0094055

FINAL REPORT

CONSTRUCTION QUALITY ASSURANCE (CQA)

SECTION

1 OF 20

0094055

FINAL REPORT
CONSTRUCTION QUALITY ASSURANCE (CQA)

ENVIRONMENTAL RESTORATION DISPOSAL FACILITY (ERDF)

SUPER CELL 9

SUBCONTRACT NO. S013213A00

WCH
Washington Closure Hanford

ENVIROTECH
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Attached to: 0094053 & 0094055

TABLE OF CONTENTS

1. INTRODUCTION

ENVIROTECH ENGINEERING & CONSULTING, INC. (ENVIROTECH) was retained by Washington Closure Hanford, LLC (WCH) to provide Construction Quality Assurance (CQA) observation and testing services during construction of Super Cell 9 at the Environmental Restoration Disposal Facility (ERDF). The ERDF is located approximately 30-mi. north of Richland, WA, in the 200 West Area of the Hanford Nuclear Reservation. The U.S. Department of Energy (DOE) administers the Hanford Nuclear Reservation and ERDF. WCH is under contract to the DOE for construction of ERDF Super Cell 9, and ENVIROTECH'S work was conducted under WCH Subcontract S013213A00, with the excavation portion of this contract conducted under Subcontract S66X528A00.

This is the fourth in a series of four (4) reports that document the CQA activities associated with construction of ERDF Super Cell 9. The following is a summary of the reports utilized to generate this final report:

- Soil Liner Test Fill Report;
- Excavation CQA Report;
- Liner System CQA Report; and
- *Final Report.*

This report provides a summary of the CQA observations and testing associated with construction of Super Cell 9.

1.1 Scope of Work. The scope of ENVIROTECH'S services outlined in *Exhibit D - Scope of Work* consisted of the following:

A. *Mobilization Activities.*

- Training requirements and certifications, as outlined in *Submittal 5-09 - Training Matrix.*
- Procurement and mobilization of testing equipment, supplies, and consumables.
- Development, review, and approval of submittals.

- Delivery and set-up of construction testing equipment to include calibration of laboratory and field testing equipment and associated documentation.

B. *Inspection Activities.*

- All inspection activities, as defined in the *Construction Quality Assurance Plan.*
- Verification of construction activities to ensure that Construction Quality Control (CQC) testing was completed to include:
  - Leachate transmission pipeline system, leachate storage tank system, and associated appurtenances;
  - Electrical conduit and concrete-encased duct banks;
  - Crest pad building concrete and rebar; and
  - Crest pad building electrical testing.

C. *Test Fill Testing Activities.*

- Observe construction activities and conduct subgrade and admix testing for the admix layer test fill.
- Furnish, install, operate, maintain, and monitor installation of the Two-Stage Borehole Test and ensure that the testing integrity is not compromised due to inclement weather conditions.
- Prepare a Test Fill Report for submittal to WCH.

D. *Acceptance Testing.*

- Observe and record the results of the dry-run verification of the acceptance tests conducted by TWS.
- Observe and record the results of the acceptance tests procedures (ATP) conducted by TWS.

E. *Documentation.*

- Preparation of a final certification report to document each construction component monitored by CQA, as required by the CQAP.

- Preparation and submittal of preliminary reports in order to expedite the final report review process.

F. *CQA Subcontractor Submittals.*

- Submit the subcontract documents listed in Exhibit "I" and in accordance with the requirements and procedures set forth in Exhibit "I".

G. *Receiving Inspections.*

- Conduct receipt inspections to include transportation and handling of *geosynthetic* materials.

- Conduct receipt inspections to include transportation and handling of *bentonite* materials.

H. *Review Construction Subcontractor's Submittals.*

- Review the Construction Subcontractor's (TWS) engineering submittals listed in Attachment C of the specifications.

- Review calibration data for the Construction Subcontractor's testing equipment to include pugmill scales.

I. *Progress "As-Built" Drawings and Specifications.*

- Maintain an up-to-date set of Construction Subcontract drawings and technical specifications.

J. *"As-Built" Surveys.*

- Conduct "As-Built" surveys to demonstrate that the cell's subgrade; lysimeter and liner system layer thicknesses (top of admix, secondary drainage, primary drainage, and operations layers); leachate collection; and pipeline alignments meet the requirements specified in the Construction Subcontract drawings and technical specifications.

- Incorporate the "As-Built" survey on the "As-Built" drawings and in table format that includes survey points in a 50-ft. grid corresponding to the Washington State Plane coordinate system Northing, Easting, and Elevation.

- Prepare drawings in accordance with *SC 4.3 – Subcontractor-Furnished Drawings, Data, and Samples* (Exhibit "B").

K. *Meetings.*

- Attend and participate in weekly progress meetings administrated by WCH.

- Plan supplemental meetings, as necessary, to coordinate activities with the ERDF Operations Subcontractor, WCH, and others.

L. *Work Excluded.* Work specifically excluded from the scope of work included:

- CQA support trailers and utilities;

- Construction work associated with Exhibits "E" and "F";

- Cultural/ecological assessments or reviews;

- Radiological control support/personnel monitoring; and

- Supplying radiological postings (signs and labels).

1.2 Project Specifications. The work was conducted in accordance with the following documents:

- *Construction Specifications and Drawings for Environmental Restoration Disposal Facility (ERDF), Super Cells 9 and 10, Hanford Site, Richland, Washington,* prepared for WCH by Weaver Boos, Inc., and dated November 13, 2009.

- *Construction Quality Assurance Plan (CQAP) for Environmental Restoration Disposal Facility (ERDF), Super Cells 9 and 10,* prepared for the U.S. Department of Energy by Weaver Boos, Inc., and issued for construction on November 13, 2009.

In addition, all work described in this report was conducted in conformance with all issued design clarifications and modifications as well as supplier deviation disposition requests (SDDRs) and approved contractor submittals.

1.3 Key Project Operational Organizations.

- Tradewind Industries, Inc. (TWS) of Kennewick, WA, served as the construction subcontractor for Super Cell 9.
- DelHur Industries, Inc. (DHI) of Port Angeles, WA, served as the primary construction subcontractor to TWS for the construction of Super Cell 9.
- Gundle/SLT Environmental, Inc. (GSE) of Houston, Texas, supplied the 60- and 100-mil. geomembrane material.
- Environmental Specialties International Inc. (ESI) of Baton Rouge, Louisiana, served as the liner installer/subcontractor under TWS.
- SKAPS Industries of Athens, Georgia, supplied the 8- and 16-oz. geocomposite geotextile materials (Type A and Type B, respectively) and geocomposite materials.
- ISCO Industries of Louisville, Kentucky, supplied the leachate collection and riser piping.
- American Electric of Richland, WA, served as the electrical subcontractor to TWS for construction of Super Cell 9.
- Total Energy of Richland, WA, served as a subcontractor to American Electric for the logic controls associated with the leachate transmission system.
- Several local contractors served as subcontractors to TWS for construction of a portion of the Super Cell 9 crest pad building (i.e., overhead doors, insulation, paint and interior walls).
- Baker, McHenry and Welch Constructors (BMWC) of Indianapolis, Indiana, served as the piping installer/subcontractor under TWS.
- Stratton Surveying Inc., of Kennewick, WA, served as the CQA surveyor for Super Cell 9 and provided the CQA "As-Built" drawings.

- Precision Geosynthetic Laboratories (PGL) of Anaheim, California, and Texas Research Institute, Inc. (TRI) of Austin, Texas, served as the CQA testing laboratories for geosynthetic materials.

- Texas Research Institute, Inc. (TRI) of Austin, Texas, served as the CQA secondary testing laboratory for geosynthetic materials.

1.4 Project Overview. The project was completed in two (2) separate phases identified as excavation and cell construction. On August 10, 2009, DelHur Industries, Inc. (DHI) (Construction Contractor) of Port Angeles, WA, commenced excavation activities for Super Cell 9 which was an extension of their contract for ERDF Cells 7 and 8 construction. Construction Quality Assurance (CQA) services for excavation activities were provided by ENVIROTECH under Subcontract S66X528A00, an extension of Subcontract S013213A00.

DHI excavated the trench area utilizing a CAT 5110 excavator, a CAT 385 excavator, and a fleet of Payhauler trucks. The excavated soil material was separated and depending on the soil characteristics, transported to either the base soil or operations stockpile areas, as directed by CQA personnel. Excavation activities were completed in the footprint of Super Cell 9 on October 13, 2009.

The second phase of the project commenced following award of the Super Cells 9 and 10 construction contract. Construction of Super Cells 9 and 10 was funded by the American Resource Recovery Act (ARRA) and awarded to Tradewind Services, Inc. (TWS) of Richland, WA, with DelHur Industries, Inc. (DHI) named as the primary construction subcontractor to TWS. ENVIROTECH was awarded the CQA portion of the Super Cells 9 and 10 construction contract.

Following award of the Super Cells 9 and 10 construction contract in February 2010, TWS proceeded with mobilization activities. Beginning with completion of Super Cell 9 excavation activities in the cell footprint, TWS compacted the subgrade and clipped the final surface to design grade. Following subgrade compaction activities, TWS excavated a lysimeter trench into the north embankment and installed the lysimeter riser pipe.

TWS mobilized the admix pugmill on-site for construction of the admix test pad. TWS calibrated the pugmill and produced admix material by combining native Eolian Sand with 12% bentonite. Utilizing the admix material, the test pad was constructed on the south side of Super Cell 9 between April 5 and April 6, 2010. Following completion of test pad construction and associated testing activities, a Two-Stage Borehole Infiltration Test (Boutwell) was installed on the test pad and the 14-day test was completed on April 21, 2010.

Following completion of the Boutwell testing and acceptance of the results, TWS utilized the pugmill to begin producing admix material on April 27, 2010. The soil liner was produced by combining 135,000-ton of loose base soil mined on-site with 14,500-ton of sodium bentonite purchased from Wyo-Ben, Inc., located in Wyoming. The admix material was allowed to hydrate for a minimum of 12-hr. in stockpiles adjacent to the pugmill equipment. Utilizing Payhauler trucks, the hydrated admix material was placed onto the compacted subgrade and spread with a CAT D6 LGP GPS dozer. Utilizing a CAT 825 sheepsfoot compactor, TWS placed and compacted six (6) lifts of soil liner. CQA personnel conducted the required testing on the soil liner to ensure the material met construction specifications.

ESI purchased geosynthetic material from Gundel/SLT Environmental (GSE) and SKAPS Industries. GSE produced the geomembrane material while SKAPS supplied the geotextile and geocomposite materials. Following acceptance of the soil liner, geosynthetic liner placement was commenced on Super Cell 9 on June 10, 2010. The sequence of geosynthetic liner material placement varied in order to accommodate installation constraints. The sequence of geosynthetic liner material placement is summarized in *Table 1.1*.

TABLE 1.1
SEQUENCE OF GEOSYNTHETIC LINER MATERIAL PLACEMENT

Floor	Sideslopes
Type A (8-oz.) Geotextile	
Primary Type A Drainage Gravel (Floor); Type B Drainage Gravel (Sump Only); and Leachate Collection Pipe	
Upper Primary Type B (16-oz.) Geotextile	Geocomposite
60-mil. Primary Geomembrane	60-mil. Primary Geomembrane
Lower Primary Type B (16-oz.) Geotextile (Sump Only)	
Type B Drainage Gravel (Sump Only); and Leachate Collection Pipe (Sump Only)	
Secondary Type B (16-oz.) Geotextile (Sump Only);and Geocomposite (Floor)	Geocomposite
60-mil. Secondary Geomembrane	60-mil. Secondary Geomembrane

ESI installed approximately 733,000-sf of 60-mil. HDPE secondary geomembrane over the 3-ft. admix soil liner. On the floor of Super Cell 9, ESI installed a layer of geocomposite over the secondary geomembrane. On the slopes, ESI installed a layer of geocomposite over the secondary geomembrane, followed by the primary geomembrane. ESI installed a total of 729,000-sf of primary geomembrane. On the cell floor, ESI placed a layer of 16-oz. cushion geotextile over the primary geomembrane, followed by TWS placing 16,000-cy of Type A primary drainage gravel over the geotextile. On the slopes, ESI installed a layer of primary geocomposite over the primary geomembrane. Baker, McHenry, and Welch Contractors (BMWC) fabricated a 12-in. HDPE leachate collection drainage pipe to convey leachate from the cell floor to the sump. This pipe was installed in the primary layer of drainage gravel by TWS. ESI deployed a final layer of 8-oz. geotextile over the drainage gravel and leachate collection piping system.

During placement of the secondary drainage gravel layer in the Super Cell 9 sump, a storm event introduced stormwater under the secondary geomembrane and as a result, a portion of the admix liner was impacted. The geomembrane material was temporarily removed in order to repair the admix layer. Following completion of this repair activity, water was reintroduced under the secondary geomembrane in the Super Cell 9 sump as a result of a mislogged repair. The water under the geomembrane was removed, the admix repaired, and the secondary geomembrane patched.

Placement of the operations layer commenced on September 27, 2010. Payhauler trucks delivered soil for the operations layer to Super Cell 9 via roads constructed approximately 7-ft. above the primary drainage gravel. The soil was stockpiled at the end of the roads and spread across the cell floor and up the sideslopes utilizing a CAT D6 dozer. TWS completed soil placement for the operations layer on November 16, 2010.

On April 7, 2010, TWS commenced construction of Crest Pad Building 9. Following completion of the structure, the pumps, piping, valves, and controls for the leachate collection systems were installed and satisfactory Acceptance Test Procedures (ATPs) were completed on December 16, 2010.

