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CONSTRUCTION QUALITY ASSURANCE
FINAL REPORT

ON-SITE DISPOSAL FACILITY
PHASE III CELL 1
FINAL COVER CONSTRUCTION

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

prepared by

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under

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CONSTRUCTION QUALITY ASSURANCE FINAL REPORT PHASE III - CELL 1 FINAL COVER CONSTRUCTION ON-SITE DISPOSAL FACILITY

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Fernald Environmental Management Project
Fernald, Ohio

Prepared by

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Under

Fluor Fernald, Inc.
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ACRONYM LIST

AASHTO	American Association of State Highways and Transportation Officials
ACI	American Concrete Institute
APZ	Acceptable Permeability Zone
ARAR	Applicable or Relevant and Appropriate Requirement
ASTM	American Society of Testing and Materials
CDF	Controlled Density Fill
CFC	Certified-For-Construction
CM	Construction Manager
CQA	Construction Quality Assurance
CQC	Construction Quality Control
CVH	Control Valve House
DCN	Design Change Notice
DCP	Design Criteria Package
DOE	Department of Energy
EPBA	East Field Borrow Area
EPLTS	Enhanced Permanent Leachate Transmission System
FEMP	Fernald Environmental Management Project
FMSM	Fuller, Mossbarger, Scott, and May
GCC	Geosynthetic Clay Cap
GIS	Gravity Inlet Structure
HDPE	High Density Polyethylene
HMW	Horizontal Monitoring Well
LCS	Leachate Collection System
LDS	Leak Detection System
LGP	Low Ground Pressure
LLRW	Low-Level Radioactive Waste
LTS	Leachate Transmission System
MDD	Maximum Dry Density

NCR	Nonconformance Report
O&M	Operations and Maintenance
OAC	Ohio Administrative Code
ODOT	Ohio Department of Transportation
OEPA	Ohio Environmental Protection Agency
OMC	Optimum Moisture Content
OSDF	On-Site Disposal Facility
PI	Plasticity Index
PLS	Permanent Lift Station
QA	Quality Assurance
QC	Quality Control
RCI	Request for Clarification of Information
RCRA	Resource Conservation and Recovery Act
RLCS	Redundant Leachate Collection System
SDFP	Soil and Disposal Facility Project
SWMEC	Surface Water Management and Erosion Control
SWP	Soil and Water Project
TPPFR	Test Pad Program Final Report
USCS	Unified Soil Classification System
USEPA	United States Environmental
VH	Valve House
WAC	Waste Acceptance Criteria
WAO	Waste Acceptance Organization

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GeoSyntec Consultants
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1. INTRODUCTION

1.1 Terms of Reference

This final report summarizes the Construction Quality Control (CQC) and Construction Quality Assurance (CQA) activities performed by GeoSyntec Consultants (GeoSyntec) during the On-Site Disposal Facility (OSDF) Phase III – Cell 1 Final Cover Construction project at the Fernald Environmental Management Project (FEMP), located near Fernald, Ohio. CQC and CQA activities performed by GeoSyntec will be collectively referred to as CQA activities in this report. The CQA activities performed by GeoSyntec included monitoring, testing and documentation of the construction of the various components of the Cell 1 final cover system, and included: (i) earthwork construction, and (ii) geosynthetics installation. In addition, GeoSyntec performed the appropriate and relevant CQA activities during the: (i) excavation and screening of clay liner and cap material in the East Field Borrow Area (EFBA) for future Cells 4 and 5 liners construction; (ii) construction of horizontal monitoring wells for future Cells 4 and 5; (iii) extensions of the dual-containment pipes from the valve houses (VHs) No. 4 and No. 5 stub-outs to future Cells 4 and 5 outlets, respectively; (iv) excavation, removal and backfilling of portions of the temporary leachate transmission system (LTS); (v) excavation and removal of the equipment wash pad within the footprint of future Cell 4; and (vi) removal of a portion of the above-ground interim LTS pipeline between VH-4 and VH-5. The CQA activities were performed to confirm that the construction materials, and construction and testing procedures, which were monitored and/or performed, were in compliance with the certified-for-construction (CFC) drawings, technical specifications, CQA plan, and approved design and/or specification changes.

This report was prepared for Fluor Fernald, Inc. under Subcontract 95PS005028 by Dr. Kwasi Badu-Tweneboah, P.E., Mr. Collin P. Sukow and Mr. T. Byran York, E.I.T, all of GeoSyntec.

1.2 Background

The OSDF is a mixed low-level radioactive waste (LLRW) disposal facility dedicated to the FEMP that, upon completion, will cover approximately 90 acres (36 hectares). The OSDF is owned by the Department of Energy (DOE) and is being constructed, operated for waste disposal, and closed under the management of Fluor Fernald, Inc. as part of the overall FEMP remediation activities.

DOE intends to build only one OSDF. Therefore, the OSDF is designed to accommodate all or any portion of the total volume of impacted material meeting the waste acceptance criteria (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. The OSDF is being developed in several phases. Construction of the liner systems, placement of impacted material, and construction of the final cover system for the OSDF cells are scheduled to be completed by December 2006 [Fluor Fernald, 2002]

The first year (1997) of construction included the OSDF Phase I liner system for Cell 1 and the overall Leachate Management System projects. The Leachate Management System projects consisted of: (i) the OSDF leachate transmission system (LTS) component that included manholes MH-1, MH-2, and MH-3, respectively, for Cells 1 through 3, and a dual-containment high density polyethylene (HDPE) gravity piping system from manhole MH-1 to the permanent lift station (PLS); and (ii) the Leachate Conveyance System that consisted of a force main from the PLS to the biosurge lagoon. The interface between OSDF Phase I and the overall Leachate Management System was at the stub-outs of the manholes for Cell 1 leachate collection and leak detection systems. Construction of the OSDF Phase I liner system for Cell 1, the OSDF LTS and the Leachate Conveyance System occurred between August and December 1997. A CQA Final Report for the OSDF Phase I - Cell 1 liner system and the overall Leachate Management System construction was prepared and issued by GeoSyntec in January 1998 [GeoSyntec, 1998a].

The second year (1998) of construction included the OSDF Phase II liner system for Cell 2 and placement of impacted materials in Cell 1. Construction of the Cell 2 liner system occurred between June and November 1998. A CQA Final Report for the OSDF Phase II - Cell 2 liner system construction was prepared and issued by GeoSyntec in December 1998 [GeoSyntec, 1998b]. Placement of impacted materials in Cells 1 and 2 began in June 1998 and November 1998, respectively.

The third year (1999) of construction consisted of the Cell 3 liner system and placement of impacted materials in Cells 1, 2, and 3 as part of the OSDF Phase II, Option 1 project. Construction of the Cell 3 liner system occurred between April and October 1999. A CQA Final Report for the OSDF Phase II - Cell 3 liner system construction was prepared and issued by GeoSyntec in November 1999 [GeoSyntec, 1999]. Placement of impacted materials in Cells 1 and 2 began in May 1999, while impacted materials placement in Cell 3 began in October 1999.

The fourth year (2000) of construction included placement of impacted materials in Cells 1, 2, and 3 as part of the OSDF Phase II, Option 2 project. Impacted materials placement began in March 2000 and was completed in September 2000 where Cell 1 was brought to final grades to facilitate construction of the final cover system. The fourth year of construction also included the Enhanced Permanent Leachate Transmission System (EPLTS) project that consisted of permanent LTS gravity line from Cell 1 to the permanent lift station (PLS); LTS valve houses (VHs) for each OSDF cell (a total of six); a control valve house (CVH) near the PLS; tie-in of the dual-containment pipes from Cells 1, 2, and 3 to the newly constructed VHs 1, 2, and 3, respectively; and the stub-outs from newly constructed VHs 4, 5, and 6 for future tie-in to dual-containment pipes from Cells 4, 5, and 6, respectively. A CQA Final Report for the EPLTS project was prepared and issued by GeoSyntec in October 2001 [GeoSyntec, 2001].

The Cell 1 final cover system was constructed as part of the OSDF Phase III projects in 2001 and is the primary subject of this report. This CQA Final Report presents a summary of the CQA monitoring, testing, and documentation activities performed by GeoSyntec during the OSDF Phase III - Cell 1 final cover construction project.

1.3 Report Organization

The remainder of this final report is organized as follows:

- A description of the project is provided in Section 2.
- A description of the CQA program, including a summary description of specific tasks performed under the program, and a listing of project personnel, are presented in Section 3.
- A description of the general field documentation prepared by the CQA personnel is summarized in Section 4.
- A description of the CQA monitoring, testing and documentation activities performed during the earthwork portion of the project is provided in Section 5.
- A description of the CQA monitoring, testing and documentation activities performed during the geosynthetics installation is provided in Section 6.

- A description of the CQA monitoring, testing and documentation services performed during the installation of the final cover monitoring system is provided in Section 7.

- A description of the CQA monitoring, testing and documentation activities during installation of the HDPE piping systems for future Cells 4 and 5 liner systems is provided in Section 8.

- A summary of the observations resulting from the CQA monitoring, testing and documentation activities performed by GeoSyntec; and a certification statement verifying that the OSDF Phase III - Cell 1 final cover project was constructed in general accordance with the project specifications, construction drawings, CQA plan, and approved design and/or specification changes are presented in Section 9.

2. PROJECT DESCRIPTION

The OSDF design incorporates a final cover system and other engineering controls that meet the applicable or relevant and appropriate requirements (ARARs), DOE functional requirements, and general design criteria as described in the Design Criteria Package (DCP) developed and approved for the project during the design phase [GeoSyntec, 2000]. The final cover system, designed to isolate impacted materials in the OSDF, includes the following components, from top to bottom:

- 6-in. (0.15-m) thick topsoil layer;
- 1.75-ft (0.425-m) thick vegetative soil layer;
- 6-in. (0.15-m) thick granular filter layer;
- 3-ft (0.9-m) thick biointrusion barrier with choke stone layer;
- 1-ft (0.3-m) thick cover drainage layer;
- 8-oz/yd^2 (270-g/m^2) geotextile cushion layer;
- 60-mil (1.5-mm) thick textured high density polyethylene (HDPE) geomembrane component of the composite cap;
- a geosynthetic clay cap (GCC) component of the composite cap;
- 2-ft (0.6-m) thick compacted clay cap component of the composite cap; and
- 1-ft (0.3-m) thick non-impacted contouring layer.

The Cell 1 final cover system footprint covers an area of approximately 8 acres (3.2 hectares); and is bounded on the north, west, and east by the perimeter drainage channels, and on the south by the temporary termination area for future Cell 2 final cover construction.

The Certified-For-Construction (CFC) Drawings and Technical Specifications, dated May 2000, for the Phase III construction project were prepared by GeoSyntec in accordance with the terms of Fluor Fernald Subcontract 95PS005028. The prime contractor for construction of the OSDF Phase III - Cell 1 final cover construction project was The IT Corporation (IT) of Monroeville, Pennsylvania. Installation of the

geosynthetics components of the Cell 1 final cover system was performed by The Istre Company (TIC) of Glenpool, Oklahoma, as a subcontractor to IT. Leak detection testing of the installed geomembrane cap was performed by Leak Location Services, Inc. (LLSI) of San Antonio, Texas, as subcontractor to IT. The HDPE pipes for the Cells 4 and 5 horizontal monitoring wells and extensions of the dual-containment piping systems from VH-4 and VH-5 to the Cells 4 and 5 outlets were installed by The Fred DeBra Company (DeBra) of Cincinnati, Ohio as subcontractor to IT and Fluor Fernald. The surveyor retained by IT, and later by Fluor Fernald, for the OSDF Phase III - Cell 1 final cover construction project was David E. Estes Engineering, Inc. (Estes) of Cincinnati, Ohio. (However, B.L. Payne & Associates, Inc. (Payne) of Cincinnati, Ohio was the surveyor initially retained by IT for the project. Payne therefore provided the preliminary surveys and also partially completed certification of the top of contouring layer for the Cell 1 final cover construction project, and was later replaced by Estes.) CQA monitoring, testing, and documentation were provided by GeoSyntec. Fluor Fernald Quality Assurance (QA) also conducted independent CQA monitoring of the construction activities. A list of primary personnel involved in the OSDF Phase III - Cell 1 final cover construction project is included in Section 3.2 of this report.

As required by the project specifications, Estes surveyed the required layers of the final cover system (i.e., perimeter subgrade, top of contouring layer (part of this by Payne), top of compacted clay cap, layout of geomembrane cap, top of cover drainage layer, top of biointrusion barrier layer, top of granular filter layer, top of vegetative soil layer, and the top of topsoil layer) and prepared the as-built drawings for the subgrade and top of each soil component of the final cover system. GeoSyntec prepared the record drawing for the geomembrane cap.

Primary construction activities monitored by GeoSyntec's CQA personnel for the OSDF Phase III - Cell 1 final cover construction project included the following:

- rough grading of the subgrade in the perimeter (i.e., cut and fill operations);
- placement of compacted fill material in fill areas along the perimeter subgrade and southern temporary termination area of the Cell 1 final cover;
- preparation of the surface of the select impacted material layer for placement of the contouring layer;
- construction of the contouring layer;
- construction of the compacted clay cap;
- installation of the geosynthetic clay cap;

- installation of the geomembrane cap;
- installation of the geotextile cushion layers;
- placement of the cover drainage layer;
- placement of the biointrusion barrier with choke stone layer;
- placement of the granular filter layer;
- construction of the vegetative soil layer;
- placement of the topsoil layer;
- seeding and installation of the erosion mat over the final cover;
- installation of the final cover monitoring devices and instrumentation components;
- construction of the monitoring access; and
- construction of the perimeter drainage channels along the limits of the Cell 1 final cover.

Construction activities monitored by GeoSyntec's CQA personnel for the piping systems for Cells 4 and 5 included the following:

- trenching and excavation for the HDPE piping systems;
- placement and compaction of embedment fill for pipes;
- installation and welding of HDPE piping systems, including tie-in of the dual-containment pipe extensions from the stub-outs at VH-4 and VH-5 to Cells 4 and 5 outlets, respectively;
- hydrostatic and/or pneumatic testing of the HDPE piping systems;
- placement and compaction of embedment fill and trench backfill around and over the piping systems; and
- backfilling and grading of the construction area.

The approval process for construction materials used during the OSDF Phase III - Cell 1 final cover construction project required the contractor and Fluor Fernald to submit manufacturer's data, quality control certifications, supplier's certifications, and shop drawings to the Construction Manager (CM) for review and approval. The Fluor Fernald CM, Engineering and QA, and the GeoSyntec Resident Engineer reviewed, commented (as needed), and approved construction materials for use during construction. The submittal details and approvals are summarized in the Resident Engineer's weekly reports, and are included in the appendices to this final report.

Earthwork associated with OSDF Phase III - Cell 1 final cover construction began on 6 April 2000 with the placement of the first lift of the non-impacted contouring layer Placement and compaction of the first lift of the compacted clay cap began on 9 May 2001. TIC began and completed installation of the geosynthetics for the Cell 1 final cover system on 3 July 2001 and 17 August 2001, respectively. LLSI began and completed leak detection testing of the installed geomembrane cap on 11 July 2001 and 16 August 2001, respectively. The construction of the OSDF Phase III - Cell 1 final cover system was substantially completed on 9 November 2001, prior to beginning seeding and installation of the erosion mat. Seeding of the final cover was completed on 6 December 2001, and the installation of the erosion mat was completed on 20 December 2001.

Earthwork associated with the installation of the HDPE piping systems began on 7 January 2002 and was completed in April 2002. Welding, installation, and testing of the HDPE pipes began on 1 November 2001 and was completed in May 2002. It should be noted that IT's contract for the Phase III – Cell 1 final cover construction project expired on 30 March 2002. Therefore, some of the remaining punch-list items that were not completed at the end of IT's contract were subsequently completed by Fluor Fernald in May 2002 under the self-performance program for the closure of the FEMP [Fluor Fernald, 2002].

3. CONSTRUCTION QUALITY ASSURANCE PROGRAM

3.1 Scope of Services

3.1.1 Overview

The scope of CQA services performed by GeoSyntec during the construction of the OSDF Phase III - Cell 1 final cover project included:

- review of documents;
- monitoring, testing, and documentation of field operations; and
- preparation of final report and record drawings.

These services are described in the following subsections of this report.

3.1.2 Review of Documents

As previously noted, this final report summarizes the CQA activities performed by GeoSyntec during the OSDF Phase III - Cell 1 final cover construction. The CQA activities conducted by GeoSyntec were intended to satisfy the requirements of the following documents:

- "*Technical Specifications, On-Site Disposal Facility Phase III – Cell 1 Final Cover Construction*", 20103-TS-0003, Revision 0, dated May 2000, Revision 1, dated August 2001, prepared by GeoSyntec Consultants;
- "*Construction Quality Assurance Plan, On-Site Disposal Facility*", 20100-PL-0006, Revision 1, dated May 2001, prepared by GeoSyntec Consultants; and
- "*On-Site Disposal Facility – Phase III Certified-For-Construction Drawings*", Revision 1, prepared by GeoSyntec Consultants, dated May 2000; and
- "*Impacted Materials Placement Plan, On-Site Disposal Facility*", Revision 2 PCN 1, prepared by GeoSyntec Consultants, dated June 2001.

During construction, design change notices (DCNs) were prepared which modified these documents. Documents containing the details of these DCNs are referenced in the appropriate sections of this report, and are included as an appendix to this final report.

Also included in the appendices are requests for clarifications (RCIs) and nonconformance reports (NCRs).

The above documents (including the DCNs and RCIs) will be collectively referred to as the Project Documents in this final report. Prior to the commencement of on-site CQA activities, GeoSyntec CQA personnel reviewed the Project Documents for familiarity.

