97	P	
3	1	4	19.0-21.0	20.6	Y	110.3	104.7	95	P	AVG.
3	2	7	19.0-21.0	19.4	Y	110.3	106.8	97	P	
3	2	7	19.0-21.0	23.8	N	110.3	101.0	92	F	
3	2	7	19.0-21.0	18.3	N	110.3	107.7	98	P	
3	2	7	19.0-21.0	20.5	Y	110.3	105.1	95	P	AVG.
3	3	10	19.0-21.0	19.2	Y	110.3	107.3	97	P	
3	3	10	19.0-21.0	19.9	Y	110.3	107.2	97	P	
3	3	10	19.0-21.0	20.3	Y	110.3	104.7	95	P	
3	3	10	19.0-21.0	19.8	Y	110.3	106.3	96	P	AVG.
4	1	4	19.0-21.0	18.0	N	110.3	113.1	103	P	
4	1	4	19.0-21.0	18.5	N	110.3	112.2	102	P	
4	1	4	19.0-21.0	19.3	Y	110.3	110.1	100	P	
4	1	4	19.0-21.0	18.6	N	110.3	111.8	101	P	AVG.
4	2	7	19.0-21.0	21.9	N	110.3	105.7	96	P	
4	2	7	19.0-21.0	19.8	Y	110.3	108.1	98	P	
4	2	7	19.0-21.0	17.7	N	110.3	112.8	102	P	
4	2	7	19.0-21.0	19.8	Y	110.3	108.8	99	P	AVG.
4	3	10	19.0-21.0	20.9	Y	110.3	107.9	98	P	
4	3	10	19.0-21.0	20.5	Y	110.3	108.6	98	P	
4	3	10	19.0-21.0	20.6	Y	110.3	109.0	99	P	
4	3	10	19.0-21.0	20.7	Y	110.3	108.5	98	P	AVG.

TABLE 7-1 (continued)

Lift Number	Lane Number	Number of Passes	Target Moisture (Percent)	Actual Moisture (Percent)	In Range (Y or N)	STD Proctor Max Dry Unit Weight (PCF)	Actual Dry Unit Weight (PCF)	Percent Compaction	Dry Density (Pass/Fail)	
5	1	4	18.0-20.0	19.6	Y	111.5	106.5	96	P	
5	1	4	18.0-20.0	17.4	N	111.5	110.5	99	P	
5	1	4	18.0-20.0	18.1	Y	111.5	109.3	98	P	
5	1	4	18.0-20.0	18.4	Y	111.5	108.6	97	P	AVG.
5	2	7	18.0-20.0	19.6	Y	111.5	105.8	95	P	
5	2	7	18.0-20.0	18.3	Y	111.5	108.9	98	P	
5	2	7	18.0-20.0	17.3	N	111.5	111.1	100	P	
5	2	7	18.0-20.0	19.1	Y	111.5	107.0	96	P	
5	2	10	18.0-20.0	18.2	Y	111.5	109.0	98	P	AVG.
5	3	10	18.0-20.0	17.9	N	111.5	110.1	99	P	
5	3	10	18.0-20.0	17.4	N	111.5	112.0	101	P	
5	3	10	18.0-20.0	16.4	N	111.5	112.4	101	P	
5	3	4	18.0-20.0	17.3	N	111.5	111.9	100	P	
5	3	4	18.0-20.0	17.7	N	111.5	110.7	99	P	
5	3	10	18.0-20.0	19.8	Y	111.5	106.4	95	P	
5	3	10	18.0-20.0	18.5	Y	111.5	108.9	98	P	
5	3	10	18.0-20.0	17.9	N	111.5	110.3	99	P	AVG.
6	1	4	18.0-20.0	19.2	Y	111.5	107.0	97	P	
6	1	4	18.0-20.0	19.1	Y	111.5	108.5	97	P	
6	1	4	18.0-20.0	18.9	Y	111.5	109.0	98	P	
6	1	4	18.0-20.0	19.1	Y	111.5	108.4	97	P	AVG.
6	2	7	18.0-20.0	19.4	Y	111.5	107.1	96	P	
6	2	7	18.0-20.0	18.2	Y	111.5	109.3	98	P	
6	2	7	18.0-20.0	18.4	Y	111.5	108.9	98	P	
6	2	7	18.0-20.0	18.7	Y	111.5	108.4	97	P	AVG.
6	3	10	18.0-20.0	19.7	Y	111.5	107.6	97	P	
6	3	10	18.0-20.0	20.0	Y	111.5	106.3	95	P	
6	3	10	18.0-20.0	19.4	Y	111.5	107.7	97	P	
6	3	10	18.0-20.0	19.7	Y	111.5	107.2	96	P	AVG.

TABLE 7-2

SUMMARY OF CONSTRUCTION PHASE MOISTURE DENSITY TEST RESULTS TEST PAD 2

Lift Number	Lane Number	Number of Passes	Target Moisture (Percent)	Actual Moisture (Percent)	In Range (Y or N)	STD Proctor Max Dry Unit Weight (PCF)	Actual Dry Unit Weight (PCF)	Percent Compaction	Dry Density (Pass/Fail)	
1	1	4	12.6-14.6	13.5	Y	124.2	120.3	97	P	
1	1	4	12.6-14.6	12.5	N	124.2	125.0	101	P	
1	1	4	12.6-14.6	13.2	Y	124.2	123.2	99	P	
1	1	4	12.6-14.6	13.1	Y	124.2	122.8	99	P	AVG.
1	2	7	12.6-14.6	10.8	N	124.2	128.6	104	P	
1	2	7	12.6-14.6	11.6	N	124.2	125.3	101	P	
1	2	7	12.6-14.6	12.6	Y	124.2	123.7	100	P	
1	2	7	12.6-14.6	11.9	N	124.2	124.5	100	P	
1	2	7	12.6-14.6	12.1	N	124.2	124.0	100	P	
1	2	7	12.6-14.6	15.9	N	124.2	115.5	93	F	
1	2	7	12.6-14.6	16.3	N	124.2	114.7	92	F	
1	2	7	12.6-14.6	13.6	Y	124.2	122.4	99	P	AVG.
1	2	7	12.6-14.6	13.0	Y	124.2	23.4	99	P	
1	2	7	12.6-14.6	14.0	Y	124.2	120.0	97	P	
1	2	7	12.6-14.6	12.7	Y	124.2	123.9	100	P	
1	2	7	12.6-14.6	13.1	Y	124.2	122.4	99	P	
1	3	10	12.6-14.6	12.5	N	124.2	123.5	99	P	
1	3	10	12.6-14.6	12.6	Y	124.2	123.6	100	P	
1	3	10	12.6-14.6	12.3	N	124.2	123.4	99	P	
1	3	10	12.6-14.6	14.6	Y	124.2	117.0	94	F	
1	3	10	12.6-14.6	13.0	Y	124.2	112.5	99	P	
1	3	10	12.6-14.6	14.1	Y	124.2	119.8	98	P	
1	3	10	12.6-14.6	13.2	Y	124.2	121.6	98	P	AVG.
2	1	4	12.6-14.6	12.7	Y	124.2	123.5	100	P	
2	1	4	12.6-14.6	12.7	Y	124.2	123.6	100	P	

TABLE 7-2 (continued)

Lift Number	Lane Number	Number of Passes	Target Moisture (Percent)	Actual Moisture (Percent)	In Range (Y or N)	STD Proctor Max Dry Unit Weight (PCF)	Actual Dry Unit Weight (PCF)	Percent Compaction	Dry Density (Pass/Fail)	
2	1	4	12.6-14.6	11.6	N	124.2	125.5	101	P	
2	1	4	12.6-14.6	12.7	Y	124.2	123.1	99	P	
2	1	4	12.6-14.6	13.4	Y	124.2	121.7	98	P	
2	1	4	12.6-14.6	12.7	Y	124.2	123.7	100	P	
2	1	4	12.6-14.6	12.6	Y	124.2	123.5	99	P	AVG.
2	2	6	12.6-14.6	12.9	Y	124.2	123.8	100	P	
2	2	6	12.6-14.6	13.1	Y	124.2	121.9	98	P	
2	2	6	12.6-14.6	12.7	Y	124.2	122.6	99	P	
2	2	6	12.6-14.6	12.9	Y	124.2	122.8	99	P	AVG.
2	3	8	12.6-14.6	12.8	Y	124.2	120.8	97	P	
2	3	8	12.6-14.6	14.2	Y	124.2	120.4	97	P	
2	3	8	12.6-14.6	11.0	Y	124.2	126.8	102	P	
2	3	8	12.6-14.6	12.7	Y	124.2	122.6	99	P	AVG.
3	1	4	12.6-14.6	13.3	Y	124.2	122.6	99	P	
3	1	4	12.6-14.6	11.9	N	124.2	124.8	101	P	
3	1	4	12.6-14.6	11.9	N	124.2	124.6	100	P	
3	1	4	12.6-14.6	13.9	Y	124.2	121.5	98	P	
3	1	4	12.6-14.6	14.8	N	124.2	119.8	97	P	
3	1	4	12.6-14.6	13.0	Y	124.2	123.1	99	P	
3	1	4	12.6-14.6	13.1	Y	124.2	122.7	99	P	AVG.
3	2	6	12.6-14.6	12.5	N	124.2	121.7	98	P	
3	2	6	12.6-14.6	12.5	N	124.2	122.5	99	P	
3	2	6	12.6-14.6	12.2	N	124.2	124.8	101	P	
3	2	6	12.6-14.6	13.6	Y	124.2	120.3	97	P	
3	2	6	12.6-14.6	13.4	Y	124.2	119.4	96	P	
3	2	6	12.6-14.6	13.0	Y	124.2	122.3	99	P	
3	2	6	12.6-14.6	12.9	Y	124.2	121.8	98	P	AVG.
3	3	6	12.6-14.6	12.6	Y	124.2	122.7	99	P	
3	3	8	12.6-14.6	11.9	N	124.2	121.4	98	P	

TABLE 7-2 (continued)

Lift Number	Lane Number	Number of Passes	Target Moisture (Percent)	Actual Moisture (Percent)	In Range (Y or N)	STD Proctor Max Dry Unit Weight (PCF)	Actual Dry Unit Weight (PCF)	Percent Compaction	Dry Density (Pass/Fail)	
3	3	8	12.6-14.6	11.9	N	124.2	123.1	99	P	
3	3	8	12.6-14.6	14.0	Y	124.2	119.4	96	P	
3	3	8	12.6-14.6	14.5	Y	124.2	117.8	95	P	
3	3	8	12.6-14.6	14.0	Y	124.2	118.9	96	P	
3	3	8	12.6-14.6	13.2	Y	124.2	120.6	97	P	AVG.
4	1	4	12.6-14.6	14.3	Y	124.2	118.2	95	P	
4	1	4	12.6-14.6	13.9	Y	124.2	119.3	96	P	
4	1	4	12.6-14.6	14.0	Y	124.2	117.2	94	F	
4	1	4	12.6-14.6	14.1	Y	124.2	118.2	95	P	AVG.
4	2	6	12.6-14.6	13.3	Y	124.2	120.5	97	P	
4	2	6	12.6-14.6	13.6	Y	124.2	117.6	95	P	
4	2	6	12.6-14.6	14.2	Y	124.2	118.2	95	P	
4	2	6	12.6-14.6	13.7	Y	124.2	118.7	96	P	AVG.
4	3	8	12.6-14.6	14.2	Y	124.2	117.4	95	P	
4	3	8	12.6-14.6	15.3	N	124.2	115.2	93	F	
4	3	8	12.6-14.6	13.1	Y	124.2	120.6	97	P	
4	3	8	12.6-14.6	13.7	Y	124.2	120.4	97	P	
4	3	8	12.6-14.6	14.9	N	124.2	118.6	96	F	
4	3	8	12.6-14.6	13.7	Y	124.2	119.8	97	P	
4	3	8	12.6-14.6	14.2	Y	124.2	118.7	96	P	AVG.
5	1	4	12.6-14.6	12.4	N	124.2	123.5	100	F	
5	1	4	12.6-14.6	14.4	Y	124.2	119.2	96	P	
5	1	4	12.6-14.6	14.4	Y	124.2	119.0	96	P	
5	1	4	12.6-14.6	13.7	Y	124.2	120.6	97	P	AVG.
5	2	6	12.6-14.6	13.5	Y	124.2	121.6	98	P	
5	2	6	12.6-14.6	14.0	Y	124.2	120.2	97	P	
5	2	6	12.6-14.6	14.0	Y	124.2	119.3	96	P	
5	2	6	12.6-14.6	13.8	Y	124.2	120.4	97	P	AVG.
5	3	8	12.6-14.6	12.6	Y	124.2	123.5	99	P	
5	3	8	12.6-14.6	13.0	Y	124.2	121.8	98	P	

TABLE 7-2 (continued)

Lift Number	Lane Number	Number of Passes	Target Moisture (Percent)	Actual Moisture (Percent)	In Range (Y or N)	STD Proctor Max Dry Unit Weight (PCF)	Actual Dry Unit Weight (PCF)	Percent Compaction	Dry Density (Pass/Fail)	
5	3	8	12.6-14.6	12.5	N	124.2	123.8	100	P	
5	3	8	12.6-14.6	12.7	Y	124.2	123.1	99	P	AVG.
6	1	4	12.6-14.6	12.9	Y	124.2	122.9	99	P	
6	1	4	12.6-14.6	13.2	Y	124.2	122.5	99	P	
6	1	4	12.6-14.6	13.1	Y	124.2	121.2	98	P	
6	1	4	12.6-14.6	13.1	Y	124.2	122.2	98	P	AVG.
6	2	6	12.6-14.6	13.5	Y	124.2	120.7	97	P	
6	2	6	12.6-14.6	14.0	Y	124.2	121.1	98	P	
6	2	6	12.6-14.6	12.7	Y	124.2	122.9	99	P	
6	2	6	12.6-14.6	13.4	Y	124.2	121.6	98	P	AVG.
6	3	8	12.6-14.6	13.0	Y	124.2	123.1	99	P	
6	3	8	12.6-14.6	13.2	Y	124.2	122.4	99	P	
6	3	8	12.6-14.6	12.8	Y	124.2	121.6	98	P	
6	3	8	12.6-14.6	13.0	Y	124.2	122.4	99	P	AVG.

deep at one location per lane. No poor bonding was detected. The Test Pad Contractor repaired test holes by filling the holes with moisture-conditioned borrow material and compacted the borrow material to a dry density similar to that determined for the lift. CQA personnel selected test hole locations so that they were outside the area that was subsequently used for SDRI testing. The Test Pad Contractor made a soil-bentonite mixture for repair of holes where directed by the CQA Site Manager.

- CQA personnel obtained one 15-lb (7-kg) grab sample at 1-ft deep intervals throughout the depth of the borrow area for standard Proctor compaction testing. Where a significant variation from expected results was obtained on a particular lift of a test pad, a 15-lb (7-kg) grab sample was taken for additional standard Proctor compaction testing. This condition occurred once during the construction process on lift two of Test Pad No. 1. In this case, the standard Proctor compaction test from the lift grab sample was used to verify that moisture content and dry density requirements had been achieved.

- CQA personnel obtained one Shelby-tube sample per lane per lift for permeability testing. All 36 samples were sent to the CQA geotechnical laboratory for permeability testing. The hydraulic conductivity of each specimen was evaluated at effective confining stresses of 2 psi (13.8 kPa), 5 psi (34.5 kPa), and 10 psi (68.9 kPa). A summary of hydraulic conductivity test results is presented in Table 7-3 and Table 7-4 for Test Pads 1 and 2 respectively. The laboratory report providing the results of the permeability tests on the Shelby-tube samples is presented in Appendix G and discussed in Section 8.4 of this TPPFR.