After each individual layer of Super Cell 9 was completed, Stratton Surveying of Kennewick, WA, conducted a CQA "As-Built" survey. The "As-Built" survey drawings were progressively compiled from the initial level of cell construction forward. The 11-in. x 17-in. "As-Built" drawings are included in *Appendix A*. For ease of review, please refer to the full-size (24-in. x 36-in.) drawings in CQA *Submittal 5-22 - CQA Surveys*.

2. SOIL LINER TEST FILL AND BOUTWELL TEST

2.1 Introduction. ENVIROTECH conducted CQA observation and testing during construction of the soil liner test fill to include installation and monitoring of a Boutwell test at the Department of Energy's (DOE's) Environmental Restoration Disposal Facility (ERDF). This section provides a summary of the observation and testing results associated with the test fill construction, Boutwell installation, and hydraulic conductivity testing.

2.1.1 Purpose. A soil liner test pad was installed prior to construction of Super Cell 9 to demonstrate that the contractor's personnel, equipment, and methods were suitable for installing a soil liner that would satisfy project specifications. During test pad construction activities, the contractor employed the same soil liner materials, equipment, and methods that were proposed for use during construction of Super Cell 9. Evaluation of the test fill permeability included laboratory analysis of relatively undisturbed samples of the compacted soil liner and a field permeability test (Boutwell Testing - ASTM 6391).

2.1.2 Scope of Services. The scope of services to be provided by ENVIROTECH included the following:

- Review the manufacturer's quality control testing documentation.
- Verification of the pugmill calibration results.
- Measurement of the bentonite content of the admix material and periodic visual monitoring of the admix material during production.
- Conduct pre-construction testing on the soil/bentonite admix materials.
- Observe test fill construction activities and document the compaction equipment and methods utilized during test pad construction.
- Verify both the compacted and uncompacted lift thicknesses.
- Conduct moisture-density testing and collect Shelby tube samples for permeability testing during test fill construction activities.
- Verify layer bonding.
- Conduct permeability testing on field-test fill samples.
- Provide equipment and materials for Boutwell installation.
- Install the Boutwell testing equipment, monitor the infiltrometer test, and analyze and report the infiltrometer data.

ENVIROTECH provided calibration verification of the pugmill on April 1, 2010; pugmill production monitoring on April 2 and April 5; full-time monitoring of test pad construction activities between April 5 and 6, 2010; and installation and monitoring of the Boutwell test beginning April 7, 2010.

2.2 **Test Fill Pre-Construction.** ENVIROTECH conducted pre-construction testing for the admix material test fill in accordance with Table 4.1 in the *Construction Quality Assurance (CQA) Plan*. ENVIROTECH ensured that all materials to be utilized for manufacturing the admix material for the test pad were suitable for construction.

2.2.1 **Bentonite.** The bentonite used during admix material production was the CP-200 product supplied by the American Colloid Company and comprised of a powdered, off-white clay. The manufacturer conducted quality assurance (QA) testing on the bentonite material to ensure compliance with API Specification 13A for minimum yield, maximum fluid loss, and free-swell.

2.2.2 **Base Soil.** ENVIROTECH provided continuous monitoring of the base soil stockpiling operations. The base soil from Super Cell 9 excavation activities was removed and stockpiled southeast of the excavation area. The base soil contained no large rocks, stumps or deleterious material, and only trace amounts of woody, vegetative material. Soil material that did not conform to the specification requirements was rejected by ENVIROTECH and removed from the base soil stockpile. The base soil appeared to be a brown, sandy material and ENVIROTECH conducted pre-construction testing on the soil in accordance with the referenced Table 4.1 in the CQA Plan. A hydrometer analysis (ASTM D422) confirmed that the Unified Soil Classification System (USCS) classification of the base soil was SM (silty sand) and therefore, was in compliance with the requirements set forth in the construction specifications. The laboratory analytical results are summarized in *Table 2.1* and included in *Appendix C*.

2.3 **Pugmill Operations.** ENVIROTECH observed calibration of the pugmill and verified the admix material's bentonite content from the calibrated scales. ENVIROTECH ensured that the final admix product met the requirements set forth in the construction specifications (0600X-SP-C0076 Cell Construction – Admix Layer).

2.3.1 **Pugmill Calibration.** ENVIROTECH observed TWS conducting calibrations on the pugmill equipment. TWS calibrated the base soil feed belt scale and the total product belt scale by conveying dry base soil across the scales and feeding the material into a side-dump trailer. The trailer was weighed on the calibrated truck scales and the final weight of the trailer was utilized to calibrate the belt scales.

TABLE 2.1
SUMMARY OF PRE-CONSTRUCTION TESTING RESULTS – BASE SOIL

Sample Number	Sieves			Soil Classification	Specification
	3/4-in.	No. 40	No. 200		
BS-01	100.0	72.3	34.4	SM –Silty Sand	Passes
BS-02	100.0	84.8	33.0	SM –Silty Sand	Passes
BS-03	100.0	84.5	27.9	SM –Silty Sand	Passes
BS-04	100.0	82.9	31.0	SM –Silty Sand	Passes
BS-05	100.0	84.3	40.4	SM –Silty Sand	Passes
BS-06	100.0	73.0	30.8	SM –Silty Sand	Passes
BS-07	100.0	74.9	45.9	SM –Silty Sand	Passes
BS-08	100.0	77.8	33.3	SM –Silty Sand	Passes
BS-09	100.0	86.4	26.5	SM –Silty Sand	Passes
BS-10	100.0	61.6	30.7	SM –Silty Sand	Passes
BS-11	100.0	89.7	54.2	SM –Silty Sand	Passes
BS-01*	100.0	52.7	21.2	SM –Silty Sand	Passes
BS-02*	100.0	86.0	32.9	SM –Silty Sand	Passes
BS-03*	100.0	52.7	21.4	SM –Silty Sand	Passes
BS-04*	100.0	77.8	36.8	SM –Silty Sand	Passes
BS-05*	100.0	58.4	26.7	SM –Silty Sand	Passes
BS-06*	100.0	82.0	23.7	SM –Silty Sand	Passes
BS-07*	100.0	90.4	25.7	SM –Silty Sand	Passes
BS-08*	100.0	80.6	34.2	SM –Silty Sand	Passes
BS-09*	100.0	89.4	21.0	SM –Silty Sand	Passes
BS-10*	100.0	86.2	43.5	SM –Silty Sand	Passes

* Indicates that the base soil material was part of the Super Cell 10 excavation. All base soil used in this project originated from Super Cell 9 or 10 excavation activities. However, due to mixing the base soil stockpile, it cannot be determined if the admix material produced used base soil from Super Cell 9 or 10.

Northwest Scales certified the calibration on the silo scales. TWS calibrated the silo augers by passing bentonite from the silos, through the augers, and into trucks. The truck weights were compared with the silo weights and a relationship between the auger revolutions per minute (rpm) and a bentonite feed rate was calculated.

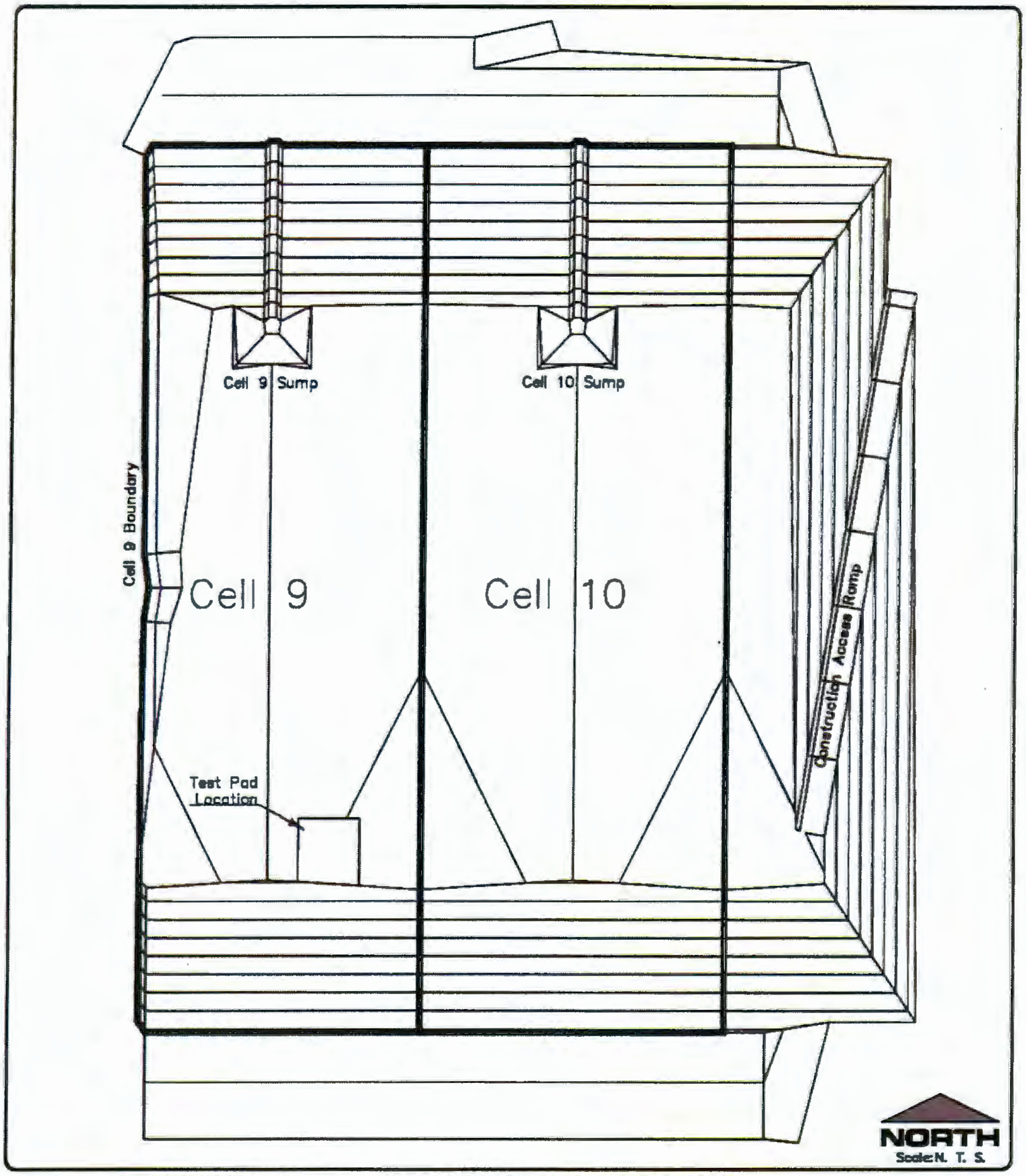
2.3.2 **Belt Scale Measurements.** During production of the admix material, ENVIROTECH periodically verified the moisture content and quantity of bentonite in the material at a frequency greater than once every 1,000-cy. ENVIROTECH recorded the silo weights at the beginning of the test and at a 6-minute interval to provide a flow rate of bentonite over the 6-minute time period. In addition, average readings for base soil and total product were recorded to calculate the average bentonite content over the 6-minute time period. ENVIROTECH observed admix material mixing activities to include the maximum clod size and natural moisture content of the referenced material. The analytical results for the belt scale and moisture content testing activities are included in *Appendix C*. CQA verified that the admix material manufactured by TWS met the requirements set forth in the TWS Submittal 05-19-001 (Admix Preparation Plan) and the construction specifications.

2.3.3 **Admix Material.** In accordance with the frequency requirements set forth in Table 4.1 in the CQA Plan, ENVIROTECH collected a sample of the processed admix material from the pugmill for analysis. Analysis of the admix material included soil density/moisture content (ASTM D 698), Atterberg Limits (ASTM D4318), and permeability (ASTM D5084). The laboratory analytical results are summarized in *Table 2.2* and included in *Appendix C*.

TABLE 2.2
SUMMARY OF PRE-CONSTRUCTION TESTING RESULTS – ADMIX SOIL

Sample	Proctor		Moist. %	Atterberg Limits			No. 200 Sieve	Shelby Tube (cm/s)	Soil Classification	Test Results
	Dry Density (lb/cf)	Moist. %		Liquid	Plastic	PI				
Specs	---	---	---	>30	---	>15	>20%	< 1.0E-7	---	---
AM-01	117	13.5	14.8	50	19	31	36.9%	1.66E-08	CH-Sandy Fat Clay	Pass

2.4 **Test Fill Construction.** On April 5 and 6, 2010, the test pad was constructed at the south toe of the slope in Super Cell 9 and opposite the Super Cell 9 sump, as graphically depicted on the Site Plan included as *Figure 2.1*. TWS utilized the following equipment during test pad construction activities:



SITE PLAN
ERDF Super Cell 9

ENVIROTECH

Figure 2.1

- Caterpillar (CAT) D-6 Dozer;
- CAT 825 Compactor;
- Water Truck;
- Two (2) International Payhauler trucks;
- CAT 320 Excavator; and
- CAT CS563D Smooth-Drum Compactor.

The 100-ft.-long x 50-ft.-wide test pad was constructed to a minimum width four times (4X) the widest piece of equipment utilized during construction activities. The Caterpillar (CAT) D-6 dozer equipped with an enabled Global Positioning System (GPS) measured 12.5-ft.-wide and as a result, the required test pad width was calculated to be 50-ft. The 100-ft.-long test pad was designed to allow the compactor to reach full speed.

Prior to April 5, 2010, TWS scarified, moisture-conditioned, and compacted the test pad subgrade. CQA tested and verified that the subgrade was compacted to 90% modified proctor. Following subgrade preparation, Stratton Surveying (CQA Surveyor) verified the final elevation of the test pad subgrade on a 50-ft. grid.