3.1.3 CQA Field Operations

The following activities were performed as part of GeoSyntec's on-site CQA services:

Earthwork:

- periodically monitoring on-site borrow area soils excavations;
- collecting pre-conformance and conformance test samples of soils considered for use as compacted clay cap, compacted fill, contouring layer, vegetative soil layer and other granular components of the Cell 1 final cover system for testing;
- performing geotechnical pre-conformance and conformance testing in either the on-site or off-site geotechnical laboratories;
- reviewing and evaluating geotechnical laboratory pre-conformance and conformance test results to ensure compliance with the requirements of the Project Documents;
- establishing acceptable permeability zones (APZs) for each clay stockpile;
- periodically monitoring grading operations on the cell perimeter subgrade;
- monitoring placement and compaction of contouring layer;
- monitoring final preparation and proofrolling of top of contouring layer;
- monitoring placement and compaction of clay cap;
- testing of the in-place moisture/density of compacted lifts of the contouring layer, clay cap and vegetative soil layer;

- monitoring surface of compacted clay cap for desiccation cracks prior to deployment of overlying GCC;
- monitoring placement and tracking of the cover drainage layer, biointrusion barrier with choke stone layer, and granular filter layer;
- monitoring placement and compaction of vegetative soil and topsoil layers;
- verifying (by means of reviewing the surveyor's data, and/or observing the surveyor's survey stakes) that the elevations and the thicknesses of the soil layers are consistent with the Project Documents;
- periodically monitoring placement of riprap materials in the perimeter drainage channels;
- periodically monitoring placement and compaction of the protective soil material in the southern temporary termination area of Cell 1 final cover;
- periodically monitoring placement and compaction of road base aggregate materials for the monitoring access along the eastern and northern perimeter of Cell 1 final cover;
- monitoring trenching operations for installation of the HDPE pipes;
- monitoring placement and compaction of embedment fill and trench backfill around pipes; and
- testing of the in-place moisture/density of the compacted trench backfill.

Geosynthetics:

- tracking the inventory of geosynthetics materials (i.e., GCC, textured HDPE geomembrane, and geotextile rolls) delivered to the site;
- monitoring geosynthetics materials delivered to the site to observe whether the materials had been damaged during transportation or handling, and if so, notifying Fluor Fernald QA and CM and marking damage for replacement or repair;

- collecting and reviewing geosynthetics manufacturers' quality control (QC) documents to verify compliance with the requirements of the Project Documents;
- collecting geosynthetics conformance samples and forwarding samples to the off-site geosynthetics testing laboratory;
- reviewing and evaluating geosynthetics laboratory conformance test results to verify compliance with the requirements of the Project Documents;
- monitoring deployment and installation of geosynthetics materials and marking damage for replacement or repair;
- monitoring overlapping and direction of shingling of adjacent GCC panels;
- monitoring placement of granular bentonite between overlapping GCC panels;
- monitoring geomembrane trial seaming operations and field testing;
- monitoring geomembrane production seaming operations;
- monitoring nondestructive testing of the geomembrane seams;
- selecting geomembrane destructive seam sample locations, monitoring sample collection and field testing using a calibrated tensiometer, distributing destructive samples to the geosynthetics testing laboratory, and reviewing laboratory test results to verify compliance with the requirements of the Project Documents;
- monitoring the installation of geotextiles and continuous sewing of adjacent panels;
- monitoring repairs to portions of the geosynthetics that were observed to have defects, or that failed destructive or nondestructive testing;
- monitoring electric leak detection testing of completed portions of the Cell 1 final cover geomembrane cap; and
- periodically monitoring the installation and stapling of erosion mat on the completed portions of the final cover.

Final Cover Monitoring System:

- monitoring the installation of the final cover monitoring devices; and
- periodically monitoring the installation of the conduits, junction boxes, cables, and other instrumentation associated with the final cover monitoring system.

HDPE Pipes:

- tracking the delivery of the HDPE pipes stockpiled on the site;
- collecting and reviewing HDPE pipe manufacturer's certification documents to verify compliance with the requirements of the Project Documents;
- visual monitoring of trial welds (including bent strap testing) and production welding of HDPE pipes;
- visual monitoring of the installation of the HDPE pipes for the HMWs at Cells 4 and 5, and the simultaneous butt-fusion welding of the tie-in of the dual-containment pipes from Cells 4 and 5 outlets to the stub-outs at VH-4 and VH-5, respectively; and
- visual monitoring of the hydrostatic pressure and pneumatic testing of the dual-containment piping system extensions to Cell 4 and 5.

During construction activities involving monitoring and/or testing, the observations made, and test results obtained, by GeoSyntec CQA personnel, were compared to the Project Documents. Fluor Fernald CM and QA and/or the appropriate contractor were notified of deficiencies in construction practices and/or materials so that the appropriate corrective actions could be taken. The corrective actions were monitored and/or tested by CQA personnel to assure compliance with the Project Documents.

As previously indicated in Section 2, IT was the prime contractor for construction of the OSDF Phase III - Cell 1 final cover construction project from April 2000 to March 2001. At the end of this period, construction was not completed for the following items:

- topsoil placement, seeding, and erosion mat installation along the access corridors and junction boxes used for installation of the final cover monitoring system;

- removal of silt fences, and repairs to the grades and erosion mats at silt fence locations; and
- installation of the LDS, LCS and RLCS pipe extensions from VH-5 stub-outs to the Cell 5 outlet.

The above items were subsequently completed, or directed, by Fluor Fernald as the weather permitted in April-May 2002, and were periodically monitored and documented by CQA personnel.

Upon substantial completion of construction and testing of each phase or component of the Cell 1 final cover project, including review of surveyor's certification data, progress reports and test results summaries were prepared and submitted to Fluor Fernald. Copies of these summaries are included in the appendices to this report. Therefore, this final certification report includes all construction required by the Project Documents for the Phase III – Cell 1 final cover construction project, with the exception of those listed below.

Items that were completed during the Phase III – Cell 1 final cover construction project but are not included in this CQA final report include the following:

- results of conformance testing performed on screened clay liner and cap material stockpiles for future Cells 4 and 5 liners construction;
- results of pre-conformance testing conducted on test pit samples in the remaining EFBA for future screening and use as clay liner and cap materials for future OSDF cell liner and cap construction projects; and
- other miscellaneous construction work performed by Fluor Fernald and/or its subcontractors during the 2001-2002 construction season.

The pre-conformance and conformance test results will be included in the CQA final reports for the appropriate cell liner or final cover system construction projects.

3.1.4 Final Report

Record drawings and this final CQA report were prepared as the final task of the CQA program. This final report summarizes the CQA monitoring, testing, and documentation activities performed by GeoSyntec.

During construction, documentation of on-site CQA activities was maintained by CQA personnel. Daily documentation consisted of daily field reports and testing and

monitoring logs. These documents were used to prepare weekly field summaries. CQA personnel also documented the results of on-site geotechnical laboratory testing and reviewed results of off-site geotechnical laboratory testing conducted as part of the CQA program. In addition, manufacturer quality control (QC) certificates and test results for the geosynthetics and other final cover system materials were provided to GeoSyntec for review; these documents are included in the appendices to this final report. Descriptions of the construction activities and the CQA documentation are presented in the narrative sections of this report.

Volume I of this CQA report contains the narrative sections of the report and Appendix A. Volume II of this report contains Appendices B and C; Volume III contains Appendix D; Volume IV contains Appendices E through H; Volume V contains Appendices I through P; and Volume VI contains Appendices Q through T. A summary of the documentation included in the appendices to the final report is provided below:

- Appendix A: Photographic Documentation
- Appendix B: Weekly Field Reports, Meeting Minutes, and Correspondence
- Appendix C: Personnel Logs
- Appendix D: Geotechnical Laboratory Test Results
- Appendix E: Manufacturers' Quality Control Documentation
- Appendix F: Field Moisture/Density Test Results
- Appendix G: Geosynthetic Conformance Test Results
- Appendix H: Contractor's Certification of Acceptance of Subgrade Surface
- Appendix I: Geomembrane Panel Placement Monitoring Logs
- Appendix J: Geomembrane Trial Seam Logs
- Appendix K: Geomembrane Production Seam Logs

- Appendix L: Geomembrane Destructive Seam Test Logs and Laboratory Test Results
- Appendix M: Geomembrane Repair Summary Logs
- Appendix N: Geomembrane Seam and Repair Location Logs
- Appendix O: Electrical Leak Detection Test Report
- Appendix P: As-Built and Geomembrane Record Drawings
- Appendix Q: HDPE Pipe Test Logs
- Appendix R: Requests for Clarification of Information (RCIs)
- Appendix S: Design Change Notices (DCNs)
- Appendix T: Nonconformance Reports (NCRs)

3.2 Personnel

3.2.1 Project Personnel

Senior personnel or representatives for the firms involved in the project are as follows:

Department of Energy (Facility Owner)
- Jay A. Jalovec, DOE Fernald OSDF Project Manager
- Robert J. Janke, DOE Fernald SWP Team Leader
- Donald A. Pfister, P.E., DOE Fernald Facility Representative

Ohio Environmental Protection Agency (Regulatory Agency)
- Tom Ontko, Federal Facilities Oversight Representative

Fluor Fernald, Inc. (Owner's Representative)
- Tom Beasley, SDFP Deputy Director
- Tom Carr, Soils Construction Coordinator
- J.D. Chiou, Ph.D., P.E., SDFP Director
- Jeffrey R. Ellis, P.E., Construction Engineer

- Corey Fabricante, Radiological Control
- Frank Flack, Construction Contracts Manager
- Michael W. Godber, Quality Assurance Team Leader
- Donald B. Goetz, Construction Engineer
- Kevin S. Harbin, Construction Engineer
- Alan Hohnhorst, Contracts and Acquisition
- Richard A. Holbrook, Contracts and Acquisition Team Leader
- Gregg K. Johnson, Safety & Health Team Leader
- Uday A. Kumthekar, P.E., Engineering Manager
- Mike Lohre, Construction Engineer
- Lee McDaniel, Soils Construction Superintendent
- Jeffrey A. Middaugh, Safety & Health Representative
- Marty Prochaska, Technology Programs Representative
- Carlos Pratt, Cost Analyst
- James T. Turner, Quality Assurance Engineer
- Perry Richardson, Waste Acceptance Organization Representative
- Anthony Snider, Engineer
- Harold Swiger, SDFP Team Technical Specialist
- Charles C. VanArsdale, P.E., Engineer
- Muriel K. Vigus, Quality Assurance
- Paul J. Volker, Quality Assurance
- Danyel Wells, Construction Administrator
- Jerry Williams, Construction Engineer
- Samuel H. Wolinsky, P.E., OSDF Project Engineer
- Eric Woods, Natural Resources/Stewardship Manager
- William A. Zebick, OSDF Construction Manager

GeoSyntec Consultants (CQA Consultant)

- Kwasi Badu-Tweneboah, Ph.D., P.E., Project Manager
- John F. Beech, Ph.D., P.E., Principal-in-Charge
- Anthony R. Dickman, Engineering Technician
- David Evans, Engineering Technician
- Kenneth Sparks, Senior Engineering Technician
- Collin P. Sukow, CQA Site Manager
- T. Byran York, E.I.T., Senior Engineering Technician

GeoTesting Express of Georgia, Inc. (off-site geotechnical laboratory)
- Barry E. Sigmon, P.G., Laboratory Manager

GeoTesting Express of Texas, Inc (off-site geosynthetics testing laboratory)
- Neelam Asher, Laboratory Manager

Golder Associates, Inc. (off-site soil-geosynthetic interaction testing)
- Henry Mock, Laboratory Manager

The IT Corporation, Inc (Contractor, key personnel only)
- Joey Allen, Superintendent
- Jeff Bodi, General Superintendent
- Pete Bolig, Safety & Health Representative
- Jeff Browning, Labor Foreman
- David Lockerd, QC Manager/Project Engineer
- Con Murphy, Vice-President of Operations
- John Nenni, Project Manager
- Dave Sablosky, Contract Administrator
- Dave Tester, Project Manager

The Istre Company, Inc. (Geosynthetics Installer, key personnel only)
- Jerry Istre, Superintendent
- Joseph Beebout, Master Seamer
- Tracy Marker, QC Inspector
- Justin McElhorne, QC Welding Technician

Leak Location Services, Inc. (Subcontractor, key personnel only)
- Glenn T. Darilek, P.E., Project Manager
- Hector Hernandez, Field Technician
- Martin Morales, Senior Lead Technician

GeoSystems Analysis, Inc. (subcontractor)
- Joe Vinson, Project Manager

Fred DeBra Company (Subcontractor, key personnel only)
- Barry Brinkman, Piping Foreman
- Mark Huber, Piping Foreman

David E. Estes Engineering, Inc. (Contractor's Surveyor)

- Lynn E. Hirsch, P.L.S., Senior Professional Land Surveyor
- Thomas J. Mack, P.S., E.I.T., Project Surveyor and Engineer

3.2.2 GeoSyntec's On-Site Personnel Schedules

GeoSyntec project personnel were present on site according to the following schedules:

K. Badu-Tweneboah, Ph.D., P.E., Project Manager	05 March 2001 – 31 May 2002
C.P. Sukow, CQA Site Manager	05 March 2001 - 14 December 2001 02 January 2002 – 31 May 2002
David Evans, Engineering Technician	05 March 2001 - 05 November 2001 12 November 2001 – 03 December 2001 13 December 2001 – 31 May 2002
Mike Humphreys, Engineering Technician	16 April 2001 - 04 May 2001
Anthony Dickman, Engineering Technician	05 March 2001 – 21 December 2001 01 April 2002 – 31 May 2002
Ken Sparks, Senior Engineering Technician	05 March 2001 - 20 April 2001 04 May 2001 - 22 May 2001 26 June 2001 - 20 November 2001 09 April 2002 – 31 May 2002
T. Byran York, E.I.T., Senior Engineering Technician	05 March 2001 - 20 April 2001 04 May 2001 - 22 May 2001 26 June 2001 – 24 December 2001 02 January 2002 – 22 April 2002
Sheila Abney, Administrative Assistant	05 March 2001 – 31 May 2002

4. GENERAL DOCUMENTATION

Documentation and record drawings on the results of the CQA monitoring and testing activities performed by GeoSyntec are contained in the appendices to this report. GeoSyntec's on-site CQA personnel used photographs to record significant events and progress of work during construction of the Phase III - Cell 1 final cover project. Photographic documentation of the construction activities is presented in Appendix A.

GeoSyntec's on-site CQA personnel recorded daily events, site conditions, construction progress, and communications on Daily Field Reports. The daily reports prepared by the CQA personnel are not included in the appendices; however, they can be made available upon request. Weekly reports of construction progress prepared by the CQA Site Manager and Resident Engineer are included in Appendix B.

GeoSyntec's key CQA personnel also attended the Weekly Contractor Coordination meetings to discuss construction-related issues and schedules, and review project requirements. Representatives from DOE, OEPA, Fluor Fernald, IT Corporation, and GeoSyntec attended these meetings. The minutes from these meetings, and other correspondence related to the Phase III - Cell 1 final cover construction project, are included in Appendix B.

Results of CQA monitoring, testing, and documentation performed by CQA personnel during the OSDF Cell 1 final cover construction were recorded on the appropriate monitoring and data forms presented in the appendices. The relevant appendices will be referenced in this CQA final report.

During construction of the OSDF Cell 1 final cover, RCIs and DCNs that provided design changes and clarifications to the CFC Drawings and Specifications were processed and approved according to procedures described in FEMP Document No. ED-12-5002 titled "Engineering Design Change Process." RCIs and DCNs were approved, as appropriate, by the design organization and the Regulatory Agency. Copies of the RCIs and DCNs are presented in Appendix R and Appendix S, respectively.

Finally, all non-conformances associated with the construction were resolved through disposition by the Fluor Fernald CM, Engineering and QA, with concurrence, where appropriate, by the GeoSyntec CQA personnel. Copies of the non-conformance reports (NCRs) that were written during the Phase III - Cell 1 final cover construction project are included as Appendix T to this CQA final report.

5. CONSTRUCTION QUALITY ASSURANCE – EARTHWORK

5.1 General

GeoSyntec monitored the construction of the earthwork components associated with the OSDF Phase III – Cell 1 final cover construction project. The components of the project completed during the construction period consisted of Cell 1 final cover system construction; installation of the HDPE pipes for the Cells 4 and 5 horizontal monitoring wells and dual-containment pipe extensions from VH-4 and VH-5 stub-outs to Cells 4 and 5 outlets, respectively; and excavation, screening of clay liner and cap material, and interim restoration of the OSDF borrow area Sub-areas 1 and 2. Different earthwork materials were used to construct the various components of the projects. These materials included existing subgrade material, compacted fill, contouring layer material, compacted clay cap, cover drainage material, biointrusion barrier and choke stone materials, granular filter, vegetative soil layer, topsoil, road base aggregate, riprap, and pipe embedment fill material. The earthwork construction activities using these materials are generally described below.

- Repairs were made to the select impacted material layer that was damaged from erosion. Fill material proposed for the contouring layer were used to repair the eroded surface of the select impacted material layer. A low ground pressure (LGP) bulldozer was used for placement, compaction and grading of the soil to complete the erosion repairs.

- The surface of the Cell 1 select impacted material layer was scarified by tracking with a bulldozer. Contouring layer material was placed and compacted in lifts to the design grades. The contouring layer material consisted of compacted fill, which was obtained from designated stockpiles or other borrow sources within the construction area. The contouring layer was placed in approximately 7- to 10-in. (180- to 250-mm) thick (maximum) loose lifts and compacted to a minimum degree of compaction of 95 percent of the maximum dry unit weight, as determined by the standard Proctor compaction test (i.e., American Society for Testing and Materials (ASTM) D 698). The material was compacted at a moisture content between 3 percent dry and 3 percent wet of the optimum moisture content (OMC) measured in the standard Proctor compaction test (ASTM D 698).

- The top of the contouring layer was proofrolled by using a loaded articulated dump truck and visually monitored by CQA personnel. Isolated areas of soft or

loose materials were either dried and compacted or undercut and replaced with contouring layer material, which was compacted as described above.

- The 2-ft (0.6-m) thick compacted clay cap for the Cell 1 final cover system was constructed using 8-in. (200-mm) thick (maximum) loose lifts; with the exception of the first lift which was placed as a 10-in. (200-mm) thick loose lift. This initial 10-in. (200-mm) thick loose lift resulted in a compacted lift thickness of about 6 in. (150 mm) when measured to the bottom of the pad foot indentation, and about 2 in. (50 mm) of material between compactor foot indentations. (This latter material was included in the second lift.) The compacted clay cap material was obtained from the screened clay material stockpiles in the east field borrow area (EFBA). Each lift was compacted to a minimum degree of compaction of 95 percent of the maximum dry unit weight, as determined by the standard Proctor compaction test (ASTM D 698). The compacted clay cap was compacted at moisture content between +0 and +3 percent of the OMC measured in the standard Proctor compaction test (ASTM D 698). The field moisture content and dry unit weight were also required to fall within the acceptable permeability zone (APZ) established for each clay stockpile, in accordance with the Technical Specifications, CQA Plan, the Test Pad Program Final Report (TPPFR) and the TPPFR Addendum. The APZ criteria were used to assure a hydraulic conductivity of less than 1×10^{-7} cm/s. Clay materials used for construction of the compacted clay cap were approved through conformance testing which included remolded hydraulic conductivity testing on composite samples from each stockpile in the off-site geotechnical laboratory and the establishment of an APZ for each clay stockpile.