- CQA personnel evaluated the moisture content and dry density of the compacted clay once per day using the sand cone test (ASTM D 1556) to provide frequent calibration of nuclear gauge test results.

- CQA personnel verified that all perforations made in the test pad for sand cone testing, nuclear gauge testing, Shelby tube sampling, and test holes

TABLE 7-3

SUMMARY OF CONSTRUCTION PHASE HYDRAULIC CONDUCTIVITY RESULTS TEST PAD-1

Lift Number	Lane Number	Shelby Tube No.	Hydraulic Conductivity (cm/s)		
			Confining Stress 2 psi	Confining Stress 5 psi	Confining Stress 10 psi
1	1	ST-1A	1.9×10^{-8}	9.5×10^{-9}	6.5×10^{-9}
1	2	ST-2A	2.1×10^{-8}	7.3×10^{-9}	4.6×10^{-9}
1	3	ST-3A	1.2×10^{-8}	8.7×10^{-9}	4.3×10^{-9}
2	1	ST-4A	5.9×10^{-8}	1.5×10^{-8}	4.4×10^{-9}
2	2	ST-5A	1.4×10^{-8}	3.9×10^{-9}	2.3×10^{-9}
2	3	ST-6A	2.6×10^{-8}	9.7×10^{-9}	4.4×10^{-9}
3	1	ST-7A	3.3×10^{-8}	1.6×10^{-8}	8.4×10^{-9}
3	2	ST-8A	1.3×10^{-8}	1.1×10^{-8}	6.9×10^{-9}
3	3	ST-9A	2.9×10^{-7}	9.8×10^{-9}	5.7×10^{-9}
4	1	ST-10A	5.9×10^{-8}	3.4×10^{-8}	2.0×10^{-8}
4	2	ST-11A	1.2×10^{-7}	2.2×10^{-8}	8.7×10^{-9}
4	3	ST-12A	3.2×10^{-8}	7.7×10^{-9}	3.0×10^{-9}
5	1	ST-13A	9.8×10^{-9}	8.0×10^{-9}	7.5×10^{-9}
5	2	ST-14A	5.3×10^{-8}	1.1×10^{-8}	3.7×10^{-9}
5	3	ST-15A	2.1×10^{-8}	1.6×10^{-8}	1.2×10^{-8}
6	1	ST-16A	1.5×10^{-8}	9.8×10^{-9}	8.8×10^{-9}
6	2	ST-17A	1.7×10^{-8}	6.1×10^{-9}	6.5×10^{-9}
6	3	ST-18A	1.8×10^{-8}	1.3×10^{-8}	9.6×10^{-9}

Notes:

TABLE 7-4

SUMMARY OF CONSTRUCTION PHASE HYDRAULIC CONDUCTIVITY RESULTS TEST PAD-2

Lift Number	Lane Number	Shelby Tube No.	Hydraulic Conductivity (cm/s)		
			Confining Stress 2 psi	Confining Stress 5 psi	Confining Stress 10 psi
1	1	ST-19A	2.4×10^{-8}	1.8×10^{-8}	1.7×10^{-8}
1	2	ST-20A	3.2×10^{-6}	9.9×10^{-8}	4.1×10^{-8}
1	3	ST-21A	3.4×10^{-8}	2.3×10^{-8}	1.7×10^{-8}
2	1	ST-22A	2.2×10^{-8}	2.0×10^{-8}	1.6×10^{-8}
2	2	ST-23A	4.5×10^{-8}	3.5×10^{-8}	1.8×10^{-8}
2	3	ST-24B	3.5×10^{-8}	3.6×10^{-8}	3.0×10^{-8}
3	1	ST-25A	6.1×10^{-8}	4.2×10^{-8}	3.2×10^{-8}
3	2	ST-26A	1.5×10^{-7}	3.5×10^{-8}	2.2×10^{-8}
3	3	ST-27A	2.8×10^{-8}	2.1×10^{-8}	1.4×10^{-8}
4	1	ST-28A	4.8×10^{-8}	2.8×10^{-8}	1.8×10^{-8}
4	2	ST-29A	4.0×10^{-7}	3.1×10^{-8}	2.0×10^{-8}
4	3	ST-30B	5.0×10^{-8}	3.8×10^{-8}	2.2×10^{-8}
5	1	ST-31A	2.0×10^{-8}	1.8×10^{-8}	1.4×10^{-8}
5	2	ST-32A	3.8×10^{-8}	2.8×10^{-8}	2.2×10^{-8}
5	3	ST-33B	8.9×10^{-8}	4.0×10^{-8}	2.3×10^{-8}
6	1	ST-34A	2.9×10^{-8}	2.8×10^{-8}	2.3×10^{-8}
6	2	ST-35A	8.1×10^{-6}	5.2×10^{-8}	2.0×10^{-8}
6	3	ST-36A	3.9×10^{-8}	2.0×10^{-8}	1.5×10^{-8}

Notes:

were repaired. The Test Pad Contractor repaired all perforations to the satisfaction of the CQA Site Manager.

- CQA personnel verified that the area of the test pads designated for SDRI testing were bladed level and lightly rolled with a smooth drum roller prior to testing.

Any identified deficiencies with the Test Pad Contractor's work were documented by CQA personnel. These deficiencies were addressed with the Test Pad Contractor for resolution. Resolution activities were fully documented.

7.5 Acceptance of Compacted Lift

As discussed in Section 7.4.3, CQA personnel evaluated the moisture content and dry density of the compacted clay at three locations per lane per lift using the nuclear gauge (ASTM D 2922 and 3017). The method of using a hand held hose from a hydroseeder to add water for moisture conditioning proved to be inadequate to achieve uniform moisture content throughout the lift (see discussion in Section 6.5). In many cases, the average moisture content for a lane was within the specified moisture range; however, individual points were either too wet or too dry. To facilitate continuation of the testing program without unreasonable delay due to difficulties in adding water, a procedure was established to accept a compacted clay lift with individual failing moisture content or dry density if both of the following conditions were met:

- the average dry density for the lane was above 95 percent of the standard Proctor maximum dry density; and

- the plot of the failing moisture/density point on the moisture-density relationship graph was above the line of optimums based on the Proctor curve for the clay in the particular lift (the line of optimums was assumed to closely approximate the degree of saturation curve, see discussion in Section 9.5).

This field approved procedure enabled the continued use of the hydroseeder for adding water for moisture conditioning the test pad soil. The procedure should not be allowed during construction of the OSDF. The contractor should be required to provide a transverse rotary mixer with an operational spray bar for adding water for moisture conditioning. The reader is referred to Section 9.4 for recommended placement and compaction procedures for construction of the compacted clay liner and cap for the OSDF.

7.6 Documentation

Documentation of the sampling, testing, construction, and maintenance operations during the test pad program was a primary responsibility of the CQA Site Manager. The CQA Site Manager produced the following documentation:

- results of the pre-construction laboratory testing program (Appendix A);
- pre-construction meeting minutes (Appendix B);
- photographic documentation (Appendix C);
- daily reports documenting construction and CQA activities for each day of construction, sampling, or field testing (Appendix D); and
- a file of laboratory test results, summaries of CQA observations and field test results, survey notes, and communications (Appendices E, F, G, and H).

Documentation of sample collection, field test results, and CQA inspections were made on the standard CQA forms presented in Appendix E of the TPWP. The use of standard forms assured that the necessary information was documented for each sampling event, field test, or inspection.

CQA personnel prepared a daily report on each day of sampling, field testing, or construction. As appropriate, the daily report documented:

- weather conditions;
- equipment and key personnel on site;
- hours of operation;
- summary of progress;
- equipment used;
- test pad number, lane, and lift under construction;
- description of construction procedures and the performance of the procedures;
- summary of field testing and CQA inspections including test frequencies and results;
- any deficiencies in the work; and
- for each deficiency noted, a description of the procedures used to resolve the deficiency.

CQA documentation is included in Appendix D through H of this TPPFR.

SECTION 8

8. FIELD PERMEABILITY TESTING

8.1 Introduction

The purpose of this section of the TPPFR is to describe the field testing techniques that were used to evaluate the hydraulic conductivity of the test pads. The field permeability testing program was conducted by the CQA Site Manager under direction of the CQA Engineer.

Two SDRI tests were used to measure the field hydraulic conductivity of two different lanes (Lanes 1 and 2) of each test pad. A total of four SDRI tests were performed. The final location and orientation of each SDRI was established by the CQA Site Manager after construction of the test pad. Locations of SDRIs are shown in Figures 8-1 and 8-2.

8.2 Sealed Double-Ring Infiltrometer Testing

8.2.1 Overview

The SDRI is a testing apparatus used for evaluating the field hydraulic conductivity of low-permeability soils. It consists of a 12 ft by 12 ft (3.6 m by 3.6 m) outer ring which is 3 ft (0.9 m) in height and a 5 ft by 5 ft (1.5 m by 1.5 m) inner ring which is 18 in. (0.45 m) in height. The outer ring is embedded in the soil to a depth of 14 to 18 in. (0.35 to 0.45 m) while the inner ring, which is centered within the outer ring, is embedded to a depth of 4 to 6 in. (0.1 to 0.15 m). The outer ring is open to the atmosphere and is filled with water to a depth of approximately 12 in. (0.3 m). The inner ring is shorter than the outer ring and includes a molded top which seals the water within the inner ring from the atmosphere. A schematic illustration of the SDRI is presented in Figure 8-3.

Measurement of infiltration in the SDRI test is accomplished by measuring the water loss from a flexible bag filled with a known mass of water connected to a port on the sealed inner ring and submerged in the annular space between the inner and outer ring. In the test, water percolates downward from both the inner and outer rings. As water leaves the inner ring and flows into the clay layer, it is replaced with an equal amount of water drawn from the flexible bag. At specific time intervals, the flexible bag is weighed. The loss in weight of the bag corresponds to the weight of water that has infiltrated into the clay layer. From a knowledge of the weight of water that has entered the clay layer, the infiltration rate can be determined. The process of evaluating the weight loss during a specified interval of time is repeated and a relationship of infiltration rate versus time is developed. The test is continued until the infiltration rate becomes steady or until it becomes equal to or less than a specified value. The infiltration rate is used to calculate the test pad hydraulic conductivity.

8.2.2 Installation of SDRI

Installation of the SDRI apparati on the test pads was performed in accordance with ASTM D 5903 and the TPWP. The following general steps describe the procedure used:

- prepare the test fill area by blading the surface and lightly rolling using a smooth-drum roller;
- excavate trenches for the inner and outer rings;
- install the rings and seal them in grout to prevent leakage under the rings;
- fill the rings slowly to check for leaks;
- install the require fittings and the flexible bag on the inner ring; and
- cover the rings with an insulated plywood deck to prevent large temperature fluctuations and water loss.

Installation of the four SDRIs was performed by the CQA Site Manager and a combination of CQA Technicians and Test Pad Contractor laborers. The final locations of the SDRIs on each test pad was established by the CQA Site Manager after completion of test pad construction. It should be noted that, during trenching for installation of the SDRI inner and outer rings, rocks exceeding 2 inches in the maximum dimensions were encountered at each SDRI location. The number and size of rocks varied. During the trenching for the outer ring of SDRI 1-1 on lane 1 of Test Pad 1, 22 rocks exceeding specified size were encountered. This amounts to 22 rocks in approximately 36 ft^3 (1.0 m^3) of compacted soil. Installation of other SDRIs generated similar quantities of rock. Most oversized particles ranged in size from 2 in. (50 mm) to 7 in. (175 mm); however, occasional particles were found as large as 6 in. (150 mm) thick with a 10 in. (250 mm) thick with a 10 in. (250 mm) by 15 in. (375 mm) trapezoidal area. This leads to the observation that the level of visual spotting and rock removal used during the test pad program did not eliminate all oversized rocks in the compacted clay material.

Tensiometers (which measure pore water suction) were installed at depths of approximately 6, 12, and 18 in. (0.15, 0.30, and 0.46 m) at three locations in the annular space between the inner and outer rings as shown in Figure 8-3. Monitoring of the tensiometer readings provided information regarding the location of the wetting front. This information is useful in estimating the hydraulic gradient in the soil during the test. The hydraulic gradient is used in the calculation of hydraulic conductivity. The tensiometers were installed in intimate contact with the test fill soils.

During installation of the SDRIs, the Test Pad Contractor provided equipment and material as follows:

- a trenching machine for excavation of a trench 18 in. (0.45 m) deep and 4 to 6 in. (0.10 to 0.15 m) wide for installation of the outer ring;
- a masonry saw to cut a trench 4.5 in. (110 mm) deep by 2 in. (50 mm) wide for installation of the inner ring;
- a large capacity grout mixer for mixing approximately 200 lbs (0.9 kN) of grout in a single batch to grout inner and outer rings;
- bentonite powder;

- a small backhoe/loader;
- a 110 volt AC generator and a 100 ft (31 m) long extension cord;
- 5-gal (19-l) plastic buckets (five required);
- cinder blocks (three required per SDRI);
- wheel barrows;
- flat-bladed shovels;
- potable water to fill the flexible bags;
- nails, 2 x 4's, plywood sheeting, and insulation to construct a cover over the outer ring of each SDRI;
- water supply and a method of transport for approximately 1,500 gal (5,700 l) of clean water per SDRI;
- 5 to 6 yd^3 (4 to 5 m^3) of loose fill soil per SDRI to build small berms around the outside of each outer ring;
- a 20 ft by 100 ft (6 m by 30 m) roll of plastic sheeting to prevent desiccation of the test fill surface; sand bags were required to anchor the sheeting; and
- 16 metal fence posts and thin wire to allow for measurement of inner-ring movement.

8.2.3 Monitoring

Monitoring of the SDRIs was performed by CQA personnel. The monitoring data included mass loss measurements of the flexible bag to evaluate flow volume, water temperature, water level measurements, swell gauge measurements, and tensiometer readings. Field data forms used for recording the data are included in Appendix H of this TPPFR.

SDRI 1-1 and SDRI 1-2 (upper horizon brown till) were installed on 25 June 1996 at the locations shown on Figure 8-1. Monitoring began immediately with daily readings through 29 July 1996 (a total of 34 consecutive days).

SDRI 2-1 and SDRI 2-2 (lower horizon brown till) were installed on 3 July 1996 at the locations shown on Figure 8-2. Monitoring began immediately with daily readings through 29 July 1996 (a total of 26 consecutive days).

The SDRI tests were conducted for a sufficient period to obtain stabilized, consistent data, demonstrating acceptable test pad hydraulic conductivity.

8.2.4 SDRI Decommissioning

After SDRI testing was completed, CQA personnel decommissioned the SDRI test apparatus. The general sequence of decommissioning activities were as follows:

- remove plugs, flexible tubing, and bags from the inner ring;
- remove inner-ring movement monitoring system;
- pump or siphon the water out of the inner ring and outer ring concurrently;
- excavate at the corners of the outer ring to expose the bolts;
- remove the bolts from the corners of the outer ring and remove the panels of the outer ring;
- carefully lift the inner ring out of its seal (the seal may need to be removed with a trowel);

- obtain the Shelby tube samples required for the post-construction laboratory testing program (see Section 8.3); and
- clean, dry, and pack the equipment for storage.