On April 5, 2010, TWS utilized a water truck to moisture-condition the subgrade in preparation for admix material placement. TWS utilized International Payhauler trucks to transport the admix material from the pugmill to the test pad.

Lift 1. The initial lift of admix material was spread in a 12-in. lift utilizing the CAT D-6 GPS dozer. TWS compacted the admix material with a CAT 825 compactor with an approximate gross weight of 70,000-lb. and equipped with pegs measuring 7 3/4-in.-long. The CAT 825 compactor speed was set at 4.2-mph for Lift 1. Following Lift 1 compaction activities, the compacted lift thickness was determined to be 4-in. and therefore, the admix material failed to meet compaction specifications due to the low density readings. TWS recompacted Lift 1 with 1 1/2 additional passes of the CAT 825 compactor. Following the failure of the second test, TWS reduced the compactor speed from 4.2-mph (3RD gear) to 2.1-mph (2ND gear). TWS placed additional material on Lift 1 to increase the thickness to 8-in., pursuant to construction specifications. TWS completed three (3) compaction passes on Lift 1 utilizing the CAT 825 compactor at a speed of 2.1-mph. Following Lift 1 compaction activities, the lift thickness was surveyed and determined to be approximately 9-in.

Lift 1 was cut with the CAT D6 GPS dozer to a surveyed thickness of 8-in., pursuant to construction specifications. ENVIROTECH tested and verified that the in-place admix material on Lift 1 met the requirements set forth in the construction specifications.

Lift 2. TWS placed a 10-in. layer of loose material for Lift 2 with the CAT D6 GPS dozer. The material was compacted utilizing the CAT 825 compactor to a compacted lift thickness of 6-in. Due to drier admix material, Lift 2 failed to meet compaction specification requirements. TWS moisture-conditioned the test pad surface and recompacted the admix material. ENVIROTECH tested and verified that Lift 2 met the requirements set forth in the construction specifications.

Lift 3. TWS constructed Lift 3 in a manner similar to that for Lift 2. ENVIROTECH verified that Lift 3 met the requirements set forth in the construction specifications, with the exception of the SW/corner of the test pad. TWS moisture-conditioned and compacted the failed area utilizing the CAT 825 compactor. ENVIROTECH tested and verified that Lift 3 of the admix material test pad met the requirements set forth in the construction specifications.

TWS static-rolled the test pad surface utilizing the CAT CS563D smooth-drum roller to seal the admix material and create a smooth surface to prevent blowing sand from infiltrating into the CAT 825 compacter's tracks and protect the admix overnight.

On April 6, 2010, TWS constructed test pad Lifts 4 through 6. TWS utilized a water truck to moisture-condition the admix material and a CAT 825 compactor to scarify the smooth surface of Lift 3.

Lift 4. TWS placed a 10-in. layer of admix material for Lift 4 and compacted the material utilizing the CAT 825 compactor. Initially, all testing on Lift 4 passed, with the exception of the SW/corner of the test pad. TWS utilized the CAT 825 compactor to continue rolling the failed area of Lift 4 until the admix material met the requirements set forth in the construction specifications.

Lift 5. Lift 5 was constructed in a manner similar to that for Lift 4. The admix material was moisture-conditioned, a 10-in. layer of loose admix material was placed over the previous lift, and the lift was compacted utilizing the CAT 825 compactor.

Lift 6. Lift 6 was constructed in a manner similar to that for Lifts 4 and 5. The admix material was moisture-conditioned, a 10-in. layer of loose admix material was placed over the previous lift, and the lift was compacted utilizing the CAT 825 compactor.

ENVIROTECH tested and verified that Lifts 1 through 6 met the requirements set forth in the construction specifications. After each lift was constructed and compacted, CQA conducted a minimum of six (6) in-place nuclear density tests (ASTM 6938) utilizing a Troxler 3430 nuclear density gauge and one (1) sand cone test (ASTM D1556). In addition, an undisturbed soil sample was collected utilizing a Shelby tube sampling device and permeability testing was conducted pursuant to ASTM 5084.

The acceptable moisture density range for the compacted admix material is defined by a trapezoidal-shaped field with four (4) corners. The dry density and moisture data must fall within the acceptable zone and meet a minimum saturation of 85%. Following test failure, the failed portion of the lift was moisture-conditioned, as necessary, and recompacted. ENVIROTECH ensured that each lift met construction specification criteria prior to construction of subsequent lifts. All field testing results are included in *Appendix C*.

Following the completion of testing on Lift 6 and as directed by CQA, TWS utilized an excavator to produce a 10-ft. x 5-ft. hole in the admix material's surface to demonstrate their repair methodology. TWS laid-back the corners of the hole to allow for compactor access. The hole was filled with admix material and compacted utilizing the CAT 825 compactor to make three (3) passes at 2.1-mph. ENVIROTECH conducted one (1) moisture density test and one (1) sand cone test in addition to collecting a Shelby tube sample to verify that the repair met the requirements set forth in the construction specifications.

Following validation of the repair process, TWS utilized the CAT D-6 dozer to cut the final lift to grade and static-rolled the test pad utilizing the CAT CS563D smooth-drum roller to smooth the finished surface. ENVIROTECH verified that the admix material was trimmed and all excess uncompacted admix material was removed. ENVIROTECH, aided by Stratton Surveying, verified the test pad met the required 3-ft.-thickness and grading tolerances outlined in the construction specifications. Loose and compacted lift thicknesses were verified by Stratton Surveying and summarized in *Table 2.3*.

TWS excavated three (3) test pits into the test fill to ensure layer bonding and test pad thickness. CQA verified that the admix material was of a similar, homogenous nature. The soil liner appeared to be one (1) continuous lift with a distinguishable partition only appearing between the soil liner and subgrade.

During test fill construction activities, ENVIROTECH observed that the test pad was constructed from six (6) lifts of admix material compacted to a maximum 6-in.-thickness. ENVIROTECH, aided by Stratton Surveying, verified the uncompacted and compacted lift thicknesses for Lifts 1 through 6. CQA, aided by TWS, began installing the Boutwell hydraulic conductivity test equipment (ASTM D6391) on April 6, 2010. At the end of the work day, CQA covered the test locations with a plastic protective cover.

TABLE 2.3
SUMMARY OF LIFT THICKNESS VERIFICATION

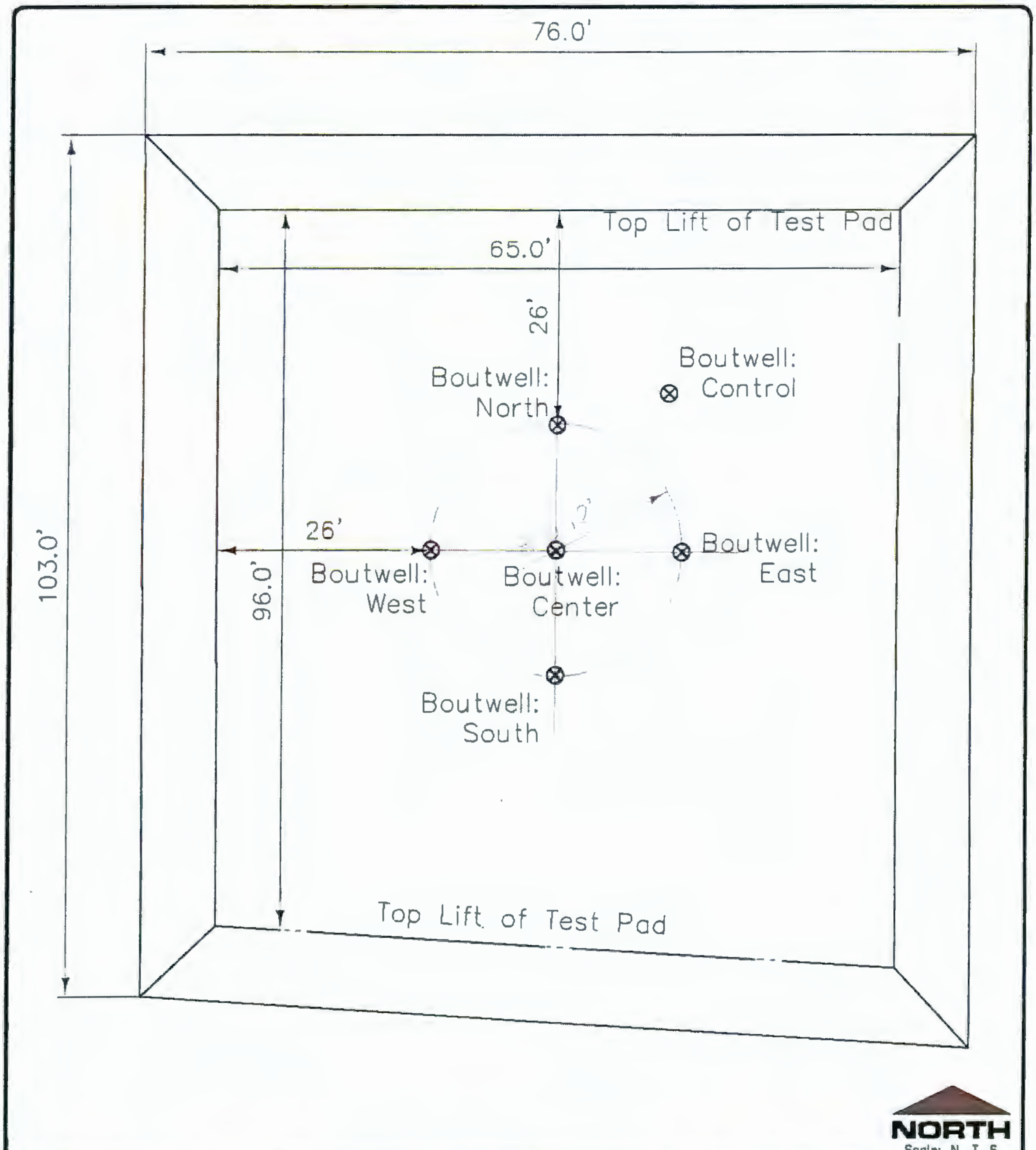
Location	Loose Lift Thickness (ft.)	Compacted Lift Thickness (ft.)
Lift 1	1.29	0.65
Lift 2	0.82	0.54
Lift 3	0.74	0.44
Lift 4	0.87	0.47
Lift 5	0.89	0.65
Lift 6	0.68	0.52
Cumulative Elevation	5.29	3.27
Final Cut Lift Thickness	---	3.08

2.5 **Boutwell Installation.** On April 6, 2010, ENVIROTECH initiated installation of the *Field Measurement of Hydraulic Conductivity Limits Using Two Stages of Infiltration from a Borehole* (ASTM D 6391-06) (i.e., a Boutwell test) manufactured by Trautwein Soil Testing Equipment. Installation activities continued through April 7 and 8, 2010. Pursuant to the CQA Plan, ENVIROTECH only conducted the first stage of the two-stage testing process.

ENVIROTECH implemented installation of the Boutwell test on the top lift of the test fill by auguring six (6) boreholes in the test pad, as graphically depicted on *Figures 2.2 and 2.3*.

Each borehole was located, at minimum, 15-ft. from any adjacent borehole and 10-ft. from the edge of the test pad. A minimum admix material thickness of 2-ft., measured from the subgrade to the bottom of the borehole, was maintained for all borings.

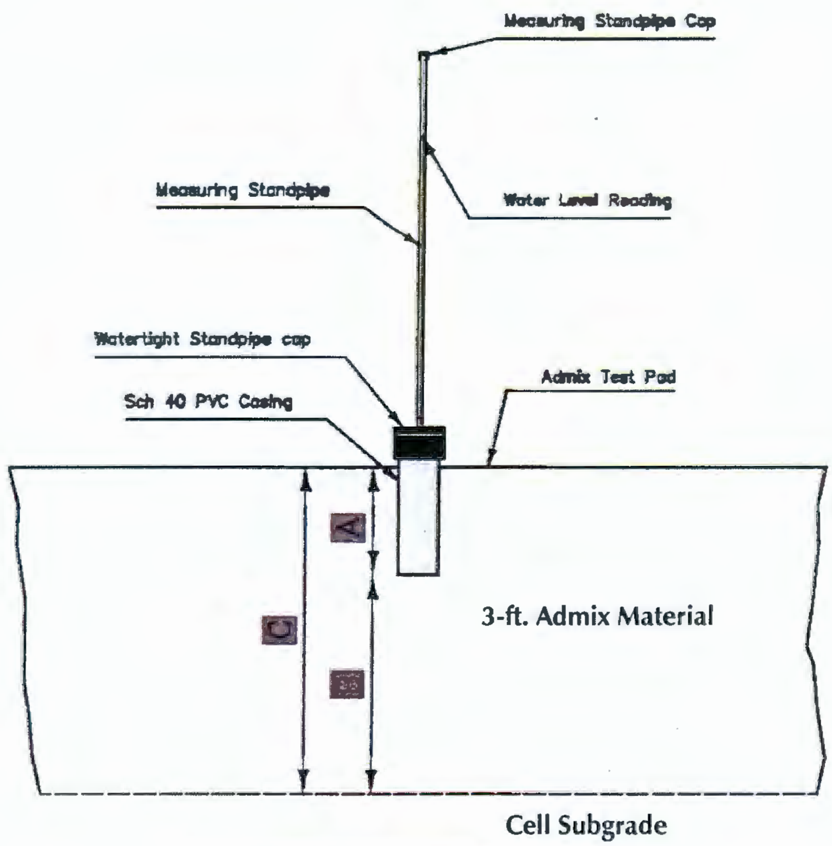
On April 7, 2010, ENVIROTECH installed four (4) test apparatus (north, east, west and south) at a test depth of 8-in. A fifth (central) apparatus was set at a test depth of 1-ft. A temperature effect gauge (TEG) was installed at the NE/corner of the test pad to measure temperature effects for flow reading corrections as a result of ambient temperature changes. Five (5) of the six (6) test boreholes are open to the underlying soil, while the TEG is capped to prevent infiltration into the test fill. All six (6) boreholes were grouted by placing powdered and granular bentonite into the annular space in 1- to 2-in. lifts. Water was added to each lift and rodded into the underlying lift.