- The cover drainage layer, which varied in thickness from 1 ft (0.3 m) on the Cell 1 final cover to 2 ft (0.6 m) along the perimeter, was constructed using material obtained from off-site borrow sources. The cover drainage layer material was approved through conformance testing of samples and review of supplier's certification test results. The material was placed and compacted in approximately 12-in. (300-mm) thick lifts using an LGP bulldozer, and 3-ft (0.9-m) thick haul roads were used for heavy traffic loads in order to protect the underlying geosynthetics.

- The 3-ft (0.9-m) thick biointrusion barrier and choke stone layer was constructed using materials obtained from off-site borrow sources. The biointrusion barrier material was placed in lifts and the final surface was choked with the choke stone material. The biointrusion barrier and choke stone materials were approved

through conformance testing of samples and review of supplier's certification test results.

- The 6-in. (150-mm) thick granular filter layer was constructed using material obtained from off-site borrow sources; the material was approved through conformance testing of samples and review of supplier's certification test results. The granular filter layer was placed in one loose lift and compacted with a LGP bulldozer.

- The vegetative soil layer was constructed to the design grades using 7- to 9-in. (175- to 225-mm) thick loose lifts. Each lift was compacted to a minimum degree of compaction of 92 percent of the maximum dry unit weight and at moisture contents between –4 to +4 percent of the OMC, as determined by the standard Proctor compaction test (ASTM D 698). The vegetative soil layer material consisted of fill material, which was obtained from designated stockpiles within the construction area and from the brown-gray till in the EFBA. Fill materials used for the vegetative soil layer construction were approved through conformance testing of samples in accordance with the requirements of the Project Documents.

- The 6-in. (150-mm) thick topsoil layer was constructed using material obtained from designated stockpiles within the construction area. Topsoil material was approved through conformance testing of samples in accordance with the requirements of the Project Documents. The topsoil layer was placed in one loose lift and compacted with a LGP bulldozer.

- Base aggregate material was used to construct the monitoring access as required by Phase III DCN No. 20103-022. The material was obtained from off-site borrow sources, and was approved through review of supplier's certification test results. The base aggregate material was placed and compacted in general accordance with Items 304.04 and 304.05 of Ohio Department of Transportation (ODOT) Specifications, to meet the requirements of the Technical Specifications.

- Riprap was used to construct drainage channel linings, placed around the final cover/monitoring access interface, and also used for temporary slope protection and other surface-water management and erosion control (SWMEC) measures. The riprap materials (both Type C and D Dumped Rock Fill) were obtained from off-site borrow sources, and were approved through review of suppliers'

certification test results. The riprap materials were placed in accordance with the requirements of the Technical Specifications.

CQA personnel monitored these earthwork construction activities and performed the appropriate geotechnical testing on the soil materials to confirm that the material properties conformed to the Project Documents, that the specific lift thicknesses were not exceeded, and that the materials were placed and compacted in accordance with the Project Documents. Geotechnical testing was performed and documented by CQA personnel. The testing was carried out either: (i) in-place; (ii) on-site, in the geotechnical laboratory; or (iii) off-site testing laboratory.

5.2 Changes in Earthwork Specifications

RCIs and DCNs of the earthwork drawings and specifications were processed and approved according to procedures described in FEMP Document No. ED-12-5002 titled "Engineering Design Change Process". RCIs and DCNs were approved, as appropriate by the design organization and the regulatory agency (i.e., OEPA). Copies of the RCIs and DCNs for the Phase III - Cell 1 final cover construction project are presented in Appendices R and S, respectively.

5.3 Pre-Conformance Testing Activities

Samples of the brown till were collected from the east field borrow area (EFBA) for the purpose of identifying candidate materials suitable to be screened for use as clay liner and cap material. The samples were collected from test pits evenly spread throughout the section of the borrow area to be screened. Test pits ranged in depth from 4 to 9 ft (1.2 to 2.7 m), with soil samples collected at approximately 2 ft (0.6 m) intervals.

The collected samples were visually described and the test pits were logged. Test pit logging included the interface between topsoil, brown till, and the gray till as well as any major features such as sand lenses and perched water that were encountered. The samples were tested for moisture content (ASTM D 2216), particle-size analyses (ASTM D 422), and Atterberg limits (ASTM D 4318). The Unified Soil Classification System (USCS) was used to classify the samples in general accordance with ASTM D 2487.

The results of the pre-conformance sampling and testing for screening clay liner and cap material from sub-areas 1 and 2 of the EFBA are presented in Appendix D.

5.4 Conformance Testing Activities

5.4.1 General

Soil samples were obtained from proposed sources, prior to construction, to verify conformance with the Project Documents for each material type. Also during construction, soil samples were obtained from the delivered material for conformance testing, as required by the Project Documents. CQA personnel obtained representative samples of fill material (for compacted fill, contouring layer, and vegetative soil layer), compacted clay cap material, granular drainage layer materials (cover drainage, biointrusion barrier and choke stone, and granular filter layers), and topsoil from the appropriate source depending on the material type.

Fill material, used in Cell 1 final cover construction for the contouring layer, vegetative soil layer and compacted fill, was obtained from designated stockpiles within the OSDF construction areas and from the brown-gray till within the EFBA. Compacted clay cap material was obtained from the screened clay material stockpiles in the EFBA. Topsoil was also obtained from on-site designated stockpiles within the construction area.

The granular materials were obtained from off-site sources. The cover drainage layer material (AASHTO No. 78 crushed aggregate) was obtained from Highland Stone (Highland) quarry located in Hillsboro, Ohio. The biointrusion barrier layer material (ODOT Type D Dumped Rock Fill) was obtained from the Highland quarry and Eagle Crushed Stone (Eagle) quarry located in Winchester, Ohio. The biointrusion choke stone material (AASHTO No. 57 crushed aggregate) was obtained from the Eagle quarry in Winchester, Ohio. The granular filter material (ODOT Type A-3 Sand) was obtained from the Welch Sand & Gravel, Inc. (Welch) plant in Ross, Ohio.

The base aggregate material (ODOT No. 304 aggregate) was also obtained from the Welch quarry in Ross, Ohio. The Type C riprap material was obtained from New Point Stone Co., Inc. (New Point) quarry located in Greensburg, Indiana. The additional Type D riprap materials, used for channel lining and other SWMEC measures, were also obtained from Highland quarry in Hillsboro, Ohio and the Eagle quarry in Winchester, Ohio.

5.4.2 Test Methods

The following geotechnical tests, when appropriate, were performed on each of the soil components of the Cell 1 final cover system:

- Moisture content tests were performed on samples of compacted fill, contouring layer, vegetative soil layer, and compacted clay cap materials. The tests were performed in general accordance with ASTM D 2216.

- Particle-size distribution tests were conducted on the fine-grained soils used for compacted fill, contouring layer, compacted clay cap, vegetative soil layer, and topsoil. The tests were performed in general accordance with ASTM D 422. Atterberg limits tests were performed in general accordance with ASTM D 4318. The USCS was used to classify the materials in general accordance with ASTM D 2487.

- Standard Proctor compaction tests were conducted on the soils used for compacted fill, contouring layer, vegetative soil layer, and compacted clay cap. The tests were performed in general accordance with ASTM D 698. Modified Proctor compaction tests were also performed on the clay cap material in general accordance with ASTM D 1557. The standard and modified Proctor compaction tests were used to establish the "line of optimums" for each clay material stockpile as part of establishing the modified APZ.

- Hydraulic conductivity tests were performed on the compacted clay cap material. Tests were conducted on remolded individual and composite samples of screened clay cap material from each stockpile. The remolded hydraulic conductivity tests were conducted in general accordance with ASTM D 5084. The results of the hydraulic conductivity tests on composite samples were used to verify the established APZ for each clay material stockpile.

- Organic content tests were performed on samples of the topsoil in general accordance with ASTM D 2974.

- Particle-size distribution tests were performed on samples of the coarse-grained soils used for the cover drainage layer, granular filter, and biointrusion choke stone in general accordance with ASTM C 136. The USCS was used to classify the materials in general accordance with ASTM D 2487.

- Carbonate content tests and hydraulic conductivity tests were conducted on the cover drainage layer material. The tests were performed in general accordance with ASTM D 3042 and ASTM D 2434, respectively.

- Bulk specific gravity and absorption tests were conducted on the biointrusion barrier and choke stone materials in general accordance with ASTM C 127.

The results of the geotechnical laboratory tests performed on the soil materials used for the Phase III – Cell 1 final cover construction project are presented in Appendix D, and summarized below.

5.4.3 Summary of Geotechnical Test Results

5.4.3.1 Compacted Fill

A total of 13 index tests (i.e., moisture content, particle-size distribution, Atterberg limits and classification tests) were performed on compacted fill material. The compacted fill material used in construction classified as GC, SC, SM, ML or CL according to the USCS when evaluated in accordance with ASTM D 2487 and the maximum particle size was 5.0 in. (130 mm). Compacted fill used for the contouring layer had a maximum particle size of 4.0 in. (100 mm). A total of 13 standard Proctor compaction tests were performed on fill materials used as compacted fill and for the contouring layer.

Table 5-1 presents a summary of the geotechnical tests conducted on the fill materials used as compacted fill and for the contouring layer. Compacted fill was also used as trench backfill for the Cells 4 and 5 horizontal monitoring well pipes and the extensions of the dual-containment pipes from VH-4 and VH-5 stub-outs to Cells 4 and 5 outlets, respectively; and for the protective layer in the temporary termination of Cell 1 final cover.

5.4.3.2 Compacted Clay Cap

As required by the Project Documents, clay materials conforming to pre-conformance testing criteria (see Section 5.3) were screened prior to conformance testing. Screened clay material meeting the clay liner and cap material requirements of the Technical Specifications is referred to as clay liner and cap material and used for the compacted clay cap construction. A total of four (4) screened clay material stockpiles, with in-place volumes (ICY) ranging from approximately 4,870 to 7,150 yd^3 (3,720 to 5,460 m^3), were used for the Cell 1 final cover construction. The screened clay material

stockpiles were designated and labeled as Stockpiles 00-1, 00-2, 00-3, and 00-4 in the EFBA. Conformance testing was performed on each clay material stockpile, in accordance with the Project Documents.

Index and standard Proctor compaction tests were performed at a minimum frequency of one set per 1,500 yd^3 (1,150 m^3) of stockpiled clay cap material. A total of 18 index tests were performed on the compacted clay cap material to verify that the consistency of the material corresponded to the requirements of the Technical Specifications. The tests indicated a variation in the plasticity index (PI) between 10 and 18, and a variation in clay content (i.e. percent of particles, by weight, finer than 0.002 mm) between 17 and 27 percent. The particle-size distribution and Atterberg limits tests all resulted in a classification of CL (i.e., lean clay) for the clay cap material, according to the USCS.

A total of 18 standard Proctor compaction tests and 10 modified Proctor compaction tests were performed on the stockpiled clay material to establish the average moisture-density relationship, including the line of optimums, for each clay material stockpile.

Off-site geotechnical laboratory hydraulic conductivity tests were performed on remolded individual and composite samples of the clay cap material from each stockpile. The composite samples were obtained on a minimum frequency of one per stockpile or one per 10,000 yd^3 (7,600 m^3) of clay liner material, in accordance with the CQA Plan and Technical Specifications. A total of five (5) remolded hydraulic conductivity tests were performed on four composite samples with each sample being representative of each clay material stockpile. Remolded hydraulic conductivity testing was also performed on six (6) individual samples from select samples to facilitate in the stockpile approval.

The results of the geotechnical laboratory conformance testing performed on the screened clay cap material stockpiles, including the established APZ for each stockpile, are presented in Appendix D. A summary of compacted clay cap material properties is presented in Table 5-2, which indicates that the clay cap material meets the requirements of the Project Documents.

5.4.3.3 Cover Drainage Layer

On-site laboratory particle-size distribution tests were performed on twelve (12) samples obtained from the on-site stockpile for the cover drainage layer material. The laboratory particle-size distribution test results are presented in Appendix D. GeoSyntec

also performed off-site laboratory hydraulic conductivity tests and carbonate content tests on representative samples of the cover drainage layer material. A summary of the testing requirements for the cover drainage layer material is presented in Table 5-3.

Based on the testing performed, the granular drainage material used in construction of the cover drainage layer classified as GP (i.e., poorly graded gravel) according to the USCS (ASTM D 2487); had 100 percent passing a 0.75 in. (19 mm) opening sieve when tested in accordance with ASTM C 136; generally met gradation requirements for No. 78 stone (except for four samples as indicated in Table 5-3); had a carbonate content of less than or equal to 5 percent when tested in accordance with ASTM D 3042 modified with a pH of 4; and the hydraulic conductivity (i.e., permeability) requirement was 0.1 cm/s or greater when evaluated in accordance with ASTM D 2434. The failing results were approved through further evaluation via NCR No. 20103-002 and 20103-003, as indicated on Table 5-3 and Appendix T. The results of the laboratory tests on the cover drainage layer material are presented in Appendix D.

5.4.3.4 Biointrusion Barrier and Choke Stone

The biointrusion barrier material was tested by the supplier (Highland and Eagle) and met the requirements of Type D Dumped Rock Fill, as required by the Project Documents. Additionally, a total of four (4) bulk specific gravity and absorption tests were conducted on the biointrusion barrier material to comply with the conformance testing requirements of the Project Documents. The results of the tests on the biointrusion barrier material are presented in Appendix D and summarized in Table 5-4.

As indicated in Table 5-4, two of the samples failed to meet the minimum bulk specific gravity of 2.6. The failing results were approved through further evaluation via NCR No. 20103-005, as indicated on Table 5-4 and Appendix T.

Two (2) particle-size distribution tests (ASTM C 136), bulk specific gravity tests (ASTM C 127) and absorption tests (ASTM C 127) were conducted on the biointrusion barrier choke stone. Test results are presented in Appendix D, and summarized in Table 5-5. The choke stone material used in construction of the biointrusion barrier layer classified as GW or GP according to the USCS when evaluated in accordance with ASTM D 2487; had 100 percent passing a 1.5 in. (38 mm) opening sieve when tested in accordance with ASTM C 136; generally met gradation requirements for AASHTO No. 57 stone; had a minimum bulk specific gravity of 2.60 when tested in accordance with ASTM C 127; and a maximum absorption of 2 percent when evaluated in accordance with ASTM C 127.

5.4.3.5 Granular Filter Layer

A total of two (2) index tests (particle-size distribution and classification tests) were performed on the granular filter layer material. The material classified as SP according to the USCS and met the requirements of the Project Documents. Test results are presented in Appendix D and summarized in Table 5-6.

5.4.3.6 Vegetative Soil Layer

A total of seven (7) index tests (i.e., moisture content, particle-size distribution, Atterberg limits and classification tests) were performed on vegetative soil layer material. The material used in construction classified as GC, SC, or CL according to the USCS (ASTM D 2487) and the maximum particle size was 4.0 in. (100 mm). A total of seven (7) standard Proctor compaction tests were performed on fill materials used as vegetative soil layer. Table 5-7 presents a summary of the geotechnical tests conducted on the fill materials used as vegetative soil layer. Test results are presented in Appendix D.

5.4.3.7 Topsoil

A total of two (2) index tests and organic content tests were performed on samples of the topsoil used for construction of the Cell 1 final cover. Test results are summarized in Table 5-8, which indicate that the topsoil had a minimum organic content of 2 percent when tested in accordance with ASTM D 2974. Test results are presented in Appendix D.

5.5 Field Monitoring Activities

5.5.1 General

GeoSyntec's CQA personnel monitored the placement of soil as previously described. Potentially nonconforming or questionable practices observed by CQA personnel were brought to the attention of the Construction Manager for review and correction.

5.5.2 Repairs to Select Impacted Material Layer

CQA personnel monitored repairs to the erosion damage to the select impacted material layer. Fill material proposed for the contouring layer were used to repair the eroded surface of the select impacted material layer. A low ground pressure (LGP)

bulldozer was used for placement, compaction and grading of the soil to complete the erosion repairs. The surface of the select impacted material layer was then scarified by tracking with the LGP bulldozer prior to placement of the contouring layer.

5.5.3 Contouring Layer

5.5.3.1 Material

The contouring layer across Cell 1 was constructed directly above the select impacted material layer. The contouring layer material consists of fill material from on-site borrow sources described in Section 5.4. The results of standard Proctor compaction tests performed on select compacted fill material (see Appendix D) were used as reference for the compaction and testing of the contouring layer.

5.5.3.2 Construction Procedure

The minimum 1-ft (0.3-m) thick contouring layer was constructed in two lifts, with the first lift being of a 10 in. (250 mm) loose thickness. Each lift was compacted to a minimum degree of compaction of 95 percent of the maximum dry unit weight and within ±3 percent of the OMC, as determined by the standard Proctor compaction test (ASTM D 698). The fill material was placed in controlled lifts using Volvo A35C articulated dump trucks and using Caterpillar D-6 LGP bulldozers to spread the material. The horizontal lifts were compacted using a Caterpillar 815 sheepsfoot compactor and sealed with a CS smooth drum roller. During placement and compaction, CQA personnel monitored the contractor's activities, including removal of visible rock particles larger than 4 in. (100 mm) and limiting clod size to 3 in. (75 mm) or less, as required by the Project Documents.

5.5.3.3 Field Testing Activities

Geotechnical Testing

CQA personnel performed in-place nuclear moisture/density tests on compacted lifts of contouring layer. These tests were performed in general accordance with ASTM D 2922 and ASTM D 3017. A total of 81 field nuclear moisture/density tests were performed on the contouring layer. The resulting frequency is 1.4 tests/10,000 ft^2/lift, which exceeds the minimum frequency of 1 test/10,000 ft^2/lift required by the CQA Plan (see Table 5-1). In addition, four (4) drive cylinder tests (ASTM D 2937) were performed as correlation tests to meet the minimum testing frequency of 1 test per 25 nuclear moisture/density tests.

The results of each field nuclear moisture/density tests were compared to the project requirements of a minimum degree of compaction of 95 percent of the maximum dry unit weight and within ±3 percent of the OMC, as determined by the standard Proctor compaction test (ASTM D 698). All tests passed this performance testing criteria. The holes left from the moisture/density tests were filled with soil-bentonite mixture. The results of the field moisture/density tests performed on the contouring layer are presented in Appendix F.

Proofrolling

Following completion of the contouring layer construction, IT proofrolled the surface of the contouring layer to detect soft or loose zones, as required by the Project Documents. The proofrolling was performed using a loaded Volvo A35C articulated dump truck with a minimum loaded weight of 20 tons (20.3 tonnes). During proofrolling, the surface was monitored by CQA personnel to confirm the firmness of the top of contouring layer for placement of the compacted clay cap.