8.3 Post-Construction Laboratory Testing

Immediately after removal of the SDRI apparatus from the test pad, samples of the test pad soil were collected from within the area of the inner ring to evaluate laboratory hydraulic conductivity, the final location of the wetting front, and other soil conditions below the SDRI. Four 30-in. (0.75-m) long Shelby tube samples were advanced into the test fill within the inner ring. The Shelby tubes were advanced at each corner of a 3 ft by 3 ft (0.9 m by 0.9 m) square area centered in the inner ring area (refer to Figures 8-1 and 8-2). Each Shelby tube was pushed to the full length of the tubes (30 in. (0.75 m)).

Two of the Shelby tube samples were used to evaluate the hydraulic conductivity of the test pads in the areas within the inner rings. Three specimens were obtained from each tube for testing. These specimens were tested in a laboratory flexible-wall permeameter in accordance with ASTM D 5084. The two remaining Shelby tube samples were used to measure the variation of moisture content, dry density, and degree of saturation of the soil as a function of depth. This evaluation was made on a series of 4-in. (100-mm) long specimens that were trimmed from each sample. Results of the post-construction laboratory testing program are presented in Tables 8-1 and 8-2. The laboratory test results are presented in Appendix G.

8.4 Evaluation

A final evaluation of each SDRI test was performed following completion of the construction phase testing program. Results of the SDRI tests were evaluated as a function of permeation time, and the average steady-state hydraulic conductivity of each target compaction condition was reported. Results of the field-scale (SDRI) test results were compared to results of the laboratory hydraulic conductivity tests to provide an

TABLE 8-1

SUMMARY OF POST-CONSTRUCTION PHASE MOISTURE DENSITY TEST RESULTS

Location	Shelby Tube Number	Sample No.	Approximate Sample Depth (in.)	Dry Density (pcf)	Moisture Content (%)	Degree of Saturation[1] (%)
Test Pad 1 Lane 1 (SDRI-1-1)	TP-1, L-1, S-2	96I10.1	0.5 to 4	106.1	20.5	93.0
		96I10.2	4 to 7	108.1	19.8	94.6
		96I10.3	7 to 10	112.3	18.3	97.4
		96I10.4	10 to 12.5	113.3	18.2	99.4
		96I10.5	12.5 to 16	110.5	19.2	97.9
	TP-1, L-1, S-4	96I11.1	1 to 4	105.3	21.4	95.2
		96I11.2	6 to 9	111.1	17.9	92.2
		96I11.3	9 to 12	114.5	17.0	96.0
		96I11.4	12 to 15	108.5	19.5	94.3
Test Pad 1 Lane 2 (SDRI 1-2)	TP-1, L-2, S-2	96I12.1	.5 to 2.5	100.8	22.8	91.2
		96I12.2	3.5 to 6	103.1	21.9	92.8
		96I12.3	7 to 9	106.6	19.4	89.5
		96I12.4	9 to 11.5	107.2	19.8	92.5
		96I12.5	11.5 to 13	107.1	19.6	91.8
		96I12.6	13 to 15	105.8	20.9	94.5
	TP-1, L-2, S-4	96I13.1	3 to 5.5	101.3	22.6	91.5
		96I13.2	5.5 to 9.5	107.2	20.4	95.3
		96I13.3	9.5 to 13.5	109.5	19.5	96.1
		96I13.4	13.5 to 17.5	110.0	19.4	97.6

Notes: 1. Specific gravity determined during preconstruction laboratory testing (ASTM D854) was 2.72 for upper horizon soil used in construction of Test Pad 1. Refer to Table 4-2.

TABLE 8-1 (continued)

Location	Shelby Tube Number	Sample No.	Approximate Sample Depth (in.)	Dry Density (pcf)	Moisture Content (%)	Degree of Saturation (%)
Test Pad 2 Lane 1 (SDRI-2-1)	TP-2, L-1, S-2	96I14.1	8 to 11	122.8	13.0	92.6
		96I14.2	11 to 14	122.7	12.8	91.0
		96I14.3	14 to 17	120.5	13.6	91.0
	TP-2, L-1, S-4	96I15.1	3 to 5.5	120.6	13.1	87.7
		96I15.2	5.5 to 8.5	122.8	13.3	95.1
		96I15.3	8.5 to 11	120.3	14.2	94.1
		96I15.4	12 to 15	120.9	14.4	97.1
Test Pad 2 Lane 2 (SDRI 2-2)	TP-2, L-2, S-2	96I16.1	0.5 to 3	119.5	13.6	88.4
		96I16.2	9 to 12	123.4	13.7	99.6
		96I16.3	12.5 to 15.5	124.3	12.7	94.4
	TP-2, L-2, S-4	96I17.1	3 to 6	120.9	13.3	89.8
		96I17.2	6 to 9	121.0	13.6	92.4
		96I17.3	9 to 12	121.4	14.0	95.7
		96I17.4	12 to 15	123.9	12.8	94.0

Notes: 1. Specific gravity determined during preconstruction laboratory testing (ASTM D 854) was 2.71 for lower horizon soil used in construction of Test Pad 2. Refer to Table 4-2.

TABLE 8-2

SUMMARY OF POST-CONSTRUCTION PHASE HYDRAULIC CONDUCTIVITY TEST RESULTS

Location	Shelby Tube Number	Sample Number	Approximate Sample Depth (in.)	Dry Density (pcf)	Moisture Content (%)	Consolidation Pressure (psi)[1]	Hydraulic Conductivity (cm/s)
Test Pad 1 Lane 1 (SDRI-1-1)	TP-1 L-1 S-1	96I01.1	Upper	106.9	20.6	2	3.1×10^{-8}
						5	1.3×10^{-8}
						10	8.2×10^{-9}
		96I01.2	Middle	112.1	19.8	5	1.5×10^{-8}
		96I01.3	Lower	111.1	18.4	5	1.1×10^{-8}
	TP-1 L-1 S-3	96I02.1	Upper	107.8	19.5	5	1.5×10^{-8}
		96I02.2	Middle	109.5	19.1	2	1.3×10^{-8}
						5	1.2×10^{-8}
						10	8.2×10^{-9}
		96I02.3	Lower	111.3	18.4	5	8.0×10^{-9}
Test Pad 1 Lane 2 (SDRI 1-2)	TP-1 L-2 S-1	96I03.1	Upper	103.0	22.1	5	1.0×10^{-8}
		96I03.2	Middle	110.8	18.6	5	2.8×10^{-8}
		96I03.3	Lower	109.1	19.6	2	2.3×10^{-8}
						5	1.1×10^{-8}
						10	4.4×10^{-9}
	TP-1 L-2 S-2	96I12.1	Upper	103.2	21.9	5	7.8×10^{-9}
		96I12.2	Middle	107.2	19.8	5	9.5×10^{-9}
		96I12.6	Lower	105.8	20.9	2	9.4×10^{-9}
						5	5.0×10^{-9}
						10	3.9×10^{-9}

Notes: 1. One sample from each thin-walled tube was tested at consolidation pressures of 2, 5, and 10 psi to allow correlation, if needed, with pre-construction testing and SDRI results. Other samples from each thin-walled tube were tested at a consolidation pressure of 5 psi which provides a conservative approximation of conditions expected for the OSDF clay cap.

TABLE 8-2 (continued)

Location	Shelby Tube Number	Sample Number	Sample Location (Section of Table) (in.)	Dry Density (pcf)	Moisture Content (%)	Consolidation Pressure (psi)[1]	Hydraulic Conductivity (cm/sec)
Test Pad 2 Lane 1 (SDRI 2-1)	TP-2 L-1 S-1	96I04.1	Upper	120.3	14.5	2	6.3×10^{-8}
						5	3.3×10^{-8}
						10	2.1×10^{-8}
		96I04.2	Middle	121.6	14.0	5	2.2×10^{-8}
		96I04.3	Lower	122.1	13.3	5	2.1×10^{-8}
	TP-2 L-2 S-1A	96I05.1	Upper	121.0	13.7	5	4.5×10^{-8}
		96I05.2	Middle	120.2	14.3	2	4.6×10^{-8}
						5	3.1×10^{-8}
						10	1.7×10^{-8}
		96I05.3	Lower	117.8	12.2	5	1.6×10^{-8}
Test Pad 2 Lane 2 (SDRI 2-2)	TP-2 L-2 S-3	96I09.1	Upper	116.6	14.6	5	1.6×10^{-8}
		96I09.2	Middle	120.4	14.2	5	1.5×10^{-8}
		96I09.3	Lower	122.8	14.1	2	3.6×10^{-8}
						5	2.2×10^{-8}
						10	2.0×10^{-8}
	TP-2 L-2 S-1	96I08.1	Upper	120.0	12.6	5	2.2×10^{-8}
		96I08.2	Middle	118.2	14.6	2	2.5×10^{-8}
						5	2.0×10^{-8}
						10	1.5×10^{-8}
		96I08.3	Lower	120.6	14.2	5	2.2×10^{-8}

Notes: 1. One sample from each thin-walled tube was tested at consolidation pressures of 2, 5, and 10 psi to allow correlation, if needed, with pre-construction testing and SDRI results. Other samples from each thin-walled tube were tested at a consolidation pressure of 5 psi which provides a conservative approximation of conditions expected for the OSDF clay cap.

assessment of the correlation between the two test methods.

Methods of SDRI data interpretation are presented in detail in Appendix I of this TPPFR. The two methods used to interpret the SDRI data were:

- Method 1 - incremental flow analysis as described in ASTM D 5093, modified to account for the estimated average hydraulic gradient during each increment in time; and

- Method 2 - cumulative flow analysis wherein field data points are "smoothed" using a curve fitting procedure.

Key assumptions used in data interpretation which are detailed in Appendix I are:

- inner ring movement effects are neglected; this results in a conservative estimate of inflow and hydraulic conductivity; and

- temperature effects are neglected due to consistent measurements at the same time of day (early morning) and level of insulation provided for SDRIs (see photographs in Appendix C).

Detailed results of the interpretation of the SDRI data are presented in tables for each SDRI in Appendix I. These data were used to plot hydraulic conductivity versus time for each SDRI as shown in Figures 8-4, 8-5, 8-6, and 8-7.

Post-construction laboratory testing included measurement of moisture content with depth, and calculation of the degree of saturation of the soil with depth (refer to Table 8-2) Plots of moisture content versus depth are shown in Figures 8-8, 8-9, 8-10, and 8-11.

Based on the results presented in the figures and tables in this section, the following observations are provided.

- The final, stabilized hydraulic conductivities obtained from the four SDRI tests are:

- SDRI 1-1 $k = 1.5 \times 10^{-8}$ cm/s;
- SDRI 1-2 $k = 1.4 \times 10^{-8}$ cm/s;
- SDRI 1-3 $k = 2.3 \times 10^{-8}$ cm/s; and
- SDRI 1-4 $k = 2.1 \times 10^{-8}$ cm/s.

These results demonstrate that the materials and methods used for construction of the lower horizon brown till and upper horizon brown till test pads in all cases produced test pads with acceptable hydraulic conductivity.

- Pre-construction phase testing was conducted to establish APZs for test pad construction. A comparison of pre-construction hydraulic conductivity results with SDRI results is presented in Table 8-3. The initial degree of saturation of each point is shown. The hydraulic conductivity data correlate reasonably well with degree of saturation. Samples with a degree of saturation less than 85 to 90 percent generally had hydraulic conductivity values greater than 1×10^{-7} cm/s. Samples with a degree of saturation greater than 85 to 90 percent generally had hydraulic conductivity of less than 1×10^{-7} cm/s. Discussion on use of the degree of saturation in development of the APZ for construction of the OSDF compacted clay liner and cap is presented in Section 9.

- Construction-phase testing and post-construction phase testing of hydraulic conductivity on undisturbed Shelby-tube samples tested in accordance with ASTM D 5084 at a confining stress of 2 psi compare favorably with hydraulic conductivity measured from SDRIs installed on the completed test pads. (See comparison presented in Table 8-4). For example, SDRI 1-1 installed on Test Pad 1, Lane 1 had a stabilized SDRI-based hydraulic conductivity of 1.5×10^{-8} cm/s. Hydraulic conductivity measured in accordance with ASTM D 5084 ranged from a high of 5.1×10^{-8} to a low of 9.8×10^{-9} cm/s. Likewise, with the exception of one data point on Test Pad 2, Lane 2, other SDRI testing results compared favorably. The one data point with unsatisfactory hydraulic conductivity is discussed in the note on Table 8-4.

TABLE 8-3

COMPARISON OF PRE-CONSTRUCTION HYDRAULIC CONDUCTIVITY TEST RESULTS TO SDRI TEST RESULTS

Soil Tested	Testing Method[1]	Phase of Work	Moisture Content (Percent)	Dry Density (PCF)	Degree of Saturation (Percent)	Hydraulic Conductivity 2 PSI Confining Stress (cm/s)	Figure ID No.[1]
Upper Horizon Brown Till	Flexible Wall Falling Head ASTM D 5084 (Remold Samples)	Pre-Construction	16.7	106.3	76.1	5.2×10^{-5}	1
			17.0	110.9	87.2	6.4×10^{-7}	2
			18.4	108.3	88.2	8.4×10^{-8}	3
			18.6	110.2	93.7	4.8×10^{-8}	4
			20.7	106.3	94.4	1.1×10^{-8}	5
			18.5	107.1	86.1	1.2×10^{-6}	6
			17.3	108.3	83.0	6.7×10^{-6}	7
			12.4	119.3	79.8	1.4×10^{-7}	8
			17.2	112.8	92.7	2.1×10^{-8}	9
			19.2	106.4	82.7	5.5×10^{-8}	10
	SDRI ASTM D 5093	Post-Construction	19.4	106.8	89.6	1.5×10^{-8}	11
			19.3	107.2	90.0	1.4×10^{-8}	12
Lower Horizon Brown Till	Flexible Wall Falling Head ASTM D 5084 (Remold Samples)	Pre-Construction	11.9	118.7	75.3	1.5×10^{-5}	13
			11.7	124.7	88.1	5.3×10^{-6}	14
			13.6	121.5	93.2	3.0×10^{-8}	15
			14.0	123.4	101.4	2.8×10^{-8}	16
			15.7	118.4	98.5	2.8×10^{-8}	17
			13.7	118.3	85.7	5.6×10^{-8}	18
			9.8	128.3	82.6	6.8×10^{-7}	19
			11.9	125.1	90.7	1.2×10^{-7}[2]	20
			12.3	126.8	98.8	9.1×10^{-8}	21
			13.1	120.1	86.2	9.0×10^{-8}	22
	SDRI ASTM D 5093	Post-Construction	12.7	123.2	91.5	2.3×10^{-8}	23
			13.5	121.2	91.7	2.1×10^{-8}	24

Notes:
1. Data points are plotted on the figures showing the recommended APZs (Figures 9-1 and 9-2)
2. Hydraulic conductivity at 5 PSI confirming stress was 3.6×10^{-8} con/sec.