TEST PAD – BOUTWELL LOCATIONS
ERDF Super Cell 9

ENVIROTECH ENGINEERING & CONSULTING, INC.

Figure 2.2



Boutwell	Measurement A	Measurement B	Measurement C
North	0.82	2.25	3.07
South	0.73	2.34	3.07
East	0.78	2.29	3.07
West	0.85	2.23	3.08
Center	1.12	2.01	3.13
Control (Estimated)	0.80	2.28	3.08

Scale: N.T.S.

TEST PAD – BOUTWELL INSTALLATION DETAILS - Super Cell 9

ENVIROTECH

Figure 2.3

After the casings were grouted into place, the bentonite was allowed to hydrate for a minimum of 12-hr.

On April 8, 2010, ENVIROTECH completed installation of the Boutwell tests. Due to concerns over freezing conditions, each borehole was filled with a 5:1 de-aired water/ethanol mixture. The top standpipe and seal were installed and each standpipe was filled with water. Care was taken to reduce the amount of entrained air in the standpipe as it could possibly affect flow properties.

ENVIROTECH initiated Boutwell reading collection activities on April 8, 2010, at approximately 11:30 a.m. Readings were initially sequenced, as outlined in ASTM D6391. Following collection of the initial readings, ENVIROTECH monitored the test readings twice daily at 8:00 a.m. 4:00 p.m. For each reading, ENVIROTECH recorded the time and water level reading in centimeters for each standpipe as well as the water temperature from the TEG and the ambient temperature from the Hanford Meteorological Station (HMS).

2.6 Test Fill Permeability Results

2.6.1 Laboratory Analytical Results. The laboratory analytical results for the final permeability testing conducted on the Shelby tube samples collected from the test fill indicated that each sample had a permeability of less than 1×10^{-7} cm/s. These tests were conducted to demonstrate that the contractor's methods, equipment, materials, and personnel were capable of blending the materials in the correct proportions and properly moisture-conditioning, placing, and compacting the material to achieve the required permeability of less than, or equal to, 1×10^{-7} cm/s. The laboratory analytical results for permeability testing conducted on the admix material are summarized in *Table 2.4* and included in *Appendix C*.

2.6.2 Boutwell Test Results. Boutwell test monitoring was initiated after nine (9) days, or after the initial saturation and unsteady state issues were resolved. Boutwell monitoring continued for five (5) days with the test concluding on April 22, 2010.

Based on the Boutwell testing data, the test fill's permeability was determined using the following relationship outlined in ASTM 6391 – 06:

$$K = R_t \times G_1 \times \ln(H_1/H_2)/(t_2-t_1)$$

where

K = Permeability (cm/sec)
H = Effective Head (cm)
R_t = Temperature Correction Factor, based upon the TEG reading
t = Time (sec)

$G_1 =$ Geometric Coefficient $= (\pi d^2/11 \times D_1)\,[1+a\,(D_1/4 \times b_1)]$

where

$b =$ Thickness of Tested Material
$a =$ -1 for a Permeable Base at b_1
$D_1 =$ Inner Diameter of Boutwell Casing
$d =$ Inner Diameter of Standpipe

TABLE 2.4
SUMMARY OF PERMEABILITY TESTING RESULTS (ASTM D 5084) – ADMIX MATERIAL

Sample No.	Sample Type	Lift No.	Date Collected	Permeability	Specification
TP-04	Shelby Tube	1	April 5, 2010	1.38×10^{-8}	Pass
TP-11A	Shelby Tube	2	April 5, 2010	1.61×10^{-8}	Pass
TP-13	Shelby Tube	3	April 5, 2010	1.38×10^{-8}	Pass
TP-20	Shelby Tube	4	April 6, 2010	1.61×10^{-8}	Pass
TP-28	Shelby Tube	5	April 6, 2010	3.25×10^{-8}	Pass
TP-34	Shelby Tube	6	April 6, 2010	5.80×10^{-8}	Pass
TP-37	Shelby Tube	Repair	April 6, 2010	1.63×10^{-8}	Pass
AM-01	Recompacted	N/A	April 2, 2010	1.66×10^{-8}	Pass

The permeability is measured over a time difference with the change in the effective head (height of water in the standpipe) being evaluated over a given time period. The larger the drop in effective head for a given time period, the higher the permeability. Each Boutwell test was evaluated independently with an average permeability value calculated from the resulting readings from each test location. The permeability values are summarized in *Table 2.5* and included in *Appendix C.*

Based on the results presented in *Table 2.5* and *Appendix C,* the permeability determined by utilizing the Boutwell tests is approximately 2.27×10^{-9} cm/sec. which represents a conservative estimate of the test fill permeability. The test pad permeability measured by the Boutwell testing apparatus compares favorably with the laboratory-measured permeabilities of the Shelby tube samples and recompacted permeability sample.

2.7 **Test Fill Permeability Results.** Based on the Boutwell testing data, the test pad permeability is approximately 2.27×10^{-9} cm/sec. Therefore, the proposed materials, contractor's equipment, blending, moisture-conditioning, placement, and compaction procedures are sufficient to install a soil liner that meets the specification's permeability requirement of less than, or equal to, 1×10^{-7} cm/s. In addition, the permeabilities determined using the Boutwell data agree with the laboratory-determined permeabilities from the Shelby tube samples.

TABLE 2.5
SUMMARY OF PERMEABILITY TESTING RESULTS (ASTM D 6391) - BOUTWELL

Boutwell Location	Sample Depth (ft.)	Permeability	Specification
North	2.25	2.58E-09	Pass
East	2.29	1.94E-09	Pass
West	2.23	1.78E-09	Pass
South	2.34	3.33E-09	Pass
Central	2.01	1.73E-09	Pass
AVERAGE	*2.28*	*2.27E-09*	*Pass*

3. EXCAVATION AND SOILS

3.1 **Introduction.** ENVIROTECH was retained by Washington Closure Hanford, LLC (WCH) to provide Construction Quality Assurance (CQA) observation and testing services during excavation activities and embankment construction of Super Cell 9 at the Environmental Restoration Disposal Facility (ERDF) at the Hanford Nuclear Reservation. ENVIROTECH'S work was conducted under WCH Subcontract S66X528A00 as an extension to the contract for Cells 7 and 8 construction. This section provides a summary of the CQA observations and testing associated with excavation and embankment construction of Super Cell 9.

3.2 **Scope of Services.** The scope of ENVIROTECH'S services outlined in the Construction Quality Assurance Plan (CQAP) included the following:

- Provide pre-construction testing services on embankment and backfill materials;
- Monitor the excavation activities and determine the material types for stockpiling; and
- Conduct density tests during embankment construction and backfill placement.

3.3 Excavation. ENVIROTECH provided full-time monitoring of these activities from August 10 to October 13, 2009. DelHur Industries, Inc. (DHI) of Port Angeles, WA, excavated ERDF Super Cell 9 which consisted of compacted Eolian sand as well as compact-to-dense sand and gravel deposits. Excavation activities for Super Cell 9 were initiated on August 3, 2009. Approximately 100,000-cy of Eolian sand and 75,000-cy of embankment fill material (based on Payhauler truck load counts) was excavated and transported to the appropriate stockpile or embankment/operations fill area.

DHI utilized the following equipment during excavation operations:

- One (1) CAT 5110 Excavator;
- One (1) CAT 385 Excavator;
- One (1) CAT D6 Dozer;
- One (1) CAT D6 LGP GPS Dozer;
- One (1) CAT D8N Dozer;
- Four (4) International Payhauler trucks;
- Three (3) Komatsu Payhauler trucks;
- One (1) CAT 140H Road Grader;
- One (1) CAT 834 Rubber Tire Dozer with attached Grader;
- One (1) International Payhauler Water Truck;
- One (1) CAT Motor Scraper Water Truck; and
- One (1) Water Truck

The soil was separated into two (2) stockpiles (base soil and operations soil.) The base soil stockpile was located southeast of the waste trench and the operations soil stockpile was located south of the waste trench. The excavation of Super Cell 9 was monitored to ensure that the excavated materials were placed in the proper stockpiles. During base soil stockpiling operations, CQA continuously monitored excavation operations to ensure that only materials identified as Eolian sands were placed into the base soil stockpile. During backfill operations, CQA monitored excavation activities to identify changes in materials in order to select the proper moisture-density relationship for testing purposes.

3.4 **Subgrade Preparation.** DHI prepared the subgrade for embankment fill placement by grading and compacting the subgrade surface utilizing the following procedures:

- The subgrade was scarified utilizing the D8 Dozer;
- The subgrade was moisture-conditioned;
- The subgrade was fine-graded with a Caterpillar D6 GPS dozer equipped with a GPS system;
- The subgrade was compacted utilizing the Payhauler water truck and motor scraper water truck; and
- The trench floor subgrade was compacted to at least 90% of the maximum dry density (ASTM D1557).

Field moisture-density tests were conducted by ENVIROTECH personnel on the compacted subgrade utilizing a Troxler Model 3430 nuclear moisture-density gauge (ASTM D2922). A total of six (6) moisture-density tests were conducted on recompacted subgrade on the embankment floor at a frequency of one (1) test per 26,700-sf. This testing frequency did not meet the specified frequency of one (1) test per 9,688-sf and therefore, an SDDR 9-01 was submitted to WCH detailing the non-conforming condition.

The moisture-density test results were compared to Modified Proctor results to determine the amount of relative compaction. A total of two (2) Modified Proctors (ASTM D1557) and two (2) soil classifications (ASTM D422 and D4318) were conducted and represent the various subgrade materials encountered. Summaries of the laboratory analytical results and field subgrade density testing results are included in *Appendix D*.

3.5 **Embankment Fill.** To construct the cell perimeter to design grade, embankment fills were constructed on the north and south sides of Super Cell 9. DHI constructed the embankment fills concurrent with cell excavation. A total 75,000-cy of fill material was required to construct the embankments utilizing material obtained from the excavation of Super Cell 9. The material was transported to the fill site utilizing Payhauler truckss and spread with a Caterpillar D6 dozer. The first few feet of backfill was moisture-conditioned and compacted to 90% of the maximum dry density, as determined by Modified Proctor (ASTM D1557), utilizing a Payhauler water truck and motor scraper water truck. The top 5-ft. of fill was moisture-conditioned and compacted to 95% of the maximum dry density, as determined by

Modified Proctor (ASTM D1557), utilizing a Payhauler water truck and a motor scraper water truck.

CQA collected ten (10) soil samples to conduct Modified Proctor (ASTM D1557) and grain-size distribution (mechanical sieve) tests pursuant to ASTM D2487 (Classification of Soils for Engineering Purposes); ASTM D4318 (Atterberg Limits); and ASTM D422 (sieve analyses). Modified Proctor and grain-size distribution testing were conducted at a frequency of one (1) test per 7,500-cy of material placed. Both the grain-size analysis and Modified Proctor frequencies exceeded the project specification requirements of one (1) test each per 7,848-cy of fill placed. Results of the grain-size distribution analysis indicate that fill material utilized for embankment construction met the requirements set forth in the project specifications. A summary of the Modified Proctor and grain-size distribution test results are included in *Appendix D.*

ENVIROTECH personnel monitored fill placement and compaction activities to ensure that the lift thickness and materials used met project specification requirements. Field moisture-density tests were conducted by ENVIROTECH personnel on the compacted embankment fill utilizing a Troxler Model 3430 nuclear moisture-density gauge (ASTM D2922). When soil conditions changed, new proctors were obtained. In addition, at least one (1) sand cone density test (ASTM D1556) was conducted per day at the location of a previously-conducted nuclear moisture-density test to provide correlation with the Troxler nuclear densiometer.

A total of 100 moisture-density tests (not including retests) were conducted. This frequency exceeded the specified frequency of one (1) test per 49,514-sf/lift. The moisture-density test results were compared to Modified Proctor results to determine the amount of relative compaction. In areas where test results indicated that compaction did not meet the specified requirement, the contractor reworked and recompacted the areas in question until passing test results were achieved. A summary of the berm field density testing results is included in *Appendix D.*

3.6 Excavation Summary. Excavation activity on Super Cell 9 commenced on August 3, 2009, with the excavation of 1.2-million-cy in the Super Cell 9 "footprint". The north and south berms were constructed concurrently with the excavation of the cell's "footprint" and completed on October 13, 2009.

4. LINER SYSTEM

4.1 Introduction. A summary of the CQA observations and testing associated with construction of the soil and geosynthetic liner system as well as the drainage layer for Super Cell 9 is presented in the following sub-sections of this report. From the bottom up, liner system construction included the following seventeen (17) elements:

- Cell Subgrade;
- Tertiary Lysimeter Geomembrane (sump only);
- Lysimeter Geotextile Type B (sump only);
- Lysimeter Type C Drainage Gravel (1.5-ft., sump only);
- Lysimeter Geotextile Type A (sump only);
- Soil Liner (3-ft.);
- Secondary Geomembrane (60-mil.);
- Secondary Geocomposite;
- Secondary Type B Drainage Gravel (1- to 1.5-ft., sump only);
- Secondary Type B Geotextile (sump only);
- Primary Geomembrane (60-mil.);
- Geomembrane Rub Sheet (sump only, 100-mil.);
- Primary Type B Geotextile (floor);
- Primary Type B Drainage Gravel (1- to 5-ft., sump only);
- Primary Type A Drainage Gravel (1-ft., floor only);
- Primary Geocomposite (slope); and
- Primary Type A Geotextile (floor only).