5.5.3.4 Certification

The surveyed areas of the surface of the contouring layer were found to be within the project tolerance of -0.3 to +0.1 ft (-0.09 to +0.03 m) from the design elevations, with a minimum thickness of 1 ft (0.3 m), as required by the Project Documents (including DCN No. 20103-013 and NCR No. 20103-004). The as-built top of contouring layer certification drawings, prepared by Payne and Estes (IT's surveyors), are included in Appendix P.

5.5.4 Compacted Clay Cap

After completing the contouring layer construction operations, CQA personnel monitored the placement and compaction of the clay cap material by IT. The compacted clay cap consisted of a minimum of 2 ft (0.6 m) thick layer, as shown on the CFC Drawings, placed and compacted in lifts, as described below.

5.5.4.1 Materials

The compacted clay cap was constructed using clay liner and cap material from the on-site screened clay material stockpiles (00-1 to 00-4) in the EFBA described in Section 5.4. As previously described, clay liner and cap materials used for the compacted clay cap were: (i) processed on-site using a bar screening plant and stockpiled in preparation for transportation to the Cell 1 construction area; (ii) a water

bar attachment on the screening plant added water to the material to hydrate the clay and maintain the moisture content within the stockpile; and (ii) each stockpile was approved through conformance testing which included hydraulic conductivity testing of remolded composite samples from each stockpile in an off-site geotechnical laboratory and establishment of an APZ (see Appendix D).

5.5.4.2 Construction Procedure

Construction of the compacted clay cap was performed in accordance with the Project Documents and patterned after the Test Pad Program. Two compacted clay liner/cap test pads were constructed prior to the construction of the Cell 1 compacted clay liner. The results of the test pad program were used to develop the specifications for compacted clay liner and cap materials and construction. The test pad program is described in a report entitled "Test Pad Program Final Report", Revision 0, dated June 1997. A "Test Pad Program Final Report Addendum No. 1", Revision 0, dated January 1999 modified the left boundary of the APZ from the 90% degree of saturation line to a line defined by the "line of optimums" for the clay liner and cap material in use. This modified APZ was established for each stockpile that was used for the compacted clay cap construction for Cell 1 final cover system. The construction sequence of the compacted clay cap is described below:

- the contouring layer surface and the top surface of each lift of compacted clay was scarified using a HAMM RACO 250 soil stabilizer; other areas that were inaccessible with the soil stabilizer were scarified with the tracks of a Caterpillar D-6 LGP bulldozer;
- the clay liner and cap material was hauled from each stockpile in the EFBA by articulated dump trucks and placed in the cell;
- the compacted clay was spread in approximately 7- to 8-in. (180- to 200- mm) thick (loose) lifts using a D-6R bulldozer;
- after spreading, the soil stabilizer was used to break up clods of compacted clay; water was added as necessary to increase the moisture content of the clay material within 0 to +3 percent of the OMC as determined by the standard Proctor compaction test (ASTM D 698);
- after each lift was stabilized using the soil stabilizer, visible rock particles greater than 2 in. (50 mm) in size were removed by laborers;

- each lift of compacted clay was compacted using a Caterpillar 815 sheepsfoot compactor making a minimum of six one-way passes;
- lift thickness was controlled for the first lift by grade stakes placed by the contractor at an approximate spacing of 50 ft (15 m); CQA personnel visually monitored the placement and compaction of the compacted clay relative to these stakes to provide a check of lift thickness; the stakes were removed immediately before the material adjacent to the stakes was compacted; subsequent lifts were visually monitored by the contractor using traffic cones for grade control;
- a D-6 LGP bulldozer was used in conjunction with a laser plane survey system to grade the compacted clay cap surface;
- the final grade was rolled with a vibratory smooth drum roller to seal the top surface of the compacted clay cap; and
- after final grading of the compacted clay surface, the surveyor confirmed final grade elevations.

The compacted clay cap was generally constructed in four compacted lifts to a total thickness of 2 ft (0.6 m), as shown on the CFC Drawings. The contractor periodically added water during or after compacted clay cap placement and compaction to limit drying or desiccation cracking of the surface.

GeoSyntec CQA personnel monitored the compacted clay cap placement and compaction process described above. CQA personnel visually monitored that IT utilized six or more passes with the compactor across the clay cap lift. CQA personnel also visually monitored that IT protected completed compacted clay cap from significant drying or the surface from desiccation cracking by routine watering and sealing with the smooth drum roller. If significant drying or cracking of the compacted clay cap surface was observed, the contractor was instructed to moisture condition and rework the affected area.

In late June 2001, when construction of the compacted clay cap was considered by IT to be completed, CQA personnel expressed concern about the thickness of the compacted clay cap at the toe of the Cell 1 final cover (i.e., Area 2 on the CFC Drawings). Fluor Fernald CM directed the contractor to excavate test pits to verify the thickness of the compacted clay cap in the toe. The excavated test pits confirmed that the compacted clay cap did not meet the minimum thickness of 2 ft (0.6 m) required by

the Project Documents. Apparently, during repairs to the select impacted material layer and construction of the contouring layer, excess material had been placed in Area 4 of the CFC Drawings to the extent that the minimum 2 ft (0.6 m) thickness for the compacted clay cap could not be achieved. (It should be noted that survey of the select impacted material layer and contouring layer surfaces were performed by Payne, (IT's initial surveyor), who was later replaced by Estes.)

Fluor Fernald CM subsequently directed the contractor to reconstruct the compacted clay cap at the toe of Cell 1 final cover. The reconstruction included removal of the excess contouring layer material, survey certification of the revised contouring layer grades at the toe, and placement and compaction of clay cap material in lifts as previously described above.

CQA personnel monitored and documented the reconstruction of the compacted clay cap at the toe of the Cell 1 final cover. Documentation on the toe reconstruction is documented in the Daily Field Reports and Field Monitoring Logs (in Appendix F), and also in Appendix B (Correspondence) of this CQA final report.

5.5.4.3 Field Testing Activities

CQA personnel performed in-place nuclear moisture/density tests as the clay cap material was placed and compacted. The tests were performed in general accordance with ASTM D 2922 and ASTM D 3017. For the maximum disturbed area of approximately 6 acres (2.4 hectares), a minimum of 30 tests per lift were needed to meet the minimum frequency of 5 tests per acre (12 tests per hectare) per lift required by the Project Documents for the Cell 1 compacted clay cap (see Table 5-2). A total of 301 field moisture/density tests were performed on the Cell 1 compacted clay cap. In addition, 12 drive cylinder tests (ASTM D 2932) were performed as correlation tests to meet the minimum testing frequency of 1 test per 25 nuclear moisture/density tests. The results of each field moisture/density test were checked to see if it was within the established APZ for each clay liner and cap material stockpile, as required by the Project Documents. A total of 18 tests failed to meet the minimum degree of compaction requirement of 95 percent of the maximum dry unit weight and at moisture content of 0 to 3 percent of the OMC, as determined by the standard Proctor compaction tests and within the established APZ. For each failed test, the contractor reworked and recompacted the area surrounding the failure and then CQA personnel retested the area. This procedure was repeated until satisfactory moisture/density test results were obtained. The results of the field moisture/density tests are presented in Appendix F. The holes left from the moisture/density tests, were filled with bentonite granules and

clay liner and cap material. The mixture was manually compacted in the holes using a steel rod.

5.5.4.4 Certification

The surveyed areas of the surface of the compacted clay cap were found to be within the tolerances of +0.0 to +0.3 ft (+0.0 to +0.09 m) of the thickness and within ±0.2 ft (±0.06 m) of the grades shown on the CFC Drawings. The as-built compacted clay cap certification drawing, prepared by Estes (IT's surveyor), is included in Appendix P.

5.5.5 Cover Drainage Layer

5.5.5.1 Material

CQA personnel monitored the placement of the cover drainage layer material for the Cell 1 final cover. The cover drainage layer was constructed using granular material obtained from Highland Stone, as described in Section 5.4. The cover drainage material was stockpiled in an area west of the Cell 1 final cover construction area.

5.5.5.2 Construction Procedure

The construction sequence of the cover drainage layer was as follows:

- Volvo articulated dump trucks hauled the granular material from the stockpile to the cell area using a minimum 3-ft (0.9-m) thick haul roads constructed of the granular material;
- the granular material was spread in approximately one 1-ft (0.3-m) thick (loose) lift using Caterpillar D-6R LGP bulldozers; and
- a contractor's laborer was utilized during the spreading operation to control and prevent wrinkle formation in the underlying geosynthetics.

5.5.5.3 Field Monitoring Activities

During placement of the cover drainage layer, CQA personnel monitored the contractor's activities to assure that geomembrane wrinkling and the risk of damage to the underlying geomembrane was minimized. CQA personnel also checked that the contractor operated LGP bulldozers in areas where at least a 1-ft (0.3-m) thick layer of cover drainage layer material was maintained over the geosynthetics, and that a 3-ft

(0.9-m) thick layer of cover drainage layer material was maintained over the underlying geosynthetics in heavily trafficked areas.

5.5.5.4 Certification

Upon completion of grading and tracking using the bulldozer, the surface of the cover drainage layer was surveyed and certified by Estes. The surveyed areas of the surface of the cover drainage layer were found to be within the project tolerances of 0.0 to +0.1 ft (0 to +0.03 m) of the thickness shown on the CFC Drawings. The as-built top of cover drainage layer, prepared by Estes, is included in Appendix P.

5.5.6 Biointrusion Barrier and Choke Stone Layer

5.5.6.1 Materials

CQA personnel monitored the placement of the biointrusion barrier and choke stone layer materials for the Cell 1 final cover. The biointrusion barrier and choke stone layer was constructed using granular materials obtained from Highland Stone and Eagle Stone quarries, as described in Section 5.4. The materials were stockpiled in an area west of the Cell 1 final cover construction area.

5.5.6.2 Construction Procedure

The construction sequence of the biointrusion barrier and choke stone layer was as follows:

- Volvo articulated dump trucks hauled the biointrusion material from the stockpile to the cell area using a minimum 3-ft (0.9-m) thick haul roads constructed of the granular material;
- the biointrusion barrier material was spread in approximately one 1-ft (0.3-m) thick (loose) lift using Caterpillar D-6R LGP bulldozers;
- the choke stone material were then hauled and spread over the top of the biointrusion barrier material;
- the bulldozer and Volvo articulated dump trucks were used to compact or track-in the choke stone to the final design grades.

5.5.6.3 Field Monitoring Activities

During placement of the biointrusion barrier and choke stone layer, CQA personnel periodically monitored the contractor's activities to assure that and the risk of damage to the underlying geosynthetics was minimized. CQA personnel also checked that a 3-ft (0.9-m) thick layer of granular material was maintained over the underlying geosynthetics in heavily trafficked areas.

5.5.6.4 Certification

Upon completion of grading and tracking using the bulldozer and articulated dump trucks, the surface of the biointrusion barrier layer was surveyed and certified by Estes. The surveyed areas of the surface were found to be within the project tolerances of -0.1 to +0.3 ft (-0.03 to +0.09 m) of the thickness shown on the CFC Drawings. The as-built top of biointrusion barrier layer, prepared by Estes, is included in Appendix P.

5.5.7 Granular Filter Layer

CQA personnel monitored the placement operations for the granular filter layer. The granular filter was constructed using Type A-3 sand material obtained from off-site borrow sources, as indicated in Section 5.4. The material was placed in a nominal 6-in. (150-mm) thick loose lift and was tracked with a Caterpillar D-6R LGP bulldozer.

Upon completion of grading and tracking, the surface of the granular filter layer was surveyed and certified by Estes. The surveyed areas of the surface were found to be within the project tolerances of 0 to +0.1 ft (0 to +0.03 m) of the thickness shown on the CFC Drawings. The as-built top of granular filter layer, prepared by Estes, is included in Appendix P.

5.5.8 Vegetative Soil Layer

5.5.8.1 Material

The vegetative soil layer across Cell 1 was constructed directly above the granular filter layer. The vegetative soil layer material consisted of fill material from on-site borrow sources described in Section 5.4. The results of standard Proctor compaction tests performed on select compacted fill material (see Appendix D) were used as reference for the compaction and testing of the vegetative soil layer.

5.5.8.2 Construction Procedure

The minimum 1.75-ft (0.53-m) thick layer was constructed in three lifts, with the first lift being of a 10 in. (250 mm) loose thickness. Each lift was compacted to a minimum degree of compaction of 92 percent of the maximum dry unit weight and within ±4 percent of the OMC, as determined by the standard Proctor compaction test (ASTM D 698). The subsequent lifts of fill material was placed and spread in 8-in. (200-mm) ±1 in. (25-mm) thick loose lifts using Volvo A35C articulated dump trucks and using Caterpillar D-6 LGP bulldozers to spread the material. The horizontal lifts were compacted using the bulldozer tracks and sealed with a smooth drum roller. During placement and compaction, CQA personnel monitored the contractor's activities, including removal of visible rock particles larger than 4 in. (100 mm), roots and other deleterious material; and minimizing large clods by breaking them with the bulldozer tracks.

5.5.8.3 Field Testing Activities

CQA personnel performed in-place nuclear moisture/density tests on compacted lifts of vegetative soil layer. These tests were performed in general accordance with ASTM D 2922 and ASTM D 3017. A total of 96 field nuclear moisture/density tests were performed on the vegetative soil layer. The resulting frequency is 4.9 tests/acre/lift, which exceeds the minimum frequency of two tests/acre/lift (5 tests/hectare/lift) required by the CQA Plan (see Table 5-8). In addition, four (4) drive cylinder tests (ASTM D 2937) were performed as correlation tests to meet the minimum testing frequency of one test per 25 nuclear moisture/density tests.

The results of each field nuclear moisture/density tests were compared to the project requirements of a minimum degree of compaction of 92 percent of the maximum dry unit weight and within ±4 percent of the OMC, as determined by the standard Proctor compaction test (ASTM D 698). All tests passed this performance testing criteria. The holes left from the moisture/density tests were filled with soil-bentonite mixture. The results of the field moisture/density tests performed on the vegetative soil layer are presented in Appendix F.

5.5.8.4 Certification

The surveyed areas of the surface of the vegetative soil layer were found to be within the project tolerance of ±0.1 ft (±0.03 m) of the thickness required by the Project Documents. The as-built top of vegetative soil layer certification drawing, prepared by Estes (IT's surveyor), is included in Appendix P.

5.5.9 Topsoil

GeoSyntec's on-site CQA personnel periodically monitored the hauling and placement of topsoil over the surface of the vegetative soil layer. Topsoil placement operations were performed by IT. The topsoil material was transported from designated stockpiles in the OSDF construction area. CQA personnel periodically monitored the topsoil placement operations to assure the following:

- approved equipment was used for topsoil placement;
- the surface of the vegetative soil layer was scarified to the depths required by the Specifications and DCN No. 20103-035; and
- a minimum thickness of 6 in. (150 mm) of topsoil was placed over the vegetative soil layer.

The surveyed areas of the surface of the topsoil were found to be within the project tolerances of ±0.1 ft (±0.03 m) of the thickness and within 0 to +0.5 ft (0 to 0.15 m) of the grades required by the Project Documents. The as-built top of topsoil layer certification drawing, prepared by Estes (IT's surveyor), is included in Appendix P.

5.5.10 Vegetation

Seeding of the topsoil was performed by IT with the assistance of a landscape contractor. The seed mix and application rates are presented in Appendix E. Seeding of the one-half (western part) of the Cell 1 final cover was performed using the seed-drill method, as originally required by the Technical Specifications. The eastern half was seeded using the broadcast method in accordance with DCN No. 20103-036. Erosion mat was manually installed and stapled over the seeded topsoil in accordance with the manufacturer's recommendations and the Project Documents (see Section 6.6).

GeoSyntec CQA personnel periodically monitored the seeding and installation of the erosion mat over the Cell 1 final cover. As previously indicated the access corridors for the Cell 1 final cover monitoring instruments were not seeded by IT due to inclement weather conditions. These areas were subsequently completed by Fluor Fernald in May 2002.

TABLE 5-1

PHASE III - CELL 1 FINAL COVER CONSTRUCTION COMPACTED FILL MATERIAL PROPERTIES SUMMARY

DESCRIPTION	TEST STANDARD	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY (yd^3)	APPROXIMATE NUMBER OF TESTS REQUIRED[2]	NUMBER OF TESTS PERFORMED (FAILURES)
LABORATORY TEST					
Particle Size: Sieve	ASTM D 422	100% Finer than 5.0 in.[3]	1 per 5,000 yd^3	3	13 (0)
Compaction	ASTM D 698	---	1 per 5,000 yd^3	3	13
Moisture	ASTM D 2216 ASTM D 4643	---	1 per 5,000 yd^3	3	11
Soil Classification	ASTM D 2487	GC, SC, SM, ML, CL or CH	1 per 5,000 yd^3	3	13 (0)
Atterberg Limits	ASTM D 4318	---	1 per 5,000 yd^3	3	13
FIELD TEST					
Drive Cylinder Soil density Soil moisture	ASTM D 2937 ASTM D 2216	≥95% MDD[4] ± 3% OMC ...	1 per 25 passing nuclear tests	3	3 (0)
Nuclear Gauge: Soil density Soil moisture	ASTM D 2922 ASTM D 3017	≥95% MDD ± 3% OMC	1/10,000 ft^2/lift	30	52 (0)

NOTES:
(1) Reference Section 02200 of the Specification and Section 6 of the CQA Plan for further details.
(2) The approximate number of tests required is based on a total volume of 10,889 yd^3 for the Phase III - Cell 1 final cover construction project.
(3) Compacted fill material was also used for construction of the contouring layer. The maximum particle size was 4.0 in. (see Section 02240 of Specification).
(4) MDD = maximum dry density (unit weight); OMC = optimum moisture content

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TABLE 5-2

PHASE III - CELL 1 FINAL COVER CONSTRUCTION COMPACTED CLAY CAP PROPERTIES SUMMARY

DESCRIPTION	TEST STANDARD	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY (yd^3)	APPROXIMATE NUMBER OF TESTS REQUIRED[2]	NUMBER OF TESTS PERFORMED (FAILURES)
LABORATORY TEST					
Particle Size: Sieve & Hydrometer Percent Finer than 2.0 in. Percent Finer than 0.75 in. Percent Finer than No. 200 Percent Finer than 0.002 mm	ASTM D 422	 100% ≥90% ≥50% ≥15%	1 per 1,500 yd^3	18	18 (1)[4]
Compaction Standard/Modified	ASTM D 698/ ASTM D 1557	---	1 per 1,500 yd^3/ as required	18/10	18/10
Moisture	ASTM D 2216 ASTM D 4643	---	1 per 1,500 yd^3/ as required	18	18
Soil Classification	ASTM D 2487	CL or CH	1 per 1,500 yd^3	18	18 (0)
Atterberg Limits	ASTM D 4318	$10 \leq PI \leq 40$	1 per 1,500 yd^3	18	21 (1)[4]
Hydraulic Conductivity: Individual samples (Remold) Composite samples (Remold)	ASTM D 5084	$\leq 1 \times 10^{-7}$ cm/s	1 per 10,000 or 1 per stockpile	 4 4	 6 (1)[5]
FIELD TEST					
Drive Tube: Soil density Soil moisture	 ASTM D 2937 ASTM D 2216	Within APZ and ≥95% MDD[3] 0 - 3% OMC	1 per 25 passing density tests	 12 12	 12 12
Nuclear Gauge or Drive Cylinder Soil density Soil moisture	 ASTM D 2937 ASTM D 2216	Within APZ and ≥ 95% MDD 0 - 3% OMC	5/acre/lift	 132 132	 301 (18) 301 (18)
Depth Verification Survey	Visual	As shown on drawings	--	--	--

NOTES:
(1) Reference Section 02225 of the Specification and Section 6 of the CQA Plan for further details.
(2) The approximate number of tests required is based on a stockpile volume (from the Contractor's survey of screened clay material) and the area of the compacted clay cap for the Phase III - Cell 1 final cover construction.
(3) MDD = maximum dry density (unit weight);
OMC = optimum moisture content;
APZ = acceptable permeability zone
PI = plasticity index
(4) See NCR Nos. 20103-001 and 20103-006.
(5) Stockpile 00-4 composite sample (CC-22) failed in the first test, but passed on two retests (see Appendix D).