TABLE 8-4

COMPARISON OF HYDRAULIC CONDUCTIVITY TEST RESULTS CONSTRUCTION AND POST-CONSTRUCTION PHASE TESTING

Location	Testing Method	Phase of Work	Moisture Content (Percent)	Dry Density (PCF)	Degree of Saturation (Percent)	Hydraulic Conductivity 2 PSI Confining Stress (cm/s)	Figure ID No.[2]
Test Pad 1 Lane 1	Flexible Wall Falling Head ASTM D 5084	Construction	19.0	111.5	99.6	9.8×10^{-9}	25
			20.5	107.3	95.8	1.5×10^{-8}	26
	Flexible Wall Falling Head ASTM D 5084	Post-Construction	20.6	106.9	95.3	5.1×10^{-8}	27
			19.1	109.5	94.5	1.3×10^{-8}	28
	SDRI ASTM D 5093	Post-Construction	19.4	106.8	89.6	1.5×10^{-8}	11
Test Pad 1 Lane 2	Flexible Wall Falling Head ASTM D 5084	Construction	20.1	110.2	101.2	5.3×10^{-8}	29
			19.6	108.3	94.0	1.7×10^{-8}	30
	Flexible Wall Falling Head ASTM D 5084	Post-Construction	19.6	109.1	95.9	2.3×10^{-8}	31
			20.9	105.8	94.1	94×10^{-9}	32
	SDRI ASTM D 5093	Post-Construction	19.3	107.2	90.0	1.4×10^{-8}	12
Test Pad 2 Lane 1	Flexible Wall Falling Head ASTM D 5084	Construction	13.4	122.8	95.4	2.0×10^{-8}	33
			13.8	121.6	94.8	2.9×10^{-8}	34
	Flexible Wall Falling Head ASTM D 5084	Post-Construction	14.5	120.3	96.0	6.3×10^{-8}	35
			14.3	120.2	94.4	4.6×10^{-8}	36
	SDRI ASTM D 5093	Post-Construction	12.7	123.2	91.5	2.3×10^{-8}	23
Test Pad 2 Lane 2	Flexible Wall Falling Head ASTM D 5084	Construction	13.7	122.3	96.1	2.8×10^{-8}	37
			12.7	118.9	80.8	8.1×10^{-6} [1]	38
	Flexible Wall Falling Head ASTM D 5084	Post-Construction	14.6	118.2	91.1	3.0×10^{-8}	39
			14.1	122.8	100.4	3.6×10^{-8}	40
	SDRI ASTM D 5093	Post-Construction	13.5	121.2	91.7	2.1×10^{-8}	24

Notes: 1. At a confining stress of 5 psi, the hydraulic conductivity of this sample was measured as 5.2×10^{-8} cm/s, and at a confining stress of 10 psi, the hydraulic conductivity of this sample was measured as 2.0×10^{-8} cm/s.
2. Data points are plotted on the figures showing the recommended construction APZs (Figures 9-1 and 9-2.

- Evaluation of all of the available data suggests that acceptable hydraulic conductivity will be achieved with a high degree of reliability if the degree of saturation of the upper or lower horizon brown till is above 90 percent. The data also suggests that the probability of achieving acceptable hydraulic conductivity decreases significantly for degrees of saturation below 85 percent. It is interesting to note that the standard Proctor optimum moisture content of the upper horizon brown till occurs at a degree of saturation of 91 percent, whereas the optimum moisture content of the lower horizon brown till occurs at a degree of saturation of 86 percent. Of particular interest in the lower horizon soils are data points from pre-construction laboratory testing which plot to the right of (wet of) the line of optimums (refer to Table 8-3 and Figure 9-2) and had hydraulic conductivity results of greater than 1 x 10^{-7} cm/sec. Figure identification number (ID) 14 with a degree of saturation of 88% plots above the line of optimums and had hydraulic conductivity results of greater than 1 x 10^{-7} cm/sec at confining stresses of 2, 5, and 10 psi. Figure ID 20 with a degree of saturation of 90.7% had hydraulic conductivity results of 1.2 x 10^{-7} cm/sec at a confining stress of 2 psi and 3.6 x 10^{-8} cm/sec at a confining stress of 5 psi. This point is considered to fall within the acceptable degree of saturation for satisfactory permeability results for clay liner and cap system. These results support the selection of the line defining a degree of saturation of 90% as the left boundary of the APZ.

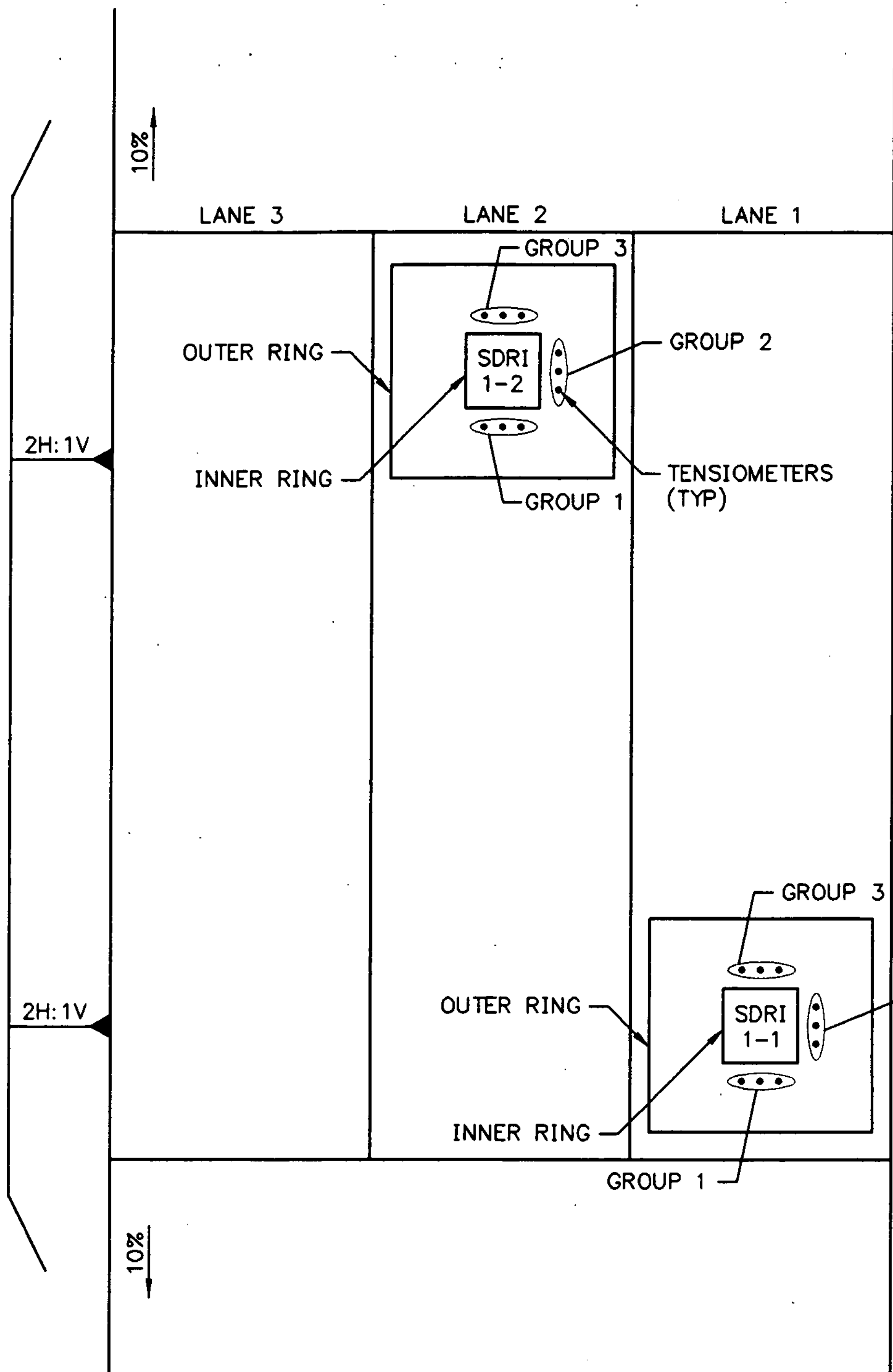
- The depth of the wetting front was calculated as described in Appendix I during analysis of SDRI testing data. The calculated depth of the wetting front for each SDRI is as follows:

  - SDRI 1-1 5 in. (125 mm)
  - SDRI 1-2 7 in. (100 mm)
  - SDRI 2-1 7 in. (175 mm)
  - SDRI 2-2 7 in. (175 mm)

- Tensiometers were used to measure soil suctions at three different depths (6, 12, and 18 in. (150, 300, and 450 mm) beneath the SDRI on a daily basis for the entire test period. The measured suctions wre evaluated to provide information regarding the advancement of the wetting front into the soil with time. Suction in the soil decreases as the water content of the soil increases and diminishes as the sol becomes nearly saturated. Therefore, suction at a certain depth becomes negligible as the wettng front advances beyond this depth. The magnitudes and trends of the sucton date collected for this project appear to be consistent with measurements collected by GeoSyntec at other sites and are in agreement with information reported in the literature. The suction data seems to be in general agreement with the wetting front depths calculated as part of the hydraulic conductivity analysis. By the end of the test period, the 6-in. deep tensiometers showed neglibible suctions, indicating significant hydration. The 12-in. and 18-in. deep tensiometers showed much less hydration than the 6-in. deep tensiometers. The hydraulic conductivity analysis assumed maximum wetting front depths of 4 to 7 in. (100 to 175 mm) for the four SDRIs.

It is noted that tensiometers were developed for agricultural purposes to indicate when irrigation of the soil is needed. Tensiometers provide oly approximate estimates of soil suction. Furthermore, GeoSyntec is not aware of any detailed method published in the technical literature that describes analysis of tensiometer readings to accurately estimate depth of wetting front. These limitations prevented further conclusions be drawn from the tensiometer readings.

OSDF TEST PAD 1



SDRI LOCATION PLAN

SCALE: NTS

• TENSIOMETER LOCATIONS

000107

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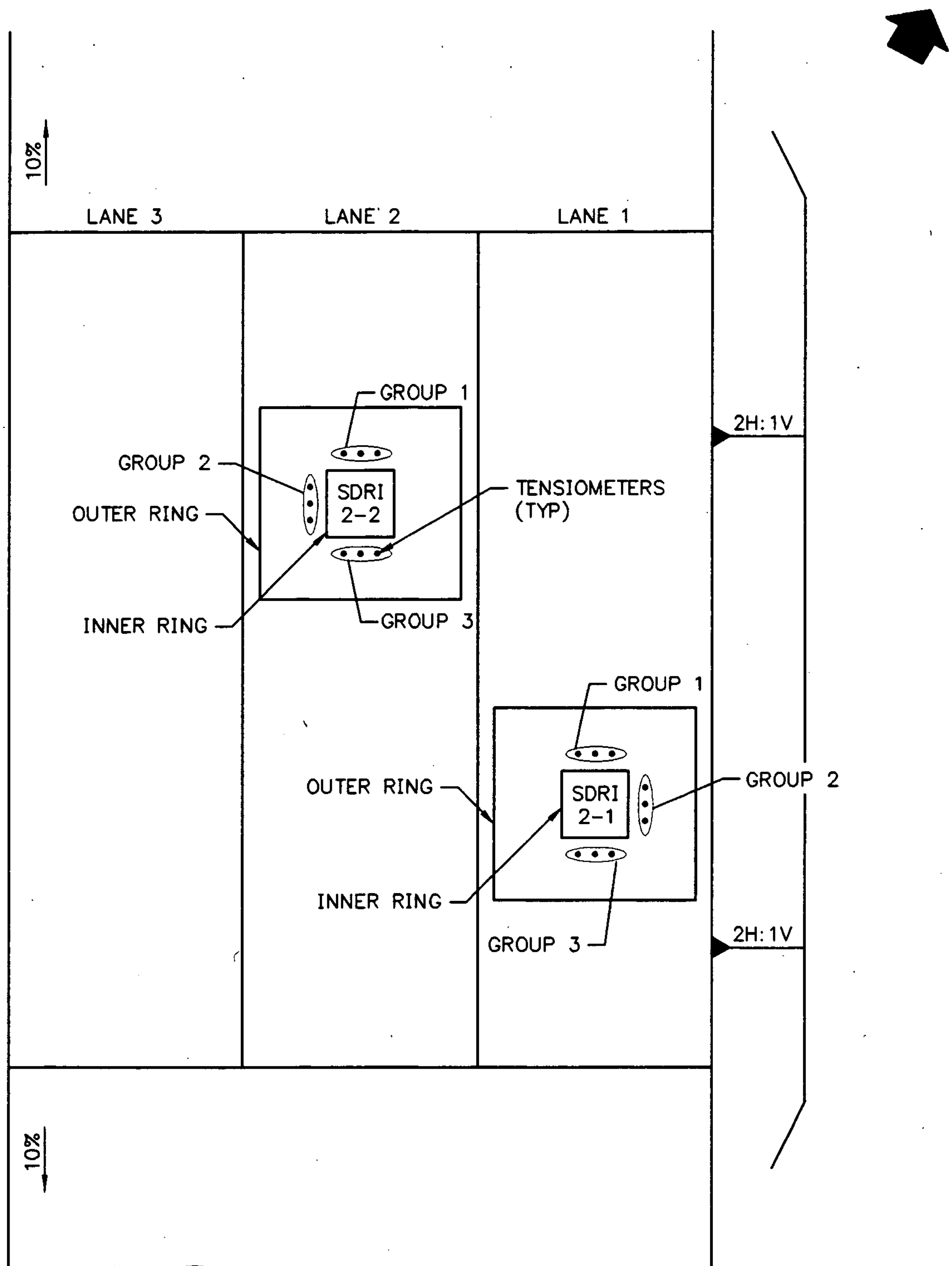
FIGURE NO.	8-1
PROJECT NO.	GE3900-5.4
DOCUMENT NO.	F9630212.CDO
FILE NO.	39000018.DWG

OSDF TEST PAD 2



SDRI LOCATION PLAN
SCALE: NTS

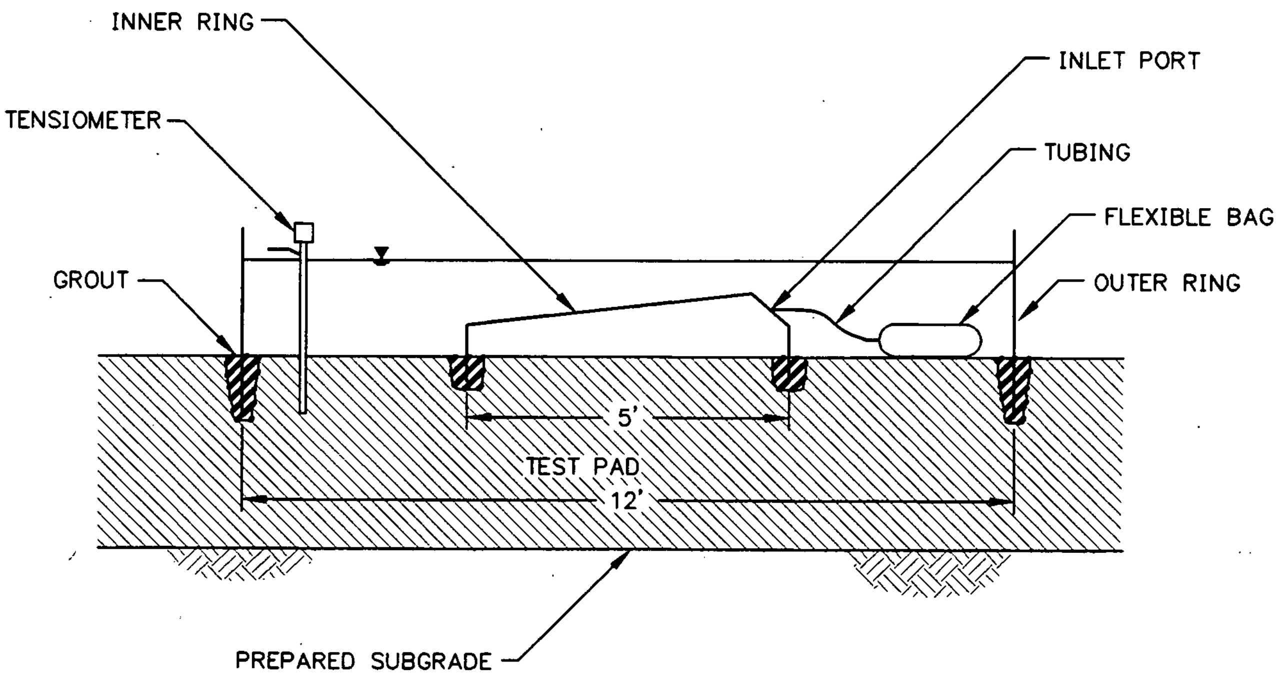
• TENSIOMETER LOCATIONS

000108

GEOSYNTEC CONSULTANTS
ATLANTA, GEORGIA

FIGURE NO.	8-2
PROJECT NO.	GE3900-5.4
DOCUMENT NO.	F9630212.CDO
FILE NO.	39000017.DWG

SCHEMATIC OF SDRI INSTALLED ON TEST PAD



000109

NOTE: SEE APPENDIX B FOR ADDITIONAL SDRI TEST DETAILS.