4.2 **Scope of Services.** The scope of ENVIROTECH'S services conformed to the requirements set forth in the *Construction Quality Assurance Plan (CQAP) for ERDF Cells 9 and 10* and consisted of the following:

- Conduct pre-construction and conformance testing on the soil liner, drainage gravel, and geosynthetic components of the liner system;

- Monitor admixing of the bentonite with base material for soil liner material preparation;
- Monitor construction of the soil liner;
- Monitor construction of the geosynthetic liner components;
- Monitor construction of the gravel drainage layer components;
- Monitor placement of the geosynthetic drainage layer and associated piping components; and
- Monitor placement of the filter and cushion geotextiles.

ENVIROTECH personnel monitored the above-referenced activities full-time from February 10 to November 5, 2010, as documented in the daily field book entries by all on-site personnel. Following his review, the CQA Engineer summarized the daily reports into weekly summary reports for submittal to WCH.

4.3 Geosynthetic Material Conformance and Friction Angle Testing.

4.3.1 HDPE Membrane. Approximately 3,135,000-sf of white, 60-mil.-thick GSE (textured) and 24,000-sf of white, 100-mil.-thick GSE (smooth) HDPE geomembrane liner material was delivered on-site for Super Cell 9 construction. An ENVIROTECH representative observed the manufacturing process of the geomembrane, and PGL personnel collected samples of selected rolls at the GSE plant according to the specified frequency outlined in the CQA Plan. Documentation associated with the factory inspection visit is included in *Appendix E*. The samples were shipped to Precision Geosynthetics Laboratory in Anaheim, CA, for conformance testing.

As part of the CQA testing program, samples collected from a total of seventy-three (73) rolls of 60-mil. HDPE geomembrane liner were tested to ensure conformance with the project specifications. This resulted in a CQA testing frequency of one (1) test per 43,000-sf for the 60-mil. HDPE geomembrane. In addition, a sample collected from one (1) roll of 100-mil. HDPE geomembrane was tested to ensure conformance with the project specifications. This resulted in a CQA testing frequency of one (1) test per 24,000-sf for the 100-mil. HDPE geomembrane.

The CQA conformance testing frequency exceeded the CQA testing requirement of one (1) conformance test for every 50,000-sf of geomembrane liner delivered to the site. The test results were reviewed by ENVIROTECH personnel and determined to be in compliance with the project specifications. The conformance test results are summarized in *Appendix E.*

In addition to the conformance tests, the geosynthetic (GSE) manufacturer provided a quality control documentation summary for each roll of HDPE geomembrane. The quality control documents and test results were reviewed by ENVIROTECH personnel and determined to be in compliance with the project specifications.

4.3.2 Geotextile. The geotextile materials delivered on-site were SKAPS product GE180 (8-oz. Type A) and SKAPS GE116 (16-oz. Type B), non-woven, needle-punched, polypropylene fabrics. Approximately 1,080,000-sf of Type A and 1,161,000-sf of Type B geotextile materials were delivered to the site. PGL personnel collected conformance samples from selected rolls at the manufacturer's facilities for shipment to the PGL laboratory in Anaheim, CA, for testing.

As part of the CQA testing program, samples were collected from twenty-two (22) rolls of Type A and twenty-four (24) rolls of Type B geotextile and analyzed for conformance with the project specifications. This resulted in an approximate geotextile CQA testing frequency of one (1) test per 49,091-sf for the Type A and one (1) test per 48,375-sf for the Type B geotextile delivered on-site. The CQA conformance testing frequency exceeded the CQA testing requirement of one (1) conformance test for every 50,000-sf of geotextile delivered to the site. The test results were reviewed by ENVIROTECH personnel and determined to be in compliance with the project specifications. The conformance test results are included in *Appendix E.*

The manufacturer of the geotextiles (SKAPS) provided quality control documentation for both Type A and Type B geotextile. The quality control documents were reviewed by ENVIROTECH personnel and determined to be in compliance with the project specifications.

4.3.3 Geocomposite. Approximately 2,071,000-sf of SKAPS product TN 300-2-8 geocomposite was shipped to the site. The geocomposite components consisted of geonet with a layer of Type A geotextile bonded to each side. As part of the CQA testing program, samples were collected from fifty (50) rolls of geocomposite and analyzed for conformance with the project specifications. This resulted in a geocomposite CQA testing frequency of one (1) test per 41,429-sf. The geocomposite CQA conformance testing frequency met the CQA testing requirement of one (1) conformance test for every 50,000-sf of geocomposite delivered to the site.

The conformance samples collected at the manufacturer's facilities by PGL personnel were shipped to PGL in Anaheim, California, for testing. The test results were reviewed by ENVIROTECH personnel and determined to be in compliance with the project specifications. The conformance test results are included in *Appendix E.*

4.3.4 Friction Angle Testing. The specification requires that two (2) sets of Interface Friction Testing be conducted according to ASTM D5321 for each of the listed interfaces:

- 60-mil. textured geomembrane and the soil/bentonite admix;
- 60-mil. textured geomembrane and geocomposite; and
- Geocomposite and operations layer material (sand).

The specification further requires that the tests be conducted under saturated conditions at nominal loads of 200-, 400- and 600-psf to determine the peak angle and residual angle measured at 2-in. displacement. The specified minimum residual friction angles (when evaluated at 400-psf, 2-in. of displacement and cohesion of 0.00) are summarized as follows:

- 60-mil. geomembrane/soil-bentonite admix.. 24.0°
- 60-mil. geomembrane/geocomposite.. 24.0°
- Geocomposite/operations layer material (sand)..................................... 24.0°

TRI/Environmental, Inc., located in Austin, Texas, conducted interface friction angle testing. TRI collected geosynthetic samples for testing while ENVIROTECH provided the soil/bentonite admix and operations layer material. The laboratory analytical results are included in *Appendix E*. The data provided by TRI in the box annotated *"Test Results"* is not the friction angle, as defined in the above-referenced specification. A summary of the Interface Friction Angle testing results are summarized in *Table 4.1* and include the following:

- ERDF specification Friction Angle (Friction Angle between 400-psf and 0); and
- ERDF specification Minimum Friction Angle.

TABLE 4.1
SUMMARY OF INTERFACE FRICTION TESTING RESULTS

Test	ERDF Friction (Angle-Degrees)	ERDF Min. Friction (Angle-Degrees)
Admix vs. 60-mil. Geomembrane (Test 1 of 2)	24.8°	24.0°
Admix vs. 60-mil. Geomembrane (Test 2 of 2)	28.7°	24.0°
Geocomposite vs. 60-mil. Geomembrane (Test 1 of 2)	25.2°	24.0°
Geocomposite vs. 60-mil. Geomembrane (Test 2 of 2)	26.0°	24.0°
Geocomposite vs. Operations Layer (Test 1 of 2)	29.2°	24.0°
Geocomposite vs. Operations Layer (Test 2 of 2)	35.0°	24.0°

A review of the laboratory analytical results summarized in *Table 4.1* reveals that all testing met the minimum requirements of the specified minimum interface friction angle of 24.0-degrees. The interface friction angle test report is included in *Appendix E*.

4.4 Cell Subgrade Preparation. Super Cell 9 subgrade preparation includes subgrade testing, tertiary geomembrane, lysimeter sump and trench, lysimeter riser pipes, and lysimeter gravel backfill.

4.4.1 Construction Activities. Following completion of excavation activities, TWS prepared the Super Cell 9 subgrade for admix placement. The sideslopes of Super Cell 9 were compacted utilizing water and a CAT D6 dozer to produce a firm and stable subgrade. The floor of Super Cell 9 was compacted with a CAT CS 563 smooth-drum compactor to 90% modified proctor. Field compaction testing documentation is included in *Appendix D*.

The lysimeter sumps were excavated to the required depth and geometry, and the subgrade was compacted to 90% of the modified proctor. A 60-mil. textured tertiary geomembrane was installed on the compacted subgrade. The individual liner panels were placed and joined, as per the project specifications. A 16-oz. Type B geotextile fabric was placed on top of the 60-mil. liner material to provide a cushion between the geomembrane and lysimeter gravel backfill.

An 8-in.-dia. HDPE lysimeter pipe trench was excavated from the slope's north shoulder and extended down the embankment into the lysimeter sump. An

8-in.-dia. HDPE lysimeter access pipe was placed in the trench prior to backfilling with Type II fill and compacting to 90% of the modified proctor. The lysimeter sump pipe was connected to the 60-mil. geomembrane with a bootless pipe penetration and placed on top of both the 60-mil. geomembrane and 16-oz. textile, and extended into the bottom of the lysimeter sump. The pipe was perforated from the sideslope transition point to the end cap.

A 2.5-ft.-thick layer of Type C drainage gravel was placed on top of the 16-oz. geotextile and around the lysimeter sump pipe. The gravel was compacted to 90% of the standard proctor. An 8-oz. Type A geotextile fabric was placed over the Type C drainage gravel in the lysimeter sump area. Field compaction testing documentation is included in *Appendix D*.

Stratton Surveying of Kennewick, WA, conducted a CQA "As-Built" survey following completion of subgrade compaction activities. In addition, Stratton conducted a survey of the lysimeter pipe as well as the locations of seams and repairs to the tertiary (lysimeter sump) geomembrane. From these surveys, an "As-Built" lysimeter subgrade drawing and subgrade point drawing were prepared and used for comparison to the design drawing. The "As-Built" coordinates correspond with the design coordinates and are included in *Appendix A*.

4.4.2 CQA Activities.

4.4.2.1 Cell Subgrade. CQA personnel monitored compaction of the Super Cell 9 subgrade. CQA conducted compaction testing to verify conformance with the moisture density requirements set forth in the construction specifications. The laboratory analytical results are included in *Appendix D*.

4.4.2.2 Lysimeter Trench. CQA personnel conducted compaction testing on the lysimeter trench backfill material. The laboratory analytical results for this testing event are included in *Appendix D*.

4.4.2.3 Tertiary Geomembrane. CQA activities associated with installation of the 60-mil. geomembrane were similar to those described in *Sections 4.6.2.1 through 4.6.2.5*. Geosynthetic testing results for the tertiary liner are included in *Appendix F*. CQA "As-Built" drawings of the tertiary geomembrane are included in *Appendix A*.

4.4.2.4 Geotextile Installation. CQA activities associated with installation of both the 8-oz. Type A and 16-oz. Type B geotextile were similar to those described in *Section 4.7.2.1*.

4.4.2.5 Lysimeter Riser Pipe. CQA activities associated with installation of the 8-in. HDPE lysimeter pipe were similar to those described in *Section 4.7.2.3.*

4.4.2.6 Lysimeter Type C Gravel Backfill. CQA activities associated with Type C drainage rock were similar to those described in *Section 4.7.2.2.* In addition, CQA conducted compaction testing on the in-place lysimeter drainage gravel, and the laboratory analytical results are included in *Appendix D.*

4.5 Soil Liner. This section details all work associated with construction and testing of the soil liner system.

4.5.1 Construction Activities. All work associated with construction of the soil liner for Super Cell 9 was conducted by TWS. Work on the soil liner was initiated on February 10, 2010, with stockpiling the soil liner base material obtained from the mass excavation activity. Admix production commenced on April 27, 2010, and admix placement commenced on May 7, 2010. Admix placement was completed on September 30, 2010.

The soil liner material consisted of a mixture of native Eolian sand along with bentonite and water. Approximately 80,000-cy of compacted admix soil liner material was produced during construction of Super Cell 9. Approximately 135,000-ton of loose, stockpiled base soil and 14,500-ton of bentonite were used to produce the soil liner material. The bentonite supplier provided quality control documents demonstrating that the bentonite met the minimum project specification requirements.

Prior to producing the admix material, all scales, meters, and measurement devices were calibrated. A pugmill mixer was used to mix the base soil, bentonite, and water to produce a soil liner material that met the specified bentonite and moisture contents. The bentonite content of the admix material was maintained between 11.2% and 13.3% with a nominal bentonite content of 11.7%. The moisture content of the soil liner material was maintained between 13.5% and 22.4% with an average of 17.2%. The soil liner material was allowed to cure in the stockpile area for a minimum of 12-hr. prior to placement in Super Cell 9.

From the curing stockpile, the soil liner material was transported to Super Cell 9 utilizing International Payhauler trucks. The material was spread in 10-in.-thick loose lifts with a Caterpillar (CAT) D6 dozer and compacted to a 6-in. thickness utilizing a CAT 825 sheepsfoot compactor. The material's moisture content was maintained between 15% and 18%. This material was compacted to a dry density corresponding to a minimum saturation of 85% based on a specific gravity of 2.7. The final soil liner surface was finished utilizing a smooth-drum roller. Repairs to the admix surface were conducted in accordance with procedures developed and tested during test pad construction activities.

The east edge of the soil liner from ERDF Cells 7 and 8 was exposed by removing the operations layer, geosynthetic materials, and drainage gravel. This liner was then evaluated, pursuant to the construction specifications, to ensure that any dry, cracked, or otherwise unsuitable areas of the existing admix liner were removed before the soil liner for Super Cell 9 was kneaded/blended-in along the tie-in edge.

Stratton Surveying, Inc., of Kennewick, WA, conducted a CQA "As-Built" survey following completion of soil liner placement, compaction, and surface finishing. From this survey, an "As-Built" subgrade point drawing was prepared and used to determine minimum point elevations for the soil liner. The "As-Built" drawing *(Admix Liner Thickness)* indicated that the soil liner system met the minimum 3-ft.-thick construction specification requirement.