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TABLE 5-3

PHASE III - CELL FINAL COVER CONSTRUCTION COVER DRAINAGE LAYER PROPERTIES SUMMARY (NO. 78 STONE)

DESCRIPTION	TEST STANDARD	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY (yd^3)	APPROXIMATE NUMBER OF TESTS REQUIRED[2]	NUMBER OF TESTS PERFORMED (FAILURES)
LABORATORY TEST					
Particle Size: Sieve	ASTM C 136	3/4 in. 100 1/2 in. 85-100 3/8 in. 40-75 No. 4 5-25 No. 8 0-10 No. 16 0-5 No. 200 0-2	1 per 3,000 yd^3	4	12 (3)[3]
Soil Classification	ASTM D 2487	GP	1 per 3,000 yd^3	4	12 (0)
Carbonate Content	ASTM D 3042	≤5% at pH=4	1 per 5,000 yd^3	2	6 (0)
Hydraulic Conductivity	ASTM D 2434	≥ 0.1 cm/s	1 per 3,000 yd^3	4	11 (0)
FIELD TEST					
Depth Verification: Survey	Visual	As shown on drawings	--	--	--

NOTES: (1) Reference Section 02710 of the Specification and Section 6 of the CQA Plan for further details.
(2) The approximate number of tests required is based on a total volume of 9,155 for the Phase III - Cell 1 final cover construction project.
(3) See NCR Nos. 20103-002 and 20103-003.

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TABLE 5-4

PHASE III - CELL 1 FINAL COVER CONSTRUCTION BIOINTRUSION BARRIER LAYER PROPERTIES SUMMARY (TYPE D RIPRAP)

DESCRIPTION	TEST STANDARD	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY (yd^3)	APPROXIMATE NUMBER OF TESTS REQUIRED[2]	NUMBER OF TESTS PERFORMED (FAILURES)
LABORATORY TEST					
Bulk Specific Gravity	ASTM C 127	≥2.60	1 per 10,000 yd^3	3	4 (2)[3]
Absorption	ASTM C 127	≤2%	1 per 10,000 yd^3	3	4 (0)
FIELD TEST					
Depth Verification: Survey	Visual	As shown on drawings	---	---	---

NOTES: (1) Reference Section 02280 of the Specification and Section 6 of the CQA Plan for further details.
(2) The approximate number of tests required is based on a total volume of 26,687 yd^3 for the Phase III - Cell 1 final cover construction project.
(3) See NCR No. 20103-005.

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TABLE 5-5

PHASE III - CELL 1 FINAL COVER CONSTRUCTION BIOINTRUSION CHOKE STONE PROPERTIES SUMMARY (NO. 57 STONE)

DESCRIPTION	TEST STANDARD	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY (yd^3)	APPROXIMATE NUMBER OF TESTS REQUIRED[2]	NUMBER OF TESTS PERFORMED (FAILURES)
LABORATORY TEST					
Particle Size: Sieve	ASTM C 136	1 1/2 in. 100 1 in. 95 - 100 1/2 in. 25 - 60 No. 4 05 - 10 No. 8 0 - 5	1 per 10,000 yd^3	1	2 (0)
Soil Classification	ASTM D 2487	GP	1 per 10,000 yd^3	1	2 (0)
Bulk Specific Gravity	ASTM C 127	≥2.60	1 per 10,000 yd^3	1	2 (0)
Absorption	ASTM C 127	≤2%	1 per 10,000 yd^3	1	2 (0)
FIELD TEST					
Depth Verification: Survey	Visual	As shown on drawings	---	---	---

NOTES: (1) Reference Section 02280 of the Specification and Section 6 of the CQA Plan for further details.
(2) The approximate number of tests required is based on a total volume of 2,689 yd^3 for the Phase III - Cell 1 final cover construction project.

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TABLE 5-6

PHASE III - CELL 1 FINAL COVER CONSTRUCTION GRANULAR FILTER PROPERTIES SUMMARY (ODOT TYPE A-3 SAND)

DESCRIPTION	TEST STANDARD	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY (yd^3)	APPROXIMATE NUMBER OF TESTS REQUIRED[2]	NUMBER OF TESTS PERFORMED (FAILURES)
LABORATORY TEST					
Particle Size: Sieve	ASTM C 136	No. 4 100 No. 50 95 - 100 No. 200 25 - 60	1 per 5,000 yd^3	2	2 (0)
Soil Classification	ASTM D 2487	SW, SP	1 per 5,000 yd^3	2	2 (0)
FIELD TEST					
Depth Verification: Survey	Visual	As shown on drawings	---	---	---

NOTES: (1) Reference Section 02712 of the Specification and Section 6 of the CQA Plan for further details.
(2) The approximate number of tests required is based on a total volume of 5,769 yd^3 for the Phase III - Cell 1 final cover construction project.

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TABLE 5-7

PHASE III - CELL 1 FINAL COVER CONSTRUCTION VEGETATIVE SOIL LAYER PROPERTIES SUMMARY

DESCRIPTION	TEST STANDARD	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY (yd^3)	APPROXIMATE NUMBER OF TESTS REQUIRED[2]	NUMBER OF TESTS PERFORMED (FAILURES)
LABORATORY TEST					
Particle Size: Sieve	ASTM D 422	100% Finer than 4.0 in.	1 per 5,000 yd^3	5	7 (0)
Compaction	ASTM D 698	—	1 per 5,000 yd^3	5	7
Moisture Content	ASTM D 2216 ASTM D 4643	—	1 per 5,000 yd^3	5	7
Soil Classification	ASTM D 2487	GC, SC, CL	1 per 5,000 yd^3	5	7 (0)
Atterberg Limits	ASTM D 4318	—	1 per 5,000 yd^3	5	7
FIELD TEST					
Drive Cylinder Soil density	ASTM D 2937	≥92% MDD	1 per 25 passing nuclear tests	4	4 (0)
Soil moisture	ASTM D 2216	±3% OMC		4	4 (0)
Nuclear Gauge: Soil density	ASTM D 2922	≥92%	2/acre/lift	42	98 (2)
Soil moisture	ASTM D 3017	±3% OMC		42	98 (2)

NOTES: (1) Reference Section 02250 of the Specification and Section 6 of the CQA Plan for further details.
(2) The approximate number of tests required is based on a total volume of 22,421 yd^3 for the Phase III - Cell 1 final cover construction project.
(3) MDD = maximum dry density (unit weight); OMC = optimum moisture content

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TABLE 5-8

PHASE III - CELL 1 FINAL COVER CONSTRUCTION TOPSOIL PROPERTIES SUMMARY

DESCRIPTION	TEST STANDARD	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY (yd^3)	APPROXIMATE NUMBER OF TESTS REQUIRED[2]	NUMBER OF TESTS PERFORMED (FAILURES)
LABORATORY TEST					
Particle Size: Sieve	ASTM D 422	No. 10 0-40	1 per 5,000 yd^3	2	2 (0)
Organic Content	ASTM D 698	—	1 per 5,000 yd^3	2	2
Soil Classification	ASTM D 2487	GC, SC, CL	1 per 5,000 yd^3	2	2 (0)
Atterberg Limits	ASTM D 4318	—	1 per 5,000 yd^3	2	2
FIELD TEST					
Depth Verification: Survey	ASTM D 2937	As shown on drawings	—	—	—

NOTES: (1) Reference Section 02920 of the Specification and Section 6 of the CQA Plan for further details.
(2) The approximate number of tests required is based on a total volume of 5,000 yd^3 for the Phase III - Cell 1 final cover construction project.

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6. CONSTRUCTION QUALITY ASSURANCE - GEOSYNTHETICS

6.1 General

GeoSyntec monitored the installation of the geosynthetics components of the Cell 1 final cover system. Principal field activities are summarized in Section 3.1.3. Non-conforming or questionable practices observed by CQA personnel were brought to the attention of the Fluor Fernald QA and the CM for review and correction.

The total quantity of geomembrane installed during the Phase III - Cell 1 final cover construction, as measured by CQA personnel, was 273,093 ft^2 (270,000 m^2). The panel layout record drawing for the geomembrane cap is presented in Appendix P.

6.2 Changes in Geosynthetics Specifications

RCIs and DCNs of the geosynthetics drawings and specifications were processed and approved according to procedures described in FEMP document number ED-12-5002 entitled "Engineering Design Change Process." These RCIs and DCNs were approved, as appropriate, by the design organization. Copies of the RCIs and DCNs issued for Phase III - Cell 1 final cover construction project are presented in Appendices R and S, respectively.

6.3 CQA of Geosynthetic Clay Cap

6.3.1 Conformance Testing and Documentation

A geosynthetic clay cap (GCC) was used as a component of the geosynthetics in the Cell 1 final cover system. Rolls of the Bentomat ST GCL, manufactured by Colloid Environmental Technologies Company (CETCO) in Fairmont, Georgia were used for the Phase III - Cell 1 final cover system construction.

For the Bentomat ST GCC, four (4) samples (Nos. GCC 01-1 through GCC 01-4) from GCC Lot No. 200110FA3 were collected for conformance testing. Two representatives from Fluor Fernald and one representative from GeoSyntec visited the CETCO plant in Fairmont, Georgia to observe production, review procedures, and sample material on 6-8 March 2001. All of the 4 Bentomat ST conformance samples were obtained at the factory prior to shipment of materials. The sampling frequency exceeded the minimum acceptable sample frequency of one per 100,000 ft^2 (9,300 m^2) required by the Project Documents. Conformance samples were forwarded to

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GeoTesting Express Testing Laboratory, Atlanta, Georgia for hydraulic conductivity testing and to GeoSyntec's SGI Testing Laboratory for direct shear testing. Based on the conformance sampling and testing results, including the supplier's testing, the lot stated above was approved for construction.

The conformance test results and the manufacturer's quality control (QC) certificates were reviewed by GeoSyntec CQC, Fluor Fernald QA, and Engineering. A summary table for Phase III - Cell 1 GCC approval is presented in Table 6-1. The manufacturer's QC documentation is presented in Appendix E. The conformance test results are presented in Appendix G. A summary of the physical properties of the GCC and the conformance test frequency is presented in Table 6-2.

TABLE 6-1

PHASE III – CELL 1 FINAL COVER CONSTRUCTION
GEOSYNTHETIC CLAY CAP (GCC) CONFORMANCE TESTING APPROVAL SUMMARY

LOT No.	CQA Roll No. (1)	MQC Roll No. (2)	CQA Test Results	MQC Test Results	Roll Nos. Approved for Construction	Date (3) Approved	No. of Rolls (4)	Square Footage (5)
200220FA3	GCL01-01	00000714	Pass	Pass	687-689 691-706 708-715 725-742	07 May 01	44	99,000
200110FA3	GCL01-02	00000761	Pass	Pass	743-759 761-763 765-777 779-785 787-790	07 May 01	44	99,000
200110FA3	GCL01-03	00000811	Pass	Pass	791-796 798-805 808-826 828-838	07 May 01	44	99,000
200110FA3	GCL-01-04	00000862	Pass	Pass	839-842 844-847 849-860 862-871	07 May 01	30	67,500

Notes:
1. CQA Roll No. is roll used for conformance testing (direct shear and hydraulic conductivity).
2. MQC Roll No. is roll used for manufacturer's QC testing (direct shear and hydraulic conductivity).
3. Date given is date GeoSyntec conformance testing approved. Manufacturer's tests were approved at later date.
4. Number of rolls given is total delivered to site and used in Phase III - Cell 1 final cover construction.
5. Square footage for total number of rolls given.

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TABLE 6-2

PHASE III – CELL 1 FINAL COVER CONSTRUCTION
GEOSYNTHETIC CLAY CAP PHYSICAL PROPERTIES SUMMARY

DESCRIPTION	TEST STANDARD	MANUFACTURER SPECIFICATIONS[3]	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY[5] (ft^2)	
				Manf. QC	Conformance QA
Bentonite Content (lb/ft^2)	ASTM D 5993	1.0 lb/ft^2 @ 25% moisture	≥ 1.0	40,000	NA
Bentonite Moisture Content (%)	ASTM D 4643	25% max	≤ 25	40,000	NA
Direct Shear[4]	ASTM D 6243	NA	LD Shear - 12° (5 psi) LD Shear - 7° (20 psi) LD Shear - 6.5° (45 psi) Peak Shear - 17°	100,000	100,000 or per lot
Grab Elongation (%)	ASTM D 4632	10 % Typical	NA	40,000	NA
Peel Strength (lb/in.)	ASTM D 4632	15 min	≥ 15 lb/in	40,000	NA
Grab Strength (lb)	ASTM D 4632	90 MARV	NA	40,000	NA
Hydraulic Conductivity (cm/s) (σ' = 5 psi)	ASTM D 5887	$\leq 5x10^{-9}$	$\leq 5x10^{-9}$	40,000	100,000
Fluid Loss (ml)	ASTM D 5891	18 max	≤ 18 ml	40,000	NA
Bentonite Free Swell (ml/2g)	ASTM D 5890	24	≥ 24	40,000	NA

Total No. of Bentomat ST Rolls Delivered to Site: 162 Total No. of Conformance Samples: 4

Notes: (1) Reference Section 02772P of the Procurement Specifications and Section 8 of the CQA Plan for further details.

(2) Ambient placement temperatures are between 40°F and 104°F. The GCL rolls are overlapped a minimum of 6 in. along edges, with a 24 in. end overlap. No horizontal seams are allowed on the slopes (≥5H:1V). Patches extend 12 in. beyond a defect on ≤5% slope areas and 24 in. on ≥5% slope areas. Granular bentonite is placed between seams involving Bentomat ST.

(3) Bentomat ST is the GCL used for Cell 1 final cover construction. Roll dimensions are 15 ft by 150 ft.

(4) Peak Shear Strength and Large-Displacement (LD) shear strength at normal stress of 5, 20, 45 psi, reported as Secant Angle in degrees.

(5) Testing shall be performed at a frequency of one per lot or at listed frequency, whichever is greater. A lot is defined by ASTM D 4354.

MD = Machine Direction; XD = Cross-Machine Direction; NA = Not Applicable; σ' = Effective Confining Stress.

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6.3.2 Field Monitoring Activities

6.3.2.1 Delivery and On-Site Storage

Upon delivery, GCC rolls were unloaded in a laydown area located in the northeast corner of the OSDF construction area and covered with a tarpaulin. The GCC rolls had a plastic wrapping to protect against water and premature hydration. An all-terrain lift truck or a front-end loader transported the rolls. The rolls were temporarily stored adjacent to the construction area prior to deployment. CQA personnel periodically monitored the installer's delivery, unloading, and storage procedures. Potentially nonconforming or questionable practices observed by CQA personnel were brought to the attention of the CM for review and correction. The CQA personnel observed that the material was stored and handled in an appropriate manner or corrective action was taken, where appropriate.

6.3.2.2 Deployment

CQA personnel monitored the deployment of the GCC rolls. During deployment, the CQA personnel checked for the following:

- manufacturing defects;
- evidence of premature hydration of the bentonite;
- damage that may have occurred during shipment, storage, and handling; and/or
- damage resulting from installation activities.

If materials were observed to be damaged, the installer was notified and the damaged materials were either discarded or repaired. CQA personnel observed repair locations, during and after repair.

CQA personnel monitored the deployment of the GCC, as well as its condition after installation, to verify that the installer followed the following procedures:

- prior to deployment, the installer signed a Certificate of Acceptance of subgrade (presented in Appendix H);
- the GCC was unrolled and placed in a manner which kept the roll of GCC in sufficient tension to avoid excessive wrinkling using low ground-pressure rubber-tracked equipment;

- the rolls were deployed with the geotextile printed with the manufacturer's name facing upwards (i.e., woven geotextile up and nonwoven geotextile in contact with the underlying soil component);
- measures were taken to avoid entrapment of stones or other objects in the GCC panels;
- measures were taken to avoid damage to the underlying clay surface during deployment of the rolls;
- measures were taken to keep the GCC free of contamination and protected from premature hydration; and
- geomembrane installation immediately followed installation of the GCC.

After deployment of the GCC, CQA personnel observed that the adjacent rolls of GCC were joined using the following procedures:

- adjacent GCC panels were shingled in the direction of the slope to prevent the potential for runoff flow to enter the overlapped panel;
- adjacent GCC panels were overlapped a minimum of 6 in. (150 mm) along the length of the panels and a minimum of 24 in. (600 mm) along the width of the panels; and
- dry bentonite granules were applied between seams of overlapped panels in accordance with the GCC manufacturer's recommendation.

Observed holes or tears in the GCC were repaired by the installer by placing a patch of the same material over or under the hole or tear and at a distance of at least 2 ft (0.6 m) beyond the edges of the hole on slopes greater than 5 percent or 1 ft (0.3 m) beyond the edges of the hole or tear on slopes less than 5 percent. In areas where premature hydration of the GCC was detected, the GCC was removed and replaced with new approved material.