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FIGURE NO.	8–3
PROJECT NO.	GE3900–5.4
DOCUMENT NO.	F9630212.CDO
FILE NO.	39000006

FIGURE 8-4
TEST PAD NO. 1, SDRI NO. 1
HYDRAULIC CONDUCTIVITY VERSUS TIME

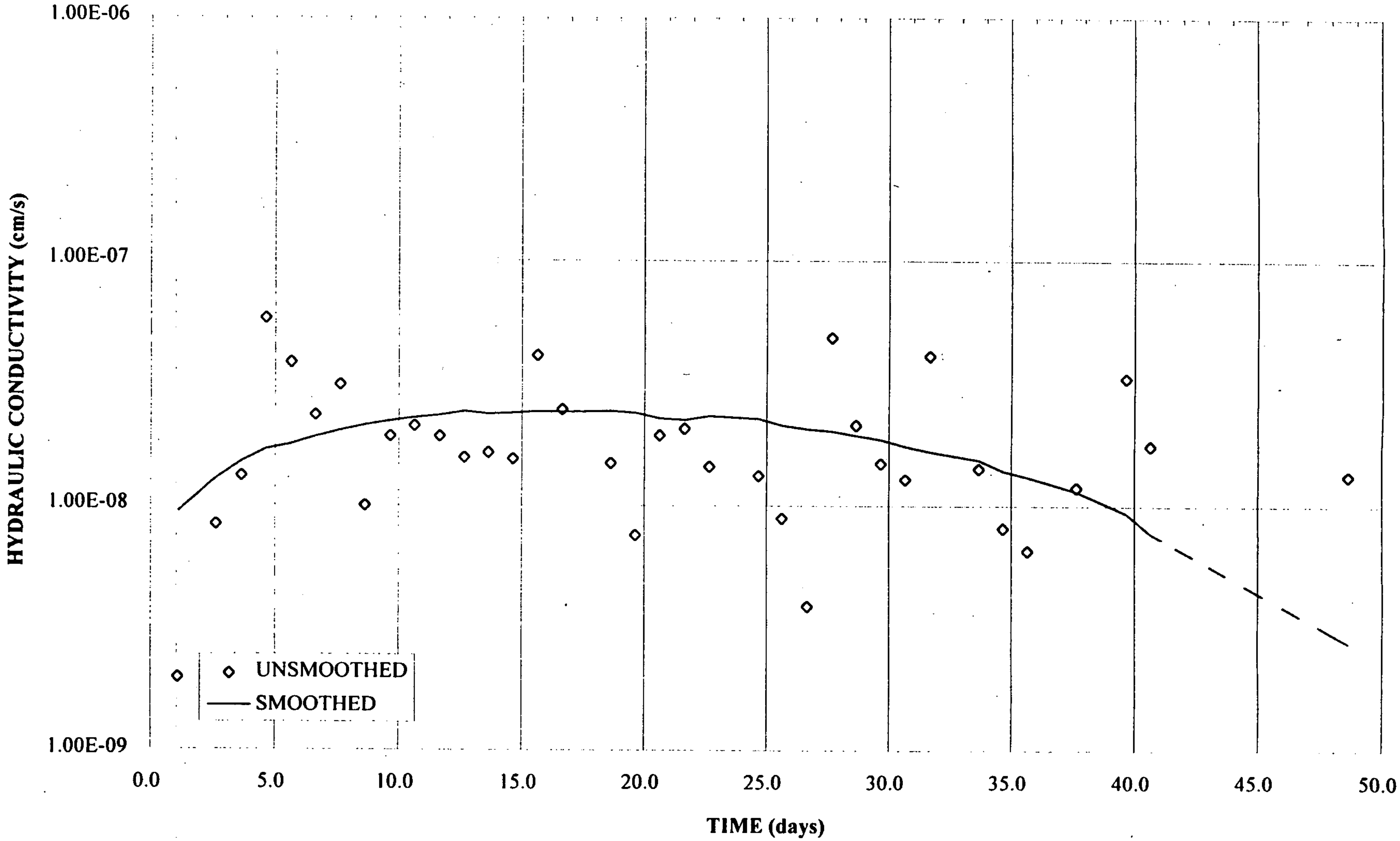

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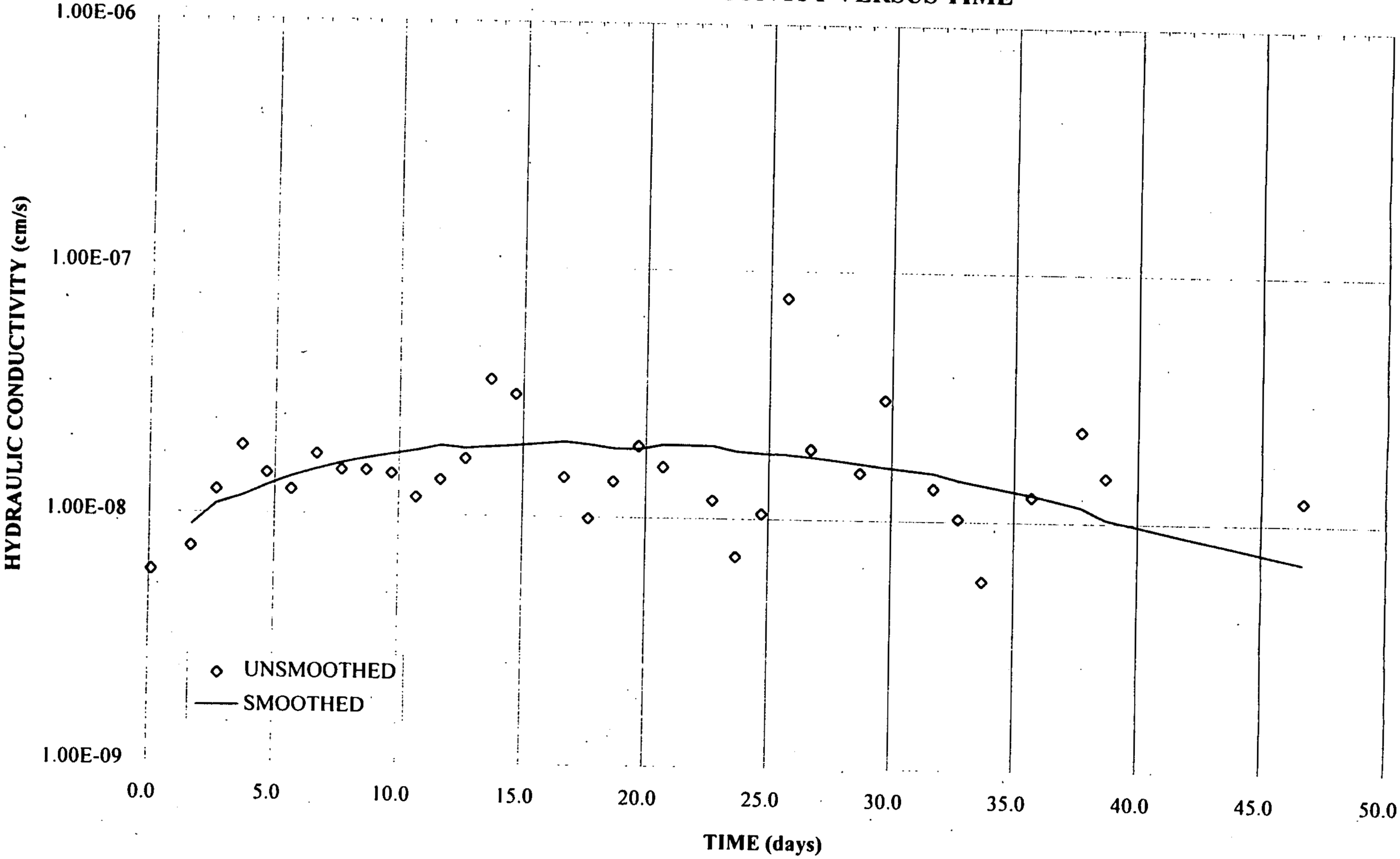
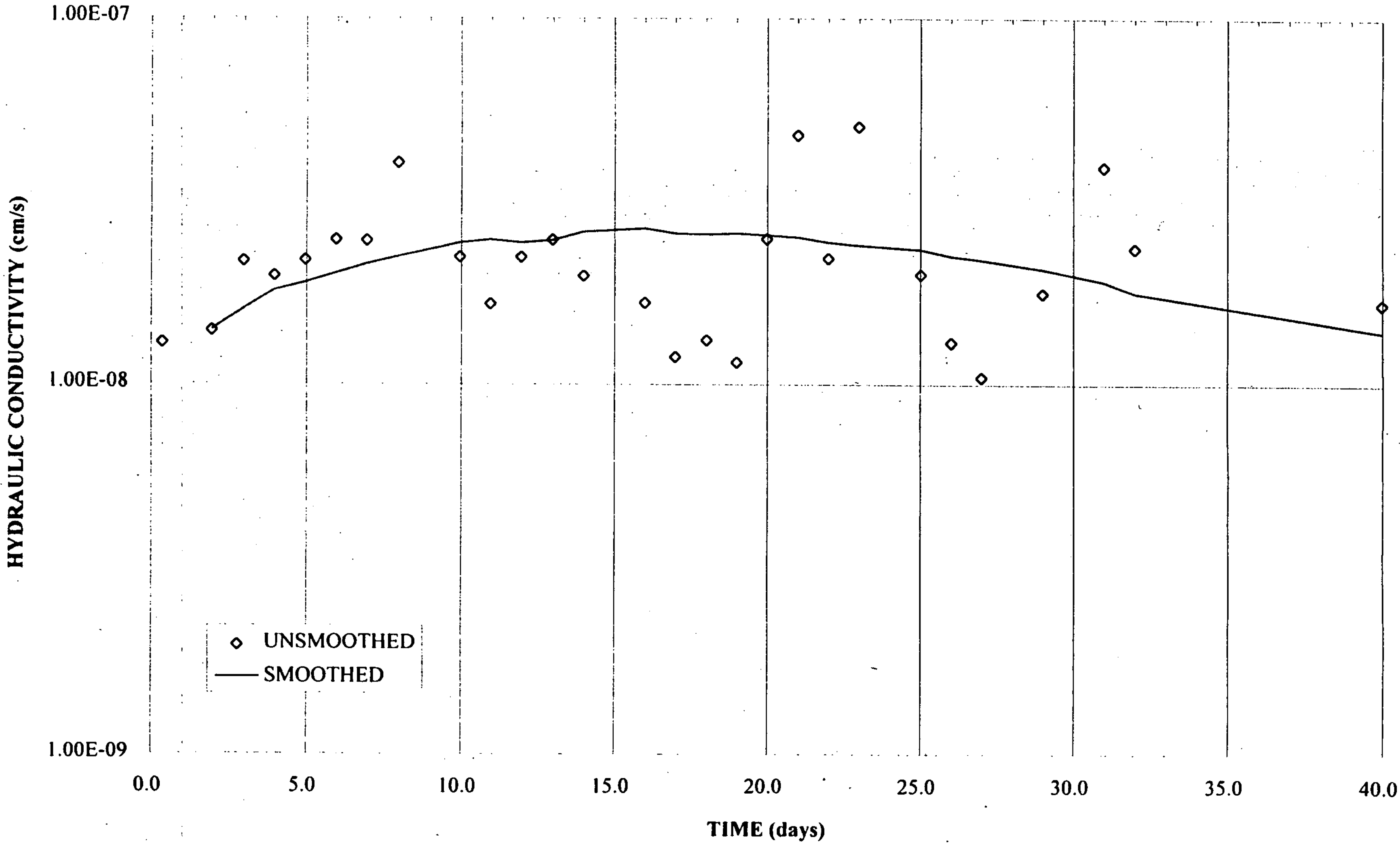
FIGURE 8-5
TEST PAD NO. 1, SDRI NO. 2
HYDRAULIC CONDUCTIVITY VERSUS TIME