4.5.2 CQA Activities.

4.5.2.1 Soil Liner Test Pad. Prior to commencement of soil liner placement activities, a soil liner test pad was constructed. Reference *Soil Liner Test Fill Report*.

4.5.2.2 Construction Monitoring. Prior to and during soil liner placement activities, ENVIROTECH personnel conducted CQA testing of the soil liner materials (base soil, bentonite and admix) to confirm that the materials met the project specification requirements. The type and frequency of testing is summarized in *Table 4.2* for both Super Cells 9 and 10.

All laboratory analyses of the soil liner material, with the exception of the permeability testing, were conducted in ENVIROTECH'S on-site laboratory. Permeability testing was conducted by ENVIROTECH in its permeability laboratory in Enid, Oklahoma. Pre-construction test samples of the soil liner material were collected from the soil liner stockpile prior to it being placed in Super Cell 9. Test samples of the base soil were collected from the base soil stockpile. Undisturbed permeability test samples were collected from Super Cell 9 by advancing 3-in.-dia. Shelby tubes into the compacted soil liner.

TABLE 4.2
TYPE AND FREQUENCY OF SOIL LINER MATERIAL, BASE SOIL, AND BENTONITE TESTING

Phase	Material	Test	Required Frequency	No. of Tests Required	No. of Tests Conducted	Actual [1] Frequency
Pre-Construction	Bentonite	QC Certificates	1 per 500 tons delivered	60	64	1/468-tons
	Admix	Recompacted Permeability (ASTM D5084)	1/20,000-yd.^{3}	8	10	1/16,000-yd.^{3}
		Proctor (ASTM D698)	1/20,000-yd.^{3}	8	10	1/16,000-yd.^{3}
		Atterberg Limits (ASTM d4318)	1/5,000-yd.^{3}	32	34	1/4,700-yd.^{3}
		Natural Moisture (ASTM D2216)	1/1,000-yd.^{3}	160	206	1/777-yd.^{3}
		Max. Clod Size	Visual	Visual	Visual	Continual
		Belt Scale Measurements	1/5,000-yd.^{3}	32	206	1/777-yd.^{3}
	Base Soil	Hydrometer (ASTM D422)	1/10,000-yd.^{3}	16	21	1/7,620-yd.^{3}
Construction	Admix	Field Moisture Nuclear Density (ASTM D2922)	5/acre/lift	941	1,036	5.5/acre/lift
		Field Moisture Density [2] Sandcone (ASTM D2922)	1/Day (Cell Floor Only)	61	61	1/Day
		Permeability Shelby Tube (ASTM D5084)	1/5,000-yd.^{3}	32	32	1/5,000-yd.^{3}
		Moisture Content (ASTM D2216, 4643)	1/day	61	61	1/Day

[1] All admix frequencies were developed based on a calculated volume of compacted admix placed.

[2] Testing quantities include the testing required and conducted for both Super Cells 9 and 10.

The field and laboratory analytical results indicated that the placed and compacted soil liner material met the requirements of the project specification requirements. In the event of a failing field density test, the contractor reworked the area by recompacting and/or adjusting the moisture content and the area was retested. The original test identification with a letter suffix was used to designate retests of failing areas. Results of pre-construction and construction soil liner testing are included in *Appendix C*.

Along with the testing activities summarized in *Table 4.2*, ENVIROTECH personnel observed placement and compaction of the soil liner material to confirm that the specified lift thickness, mixing, moisture, and material quality were maintained. All penetrations made in the soil liner during the course of testing activities were backfilled with bentonite material. The backfill material was compacted by hand in the same manner as successfully demonstrated during construction of the soil liner test pad.

4.6 Secondary Geomembrane Liner. The following section details the construction and CQA activities associated with installation of the secondary HDPE geomembrane liner in Super Cell 9.

4.6.1 Construction Activities. Construction of the secondary geomembrane liner was initiated on June 10, 2010, and completed on August 25, 2010. The geomembrane material used in construction of the secondary geosynthetic liner system for Super Cell 9 consisted of white 60-mil.-thick textured, high-density polyethylene (HDPE) geomembrane. The secondary geomembrane liner panels were deployed south-to-north from the Cell 8/9 tie-in at the west end of Super Cell 9 and proceeded east across the Super Cell 9 slope and cell floors. On the cell floor, the panels were deployed east-to-west. Following completion of the tie-in, north slope and floor, ESI deployed the secondary geomembrane south-to-north on the Super Cell 9 slope and floor and proceeded east from the Cell 8/9 tie-in across the slope. The secondary geomembrane was deployed pursuant to the approved *Panel Placement Plan* submitted by TWS.

Prior to deployment of the geomembrane liner, ENVIROTECH and the liner contractor observed the soil liner surface to ensure conformance with the project specification requirements. When the soil liner surface conformed to the project specifications, in the opinion of the liner contractor and ENVIROTECH, a Subgrade Acceptance Certificate was issued and signed by the liner contractor for each area where geomembrane was to be deployed. Subgrade acceptance notification documents are included in *Appendix F*.

The geomembrane liner panels were deployed using laborers, a forklift, a low-ground-pressure ATV, and a track bobcat. A minimum overlap of 5-in. was maintained between adjoining panels when joined by the fusion welding process. A minimum overlap of 3-in. was maintained between adjoining panels when joined by the extrusion welding process. The edges of the deployed geomembrane panels were temporarily held in-place with sandbags to prevent movement due to wind. The sandbags were removed following welding of the panels together.

The Super Cell 9 secondary geomembrane was not terminated, but instead continuously deployed over the Super Cell 9/10 grade break and into Super Cell 10.

The geomembrane liner panel seaming process proceeded concurrently with panel deployment activities. The majority of seams were made using a double hot-wedge fusion welder and repairs were made using an extrusion welder. ESI repaired defects in the secondary geomembrane liner resulting from manufacturing defects, testing activities, environmental factors, and installation procedures during installation. In addition, ESI conducted quality control (QC) testing for the seaming and repairs conducted on the secondary geomembrane. Geosynthetic field testin results are included in *Appendix F*.

Secondary geomembrane installation was occasionally curtailed due to high winds or precipitation events. During these occurrences, the installed geomembrane was temporarily sealed to prevent stormwater runoff from migrating under the geomembrane liner and impacting the soil liner. In the event of high winds, the installed geomembrane edges were heavily anchored with sandbags.

Anchor trenches were excavated by TWS at the top-of-slopes in Super Cell 9. ESI extended the secondary geomembrane liner into the anchor trenches at the top of the north and south slopes, and welded the secondary geomembrane to the primary geomembrane.

Stratton Surveying, Inc., of Kennewick, WA, conducted a geomembrane seam survey of the secondary geomembrane. A secondary seam survey drawing was prepared that graphically detailed the location of each secondary geomembrane panel and repair location.

4.6.2 CQA Activities.

4.6.2.1 HDPE Geomembrane Liner Deployment. ESI submitted a proposed panel layout drawing graphically depicting the number and orientation of the geomembrane panels prior to deployment of the geomembrane. During deployment activities, ENVIROTECH recorded the approximate location of the panels deployed. The secondary geomembrane liner panel layout is graphically depicted on the drawing included in *Appendix A*.

During deployment of the geomembrane liner panels, ENVIROTECH personnel provided the following services:

- Admix surface inspection;

- Confirmation of panel overlap;
- Visual observation of overall sheet quality; and
- Assignment of a unique identification number to each panel deployed.

4.6.2.2 HDPE Geomembrane Liner Seaming. All HDPE geomembrane seaming was conducted by ESI personnel and observed by ENVIROTECH personnel. Trial seams were made by each welding technician at the beginning of the shift and at mid-shift utilizing the type of welder to be operated. In addition, trial seams were required in the event the type(s) of material being welded changed. Sample coupons were cut from each trial seam and tested in the peel-and-shear test modes using a calibrated tensiometer provided by ESI. If a trial seam failed during field testing, the welder and welding technician associated with the failing trial seam were not allowed to weld on the geomembrane liner until they completed a trial seam that passed the field testing requirements set forth in the specifications. A summary of the trial seam testing results is presented in *Appendix F*.

All seaming operations were observed and documented by ENVIROTECH personnel. The entire length of all seams, patches, or other repairs were observed and documented either during or shortly after completion. Approximately 33,700-lf of welding was required to join the secondary geomembrane liner panels. A summary of CQA seaming observations is presented in *Appendix F*. The approximate locations of the secondary geomembrane liner seams are graphically depicted on the drawing included in *Appendix A*.

4.6.2.3 Non-Destructive Seam Continuity Testing. The non-destructive seam continuity testing was conducted by ESI personnel and observed by ENVIROTECH personnel. All seams between panels as well as repairs made to the geomembrane liner system were non-destructively tested. The three (3) types of non-destructive tests used for this project are as follows:

- Vacuum box testing on extrusion welds;
- Air pressure testing on double hot-wedge fusion welds; and
- Spark testing on pipe boots and skirts.

Vacuum box, air pressure, and spark testing were conducted in accordance with the requirements outlined in the project specifications.

All leaks or discontinuities detected in the seams were marked and subsequently repaired in accordance with the project specification requirements. Documentation summarizing the observations made during non-destructive testing of the seams and repairs is presented in *Appendix F*.

4.6.2.4 Secondary Geomembrane Liner Repairs. Defects observed in the secondary geomembrane liner were assigned a unique identification number by ENVIROTECH who located and marked the defects in the field for repair. The defects were repaired and non-destructively tested by ESI in accordance with the project specification requirements. A summary of the defects and associated repairs is presented in *Appendix F*. The approximate defect repair locations are graphically depicted on the drawing included in *Appendix A*.

4.6.2.5 Destructive Testing. A total of eighty-three (83) initial destructive test samples were collected (70 fusion-weld samples) and tested using a calibrated tensiometer in ENVIROTECH'S on-site laboratory. The destructive testing frequency requires at least two (2) destructive test samples for factory panel or one (1) test per 500-lf/welder. The seventy (70) fusion-weld destructs exceeds the number of destructs required by the sixty-five (65) deployed factory panels of secondary geomembrane. The test sample locations were selected by ENVIROTECH personnel based either on observations of the welded seams or random placement. ESI personnel cut the destructive seam samples and delivered them to ENVIROTECH for testing. One (1) initial secondary seam test sample failed to meet CQA testing specifications.

In the event of a destructive test failure, additional samples were removed from the seam at minimum 10-ft. intervals on either side of the failing test location and tested until passing retests bounded the original test, or until the extent of the welding performed by the apparatus in question had been exhausted. The seam between the passing tests (or to the extent of welding in question) was then capped. The approximate destructive test sites may be located by first referring to the specific destructive test in the Secondary Geomembrane Seam Destructive Log included in *Appendix F*. From this log, the assigned Repair Number is graphically depicted on the drawing included in *Appendix A*. The destructive test and repair location are the same.

Destructive samples were cut into three (3) sections and distributed as follows:

① One (1) section was forwarded to ENVIROTECH'S on-site geosynthetic laboratory for CQA destructive seam testing;

② One (1) section was forwarded to the geomembrane installer for testing; and

③ One (1) section was retained as an archive sample and submitted to WCH at project completion.

For CQA destructive seam testing, ten (10) test coupons were cut from each destructive test sample. Five (5) coupons were tested for adhesion (peel test mode) and five (5) coupons were tested for bonded seam strength (shear test mode). The specified acceptance criteria for destructive tests is summarized in *Table 4.3,* and a summary of the destructive test results is presented in *Appendix F.*

TABLE 4.3
SUMMARY OF DESTRUCTIVE TEST CRITERIA

Welding Method	Peel Test Mode	Shear Test Mode
Extrusion Welding	**1.** Five (5) of the five (5) test coupons per track must have a minimum peel strength of 78-lb/in. **2.** Five (5) of the five (5) test coupons per track must not fail in the weld (FTB*).	**1.** Five (5) of the five (5) test coupons must have a minimum yield strength of 120-lb/in. width. **2.** Five (5) of the five (5) test coupons must not fail in the weld (FTB*).
Fusion Welding	**1.** Five (5) of the five (5) test coupons per track must have a minimum peel strength of 91-lb/in. **2.** Five (5) of the five (5) test coupons per track must not fail in the weld (FTB*).	**1.** Five (5) of the five (5) test coupons must have a minimum yield strength of 120-lb/in. width. **2.** Five (5) of the five (5) test coupons must not fail in the weld (FTB*).
*FTB = Film Tear Bond		

4.7 Secondary Leachate Collection System.

4.7.1 Construction Activities. Installation of the secondary leachate collection system occurred from June 23 to September 9, 2010. The components of the secondary leachate collection system were generally installed as soon as the underlying material was accepted as complete. From the bottom up, the secondary leachate collection system consisted of the following:

- Geocomposite on the slopes and floor, Type B secondary geotextile in the sump;
- 1.5-ft. of Type B drainage gravel in the sumps only;
- Type B lower primary geotextile in the sumps only; and
- Two (2) 12-in. leachate riser pipes.

Although the secondary leachate system also includes pumps, transducers, tanks, and other associated valves and controls as well as pipe testing and backfill, these items are included in the *Operations Layer, Acceptance Test Procedures, Leachate Storage Tank, and Leachate Systems Report*.

ESI installed the geotextile and geocomposite materials, and TWS installed the HDPE piping and placed the drainage gravel. The drainage rock used in the leachate collection system was produced by TWS utilizing a gravel screen plant located in Pit 30 which is approximately 2-mi. north of ERDF Super Cell 9. TWS transported the gravel by trucks equipped with trailers from Pit 30 to the construction site. The Type B drainage gravel was stockpiled east of Super Cell 10. Construction testing was conducted on the drainage gravel in the stockpiles and the associated test results are included in *Appendix H*.