As required by the Project Documents and indicated above, geomembrane installation immediately followed the installation of the GCC on portions of the Cell 1 final cover. On the morning of 18 July 2001, it was discovered that an overnight storm had caused approximately 8,000-ft^2 (740-m^2) of the installed geomembrane on the top slopes of the final cover to be blown off (i.e., uplifted), thereby exposing the underlying

GCC. There was concern that the GCC might have hydrated from the approximately 0.8 in. (20 mm) of rain that resulted from the overnight storm.

CQA personnel examined the exposed GCC and collected samples for the laboratory determination of the GCC moisture contents (per ASTM D 4643). The resulting moisture contents were all less than the 40 percent minimum value for the GCC to be considered hydrated, as defined in Section 02772, Part 3.03.I of the Technical Specifications. Based upon this determination and visual examination of the exposed GCC, it was concluded that the GCC was not hydrated to warrant removal and replacement. Appendix A includes photographic documentation of the "apparent wind damage" to the geomembrane and GCC during the OSDF Phase III – Cell 1 final cover construction.

6.4 CQA of Gemembrane

6.4.1 Conformance Testing and Documentation

The 60-mil (1.5-mm) thick textured HDPE geomembrane was supplied by GSE Lining Technology, Inc, Houston, Texas. Prior to Cell 1 final cover construction, geomembrane conformance samples were taken randomly from the 60-mil (1.5-mm) thick textured HDPE geomembrane rolls used to construct the final cover system. A total of five (5) conformance samples were obtained by CQA personnel at the manufacturing plant prior to delivery to the site. These samples represented 2 lots of geomembrane, which comprised 32 geomembrane rolls. The total number of conformance samples exceeds the minimum acceptable sampling frequency of one per 100,000 ft^2 (9,300 m^2) or one per lot as required by the Project Documents.

The conformance samples were forwarded to GeoTesting Express Testing Laboratory, Austin, Texas for testing. The conformance test results and the manufacturer's QC certificates, for each roll, were reviewed by CQA personnel and were found to be in compliance with the Project Documents. The geomembrane manufacturer's QC documentation included resin and geomembrane certifications, and is presented in Appendix E. The geomembrane manufacturer's roll numbers, GeoSyntec's conformance sample logs, and GeoTesting Express' conformance test results are presented in Appendix G. A summary of the physical properties of the geomembrane and the conformance test results are presented in Tables 6-3.

In addition to geomembrane conformance testing, the Project Documents specified a manufacturer's certification letter of conformance for the extrudate welding rod. CQA

personnel obtained one letter of certification for the extrudate rod during construction of Cell 1 final cover system. The certification letter is presented in Appendix E.

6.4.2 Field Monitoring Activities

6.4.2.1 Delivery and On-Site Storage

Upon delivery to the site, geomembrane rolls were stored in a laydown area located to the northeast of the OSDF construction area. The rolls of geomembrane had nylon straps, which were used to lift the rolls. The rolls were transported by a front-end loader. Occasionally, the rolls were temporarily stored adjacent to the construction area prior to deployment. CQA personnel periodically monitored the delivery, unloading, and storage procedures. The CQA personnel compared the roll numbers to the geomembrane rolls that were sampled at the manufacturer's plant and also to the bill of lading. The CQA personnel observed that procedures were used that minimized the potential for damage to the rolls.

6.4.2.2 Deployment

The geomembrane rolls were lifted using a spreader bar attached to a front-end loader. A rubber-tired all-terrain vehicle was used in the deployment of geomembrane panels over the previously installed GCC panels using procedures approved by the CM to assure no damage to the GCC. The installer generally deployed the geomembrane panels from: (i) south to north across the west and east slopes; and (ii) west to east across the north slope and in accordance with the approved panel layout drawing. The installer used laborers to manually position the panels.

CQA personnel monitored the deployment of each geomembrane panel or roll. During deployment, the CQA personnel checked for the following:

- manufacturing defects;
- damage that may have occurred during shipment, storage, or handling; and/or
- damage resulting from installation activities, including damage as a consequence of panel placement, seaming operations, or weather.

If the materials were observed to be damaged or deficient, the installer was notified and the damaged materials were either discarded or repaired. CQA personnel observed repair locations, either during or after the repair were complete.

Details of the geomembrane panel placement were recorded by CQA personnel on the panel placement monitoring logs that are presented in Appendix I.

6.4.2.3 Trial Seams

Prior to production seaming, the installer prepared geomembrane trial seams at the beginning of each seaming period, and at least once each four hours, for each piece of seaming equipment used that day prior to seaming. Also, each seamer prepared at least one trial seam each day that seaming was performed by that seamer using a specific piece of seaming equipment. CQA personnel observed the trial seaming operations. The following procedure was used to evaluate the trial seams:

- trial seam samples varying in length from 3 to 15 ft (0.9 to 4.5 m) and having a width of approximately 12 in. (0.3 m) wide were welded under similar conditions as for production seaming;
- test strips were cut across the trial seam at random locations using a manual dye press; each test strip was approximately 1 in. (25 mm) wide by 8 in. (200 mm) long;
- two test strips were tested in peel and two were tested in shear using a field tensiometer;
- the passing criteria for the tests were as follows:

Fusion

- *Peel test* - a minimum bonded seam strength of 88 lb/in. (15 kN/m) and the observation of a Film Tearing Bond (FTB), and
- *Shear test* - a minimum bonded seam strength of 113 lb/in. (20 kN/m); and the observation of a FTB;

Extrusion

- *Peel test* - a minimum bonded seam strength of 63 lb/in. (11 kN/m); and the observation of a FTB, and
- *Shear test* - a minimum bonded seam strength of 113 lb/in. (20 kN/m); and the observation of a FTB;

- if any of the strips failed, corrective actions to the welding procedure were implemented, a new trial seam was fabricated, and the test procedure repeated; passing tests in both peel and shear were achieved prior to acceptance of the trial seam; if these retest strips failed, the welder and/or the equipment were rejected until the problem was corrected and two consecutive passing trial seams were completed; and

- once a trial seam passed both tests, the technician was authorized to proceed with production seaming following the procedures and controls used to prepare the accepted trial seams.

A total of 59 trial seams were observed by CQA personnel during Cell 1 final cover construction. A total of 24 trial seams were made using double-track fusion (i.e., hot wedge) welders and 35 were made using extrusion welders.

Trial seam samples were not archived. The trial seam test results are presented in Appendix J.

6.4.2.4 Production Seams

Geomembrane production seaming operations were monitored by CQA personnel. The majority of the geomembrane production seams were fabricated using double-track fusion (i.e., hot wedge) welders. Geomembrane seam repairs were made using hand-held extrusion welders. During or after fabrication, the geomembrane seams were visually examined for workmanship and continuity. Geomembrane production seaming logs are presented in Appendix K.

A cold weather seaming plan was submitted by the installer in the event ambient temperatures dropped below 40°F (5°C). However, the cold weather seaming specifications were not implemented during the Cell 1 final cover construction season. Production seaming activities were not performed below 40°F (5°C) during the Cell 1 final cover construction project.

6.4.3 Nondestructive Seam Testing

6.4.3.1 Scope

Nondestructive testing of geomembrane seams was periodically monitored by CQA personnel. Geomembrane seams were nondestructively tested by the installer for continuity using the air pressure or the vacuum-box test procedures. Double-track

fusion seams were tested using air pressure test methods. The vacuum-box test method was used for seams made with extrusion welders. Failed air pressure test seams were capped and retested using vacuum-box test methods after minimizing the failed seam length. Leaks identified using the vacuum-box method were repaired and retested, as described in Section 6.4.5 of this report.

6.4.3.2 Air Pressure Testing

Accessible double-track fusion seams were nondestructively tested using the air pressure test. The procedure used by the installer for air pressure testing was as follows:

- CQA personnel visually observed the integrity of the annulus of the section of seam being tested;
- a test section was isolated by sealing the ends of the annulus using heat and pressure;
- the needle of a pressure test apparatus was inserted into the annulus at one end of the seam;
- the annulus was inflated to a gauge pressure of approximately 25 to 30 psi (170 to 200 kPa) with an air pump;
- the gauge pressure was maintained for at least five minutes;
- if the pressure loss exceeded 3 psi (23 kPa), or if the pressure did not stabilize, the faulty area was repaired in accordance with Section 6.4.5 of this report;
- the location of the test was recorded along with the testing pressures; and
- upon completion of the test, air flow through the entire annulus was confirmed by releasing the air from the seam at the opposite end from where the needle was inserted.

Geomembrane air pressure test logs are presented in Appendix K.

6.4.3.3 Vacuum-Box Testing

The vacuum-box was used by the installer to nondestructively test extrusion seams and repairs. The procedure used by the installer for vacuum testing was as follows:

- vacuum-box assembly was connected to the vacuum pump;

- a strip of seam was wetted with a soapy solution;
- the vacuum-box assembly was placed over the wetted area;
- the bleed valve was closed and the vacuum valve was opened, if necessary;
- the box was forced onto the sheet until a vacuum was established as evidenced by a negative box pressure of approximately 5 psi (34 kPa);
- the seam was examined through the viewing window for a period of approximately 20 seconds for the occurrence of air bubbles;
- the location of any leaks were recorded;
- the vacuum valve was closed and the bleed valve was opened, if necessary; and
- the assembly was removed and the process was continued along the seam overlapping previous test area.

When nondestructive testing indicated repairs were necessary, repairs were made in accordance with procedures presented in Section 6.4.5 of this report and the vacuum-box testing repeated. Vacuum test logs are presented in Appendix K.

6.4.4 Destructive Seam Sample Testing

6.4.4.1 Scope

In accordance with the CQA Plan, CQA personnel identified and collected geomembrane seam samples for destructive testing. The samples were forwarded to GeoTesting Express, Inc. for destructive seam testing.

A total of 31 geomembrane seam sample locations were identified during Cell 1 final cover construction; 30 passing and 1 failing tests on the Cell 1 final cover geomembrane. Approximately 13,600 linear ft (4,150 linear meters) of seams were constructed. This corresponds to an approximate sample frequency of one per 453 linear feet (138 linear meters) of seam. This frequency meets the minimum acceptable sample frequency of one per 500 linear feet (150 linear meters) required by the CQA Plan. Prior to the removal of a full seam sample, the installer took two geomembrane test strips from either end of the destructive sample. Each strip was tested in the field in peel. If the peel samples exhibited a FTB failure mode and minimum required strength, the adjacent destructive seam sample was shipped to the laboratory for testing.

For a destructive seam sample to be considered as passing, the following seam strength criteria had to be met on four out of the five tests performed on each of the destructive seam specimens obtained from each of the destructive seam samples. In addition, a non-FTB was considered to exhibit more than 10 percent seam separation.

Fusion

- *Peel test* - a minimum bonded seam strength of 88 lb/in. (15 kN/m), and the observation of a FTB; and
- *Shear test* - a minimum bonded seam strength of 113 lb/in. (20 kN/m), and the observation of a FTB; and

Extrusion

- *Peel test* - a minimum bonded seam strength of 63 lb/in. (11 kN/m), and the observation of a FTB; and
- *Shear test* - a minimum bonded seam strength of 113 lb/in. (20 kN/m), and the observation of a FTB.

In addition, if more than one non-FTB failure (i.e., greater than or equal to 10 percent seam separation) was observed, the destructive seam sample was considered to have failed.

6.4.4.2 Sampling Procedures

At each destructive seam sample location, a test sample that measured approximately 12 in. (300 mm) across the seam and 42 in. (1.1 m) along the seam was obtained. The sample was divided and distributed as follows:

- 12 in. (300 mm) wide by 12 in. (300 mm) long for owner's archives;
- 12 in. (300 mm) wide by 12 in. (300 mm) long for the installer; and
- 18 in. (500 mm) wide by 12 in. (300 mm) long for CQA laboratory testing.

6.4.4.3 Test Results

Off-site laboratory testing of geomembrane seam test samples was performed in accordance with the CQA Plan at the GeoTesting Express, Inc. Testing Laboratory. In the laboratory, 1-in. (25-mm) wide test specimens were removed from the destructive

seam sample using a die press. On a gauged tensiometer, five test specimens were tested in peel for adhesion. For fusion seams, tests were performed on both the inside and outside tracks. Additionally, five specimens were tested for shear strength. The seam-strength criteria and the acceptance/rejection criteria described in Section 6.4.4.1 were used.

For Cell 1 final cover, one failure was recorded on the initial destructive seam samples; this failure occurred in the field test strips. The failed area was isolated by selecting additional test-strip locations at a minimum distance of 10 ft (3 m) on either side of the failure. If the additional test strips had passing results, a full destructive seam sample was taken. These destructive seam samples were tested in accordance with procedures previously described in this section. Two (2) additional seam samples were obtained to isolate the failure and one (1) additional seam sample on the reconstructed seam. Seams having failing destructive samples were repaired using procedures presented in Section 6.4.5. The destructive seam test sample locations were also repaired using the procedure presented in Section 6.4.5. The destructive seam test results and a summary of the number of samples obtained are presented in Appendix L.

6.4.5 Geomembrane Repairs

The procedures presented in this subsection were used by the installer during the following repair operations:

- patching holes and tears;
- capping failed seams;
- spot-extruding impact damage or other minor scratches; and
- grinding and extrusion welding small sections of failed fusion seams (if the exposed edge was accessible).

The repair procedure for fusion seams, was to cap strip the failed seam. This procedure was used for seams with insufficient overlap and used for failing destructive tests.

In the cases where patches or caps were used to repair the damaged geomembrane (i.e., small holes, tears, or on seams which failed nondestructive or destructive tests), an approximately 12 in. (300 mm) wide capping strip was used. All panel tie-in seams (i.e.,

T-seams) were extrusion welded/repaired. During the repair or panel tie-in operations, the following provisions were implemented:

- technicians and seaming equipment used during repair operations had trial seams approved prior to use;
- geomembrane surfaces to be repaired were clean and dry at the time they were welded;
- patches or caps extended at least 6 in. (0.15 m) beyond the edge of the defect, and all corners were rounded;
- fusion annuli were ground down to the surface of the bottom geomembrane at the ends of the seams; and
- repairs were vacuum tested where accessible, and visually observed for continuity.

Appendix M presents repair summary logs for the geomembrane cap used for Cell 1 final cover construction. Seam and panel repair locations are presented in Appendix N. Complete panel layout drawing indicating the location of seam and panel repairs is shown on the Record Drawing presented in Appendix P.

6.4.6 Electrical Leak Detection Testing

The electrical leak detection testing was performed on the Cell 1 final cover geomembrane. The method uses the flow of electrical current to detect leaks or breaches in a geomembrane liner. The leak detection testing was performed by Leak Location Services, Inc. (LLSI) of San Antonio, Texas, as a subcontractor to IT. Ten leaks were detected in the geomembrane that were tested. (Some of these leaks were detected in areas that had not undergone complete repairs, as required by the Project Documents.) Appendix O presents a report on the electric leak detection testing which was conducted as part of the OSDF Phase III - Cell 1 final cover system construction.

6.5 CQA of Geotextile

6.5.1 Conformance Testing and Documentation

Two types of geotextile were used in construction of Cell 1 final cover system:

- a needlepunched nonwoven geotextile having a minimum mass per unit area of 8 oz/yd^2 (270 g/m^2) was used as the geotextile cushion layer. This geotextile was manufactured by TNS Advanced Technologies, Inc., Spartanburg, South Carolina; and

- a needle-punched nonwoven geotextile having a minimum mass per unit area of 16 oz/yd^2 (540 g/m^2) was used as the sacrificial geotextile cushion layer. This geotextile was manufactured by TNS Advanced Technologies, Inc., Spartanburg, South Carolina.

CQA personnel obtained five (5) conformance samples from the 68 geotextile rolls delivered to the site. Four (4) conformance samples were obtained from 58 rolls of geotextile cushion, and 1 conformance sample was obtained from 10 rolls of sacrificial geotextile cushion. These sampling frequencies exceed the minimum acceptable frequency of one per 100,000 ft^2 (9,300 m^2) required by the Project Documents. The conformance samples were forwarded to GeoTesting Express, Inc. for testing. The conformance test results and the manufacturer's QC certificates were reviewed by CQA personnel and were found to be in compliance with the Project Documents. The manufacturer's QC documentation is presented in Appendix E. The conformance test results are presented in Appendix G. A summary of the properties of the geotextile material and the conformance test results for the geotextile cushion and sacrificial geotextile cushion is presented in Tables 5-5 and 5-6, respectively.

6.5.2 Field Monitoring Activities

6.5.2.1 Delivery and On-Site Storage

Upon delivery to the site, geotextile rolls were stored in an area located northeast of the OSDF construction area. The geotextile rolls had a plastic wrapping to protect against ultraviolet radiation, dust, and dirt. The geotextile rolls were transported by a front-end loader. The rolls were deployed or temporarily stored adjacent to the construction area prior to deployment. CQA personnel periodically monitored the delivery, unloading, and storage procedures. The CQA personnel observed that the material was handled in an appropriate manner.

6.5.2.2 Deployment

CQA personnel monitored the deployment of the geotextile rolls for the following:

- manufacturing defects;

- damage that may have occurred during shipment, storage, and handling; and
- damage resulting from installation activities.

If any materials were observed to be damaged, the installer was notified and the damaged materials were either discarded or repaired. CQA personnel observed repair locations, either during or after the repair was complete.

CQA personnel monitored the deployment of the geotextile as well as its condition after installation, to ensure that the installer:

- unrolled the geotextile down the slope in a manner which kept the geotextile panel in sufficient tension to avoid excessive wrinkling and folding; and
- took measures to avoid the entrapment of dust, stones, and other objects in the geotextile.

After deployment of the geotextile, CQA personnel observed that the following procedures were used by the installer to join adjacent rolls of geotextile:

- geotextile panels were overlapped a minimum of 6 in. (0.15 m); and
- geotextile panels were continuously sewn.

The installer used a 2200-B Union Special sewing machine. The seams were sewn with a single-thread chain stitch using a nylon bonded thread.

The installer repaired holes or tears in the geotextile by placing a patch of the same material over the hole or tear with at least 2 ft (0.6 m) beyond the edges of the hole or tear and thermally bonded with a leister or overlapped 6 in. (150 mm) and sewn.

6.6 CQA of Erosion Mat

6.6.1 Material Types

Two types of erosion mat were used in construction of the Cell 1 final cover system:

- a biodegradable, woven jute matting having a minimum mass per unit area of 14.7 oz/yd^2 (500 g/m^2) was used as the erosion mat for the Cell 1 final cover; this jute matting was manufactured in India and supplied by the Dayton Bag and Burlap Company in Dayton, Ohio; and

- a biodegradable, woven erosion mat, made of coir (coconut) fiber and having a minimum mass per unit area of 11.8 oz/yd^2 (400 g/m^2) was used as the erosion mat in specific locations of the Cell 1 final cover; this erosion mat was manufactured by BonTerra America, Genevue, Idaho.