000111

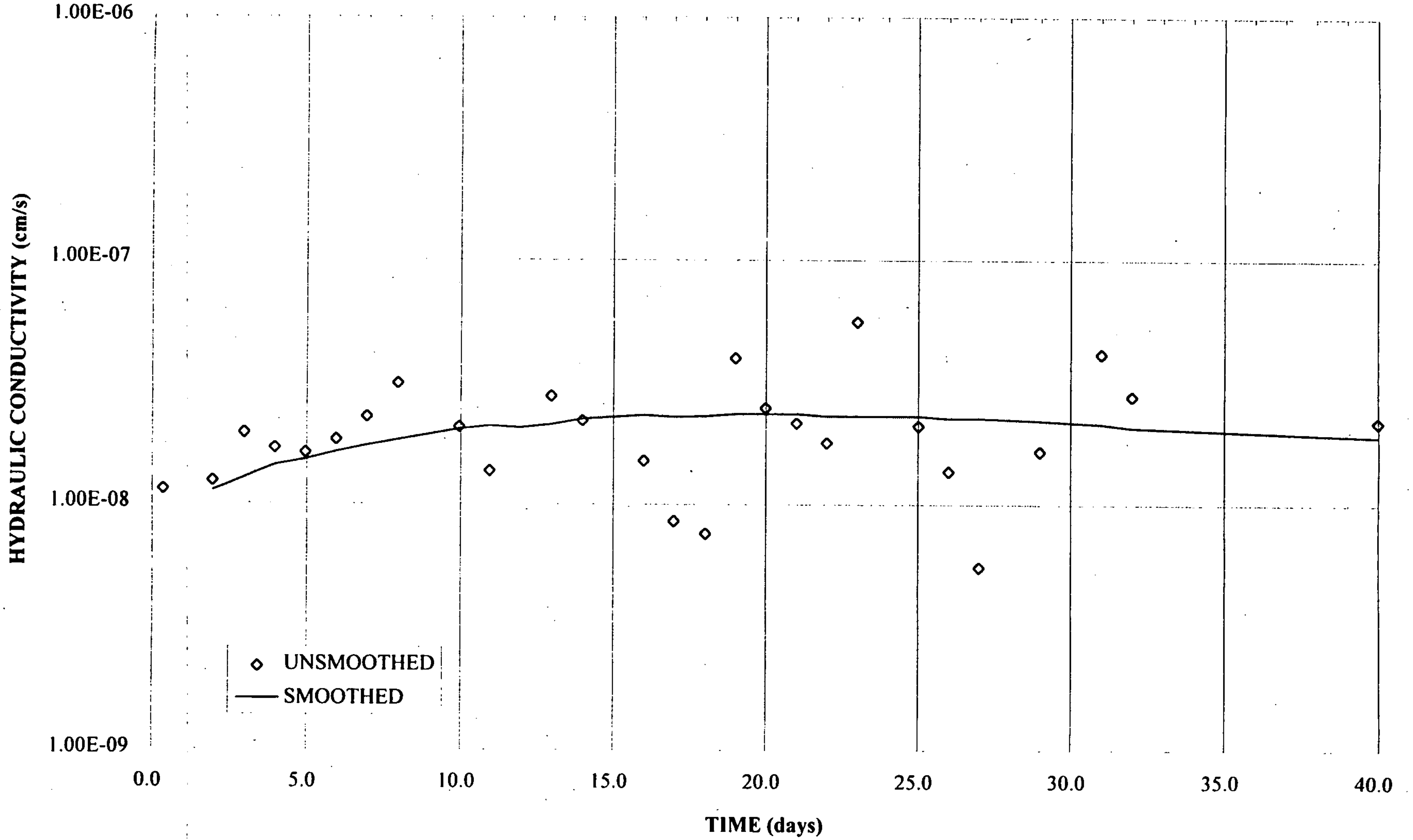
FIGURE 8-6
TEST PAD NO. 2, SDRI NO. 1
HYDRAULIC CONDUCTIVITY VERSUS TIME



000112

298

FIGURE 8-7
TEST PAD NO. 2, SDRI NO. 2
HYDRAULIC CONDUCTIVITY VERSUS TIME



0000113

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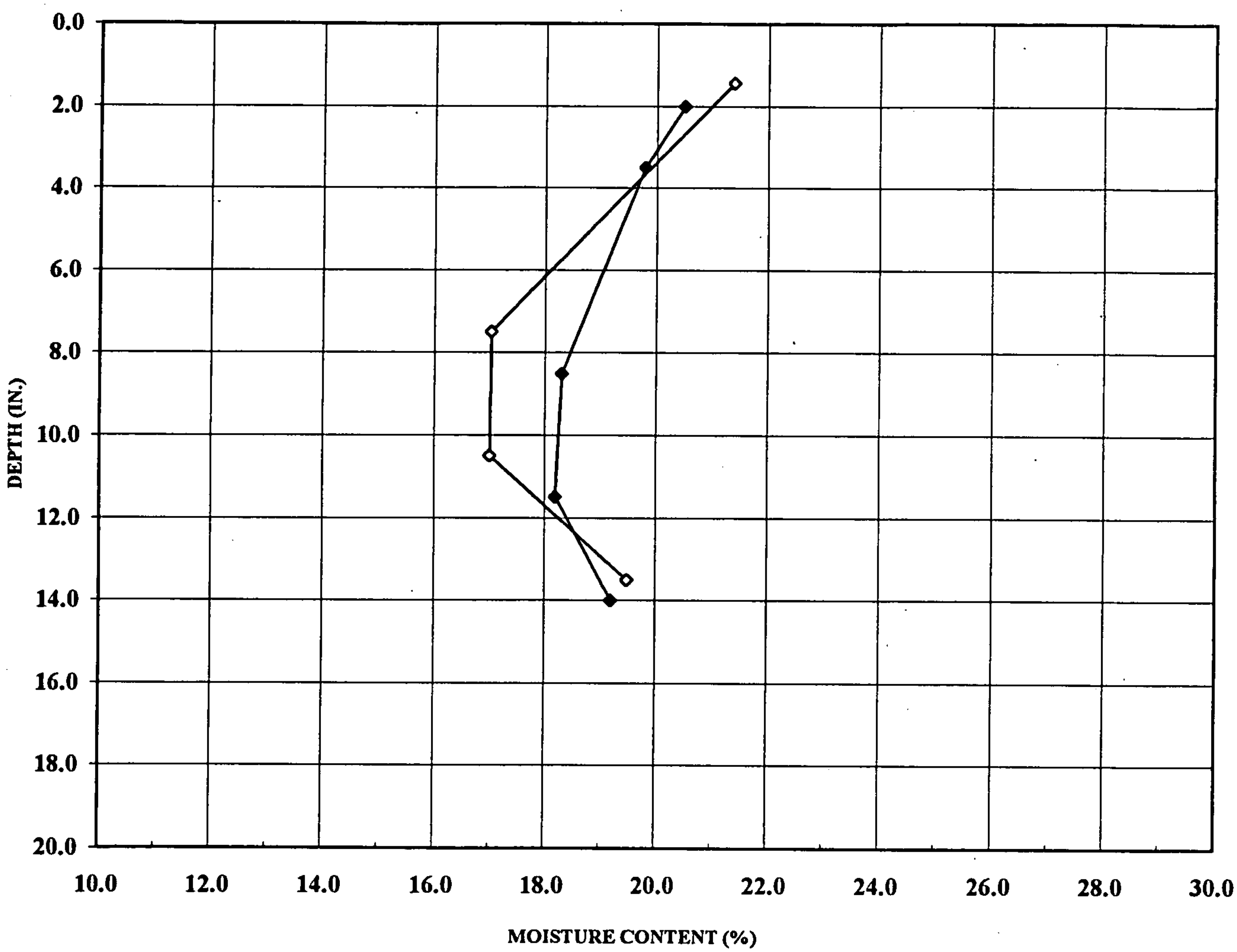
MOISTURE CONTENT PROFILE
TEST PAD NO.1, LANE NO.1
DECOMMISSIONED SDRI-1-1



SHELBY TUBE NUMBER
TP2-1-S2
TP2-1-S4

NOTE: REFER TO TABLE 8-1, SUMMARY OF POST-CONSTRUCTION PHASE MOISTURE DENSITY TEST

000114

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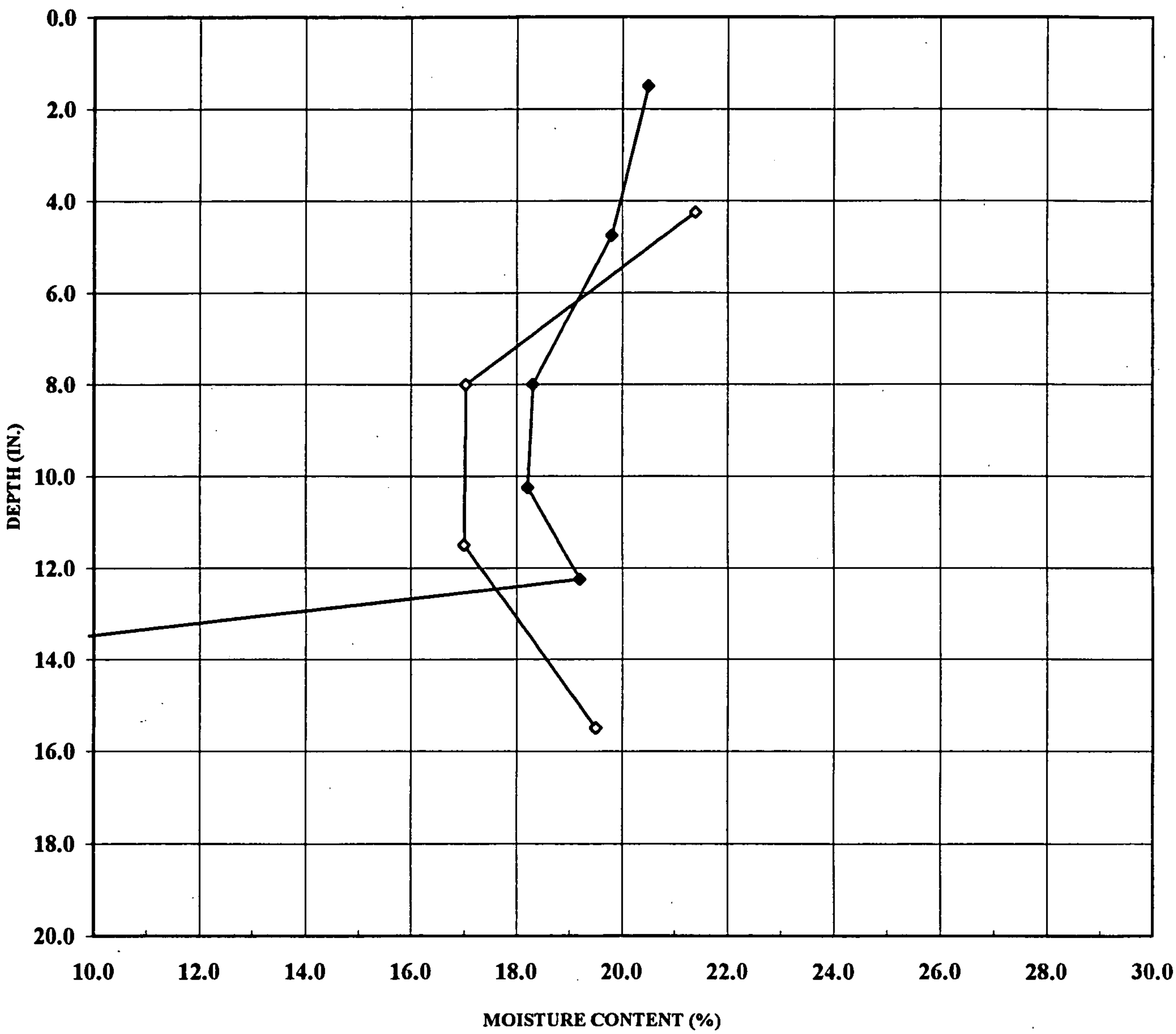
FIGURE NO.	8-8
PROJECT NO.	GE3900-514
DOCUMENT NO.	F9630212.CD0
FILE NO.	MOISTURE.XLS

MOISTURE CONTENT PROFILE
TEST PAD NO.1, LANE NO.2
DECOMMISSIONED SDRI-1-2



NOTE: REFER TO TABLE 8-1, SUMMARY OF POST-CONSTRUCTION PHASE MOISTURE DENSITY TEST RESULTS.

SHELBY TUBE NUMBER

- ◆ TP1-2-S2
- ◇ TP1-2-S4

000115

GEOSYNTEC CONSULTANTS
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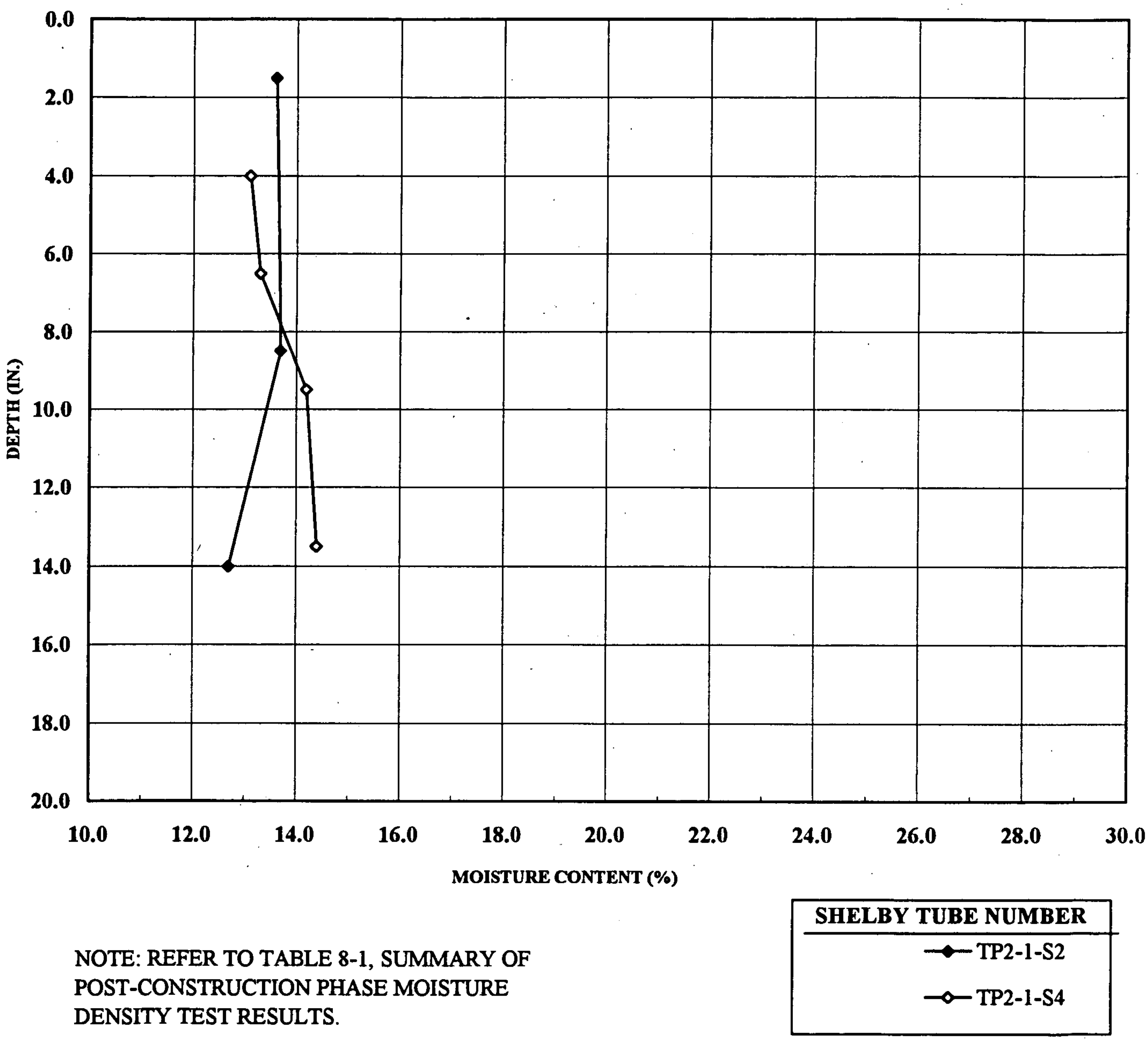
FIGURE NO.	8-9
PROJECT NO.	GE3900-514
DOCUMENT NO.	F9630212.CD0
FILE NO.	MOISTURE.XLS

MOISTURE CONTENT PROFILE
TEST PAD NO.2, LANE NO.1
DECOMMISSIONED SDRI-2-1



NOTE: REFER TO TABLE 8-1, SUMMARY OF POST-CONSTRUCTION PHASE MOISTURE DENSITY TEST RESULTS.