Geocomposite on the slopes was installed with the panel orientation parallel to the slopes, similar to the geomembrane panels. Geocomposite on the floor of the cell was deployed east-to-west and perpendicular to the slope. All side-to-side geocomposite seams were secured at 5-ft. intervals with non-metallic plastic ties, as required by the project specifications. The overlapping geotextile was continuously sewn and end-to-end seams were joined by overlapping the geonet such that it was joined with two (2) rows of non-metallic ties spaced 3-in. apart and located at 6-in. intervals. The end-to-end geotextile overlaps were continuously heat-tacked.

Repairs to the secondary geocomposite were completed by removing damaged geocomposite areas and replacing them with a patch of new geocomposite material. The geonet was joined to the existing geonet at 6-in. intervals with non-metallic ties. The geotextile was heat-tacked (or sewn) to the existing geocomposite.

ESI placed the lower secondary Type B geotextile over approved secondary geomembrane in the sump. The geotextile panels were continuously double-wedge welded (or sewn) as per the construction specifications. Two (2) 12-in.-dia. HDPE sump pipes were placed from the crest pad building and extended down the secondary sideslope riser trench and into the floor of the sump. The pipes were perforated where they extended across the length of the sump. Eight (8) 3/8-in.-dia. holes were evenly spaced around the circumference of the pipe, as graphically depicted on the project drawings. Each set of holes was spaced at a linear distance of 3-in. HDPE end caps were welded to the pipes, as graphically depicted on the project drawings. All secondary system HDPE pipe connections were made utilizing end-to-end fusion welds.

After the underlying secondary geomembrane and Type B geotextile were deployed on the floor of the sump, TWS began placing Type B drainage gravel. TWS loaded drainage gravel from the stockpiles into International Payhauler trucks for transport to the cell floor. ESI cut and folded back the secondary geomembrane to provide the trucks sump access across the exposed admix surface areas. Type B drainage gravel was placed directly into the sump and spread to design grade with a CAT 312 excavator.

The International Payhauler trucks significantly rutted the admix surface (road to the sump) during transport of the sump gravel. TWS replaced and reworked the admix to remove the rutting. Because a rainfall event occurred prior to reconnecting the secondary geomembrane layer, stormwater was introduced under the secondary geomembrane in the Super Cell 9 sump. The drainage gravel, secondary geotextile, and secondary geomembrane were removed from the affected areas of the sump. The impacted admix was returned to an acceptable state and the overlying materials replaced, as outlined in the contract specifications. A summary report of the repair is included in *Appendix B*.

Following a subsequent rainfall event, stormwater migrated under the repaired secondary geomembrane layer in the Super Cell 9 sump and during the investigation, a hole was discovered in the secondary geomembrane in the sump. Following discovery of the hole from the original sump repair, the Type B drainage gravel and secondary geotextile were removed from the affected area. A discharge hole was cut in the secondary geomembrane and the limited amount of rainwater under the secondary geomembrane was removed. The admix surface was returned to an acceptable state and the secondary geomembrane was patched. The secondary geotextile and Type B drainage gravel were replaced. A Corrective Action Plan (CAP) associated with the non-conforming condition of the secondary geomembrane and the repair procedures is included in *Appendix B*.

Stratton Surveying, Inc., of Kennewick, WA, conducted a CQA "As-Built" survey following completion of drainage gravel placement and finish grading activities. From this survey, an "As-Built" drawing was prepared and utilized to determine the thickness of the drainage gravel and riser pipe locations. The drainage rock thickness met the minimum project requirements on the sump slopes and sump floor, as graphically depicted on the drawing in *Appendix A*.

4.7.2 CQA Activities.

4.7.2.1 Geotextile and Geocomposite Installation. Prior to deployment of the geocomposite and geotextile materials, ENVIROTECH personnel monitored the surface of the secondary geomembrane for wind-blown sand and other foreign objects. In some instances, ESI used flat-nose shovels and brooms to remove excess soil clods and sand prior to installing the geocomposite and geotextile materials. ENVIROTECH personnel monitored deployment and seaming of the geotextile and geocomposite. In addition, the materials were inspected for damage and ENVIROTECH observed and documented the subsequent repairs. In addition, ENVIROTECH personnel observed removal of foreign objects from under the deployed materials.

4.7.2.2 Drainage Gravel. Prior to and during drainage gravel placement, ENVIROTECH personnel conducted CQA testing on the drainage gravel material to confirm that it met project specification requirements. The type and testing frequency is summarized in *Table 4.4* for both Super Cells 9 and 10.

The three (3) types of gravel utilized for this project include the following:

① *Type A* gravel was utilized in the drainage gravel layer above the primary liner, but not in the sump.

② *Type B* gravel was utilized in both the primary and secondary sumps.

③ *Type C* gravel was utilized in the lysimeter sump.

TABLE 4.4 TESTING FREQUENCY FOR DRAINAGE GRAVEL MATERIAL					
Material	**Test**	**Required Frequency**	**Tests Required**	**Tests Conducted**	**Actual Frequency**
TYPE A	Visual Observations	Continuous	---	---	---
	Grain Size Distribution (C136)	1/2,000-cy	19	20	1/1900-yd^3
	Permeability (D2434)	1/2,000-cy	19	20	1/1900-yd^3
TYPE B	Visual Observations	Continuous	---	---	---
	Grain Size Distribution (C136)	1/2,000-cy	2	3	1/1067-yd^3
	Permeability (D2434)	1/2,000-cy	2	3	1/1067-yd^3
TYPE C	Visual Observations	Continuous	---	---	---
	Standard Proctor	1/10,000-cy	1	1	1/1950-yd^3
	Grain Size Distribution (C136)	1/2,000-cy	1	2	1/975-yd^3
	Permeability (D2434)	1/2,000-cy	1	2	1/975-yd^3
	In-Place Moisture-Density (D6938)	1/10,000-cy	1	2	1/975-yd^3
Note:	*Testing quantities include testing required and conducted on both Super Cells 9 and 10.*				

Approximately 1,600-cy of Type B drainage rock and 1,950-cy of Type C drainage rock were placed in both the lysimeter and secondary sump systems. These quantities were used to determine the testing frequencies summarized in *Table 4.4*.

In addition, ENVIROTECH personnel visually monitored the gravel thickness (during and after placement) and monitored the underlying geosynthetics to confirm that no damage occurred and wrinkles were not formed. Stratton Surveying of Kennewick, WA, conducted a CQA survey to confirm thickness, lines, and grades. All survey points shot by Stratton were within the specified project tolerance requirements.

4.7.2.3 HDPE Pipe. ENVIROTECH personnel conducted the receiving inspection on all delivered pipe and monitored the end-fusion welding of the HDPE pipe on a procedural basis. The observed welds were made pursuant to the manufacturer's recommendations. In addition, ENVIROTECH reviewed pipe Quality Control Certificates and Welder Operator Certifications to confirm that the materials and construction methods met project specification requirements. ENVIROTECH monitored the placement and orientation of the piping for conformance with the project specifications and associated drawings.

4.8 Primary Geomembrane Liner. The following section details the construction and CQA activities associated with the primary HDPE geomembrane liner in Super Cell 9.

4.8.1 Construction Activities. Construction of the primary geomembrane liner occurred from June 29 to September 22, 2010. ESI commenced installation activities of the primary geomembrane liner at the east end of the south embankment and proceeded to the west tie-in to Cell 8. The primary liner panels were deployed south-to-north across the south slope. On the cell floor, the panels were deployed east-to-west with the end of the rolls extending into Super Cell 10. ESI deployed the primary geomembrane on the north slope from the Cell 7 tie-in east to the Super Cell 9/10 crest. The panels were positioned in a north-south direction that extended through the primary sump. ESI double-wedge fusion welded all panels together and conducted extrusion-welding repairs, as necessary. ESI's CQC conducted installation and quality control (QC) testing on the primary geomembrane liner. The primary geomembrane liner was deployed pursuant to the approved *Panel Placement Plan*.

Termination in the anchor trench was accomplished by extrusion-welding the primary geomembrane to the secondary geomembrane pursuant to the design drawings. ESI left air vent holes in the anchor trench to allow trapped air to escape from between the secondary and primary geomembrane layers. After the primary-to-secondary geomembrane weld was complete, ESI welded the air vent holes shut and TWS backfilled and compacted the anchor trench with Type II fill in 6-in. lifts.

Stratton Surveying, Inc., of Kennewick, WA, conducted a geomembrane seam survey on the primary geomembrane. A primary seam survey drawing was prepared that detailed the location of each secondary geomembrane panel and repair location.

4.8.2 CQA Activities.

4.8.2.1 HDPE Geomembrane Liner Deployment. Deployment activities for the primary geomembrane liner occurred in a manner similar to that for the secondary liner. The approximate HDPE geomembrane liner panel layout is graphically depicted on the drawing in *Appendix A*. A summary of ENVIROTECH'S deployment observations is presented in *Appendix F*.

4.8.2.2 HDPE Geomembrane Liner Seaming. Seaming activities for the primary geomembrane liner occurred in a manner similar to that for the secondary liner. A total of 34,700-lf of seaming was performed during installation of the primary geomembrane liner. A summary of the trial seam results and associated CQA seaming observations is presented in *Appendix F*. The approximate locations of the geomembrane liner seams are graphically depicted on the drawing in *Appendix A*.

4.8.2.3 Non-Destructive Seam Continuity Testing. Non-destructive testing activities for the primary geomembrane liner occurred in a manner similar to that for the secondary liner. Documentation summarizing the non-destructive test observations of the seams and repairs is presented in *Appendix F*.

4.8.2.4 HDPE Geomembrane Liner Repairs. Repair activities for the primary geomembrane liner occurred in a manner similar to that for the secondary liner. A summary of the defects and repairs is presented in *Appendix F* and the approximate defect repair locations are graphically depicted on the drawing in *Appendix A*.

4.8.2.5 Destructive Testing. Destructive testing activities for the primary geomembrane liner occurred in a manner similar to that for the secondary liner. A total of seventy-five (75) initial destructive test samples (66 fusion-weld samples) were collected and tested. The destructive testing frequency requires at least two (2) destructive test samples for factory panel or one (1) test per 500-lf/welder. This meets the number of destructs required by the sixty-six (66) deployed factory panels of secondary geomembrane. *Please Note: The two (2) termination panel destructs are included in Super Cell 10 documentation.* The test sample locations were selected by ENVIROTECH personnel, based on observations of the welded seams or random placement. One (1) initial primary seam test sample failed to meet CQA testing specification requirements. The resolution of failing primary destructive samples was managed in the manner described in *Section 4.5.2.5*. The approximate destructive test locations may be determined by first referring to the specific destructive test in the Primary Geomembrane Seam Destructive Log included in *Appendix F*. From this log, a Repair Number is identified that is graphically depicted on the drawing in *Appendix A*.

4.9 Primary Leachate Collection System. The following section details the construction and CQA activities associated with the primary leachate collection system in Super Cell 9.

4.9.1 Construction Activities. Installation of the primary leachate collection system occurred between August 13 and November 5, 2010. From the bottom up, the primary leachate collection system consisted of the following:

- 100-mil. geomembrane rub sheet (sump only);
- Geocomposite on the slopes and Type B upper primary geotextile on the floor;
- HDPE flat stock plate (sump only);
- 12-in. HDPE leachate collection pipe;
- Three (3) HDPE riser pipes;
- 1-ft. of Type A drainage gravel on the floor only; and
- 5-ft. of Type B drainage gravel in the sump only.

ESI deployed the 100-mil. geomembrane rub sheet in the sumps over the primary geomembrane. The 100-mil. geomembrane was double-wedge welded, but not attached or welded to the primary geomembrane.

The upper primary geotextile and geocomposite materials were installed in a manner similar to that for the secondary geotextile and geocomposite materials. ESI placed the upper primary geotextile (Type B) over the primary geomembrane (100-mil. rub sheet in the sump) and continuously double-wedge welded (or sewed) the geotextile together. Generally, the geocomposite was deployed and tied on the slopes following installation of the Type B geotextile on the floor. The geotextile on the floor was then peeled back and the geocomposite placed a minimum of 3-ft. over the cell floor. The geotextile was placed back over the geocomposite, leistered to the geocomposite, and covered with primary drainage gravel. ESI installed the geotextile and geocomposite materials and TWS placed the Type A drainage gravel and installed the collection pipes.

A second section of Type B primary geotextile was installed on the floor of the sump. Over the two (2) layers of geotextile on the sump floor, TWS installed a 1-in.-thick x 26.8-ft.-long x 4.5-ft.-wide HDPE flat plate. TWS placed three (3) HDPE riser pipes (6-, 12- and 18-in.) down the primary riser trench, on top of the primary geocomposite, and into the sump with the 12- and 18-in. pipes supported by the HDPE flat stock. The 12-in. riser pipes were anchored to the HDPE flat stock utilizing four (4) "U" bolt brackets and the 18-in. pipe was anchored utilizing two (2) "U" bolt brackets. All three (3) pipes were perforated.

TWS placed a 1-ft.-thick layer of Type A drainage rock over the upper primary geotextile on the cell floor. Following placement of the drainage gravel, TWS excavated a trench in the drainage gravel in the Super Cell 9 centerline. The 12-in. primary leachate collection pipe was placed in the trench and covered with a 1-ft.-high drainage gravel berm. The perforated leachate collection pipe transitioned to the non-perforated 12-in. HDPE leachate clean-out pipe at the north toe of the slope. The leachate cleanout pipe was placed in the center of the Super Cell 9 slope and extended to the top of the south embankment, pursuant to the design drawings. The north end of the leachate collection pipe was welded to the 12-in. riser pipe with a fusion coupler south of the sump.