The manufacturers' certificates for the two erosion mat products are presented in Appendix E.

6.6.2 Field Monitoring Activities

During installation of the erosion mat, CQA personnel periodically monitored the following:

- two panels (i.e., two roll widths) of the coir matting were installed at the specific locations required by DCN No. 20103-038;
- erosion mat panels were overlapped in accordance with the manufacturers' recommendations; and
- adjacent panels were stapled in accordance with manufacturers' recommendations using a minimum 6 in. (150 mm) long staples.

TABLE 6-3

60-MIL THICK HDPE GEOMEMBRANE (TEXTURED) PROPERTIES SUMMARY
PHASE III - CELL 1 FINAL COVER CONSTRUCTION

DESCRIPTION	TEST STANDARD	MANUFACTURER SPECIFICATIONS (MARV)[7]	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY (ft^2)		NUMBER OF TESTS[2]				RANGE OF CONF. QA AVERAGE TEST RESULTS	
				Manf. QC	Conf. QA[4]	REQUIRED		PASSING		MAXIMUM	MINIMUM
						Manf. QC	Conf. QA	Manf. QC	Conf. QA		
Yield Strength (lb/in.)	ASTM D 638[5]	130	≥126 [6]	40,000	100,000	9	4	32	5	151	138
Elongation at Yield (%)	ASTM D 638[5]	13	≥12	40,000	100,000	9	4	32	5	18	16
Break Strength (lb/in.)	ASTM D 638[5]	243	≥90 [6]	40,000	100,000	9	4	32	5	308	295
Elongation at Break (%)	ASTM D 638[5]	600	≥100	40,000	100,000	9	4	32	5	915	871
Thickness (mil)	ASTM D 5994	60 nominal 54 min.	Avg. 60 Min. 58	40,000	100,000	9	4	32	5	66.4	60.0
Density (g/cm^3)	ASTM D 1505	0.940	≥0.934 (resin) ≥0.940 (sheet)	40,000	100,000	9	4	11	5	0.945	0.944
Tear Resistance (lb)	ASTM D 1004 Die C Puncture	42	≥42	40,000	NA	9	NA	32	4	56.1	53.7
Puncture Resistance (lb)	ASTM D 4833		≥90	40,000	NA	9	NA	32	4	138	135
Carbon Black Content (%)	ASTM D 1603	2.0	2-3	40,000	100,000	9	4	11	5	2.6	2.5
Carbon Black Dispersion	ASTM D 5596	Category 1 or 2	Category 1 or 2	40,000	100,000	9	4	11	5	CAT-1	CAT-1
Low Temperature Brittleness (□C)	ASTM D 746B	-75	-60 max.	400,000	NA	1	NA	3	NA	NA	NA
Dimensional Stability (%) (@ 212□F, 15 min.)	ASTM D 1204	±2 max.	±2 max.	400,000	NA	1	NA	3	NA	NA	NA
NCTL (hr)[6]	ASTM D 5397	400	≥500	400,000	NA	1	NA	3	NA	NA	NA
Asperity Height	GRI-GM12	≥9	≥7	40,000	100,000	9	4	16	4	16	13

Total Number of Rolls Delivered to Site: 32 (356,025 ft^2) Total Number of Conformance Samples: 5

Notes:
(1) Reference Section 02770P of the Procurement Specifications and Section 7 of the CQA Plan for further details.
(2) The approximate number of tests required is based on total of 356,025 ft^2 for the Cell 1 final cover installation.
(3) GSE Lining Technologies, Houston, Texas is the geomembrane supplier. Roll dimensions are 23.5 ft. x 472 ft. (avg. Length)
(4) Tests performed at a frequency of one per lot or at listed frequency, whichever is greater. A lot is as defined by ASTM 4354. Minimum test frequency of resin is 1 test per railcar.
(5) ASTM D 638 is modified by NSF-54 Annex A.
(6) Time-to-failure at a tensile stress of 30% of the tensile yield strength
(7) MARV = (minimum average roll value), 95 percent lower confidence limit.

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TABLE 6-4
60-MIL THICK HDPE GEOMEMBRANE (TEXTURED)
SEAM PROPERTIES SUMMARY
PHASE III - CELL 1 FINAL COVER CONSTRUCTION

DESCRIPTION	TEST STANDARD	PROJECT[1] SPECIFICATIONS		REQUIREMENTS	APPROXIMATE NUMBER OF TESTS REQUIRED
		Fusion	Extrusion		
Panel Deployment	---	---	---	Ambient placement temperature are between 40°F and 104°F.	Assumption used for destructive seam testing is that each roll is approximately 23.5 ft by 474 ft (avg.)
Trial Seams: (peel)	ASTM D 4437	FTB 88 ppi	FTB 63 ppi	Prior to seaming period every 4 hours, or if seaming apparatus is turned off.	Minimum of: 2 no. peel per trial seam 2 no. shear per trial seam
(shear)	ASTM D 4437	FTB 113 ppi	FTB 113 ppi		

Notes: (1) Two consecutive failures require two consecutive successful trial seams. (See Section 02770; Part 3.02. I.2)

DESCRIPTION	TEST STANDARD	PROJECT[1][2][3] SPECS		TEST FREQUENCY	APPROXIMATE NUMBER OF TESTS REQUIRED	ORIGINAL NO. OF SAMPLES TAKEN	NUMBER OF FAILURES		ADDITIONAL NUMBER OF SAMPLES TO ISOLATE FAILURES	TOTAL NUMBER OF SAMPLES
		Fusion	Extrusion				FIELD	LAB		
Seam Strength[1]: Production Welds And Reconstructed Seams	ASTM D 4437	FTB 88 ppi	FTB 63 ppi	500 lin. ft	28	29	1	0	2	31
	ASTM D 4437	FTB 113 ppi	FTB 113 ppi	150 lin. Ft	---	---	---	---	---	---

Note: (1) Reference Section 02770P of the Specifications and Section 7 of the CQA Plan for further details.
(2) 1 in. wide test strips are tested at a strain rate of 2 in. per minute. One non-FTB per five specimens is acceptable provided that the strength requirements are met.
(3) FTB = Film Tear Bond (maximum 10 percent seam separation)

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TABLE 6-5

NONWOVEN GEOTEXTILE (8 oz/yd^2) CUSHION PROPERTIES SUMMARY
PHASE III - CELL 1 FINAL COVER CONSTRUCTION

DESCRIPTION	TEST STANDARD	MANUFACTURER SPECIFICATIONS (MARV)[4]	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY		NUMBER OF TESTS[2]				RANGE OF CONF. QA AVERAGE TEST RESULTS	
						REQUIRED		PASSING			
				Manf. QC	Conf. QA	Manf. QC	Conf. QA	Manf. QC	Conf. QA	MAXIMUM	MINIMUM
Mass Per Unit Area (oz/yd^2)	ASTM D 5261	8	≥8	50,000	100,000	8	4	9	4	10.6	8.0
Mullen Burst Strength (psi)	ASTM D 3786	350	≥350	50,000	100,000	8	4	9	4	501	361
Grab Strength (lb)	ASTM D 4632	200	≥200	50,000	100,000	8	4	9	4	379	219
Trapezoidal Tear Strength Tear (lb)	ASTM D 4533	75	≥75	50,000	100,000	8	4	9	4	179	91
Puncture Strength Resistance (lb)	ASTM D 4833	90	≥90	50,000	100,000	8	4	9	4	171	119
Ultraviolet Resistance (%)	ASTM D 4355	70	≥70	Cert. Ltr.	NA	NA	NA	NA	NA	NA	NA
Nonwoven Needle punched Polymer Composition (%)	—	100% polypropylene	95 polypropylene or polyester by weight	Cert. Ltr.	NA	NA	NA	NA	NA	NA	NA

Total Number of Rolls Delivered to Site: 58

Total Number of Conformance Samples: 4

Notes:
(1) Reference Section 02714P of the Specifications and Section 9 of the CQA Plan for further details.
(2) The approximate number of tests required is based on a total of 391,500 ft^2 available for the Cell 1 final cover installation.
(3) Roll dimensions are 15 ft by 450 ft for 8-oz/yd^3 geotextile manufactured by TNS Advanced Technologies, Inc., Spartanburg, South Carolina.
(4) MARV = (minimum average roll value), 95 percent lower confidence limit.

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TABLE 6-6

NONWOVEN GEOTEXTILE (16 oz/yd^2) SUPPLEMENTAL CUSHION PROPERTIES SUMMARY PHASE III - CELL 1 FINAL COVER CONSTRUCTION

DESCRIPTION	TEST STANDARD	MANUFACTURER SPECIFICATIONS (MARV)[4]	PROJECT[1] SPECIFICATIONS	TEST FREQUENCY		NUMBER OF TESTS[2]				RANGE OF CONF. QA AVERAGE TEST RESULTS	
						REQUIRED		PASSING			
				Manf. QC	Conf. QA	Manf. QC	Conf. QA	Manf. QC	Conf. QA	MAXIMUM	MINIMUM
Mass Per Unit Area (oz/yd^2)	ASTM D 5261	16	≥16	50,000	100,000	2	1	2	1	17.2	16.4
Mullen Burst Strength (psi)	ASTM D 3786	800	≥700	50,000	100,000	2	1	2	1	800	731
Grab Strength (lb)	ASTM D 4632	425	≥350	50,000	100,000	2	1	2	1	567	441
Trapezoidal Tear Strength Tear (lb)	ASTM D 4533	150	≥120	50,000	100,000	2	1	2	1	242	150
Puncture Strength Resistance (lb)	ASTM D 4833	240	≥180	50,000	100,000	2	1	2	1	270	242
Ultraviolet Resistance (%)	ASTM D 4355	70	≥70	Cert. Ltr.	NA	NA	NA	NA	NA	NA	NA
Nonwoven Needle punched Polymer Composition (%)	NA	100% polypropylene	95 polypropylene or polyester by weight	Cert. Ltr.	NA	NA	NA	NA	NA	NA	NA

Total Number of Rolls Delivered to Site: 10

Total Number of Conformance Samples: 1

Notes:
(1) Reference Section 02714P of the Specifications and Section 9 of the CQA Plan for further details.
(2) The approximate number of tests required is based on a total of 67,500 ft^2 available for the Cell 1 final cover installation.
(3) Roll dimensions are 15 ft by 450 ft for 16-oz/yd^3 geotextile manufactured by TNS Advanced Technologies, Inc., Spartanburg, South Carolina.
(4) MARV = (minimum average roll value), 95 percent lower confidence limit.

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7. CONSTRUCTION QUALITY ASSURANCE – FINAL COVER MONITORING SYSTEM

GeoSyntec CQA personnel periodically monitored the installation of the final cover monitoring system components of the Cell 1 final cover construction project. The components included: (i) monitoring devices and associated riser pipes; (ii) electrical cables, conduits and junction boxes; and (iii) instrumentation and calibration.

DCNs were processed and approved according to procedures described in FEMP document number ED-12-5002 entitled "Engineering Design Change Process" to allow for the fabrication, installation, and calibration of the final cover monitoring system. These DCNs were approved, as appropriate, by the design organization and regulatory agency. Copies of the DCNs issued for the Phase III – Cell 1 final cover construction project are presented in Appendix S.

The monitoring devices were supplied/fabricated by Fluor Fernald and installed by IT. The cables, conduits, and junction boxes were installed by 3-Phase with assistance from IT. The electrical wiring and calibration were performed by GeoSystems Analysis with support from 3-Phase and IT. Backfilling around the instruments and junction boxes were performed by IT.

CQA personnel periodically monitored the installation of the various components to confirm compliance with the Project Documents.

8. CONSTRUCTION QUALITY ASSURANCE – HDPE PIPES

8.1 General

GeoSyntec monitored the installation of the HDPE pipes for the Phase III – Cell 1 final cover construction project. Installation activities that were monitored by GeoSyntec CQA personnel included the following:

- 6-in. (150-mm) nominal diameter HDPE SDR-11 perforated pipe connected to 6-in. (150-mm) nominal diameter HDPE SDR-11 solid-wall pipe components of the horizontal monitoring wells for Cells 4 and 5 liner;
- 6-in. (150-mm) nominal diameter HDPE SDR-11 45-degree mitered lateral, solid-walled cleanout pipe and 10-in. (250-mm) nominal diameter HDPE SDR-11 solid-wall riser pipe components of the horizontal monitoring wells for Cells 4 and 5 liner;
- tie-in of approximately 140-ft (43-m) long HDPE SDR-11 dual-containment (6-in. (150-mm) nominal diameter carrier inside a 10-in. (250-mm) nominal diameter containment) piping systems for the LDS, LCS and RLCS lines from the stub-outs at VH-4 and VH-5 to Cell 4 and Cell 5 outlets, respectively; using simultaneous thermal butt-fusion welding procedures;
- hydrostatic and pneumatic pressure testing of the dual-containment piping systems; and
- trench backfilling, which included embedment fill, compacted fill, and concrete placement.

8.2 Changes in Drawings and Specifications

RCIs and DCNs were processed and approved according to procedures described in FEMP document ED-12-5002 titled "Engineering Design Change Process." Copies of the RCIs and DCNs are presented in Appendices R and S, respectively.

8.3 Pipe Conformance Testing and Documentation

The pipes for the Phase III project were manufactured by Phillips Driscopipe of Richardson, Texas, and supplied by ISCO. The manufacturer provided the QC certifications for each lot of pipe supplied. The manufacturer's QC certificates are

presented in Appendix E. CQA personnel reviewed this documentation and verified that the pipe property data were in compliance with the requirements of the Project Documents.

8.4 Field Monitoring Activities

8.4.1 Delivery and Placement

Upon delivery to the site, the pipes were placed in laydown areas approved by the Construction Manager. The pipes were transported from the laydown area to the construction area by a track hoe or a front-end forklift using nylon straps. The pipe was temporarily stored adjacent to the construction area.

Prior to installation, the approximate lengths of each pipe type were constructed in the laydown areas or construction areas. The pipe sections were joined using thermal butt-fusion welding techniques. The CQA activities associated with the pipe joining techniques are described below.

CQA personnel monitored the HDPE pipe butt-fusion welding procedures to ensure the following:

- trial butt-fusion joints were made to verify conditions were adequate at the beginning of each day for each fusion apparatus used that day (trial joining was made under the same conditions as the actual joining);
- the ends of the pipes to be joined were cleaned and the pipe sections were placed in a portable welding unit;
- the welder tightly secured the pipe section in the welding unit clamps to allow the ends of the pipes to be trimmed with the facing tool immediately prior to the application of the heat disk;
- the ends of the pipe sections were heated for approximately one minute using a 400 to 425°F heating disk;
- the welder quickly removed the heating disk and joined the pipes with pressure to create a roll back bead;
- the butt-fusion weld was allowed to cool for a minimum period of 30 minutes, prior to the joined pipes being released from the welding unit; and

- all of the above performed in general accordance with pipe and welding unit manufacturers' procedures (see pipe manufacturer's submittal in Appendix E).

The above procedures were generally used to separately join nominal lengths of the 6-in. (150-mm) pipe and the 10-in. (250-mm) diameter pipes for the horizontal monitoring wells. For the dual-containment pipes for extension to Cells 4 and 5 outlets; however, the carrier pipe was already centralized inside the containment pipe. Nominal sections of these dual-containment pipes as well as the tie-in to VH-4 and VH-5 stub-outs were simultaneously joined using the Fluid-Lok® Simultaneous Butt-Fusion Welding procedure (see Appendix E).

The constructed sections of each pipe segment were then placed into the trench. The width and depth of the trench for the pipeline varied with the location and the number of additional pipes that shared the common excavation. Embedment fill was placed in nominal 7-in. (175-mm) thick loose lifts up to one lift over the pipe. The top of the pipe was surveyed to confirm compliance with the pipe grades and tolerances required by the Project Documents. The as-built survey data were reviewed by CQA personnel prior to placement of additional lifts of embedment fill over the pipe. The as-built survey data, provided by Estes, are included in Appendix Q.

Compacted fill (cohesive material) was then used as backfill to final grade. The backfill was placed in approximately 8-in. (200-mm) thick loose lifts. Hand-operated compaction equipment was used to achieve compaction of the embedment and trench backfill materials. Details of the placement and compaction of the embedment fill and trench backfill materials are discussed in the following section.

8.4.2 Testing Activities

As part of the CQA activities, tests were performed on the installation of the HDPE pipes for the Phase III project. The following tests were conducted or monitored by CQA personnel for the compacted trench backfill, embedment fill, or piping systems:

- Particle-size distribution and classification tests were performed on samples of compacted trench backfill and embedment fill materials, as described in Section 5.4.

- In-place nuclear moisture/density tests were conducted on the compacted fill used in backfilling the pipe trenches.

- Bent strap tests were performed on trial welds made each day to confirm joint integrity, operator procedure, and fusion machine set-up. CQA personnel monitored the bent strap tests performed by DeBra.

- Preliminary and final pneumatic tests were conducted on the dual-containment pipes of LDS, LCS, and RLCS lines from VH-4 and VH-5 stub-outs to Cells 4 and 5 outlets. These tests were monitored by CQA personnel and are discussed below.

CQA personnel monitored the bent-strap and pressure testing performed by IT or Fluor Fernald and DeBra. The bent-strap test was performed on trial welds by cutting a specimen through the joint area; visually inspecting the cut surface of the pipe at the joint for voids or non-bonded areas; and bending the specimen 180 degrees so that the ends of the specimen touch to verify if the joint holds. Results of the bent strap tests are presented in Appendix Q.

A 10-psi (69 kPa) pneumatic test was initially performed as a preliminary test to check each joint. Final hydrostatic pressure tests were then performed after the complete sections of the dual-containment pipes for the LDS, LCS, or RLCS line were installed. For these tests, the contractor typically tested the pipes with water to minimum test pressures of 60 psi (414 kPa) for the carrier pipe and 15 psi (103 kPa) for the containment pipe. CQA personnel monitored the hydrostatic pressure tests for a minimum period of 3 hours during which time the pressure in the pipe was recorded. An allowance for expansion/contraction of the pipe during hydrostatic pressure testing was included in the pass/fail criterion for the pressure test.

An alternate test that consisted of pressurizing the pipes over a 4-hour period, at 70-psi (483-kPa) internal pressure for the carrier pipe and 25-psi (173-kPa) internal pressure for the containment pipe, was also performed on some sections of the installed pipe. After holding the pipe at the test pressure over a 4-hour period, the test pressure was dropped by 10 psi (69 kPa), monitored for one hour for any drop (greater than 5 percent of target value) or visible leaks.