000116

GEOSYNTEC CONSULTANTS
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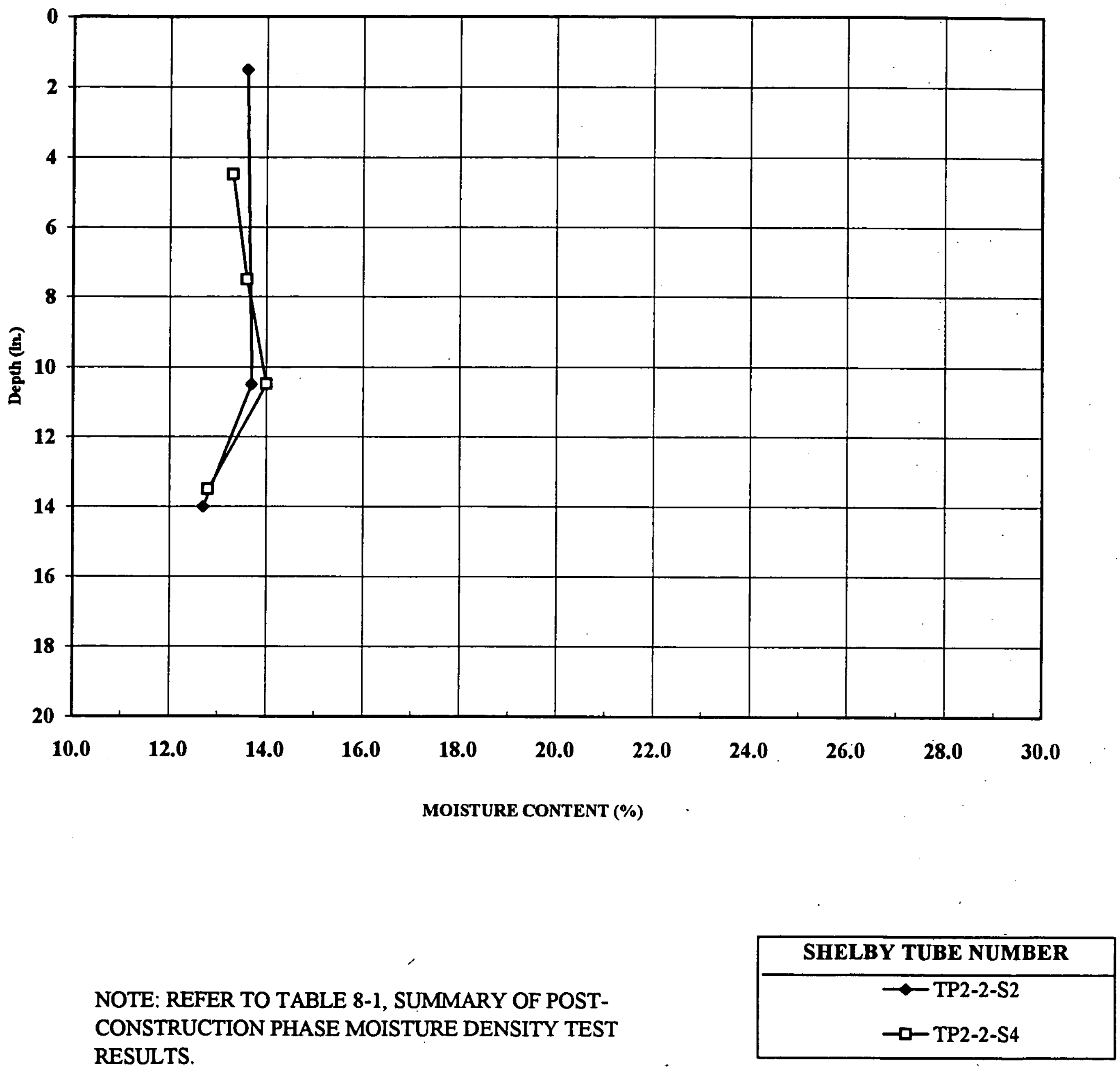
FIGURE NO.	8-10
PROJECT NO.	GE3900-514
DOCUMENT NO.	F9630212.CD0
FILE NO.	MOISTURE.XLS

MOISTURE CONTENT PROFILE
TEST PAD NUMBER 2, LANE NUMBER 2
DECOMMISSIONED SDRI-2-2



NOTE: REFER TO TABLE 8-1, SUMMARY OF POST-CONSTRUCTION PHASE MOISTURE DENSITY TEST RESULTS.

000117

GEOSYNTEC CONSULTANTS
ATLANTA, GEORGIA

FIGURE NO.	8-11
PROJECT NO.	GE3900-514
DOCUMENT NO.	F9630212.CD0
FILE NO.	MOISTURE.XLS

SECTION 9

9. DEVELOPMENT OF CONSTRUCTION RECOMMENDATIONS

9.1 Introduction

The results of the test pad program were used to develop recommendations for compacted clay liner and cap materials and construction. Specific recommendations were developed for:

- compacted clay material criteria;
- borrow material preparation procedures;
- placement and compaction procedures;
- APZ selection; and
- conformance testing.

9.2 Compacted Clay Material Criteria

Results of field and laboratory conformance tests on the brown till material are presented in Appendix G of this TPPFR. These results verify that material used in construction of the test pads meet the ARARs presented in Table 3-1 of this TPPFR, with two exceptions: (i) some of the tested brown till samples had less than 25 percent of the particles, by weight, with a maximum dimension not greater than 0.002 mm; and (ii) notwithstanding the efforts of the Test Pad Contractor, the test pad soil had particles with a maximum dimension exceeding 2 in. (50 mm). These deviations in materials from ARAR requirements are discussed in the following paragraphs.

Particle size analyses performed in accordance with ASTM D 422 were conducted on two samples from the center of the upper horizon (3 ft (0.9 m) depth) during pre-construction testing and on five samples from various depths in the upper horizon during construction-phase testing. Particle size analyses (ASTM D 422) were also conducted on two samples from the center of the lower horizon (7.5 ft (2.25 m) depth) during pre-construction testing and on six samples from various depths in the lower horizon during construction-phase testing. Results of the hydrometer portion of the tests were used to estimate percentage of clay size particles for each sample. These estimates are presented in Table 9-1. Review of the data reveals that five of seven samples from the upper horizon meet the ARAR criterion for the required percentage of particles having a maximum dimension not greater than 0.002 mm, while all seven upper horizon samples meet the alternative criterion for this index property proposed by DOE in a letter dated 26 January 1996 in accordance with OAC 3745-27-O8(c) (i.e., not less than 15 percent of the particles, by weight, having a maximum dimension not greater than 0.002 mm in maximum dimension). None of the samples from the lower horizon meet ARAR criterion of for the 0.002 mm maximum particle size. Six of the seven samples meet the alternative criterion. It is noted that using the alternative criterion proposed by DOE in the 26 January 1996 letter, the test pad program has satisfactorily demonstrated that the maximum permeability of a properly controlled compacted clay layer is less than 1 x 10^{-7} cm/sec. The construction quality assurance program has been designed to offer a high confidence that consistent performance can be achieved during construction.

The SDRI test results presented in Section 8 of this TPPFR support the alternative criterion proposed in the 13 December 1995 DOE document entitled *"Alternative to OAC Prescriptive Specifications for Compacted Soil Liners,"* wherein the average fraction, by weight, of particles smaller than 0.002 mm need only exceed 15 percent. The brown till will generally meet this criterion. The OSDF Construction Specification should incorporate this alternative criterion and not the original ARAR criterion.

Visual spotting, at the level carried out during the test pad program was found to be insufficient to remove all particles larger than 2 in. (50 mm) in maximum dimension (see discussion in Section 6.4). However, the particles greater than 2 in. (50 mm) in maximum dimension, such as those found during SDRI installation, did not negatively affect the results of the SDRI testing to the extent that the measured permeability of the compacted clay in the test pad was greater than 1 x 10^{-7} cm/s.

An alternative criterion is not being proposed for particles with a maximum dimension greater than 2 in. (50 mm). The OSDF Construction Subcontractor must

TABLE 9-1

HYDROMETER RESULTS FOR PARTICLES SMALLER THAN 0.002 mm

Upper Horizon Brown Till

Sample No.	Passing 0.002 mm (Percent)*
Lab Sample 96374	24.0
Lab Sample 96375	25.0
Field Sample UH-01	39.5
Field Sample UH-04	35.0
Field Sample UH-05	28.0
Field Sample UH-06	28.0
Field Sample UH-07	20.0

Lower Horizon Brown Till

Sample No.	Passing 0.002 mm (Percent)*
Lab Sample 96380	16.0
Lab Sample 96381	11.0
Field Sample LH-01	19.5
Field Sample LH-02	20.5
Field Sample LH-03	17.5
Field Sample LH-04	15.0
Field Sample LH-05	13.0
Field Sample LH-06	16.0

* Data estimated from grain size distribution curves.

continuously remove visible rock particles with a maximum dimension greater than 2 in. (50 mm) during clay material placement processing, and compaction. The number of processing passes and rock removal effort may be equal to or better than those used in the test pad program to remove all oversize particles. As discussed below, it is recommended that the OSDF Construction Contractor be required to propose a method to remove all oversized particles.

9.3 Borrow Material Preparation and Placement Procedures

Based on the results of the test pad program, clay material pre-processing and moisture conditioning should be accomplished using a transverse rotary mixer with spray bar (i.e., Caterpillar SS250 transverse rotary mixer, HAMM RACO 250 transverse rotary mixer, or equivalent). The spray bar is essential to ensure that water added for moisture conditioning can be evenly distributed throughout the lift (see discussion in Section 6.4 concerning adding water by means of a hose from a hydroseeder). The OSDF Construction Subcontractor should be required to make a submittal, for review and approval by the Construction Manager, of a proposed method for removing particles with a maximum dimension greater than 2 inches (50 mm).

9.4 Compaction Procedures

Based on the results of the test pad program, the OSDF Construction Subcontractor contractor should be required to:

- use a Caterpillar 815B soil compactor, or equivalent, for compaction of the clay liner and cap; and
- apply a minimum of six full coverage passes of the compactor to each lift of material; it should be noted that a greater number of passes may be required to achieve the requisite dry density.

9.5 Acceptable Permeability Zones for Construction

The construction-phase and post-construction-phase field and laboratory test results were used to establish APZs for the upper and lower horizon brown tills. These APZs are presented in Figures 9-1 and 9-2. These APZs are very similar and from them a single APZ can be defined for application during OSDF construction. This single APZ is related to the standard Proctor compaction curve for the clay, so as this curve changes due to variations in material source, the absolute locations of the APZ boundaries will also change. The APZ proposed for construction of the OSDF compacted clay liner and cap is as follows, with all values referenced to standard Proctor compaction test results:

- lower boundary defined by 95 percent standard Proctor maximum density;
- right hand boundary defined by a moisture content 3 percentage points wet of the optimum moisture content; and
- left hand boundary defined by the line of constant degree of saturation equal to 90 percent.

The rationale for the right and left boundaries of the APZ is discussed below.

During construction of the test pads, the target moisture content was 2 percentage points wet of the standard Proctor optimum moisture content, with an allowable range of 1 percentage points. The brown till in both horizons exhibited behavior at compaction moisture contents of 3 percentage points wet of the standard Proctor optimum, indicative of a soil nearing saturation. Specifically, compactor pad-foot indentations of 3 to 5 in. (75 to 125 mm) were common after the requisite number of compactive passes. Compaction of an 8 in. (200 mm) loose lift thickness resulted in a compacted lift thickness, measured to the bottom of the pad-foot indentation, of approximately 5 in. (75 mm).

Because of the deep indentations left by the compactor pad-foot at moisture contents at or above 3 percentage points wet of the standard Proctor optimum moisture content, it is recommended that the APZ right boundary be limited to 3 percentage points wet of the standard Proctor optimum moisture content. With respect to the left boundary, pre-construction phase testing, construction phase testing, and SDRI testing confirms that compaction wet of the 90 percent degree of saturation line consistently produces a compacted clay material having a hydraulic conductivity of less than 1 x 10^{-7} cm/s. High confidence in achieving satisfactory hydraulic conductivity results can be achieved by establishing a conservative APZ at or above the line at this degree of saturation.

9.6 Conformance Test Requirements

Materials used in the construction of the test pads have properties which are generally consistent with materials in the proposed borrow areas designated for construction of the OSDF as discussed in Section 3 of this TPPFR. Results of pre-construction phase testing, construction phase testing, and post-construction phase testing confirm that this material is suitable for construction of a clay barrier with a hydraulic conductivity not greater than 1 x 10^{-7} cm/s. For these reasons, the following conformance requirements are recommended.

- Material should meet the material properties in the ARARs with exception of the criterion for percentage of particles with a maximum particle size of 0.002 mm. This criterion is recommended as proposed by DOE in accordance with OAC 3745-27-O8(c) and as discussed in Section 9.2 of this TPPFR.

- Hydraulic conductivity, when tested according to ASTM D 5084 (remold) should not exceed 1 x 10^{-7} cm/s when compacted to a degree of saturation approximating the left boundary of the approved construction APZ and within the lower and right boundary of the APZ based on the standard Proctor compaction curve for the tested specimen. Retests for marginally failing results should be performed if all other soil index properties conform to the specification requirements.

- Although soil samples from a few borings did not meet the requirement for greater than 50 percent passing the 200 sieve, all soils will meet this requirement during construction of the liner.

9.7 Performance Test Requirements

Results from the test pad program clearly demonstrate that acceptable material (which is processed, placed, and compacted as specified and described in this TPPFR) will produce a compacted clay barrier with hydraulic conductivity not greater than 1 x 10^{-7} cm/s. For this reason, recommended performance testing includes:

- testing moisture content and dry density of the compacted clay barrier material with the nuclear gauge (ASTM D 2922 and 3017) to ensure material is compacted to fall within the construction APZ;
- ensuring that the OSDF Construction Subcontractor uses approved equipment, with trained operators, in accordance with the specifications;
- ensuring that the OSDF Construction Subcontractor removes oversized particles in accordance with the specifications and his approved work plan (see Section 9.3);
- ensuring that the requisite minimum number of compactor passes is provided; and
- ensuring that loose lift thicknesses are within specified limits.

Recommended performance test requirements do not include thin-walled tube sampling and laboratory hydraulic conductivity testing results. The results of the test pad program demonstrate that acceptable hydraulic conductivity will be achieved with the combination of conformance and performance testing described above.

UPPER HORIZON BROWN TILL ACCEPTABLE PERMEABILITY ZONE (APZ)