TWS placed an approximate 5-ft.-thick layer of Type B drainage rock over the leachate riser pipes and geotextile in the sump. The rock transitioned to Type A drainage gravel outside of the sump limits. Following placement of the primary drainage gravel, WCH conducted a ground-penetrating radar (GPR) survey of all gravel haul roads in the cell. The GPR survey indicated that the underlying liner material experienced no damage as a result of equipment activities. The Ground Penetrating Radar (GPR) Survey Report is included in *Appendix I*.

Stratton Surveying, Inc., of Kennewick, WA, conducted a CQA "As-Built" survey following placement and finish-grading of the drainage rock. From this survey, a drawing was prepared and utilized to determine the thickness of the primary drainage gravel layer. The *Primary Drainage Gravel Thickness* drawing, included in *Appendix A*, indicates that the thickness of the drainage gravel layer meets the minimum project requirements of 1-ft. on the cell floor.

4.9.2 CQA Activities.

4.9.2.1 Geotextile and Geocomposite. CQA activities associated with the geotextile and geocomposite were similar to those described in *Section 4.7.2.1*.

4.9.2.2 Drainage Gravel. Prior to and during drainage gravel placement, ENVIROTECH personnel conducted CQA testing on the drainage gravel material to confirm that it met project specification requirements. The type and frequency of the testing is summarized in *Table 4.4 (See Section 4.7.2.2)* for both Super Cells 9 and 10 testing.

Approximately 19,000-cy of Type A drainage gravel, 1,600-cy of Type B drainage gravel, and 1,950-cy of Type C drainage gravel were placed in both the secondary and primary systems. These quantities were used to determine the testing frequencies summarized in the previously-referenced *Table 4.4.*

ENVIROTECH personnel visually monitored the gravel thickness during and after placement in addition to the underlying geosynthetics to confirm that damage had not occurred and wrinkles were not formed.

4.9.2.3 HDPE Pipe. CQA activities associated with the primary HDPE pipe were similar to those described in *Section 4.7.2.3*

5. OPERATIONS LAYER, ACCEPTANCE TEST PROCEDURES (ATPs) AND LEACHATE PUMP SYSTEMS

5.1 Introduction. This section provides a summary of the CQA observations and testing associated with placement of the operations layer, leachate pump systems, and acceptance test procedures (ATPs) for Super Cell 9.

5.2 Scope of Services. The scope of ENVIROTECH'S services outlined in the Construction Quality Assurance Plan (CQAP) consisted of the following:

- Provide pre-construction testing on the operations materials;
- Monitor the placement and compaction of operations materials to include observation, testing, and final survey of operations soil;
- Monitor, inspect, test, and verify proper installation (i.e., alignment, configuration, etc.) of the leachate piping, pumps, and related system components;
- Observe and record the results of the dry-run verification of the acceptance tests conducted by TWS; and
- Observe and record the results of the acceptance tests procedures (ATP) conducted by TWS.

ENVIROTECH provided full-time monitoring of these activities from September 27 to December 16, 2010.

5.3 Operations Layer.

5.3.1 Operations Layer Construction. TWS of Kennewick, WA, placed approximately 75,000-cy of operations soil in Super Cell 9 from the daily operations cover (DOC) stockpile located southeast of Super Cell 9.

TWS removed soil from the DOC stockpile utilizing a Hitachi 1800 excavator and CAT 5110 excavator to load three (3) Komatsu Payhauler trucks. The Komatsu Payhauler trucks transported the soil to Super Cell 9 where it was spread utilizing a CAT D6 LGP dozer, two (2) CAT D6 LGP GPS dozers, and a CAT D8 Series dozer.

The placement of operations soil material into Super Cell 9 was monitored to ensure that no damage to the liner system occurred during placement activities. ESI left sections of the anchor trench unwelded to allow for the release of trapped air between the primary and secondary geomembranes.

Following placement activities, TWS compacted the operations soil utilizing a CAT D6 dozer to make three (3) passes on both the floor and sideslopes. TWS then cut and graded the termination and top-of-slope berms utilizing a CAT D6 LGP GPS dozer. A water truck was utilized to add moisture to the operations soil, as necessary, to meet compaction requirements. American Fencing placed and anchored the termination fence posts and erected the specified fencing on the termination berm.

5.3.2 CQA Activities. CQA classified the operations soil during excavation and placement activities to ensure that the soil met construction specification requirements. CQA completed seventy-six (76) pre-construction tests for Super Cells 9 and 10, and fifty-four (54) in-place construction tests on the operations soil based on the engineer's estimated quantity of 75,000-cy for Super Cell 9. The type and frequency of testing is summarized in *Table 5.1*. The laboratory analytical results are included in *Appendix J*.

ENVIROTECH conducted CQA field moisture-density testing on the final lift of operations soil on the floor of Super Cell 9 utilizing a Troxler Model 3430 nuclear moisture-density gauge (ASTM D2922). A total of fifty-four (54) moisture-density tests were conducted on the operations final surface and fence berm on the cell floor at a frequency of one (1) test per 10,277-sf. This testing frequency exceeded the specified frequency of one (1) test per 20,000-sf. The results of the field-testing are included in *Appendix J*. Stratton, Inc., of Kennewick, WA, conducted an "As-Built" survey of the final operations lift to ensure that thickness requirements were met. CQA verified that the operations layer thickness met the 3-ft. minimum coverage over the geosynthetic liner. The results of the field-survey are included in *Appendix A*.

TABLE 5.1
TYPE AND FREQUENCY OF OPERATIONS MATERIAL TESTING

Material	Test	Required Frequency	Material Quantity	Tests Required	Tests Conducted
Operations Soil	Visual Observations	Continuous	---	---	---
	Standard Proctor[1]	1/10,000-cy	150,000-cy	15	15
	Grain Size Distribution[1] (C136)	1/2,000-cy	150,000-cy	75	76
	In-Place Moisture-Density[2] (D6938)	1/20,000-sf	555,000-sf	32	54

Note: [1]**Testing quantities include the testing required and conducted on *both* Super Cells 9 and 10.**
[2]**Testing quantities include the testing required and conducted on Super Cell 9 *only*.**

5.4 **Leachate Transmission Piping.** Baker, McHenry and Welch Company Constructors (BMWC) installed the leachate pumps and piping. TWS excavated the north berm and installed the Super Cells 9 and 10 manholes in the north.

In order to install MH-32 in the north embankment, TWS excavated the location and lowered sections of the pre-cast concrete manhole into position. The manhole sections were then assembled together and sealed using rubber O-rings. Following completion of manhole installation activities, TWS backfilled and compacted the soil around the manhole location. The results of CQA's backfill testing are included in *Appendix D*.

BMWC initiated installation of the leachate piping in the north embankment on April 5, 2010. The piping was welded together prior to placement in the north embankment. CQA observed BMWC conducting pressure testing on all leachate transmission piping. After the pipes were pressurized, BMWC and CQA examined each weld for possible leaks. A record of all pipe testing activities is located in *Appendix K*.

Stratton Surveying, Inc., of Kennewick, WA, conducted an "As-Built" survey subsequent to the installation of the leachate transmission piping. Based on this survey, "As-Built" points were prepared to determine the location of the pipe and verify that the minimum sloping requirements for the pipe were met during installation. The "As-Built" point drawings are included in *Appendix A*.

5.5 **Crest Pad Building Construction.** TWS poured the concrete slab for the Super Cell 9 crest pad building. Intermountain Material Testing of Pasco, WA, conducted concrete testing activities and the laboratory analytical results are included in *Appendix K*. TWS retained local subcontractors to construct the Super Cell 9 crest pad building. Following completion of crest pad building construction, American Electric Inc. (electrical subcontractor) installed the electrical system and associated instrumentation for the crest pad building. In addition, Total Energy Management (instrumentation subcontractor) and American Electric calibrated and installed the transducers in the Super Cell 9 sumps and manhole.

While Total Energy and American Electric were installing the electrical system and instrumentation, BMWC constructed the PVC crest pad piping. Following installation of the PVC piping, CQA observed BMWC pressure-testing the system. Results of pressure testing conducted on the PVC piping are included in *Appendix K*.

American Electric and TWS placed the pumps into the leachate riser pipes and the associated discharge lines were connected to the crest pad's PVC piping. A 2-hr. pump test was conducted on each pump and during this test period, the installed instrumentation did not indicate that the pump output was correct. Although the primary high-flow pump was replaced, the instrumentation generated the same output readings. Upon further investigation, it was discovered that an instrumentation set value was omitted during programming operations and as a result, the instrumentation read incorrect values. Following programming corrections, TWS completed the 2-hr. pump test and the associated results are included in *Appendix L*.

CQA conducted a receipt inspection for all leachate collection system (LCS) equipment and associated components. CQA verified that all piping was hydrostatic tested to the specified pressures and reviewed the system check for the electrical components. In addition, CQA conducted a review and verified that the piping and electrical systems were tagged and labeled pursuant to specification requirements.

5.6 **Acceptance Test Procedures (ATPs).** WCH ERDF Engineer, Mr. Tim Wintel, authored the *ERDF Super Cell 9 Acceptance Test Procedures (ATPs)* with input from Mr. Dave Sterley (TWS CQC), Mr. Bill Borloug (WCH Engineer), Mr. Ryan Harris (Test Director with Total Energy), and Mr. Joseph Voss (CQA). Mr. Jake Laws (WCH Electrical Subject Matter Expert (SME) and National Electrical Code (NEC) Inspector), Mr. Ryan Harris, and Mr. Dave Sterley aided CQA with inspection and confirmation of construction specifications and electrical code requirements as documented in the prerequisites section of the ATP - Test Execution Form.

Prior to commencing with Acceptance Test Procedures (ATPs), TWS (assisted by Total Energy and CQC) conducted a "dry-run" of the leachate pump system in Super Cell 9 on December 9 and 13, 2010. The "dry-run" team tested and examined the mechanical and electrical system in the crest pad building to ensure that all components were installed correctly, with exception of the SCADA system in MO-418. During the initial "dry-run" on

December 9, 2010, the instrumentation panel generated incorrect set points and alarms and as a result, the system could not be accepted. During the second "dry-run" on December 13, 2010, Total Energy discovered that the instrumentation panel was wired incorrectly. Following a successful third "dry-run" on December 13, 2010, the crest pad building instrumentation was accepted, with the exception of the SCADA system in MO-418. The "dry-run" was documented on the ATP forms included in *Appendix L*.

TWS conducted acceptance testing of the Super Cell 9 leachate collection system on December 16, 2010, in accordance with the *ERDF Super Cell 9 Acceptance Test Procedures (ATPs) Revision*. The ATP was directed by Mr. Ryan Harris with Total Energy; Mr. Tim Wintel served as WCH Project Manager; Mr. Jack Howard was acting STR; Mr. Dave Sterley with TWS served as Subcontractor QC; and Mr. Joseph Voss served as CQA Recorder. Mr. Rod Lobos with the EPA and Mr. Owen Robertson with the DOE provided observation services during testing activities. The leachate collection system testing was completed and documented on the *ERDF Super Cell 9 Acceptance Test Procedures (ATPs) – Test Execution Forms* located in *Appendix L*.

5.7 Operations Layer, Acceptance Test Procedures (ATPs), and Leachate Pump Summary. Placement of operations layers commenced on September 27, 2010, and completed on November 16, 2008. Leachate collection system pump testing commenced with the installation of piping materials on April 7^{h}, 2010, and completed prior to ATP testing on December 13, 2010. ATP testing was completed on December 16, 2010.

6. DOCUMENTATION

6.1 Daily Reports. Daily reports were compiled from the field books maintained by each on-site CQA staff member and included the following:

- Reference to the field books utilized that day by CQA staff;
- Meteorological information;
- A summary of the day's activity; and
- Highlights of unresolved issues, if any.

A compilation of the daily reports are included in *Appendix M*.

6.2 Inspection Data Sheets. All previously-referenced field and laboratory test data was recorded on Inspection Data Sheets and included in their respective Appendices.

6.3 **CQA Progress Reports.** CQA Progress Reports were prepared weekly to summarize work activities, observations, and testing conducted by CQA. In addition, the reports provided a summary of construction activity and associated problems, if any. All CQA Progress Reports are included in *Appendix M.*

6.4 **Photograph Log.** Daily photographs were taken to provide photo documentation of the work progression, CQA-identified issues requiring special notice, and other items of interest. The Photograph Log is included in *Appendix M.*

6.5 **Supplier/Contractor Deviation Disposition Request (SDDR/CDDR) Documentation.** ENVIROTECH issued six (6) SDDRs during the course of the project. The CQA and contractor SDDR documentation affecting Super Cell 9 construction is included in *Appendix B.*

6.6 **Non-Conformance Reporting.** Two (2) non-conformance reports were issued during the course of this contract and are included in *Appendix B.*

7. CONCLUSIONS

The activities summarized in this report are associated with construction of Super Cell 9 at the Environmental Restoration Disposal Facility (ERDF) located approximately 30-mi. north of Richland, WA, in the 200 West Area of the Hanford Nuclear Reservation. ENVIROTECH ENGINEERING & CONSULTING, INC.'S personnel observed all activities associated with facility construction. Based on these observations and the results of the testing conducted, it is ENVIROTECH'S opinion that Super Cell 9 has been constructed in compliance with the design drawings and project specification requirements, including the Design Change Notices (DCNs) documented in this report.