The pressure test results and CQA documentation from the installation of the HDPE pipes are presented in Appendix Q.

In addition to the above-mentioned tests, CQA personnel performed on-site slump and air content tests on the concrete loads delivered to the site for Cells 4 and 5 horizontal monitoring well cover slabs. Concrete test cylinders were prepared and tested by an off-site material testing laboratory (Fuller, Mossbarger, Scott and May Engineers,

Inc., Cincinnati, Ohio). The concrete cylinder test results were reviewed by CQA personnel to confirm compliance to the Project Documents. Concrete test results are presented in Appendix Q.

9. SUMMARY AND CONCLUSIONS

Construction of the OSDF Phase III – Cell 1 final cover construction project for the FEMP was carried out during the period from 4 April 2001 to 31 May 2002. During this time, GeoSyntec provided on-site CQA personnel to monitor the construction of the project. As part of the CQA activities, GeoSyntec on-site CQA personnel monitored the construction and installation of the following components:

- earthwork (select impacted material layer repairs; contouring layer construction; compacted clay cap construction; cover drainage layer, biointrusion barrier and choke stone layer, and granular filter placement; vegetative soil layer construction; topsoil placement and vegetation; monitoring access construction, and riprap placement);
- geosynthetics (installation of GCC, geomembrane cap, geotextile cushion layers, and erosion mat);
- final cover monitoring system devices, instruments, and calibration;
- installation of horizontal monitoring well pipes from Cells 4 and 5 liners; and
- tie-in of LDS, LCS and RLCS dual-containment pipes from VH-4 and VH-5 stub-outs to Cells 4 and 5 outlets, respectively.

During construction of the above components, CQA personnel verified that conformance and CQA testing were performed on the construction materials at the frequencies required in the Project Documents, and that materials meeting the project requirements were used. CQA personnel also verified that conditions or materials identified as not conforming to the Project Documents were replaced, repaired, and/or retested, and that all non-conformances associated with the construction were resolved through disposition by the Fluor Fernald Construction Manager with concurrence by the Fluor Fernald Engineering, Quality Assurance and the Resident Engineer. Copies of the non-conformance reports (NCRs) written during construction of the Phase III – Cell 1 final cover system project are included as Appendix T to this CQA final report.

Based on GeoSyntec's understanding of the project requirements, the results of testing conducted as part of the CQA monitoring activities, and the documentation by GeoSyntec's on-site CQA personnel as described in this report, it is concluded that the Phase III – Cell 1 final cover construction project for the OSDF was constructed in general

accordance with the Project Documents (i.e., Technical Specifications, Construction Drawings, and all applicable RCIs and DCNs).

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APPENDIX A

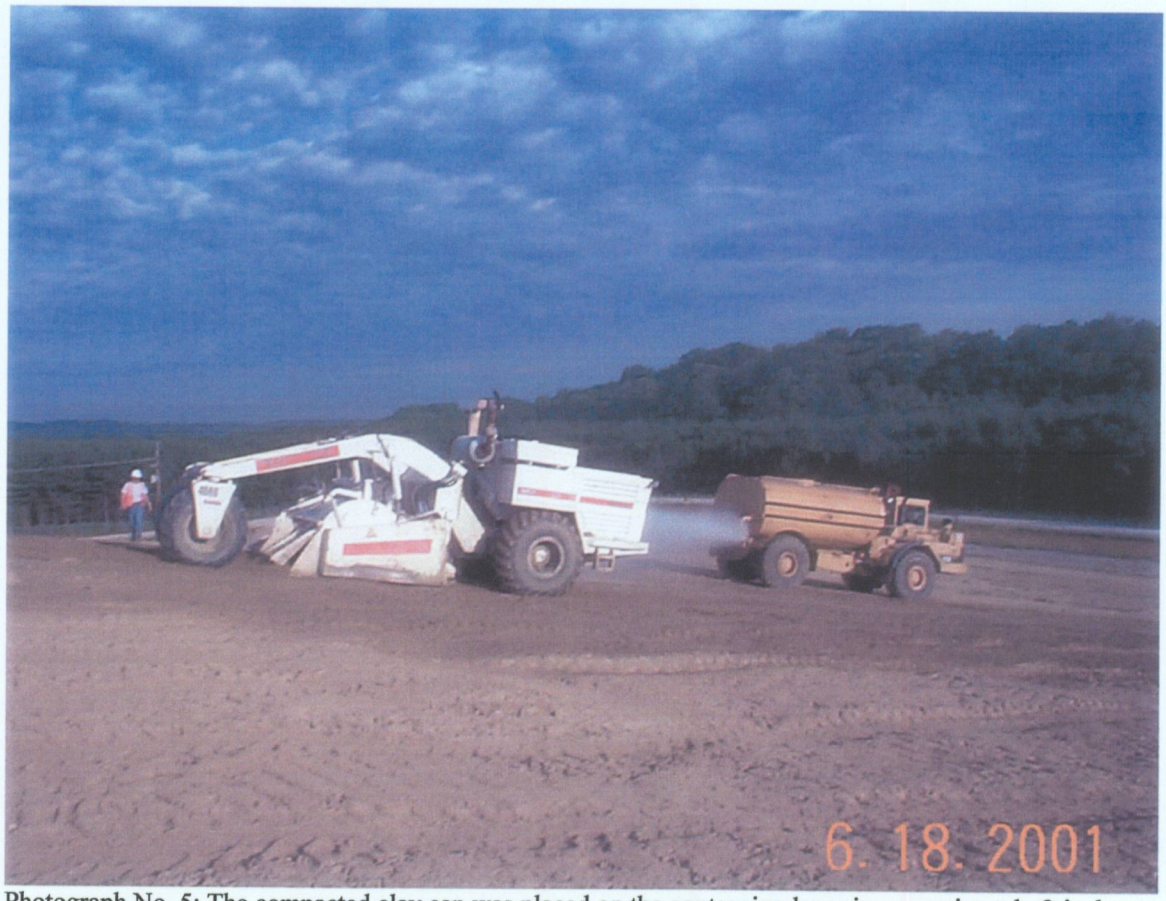
PHOTOGRAPHIC DOCUMENTATION

Photograph No. 1: A D6 Cat Dozer was used to repair the erosion damaged clay wedge during contouring layer construction.

Photograph No. 2: A proofroll inspection was performed on the contouring layer upon completion of final grading. A Volvo A35C Articulated Truck was used for the proofroll.

Photograph No. 3: Compacted clay liner material was screened and stockpiled in the east field borrow area.

Photograph No. 4: Compacted clay liner material was screened and stockpiled in the east field borrow area.



Photograph No. 5: The compacted clay cap was placed on the contouring layer in approximately 8-inch loose lifts, moistured conditioned and scarified with the soil stabilizer.

Photograph No. 6: The compacted clay cap lifts were then compacted to an approximately 6-inch thickness with an 815 Cat Sheeps Foot Compactor.

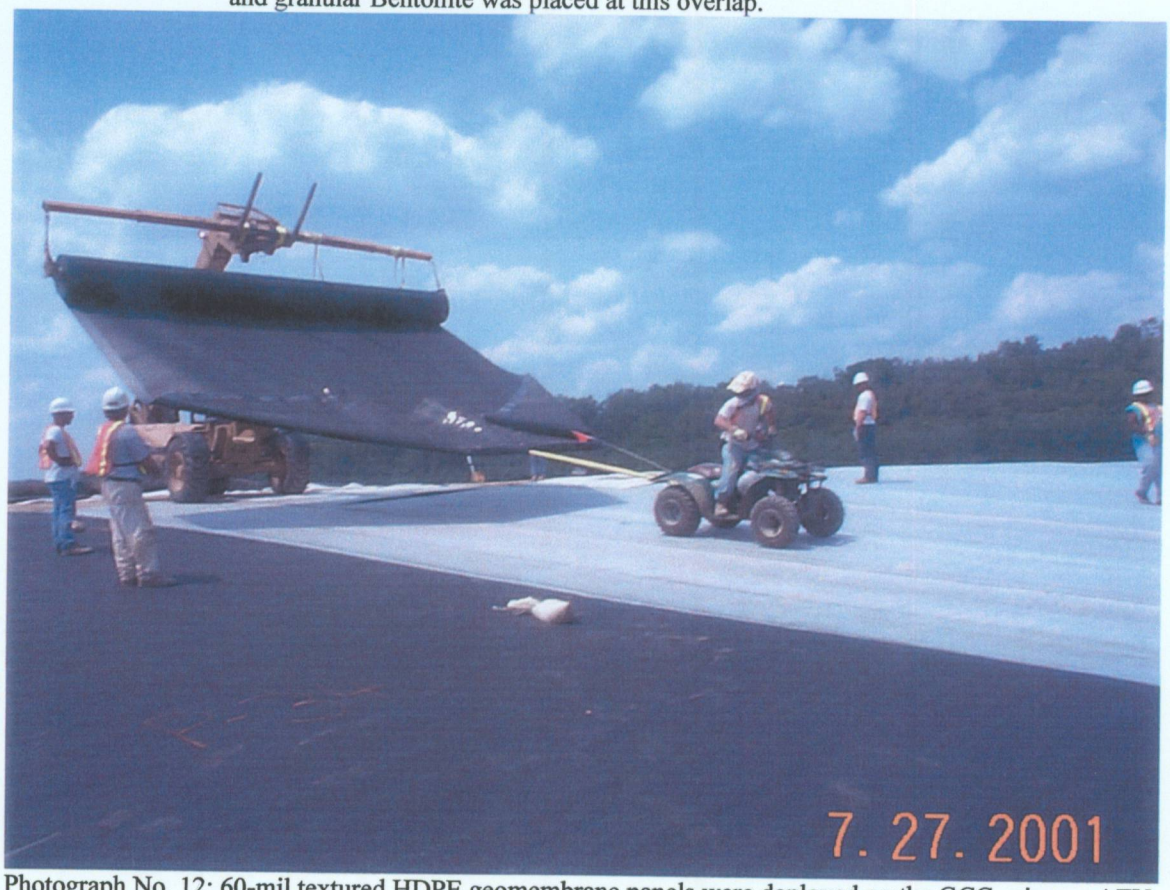
Photograph No. 7: Nuclear moisture/density tests were performed on the compacted clay cap at a frequency that exceeds the project specifications of 5 tests/acre/lift.

Photograph No. 8: Area #1 of the clay wedge was removed after the compacted clay cap was near design grades.

Photograph No. 9: The compacted clay cap surface was prepared for geosynthetic clay cap (GCC) by smooth drum rolling and hand picking of surface stones.

Photograph No. 10: The geosynthetic clay cap (GCC) rolls were deployed on the compacted clay surface using a telescopic forklift.

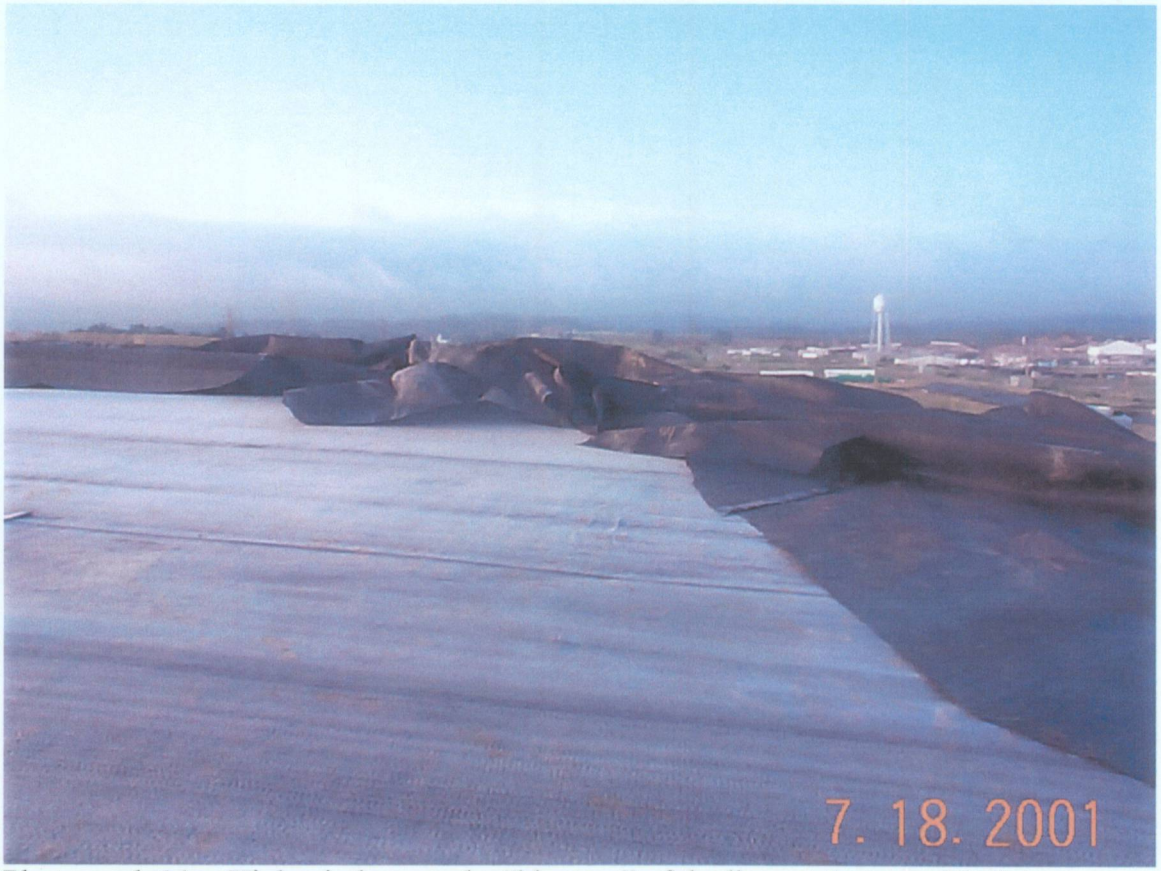
Photograph No. 11: Adjacent geosynthetic clay cap (GCC) panels were overlapped a minimum of 6-inches and granular Bentonite was placed at this overlap.



Photograph No. 12: 60-mil textured HDPE geomembrane panels were deployed on the GCC using an ATV and a telescopic forklift.

Photograph No. 13: The 60-mil textured HDPE geomembrane panels were oriented parallel to the maximum line of slope and overlapped 4 to 6 inches.

Photograph No. 14: The adjacent geomembrane panels were then welded using a double-track fusion welding machine.



Photograph 14a. High winds caused a "blowout" of the liner at the top of Cell 1.

Photograph 14b. After inspection of the GCL, the geomembrane was pulled back into place and repaired according to the specifications.

Photograph No. 15: Extrusion welded seams and repairs were prepared by heat tacking and grinding the interface between panels.

Photograph No. 16: An extrusion welding machine was then used to weld the geomembrane seams and repairs.

Photograph No. 17: Air pressure testing was used to non-destructively test the double track fusion welded seams.

Photograph No. 18: A vacuum box apparatus was used to non-destructively test the extrusion welded seam and repairs.

Photograph No. 19: Leak Location Services, Inc. (LLSI) used the above tools to detect leaks in the 60-mil textured HDPE geomembrane.

Photograph No. 20: The two white dots above are examples of leaks detected by LLSI.

Photograph No. 21: The 8 oz./yd^2 geotextile cushion panels were placed over the 60-mil textured HDPE geomembrane and overlapped approximately 6-inches.

Photograph No. 22: The 8 oz./yd^2 geotextile cushion panels were then continuously sewn using the above sewing machine.

Photograph No. 23: The cover drainage layer stone was placed over the geotextile cushion utilizing 3 ft thick haul roads.

Photograph No. 24: The cover drainage layer haul roads were maintained by a Cat D6 Dozer.

Photograph No. 25: The cover drainage layer was then graded to a 1 ft thickness using a Cat D6 Dozer.

Photograph No. 26: The biointrusion barrier stone was hauled to the cap using A35C Volvo Articulated Trucks and spread by a Cat D6 Dozer.

Photograph No. 27: The biointrusion barrier stone was placed and spread on the cover drainage layer.

Photograph No. 28: Choke stone (# 57 ODOT stone) was placed on the surface of the biointrusion layer.

Photograph No. 29: A D6 Cat Dozer was used to grade the choke stone on the biointrusion barrier.

Photograph No. 30: The granular filter layer sand was hauled to the cap by A35C Volvo Articulated Trucks.

Photograph No. 33: A 6-inch lift of topsoil was then placed over the vegetative soil layer.

Photograph No. 34: The seed-drill method was used to place grass seed in the topsoil.

Photograph No. 35: The broadcasting method was also used to place grass seed on the topsoil.

Photograph No. 36: Erosion mat was then deployed after seeding had been completed.

Photograph No. 35: The broadcasting method was also used to place grass seed on the topsoil.

Photograph No. 36: Erosion mat was then deployed after seeding had been completed.

Photograph No. 37: The erosion mat seams were stapled into the topsoil after being deployed.

Photograph No. 38: A portion of the seeded topsoil upon completion of erosion mat placement. (Note: Two types of erosion mat are shown above. Jute on the slope and coconut fiber at the toe.)

Photograph No. 39: Looking east at a portion of the monitoring access on the north perimeter of Cell # 1.

Photograph No. 40: Ground penetrating radar plates (1 ft x 1 ft x 1/4-inch stainless steel) were installed for long-term monitoring of the Cell # 1 cap.

Photograph No. 41: Laborers installing the settlement plate risor casing for the Cell # 1 cap long-term monitoring system.

Photograph No. 42: Long-term monitoring devices were installed in the Cell # 1 cap. Settlement plate and pressure transducer riser pipes are seen here on the left and right, respectively.

Photograph No. 43: Soil water nests were also installed in the vegetative soil layer as part of the long-term monitoring system.

Photograph No. 44: Embedment sand was placed and compacted in the bottom of the excavation for the VH # 5 Horizontal Monitoring Well. The HMW pipes were then placed on this embedment sand.

Photograph No. 45: A trackhoe was used to install the horizontal monitoring well risor and cleanout pipes.

Photograph No. 46: A trackhoe was used to excavate and install the LCS, RLCS, and LDS pipes from VH # 4 to Cell # 4.

Photograph No. 47: LDS, LCS, RLCS pipes from RV # 4 to Cell # 4.

Photograph No. 48: The access corridors to monitoring system were repaired in May 2002 by placing topsoil, seeding, and erosion mat.

Photograph No. 49: Silt fences used for erosion control were removed except at the junction boxes for the monitoring system.

Photograph No. 50: Repairs to the Cell 1 final cover system were completed by Fluor Fernald Construction in May 2002.