COMPOSITE SAMPLE, TEST PAD NO. 1
BASED ON TEST PAD PROGRAM RESULTS

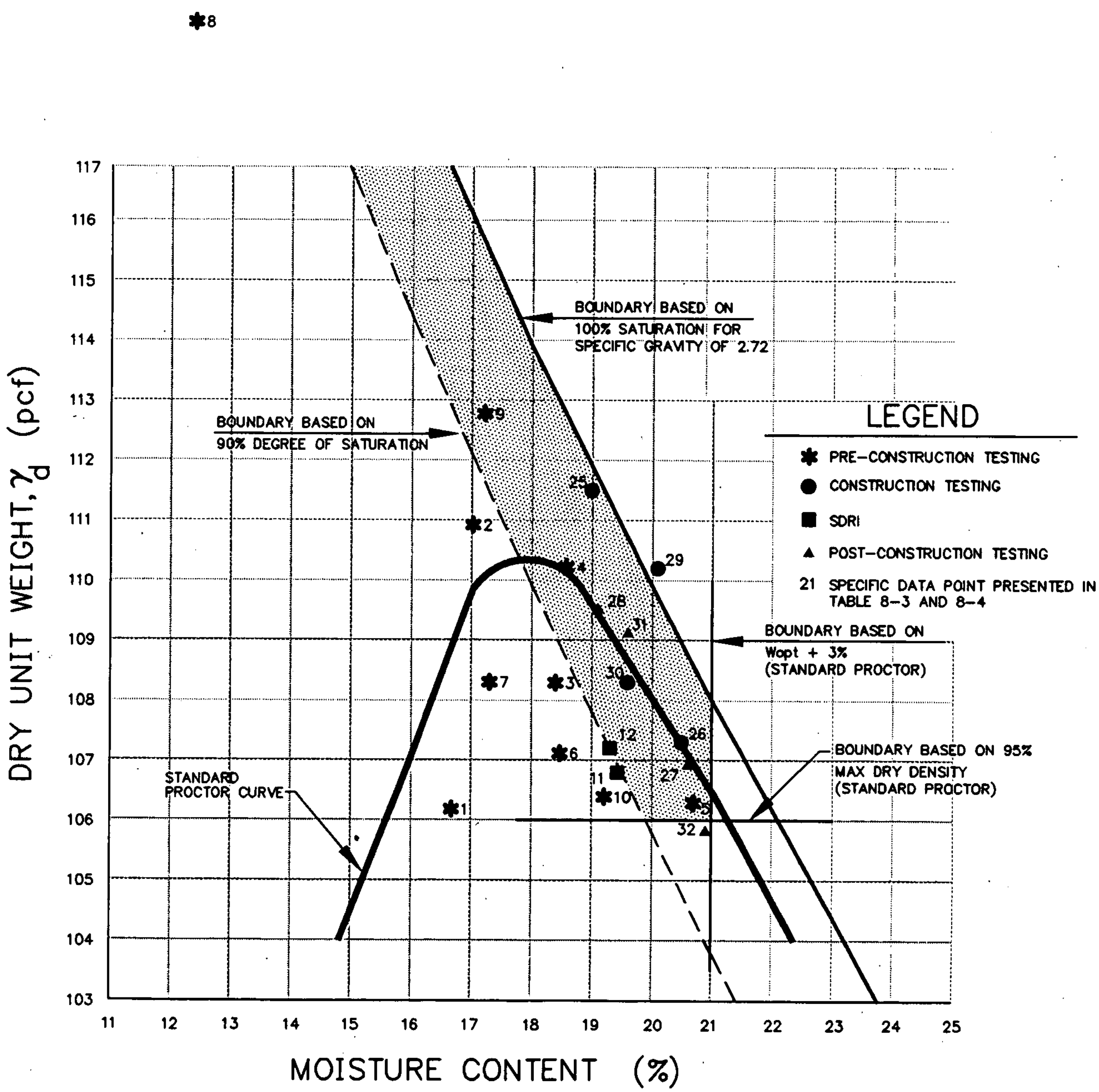


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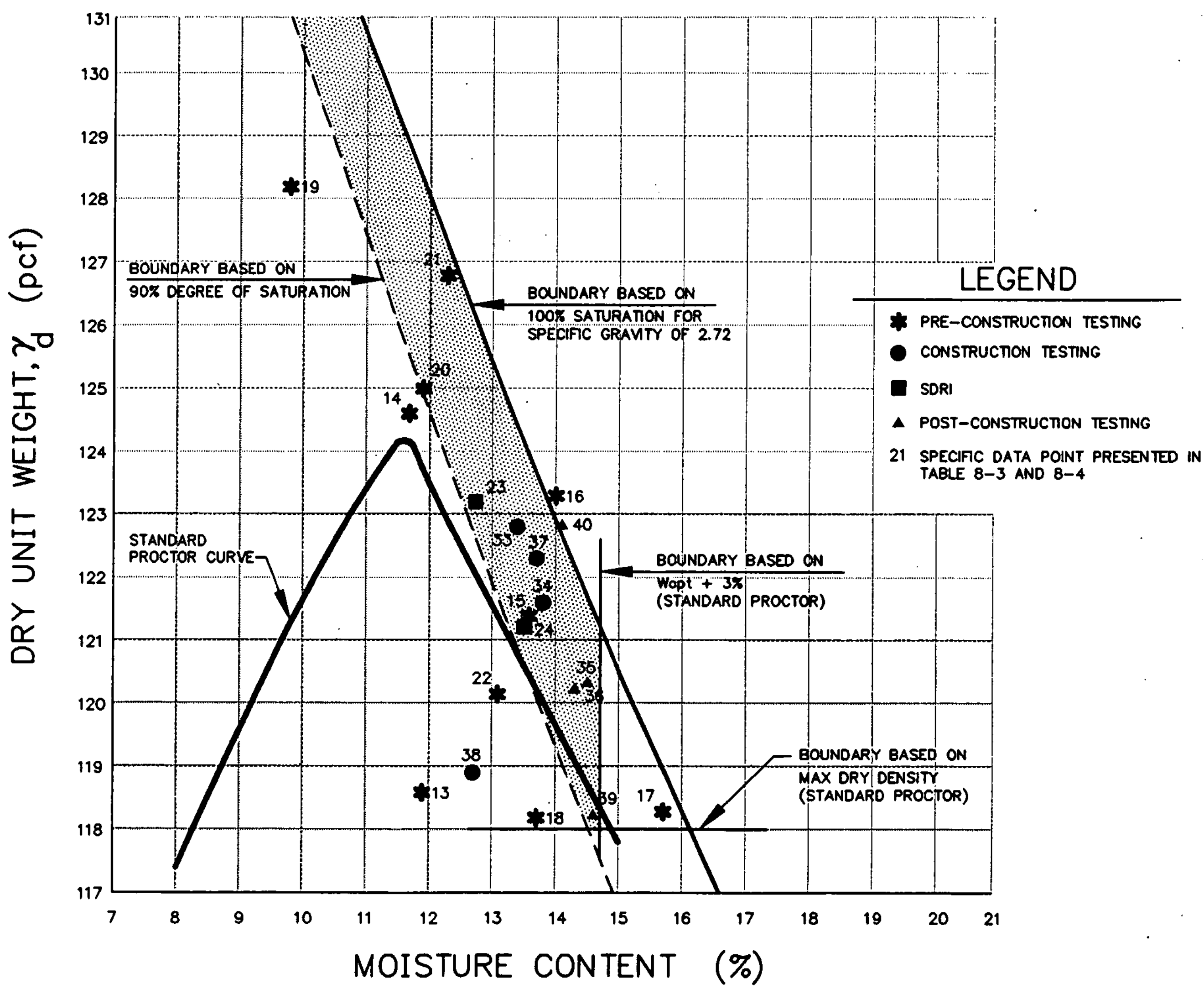
FIGURE NO.	9-1
PROJECT NO.	GE3900-05.4
DOCUMENT NO.	F9630212.CDO
FILE NO.	3900F001.DWG

LOWER HORIZON BROWN TILL
ACCEPTABLE PERMEABILITY ZONE (APZ)

COMPOSITE SAMPLE, TEST PAD NO. 2
BASED ON TEST PAD PROGRAM RESULTS



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GEOSYNTEC CONSULTANTS
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FIGURE NO.	9-2
PROJECT NO.	GE3900-05.4
DOCUMENT NO.	F9630212.CDO
FILE NO.	3900F002.DWG

GEOLOGIC CROSS SECTION

HORIZONTAL SCALE: 1" = 100'
VERTICAL SCALE: 1" = 10'

LEGEND

WELL 11492 — MONITORING WELL

BORING 11468 — GEOTECHNICAL BORING

SOUNDING 11468 — CONE PENETROMETER TEST (CPT) SOUNDING

INTERPRETED LOCATION OF COARSE GRAINED MATERIAL OBTAINED FROM CONE PENETROMETER SOUNDING

BROWN TILL – PREDOMINANTLY SILT/CLAY (CL), MIXTURES WITH LOCALIZED POCKETS OF (CH) AND (ML), SOME CLAYEY AND SILTY SAND AND SCATTERED GRAVEL. TYPICALLY STIFF TO VERY STIFF, AND MOIST. SOME LOCAL SAND LENSES. OPEN 1/8" FRACTURES.

GRAY TILL – PREDOMINANTLY SILT/CLAY (CL), MIXTURES WITH POCKETS OF SAND (SW), CLAYEY SAND (SC) AND SCATTERED GRAVEL. TYPICALLY VERY STIFF TO LOCALLY HARD, AND MOIST. SCATTERED SAND LENSES.

GREAT MIAMI AQUIFER – SAND/GRAVEL MIXTURES, VERY DENSE TO HARD

WATER LEVEL MEASURED BETWEEN 20 AND 29 MARCH 1995 IN MONITORING WELL SCREENED ACROSS BROWN TILL/GRAY TILL INTERFACE

WATER LEVEL MEASURED IN MONITORING WELL SCREENED IN GRAY TILL OR GREAT MIAMI AQUIFER

MONITORING WELL SCREEN INTERVAL

R — RANGE OF WATER LEVEL FLUCTUATION IN THE PERCHED WATER ZONE BETWEEN OCTOBER 1994 AND MARCH 1995

NOTES:

1. THIS DRAWING OBTAINED FROM SHEET X-14, "GEOLOGIC SECTION B-B", REVISION D, OF THE INTERMEDIATE DESIGN PACKAGE, ON-SITE DISPOSAL FACULITY, GEOSYNTEC CONSULTANTS.
2. ELEVATIONS ARE IN FEET ABOVE SEA LEVEL DATUM. (NOTE: "SEA LEVEL DATUM" REFERS TO THE NATIONAL GEODETIC VERTICAL DATUM [NGVD].)
3. GRID COORDINATE SYSTEM CORRESPONDS TO STATE PLANAR NORTH AMERICAN DATUM (NAD) 1983 OHIO SOUTH.
4. GEOLOGIC SECTION DATA OBTAINED FIGURE 2-4, "COARSE GRAINED MATERIAL INTERPRETED FROM CONE PENETROMETER RESULTS", OF THE "PREDESIGN INVESTIGATION AND SITE SELECTION REPORT FOR THE ON SITE DISPOSAL FACILITY, FERNALD ENVIRONMENTAL MANAGEMENT PROJECT," U.S. DEPARTMENT OF ENERGY, JULY 1995.
5. MONITORING WELL AND PERCHED ZONE INFORMATION OBTAINED FROM TABLE A-4, "BORING DEPTH AND SCREENED INTERVALS FOR PHASE II WELLS", AND TABLE A-19, "SUMMARY OF WATER LEVEL DATA, BROWN/GRAY TILL INTERFACE WELLS, MARCH 29, 1995", OF THE "PREDESIGN INVESTIGATION AND SITE SELECTION REPORT FOR THE ON SITE DISPOSAL FACILITY, FERNALD ENVIRONMENTAL MANAGEMENT PROJECT," U.S. DEPARTMENT OF ENERGY, JULY 1995.
6. GEOTECHNICAL BORING AND CONE PENETROMETER TEST (CPT) SOUNDING LOCATIONS OBTAINED FROM APPENDIX B, "BORING AND CPT COORDINATES", OF THE "GEOTECHNICAL INVESTIGATION REPORT FOR THE ON-SITE DISPOSAL FACILITY, OPERABLE UNIT 2, PROJECT ORDER 140, REVISION A," PARSONS, SEPTEMBER 1995.
7. PERCHED ZONE POTENTIOMETRIC SURFACE OBTAINED FROM FIGURE 2-20, "PERCHED GROUNDWATER CONTOURS FOR WELLS SCREENED ACROSS THE BROWN/GRAY INTERFACE" OF THE "PREDESIGN INVESTIGATION AND SITE SELECTION REPORT FOR THE ON SITE DISPOSAL FACILITY, FERNALD ENVIRONMENTAL MANAGEMENT PROJECT," U.S. DEPARTMENT OF ENERGY, JULY 1995.
8. GREAT MIAMI AQUIFER WATER TABLE INFORMATION OBTAINED FROM FIGURE 3-51, "MAXIMUM GROUNDWATER ELEVATIONS, TYPE 2 WELLS, JUNE 1990", AND FIGURE 3-52, "MINIMUM GROUNDWATER ELEVATIONS, TYPE 2 WELLS, NOVEMBER 1988", OF THE "REMEDIAL INVESTIGATION REPORT FOR OPERABLE UNIT 5, FERNALD ENVIRONMENTAL MANAGEMENT PROJECT, REMEDIAL INVESTIGATION AND FEASIBILITY STUDY", U.S. DEPARTMENT OF ENERGY, MARCH 1995.

REV. NO.	DATE	DESCRIPTION	DES BY	DR BY	CHK BY	RVW BY	APP BY

100 50 0 100 200 SCALE IN FEET

10 5 0 10 20 SCALE IN FEET

OWNER/FACILITY:

UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

CLIENT:

FERNALD ENVIRONMENTAL RESTORATION MANAGEMENT CORPORATION

PROJECT:

ON-SITE DISPOSAL FACILITY

TITLE:

GEOLOGIC CROSS SECTION
OSDF AREA

000038

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

SEAL

GEOSYNTEC CONSULTANTS
1100 LAKE HEARN DRIVE
ATLANTA, GEORGIA 30342 USA

FERMCO SUBCONTRACT NO.: 95PS005028
FERMCO DRAWING NO.:
FIGURE NO. 3-1
PROJECT NO. GE3900-4.1
DOCUMENT NO. F95-E012
FILE NO. F95-E012.DWG

TEST PAD WORK PLAN

867

LEGEND

600	EXISTING GROUND ELEVATION (FEET)
	BUTLER COUNTY/HAMILTON COUNTY LINE
	FEMP PROPERTY LINE
	BATTERY LIMIT
	IMPACTED MATERIAL DISPOSAL LIMIT
	BORROW AREA LIMIT
	SECURITY FENCE
	CONSTRUCTION CONTROL POINT

NOTES:

1. TOPOGRAPHIC MAP BASED ON 1992 SITE FLYOVER.
2. ELEVATIONS ARE IN FEET ABOVE SEA LEVEL DATUM. (NOTE: "SEA LEVEL DATUM" REFERS TO THE NATIONAL GEODETIC VERTICAL DATUM [NGVD].)
3. GRID COORDINATE SYSTEM CORRESPONDS TO STATE PLANAR NORTH AMERICAN DATUM (NAD) 1983 OHIO SOUTH.
4. ON-SITE DISPOSAL FACILITY LAYOUT AND RELATED INFORMATION OBTAINED FROM DRAWING X-14, "SITE PLAN", REVISION D, OF THE INTERMEDIATE DESIGN PACKAGE, ON-SITE DISPOSAL FACILITY, GEOSYNTEC CONSULTANTS.
5. CONTINGENCY CELL WILL ONLY BE CONSTRUCTED IF NEEDED FOR DISPOSAL OF IMPACTED MATERIAL FROM THE OPERABLE UNITS. CONTINGENCY VOLUME IS PROVIDED TO ACCOUNT FOR OVEREXCAVATION OF IMPACTED MATERIAL AND/OR INDENTIFICATION OF ADDITIONAL VOLUME OF IMPACTED MATERIAL AS A RESULT OF CONFIRMATORY SAMPLING ACTIVITIES. ONLY ON-SITE MATERIAL SATISFYING THE OSDF WASTE ACCEPTANCE CRITERIA WILL BE DISPOSED IN THE OSDF. IF THE CONTINGENCY CELL IS NOT DEVELOPED, THE SOUTHERN LIMIT OF THE OSDF WILL MOVE 400 FEET TO THE NORTH.
6. ADDITIONAL CONSTRUCTION CONTROL AND DETAILS FOR THE TEST PAD CONSTRUCTION SITE ARE SHOWN ON FIGURE 4-1.

TEST PAD CONSTRUCTION SITE CONTROL POINTS		
POINT	NORTHING	EASTING
1	482703.8	1351369.0
2	482404.7	1351370.3
3	482403.7	1351047.2
4	482702.7	1351045.9
17	482676.7	1351045.9
18	482677.4	1350996.7

REV. NO.	DATE	DESCRIPTION	DES BY	DR BY	CHK BY	RVW BY	APP BY

200 100 0 200 400
SCALE IN FEET

OWNER/FACILITY:
UNITED STATES DEPARTMENT OF ENERGY
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

CLIENT:
FERMCO Restoration Management Corporation
FERNALD ENVIRONMENTAL RESTORATION MANAGEMENT CORPORATION

PROJECT: ON-SITE DISPOSAL FACILITY

TITLE: TEST PAD PROGRAM LOCATION MAP

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

SEAL

GEOSYNTEC CONSULTANTS
1100 LAKE HEARN DRIVE
ATLANTA, GEORGIA 30342 USA

FERMCO SUBCONTRACT NO.: 95PS005028
FERMCO DRAWING NO.:
FIGURE NO.: 2-1
PROJECT NO.: GE3900-4.1
DOCUMENT NO.: F9530008
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TEST PAD WORK PLAN