RICHARDSON SMITH GARDNER & ASSOCIATES
ENGINEERING & GEOLOGICAL SERVICES

Permit No.	Date	Document ID No.
42-04	**December 17, 2010**	**12536**

December 16, 2010

Mr. Ming-Tai Chao, P.E.
Environmental Engineer II
NC DENR - Division of Waste Management
401 Oberlin Road, Suite 150
Raleigh, NC 27605

RECEIVED
December 17, 2010 via an email
Solid Waste Section
Raleigh Central Office

Re: Halifax County C&D Landfill (Permit No. 42-04)
Permit Application for Area 1 Continued Operations
Response to Comments

Dear Mr. Chao:

On behalf of Halifax County, Richardson Smith Gardner & Associates, Inc. (RSG) would like to respond to the comments in your letter dated March 16, 2010 (see **attached**), as follows. The comments stated in your letter are repeated below in *italics* and our response follows in **bold**.

Attachment A – Facility and Engineering Plan

1. *(Section 3.0 Landfill Capacity) On October 3, 2002 G.N. Richardson &Associates on behalf of the Halifax County submitted a permit extension request letter and attached figures. The Drawing S2 & S3 shown the C&DLF incremental fill sequences No. 1 through No.7 and indicated that the fill operations would be terminated at the elevation contours up to 346 feet above mean sea level (AMSL). The Solid Waste Section approved this permit extension request on December 30, 2002. The Facility Plan of this 2008 Permit Application proposes that the final fill operations will be terminated at the elevation contours up to 358 feet AMSL which results in the C&DLF containing the total gross capacity of 131,267 cubic yards. Could you please describe the volume of the approved total gross capacity of the C&DLF in October 3, 2002 permit application to demonstrate if the variance of total gross capacity results in a "substantial amendment" in accordance with NCGS 130A-294(b1)(1)?*

   The approved 2002 plan had a gross volume of approximately 75,000 CY. Thus, the currently proposed gross capacity (131,267 CY) would constitute a substantial amendment. However, the local government approval process (already conducted) appropriately noted the increased volume.

2. *(Section 5.1 Final Cover System) Since the geosynthetic material will function as a moisture barrier, will the proposed 18-inch thick vegetative support layer provide a sufficient soil depth supporting health growth of vegetation during the lengthy drought experienced in recent years in the State of North Carolina? Please clarify.*

   An 18-inch minimum cover over geosynthetics has performed elsewhere in North Carolina (reference Scotland County Phase III - closed in 1999; and Davidson County Phase 1A - closed in 2005) in recent years with no significant difficulties in maintaining a suitable stand of vegetation. Additionally, for this site, geosynthetics will only be used on the flatter top slopes, which allow less run-off than the steeper side slopes and, thus, greater moisture should be available for vegetation.

3. *(Appendix A – 1.0 Landfill Volume Study) The data of net waste capacity for remaining Area 1 presented in Sheet 3 of 9 (33,886 cy/23,720 tons) is inconsistent with that in Sheet 7 of 9 (34,975 cy/24,483 tons). The remaining service life for Area 1 is not consistent, either. Please clarify and make necessary corrections.*

The summary sheet on Sheet 7 of 9 has been updated to show the correct figures for remaining Area 1 capacity/life (from May 1, 2008) (33,886 CY/23,720 Tons/4.3 Years). Please find attached the replacement page (along with page 8 of 9).

4. *Please provide specification for constructing 12-inch-thick intermediate soil cover.*

The intermediate soil cover is placed as part of operations and is, thus, tracked in. This surface is prepared prior to placement of overlying geosynthetics. This preparation is addressed in Section 02776 (GCL) (Paragraph D.3) and 02778 (LLDPE Geomembrane) (Paragraph D.3) of the specifications.

5. *(Section 02258, Vegetative Soil Layer(VSL)) Please address the following concerns:*

   I. *The alternative soil cover system proposes to construct a 24-inch thick VSL on the 4 (horizontal) to 1 (vertical) side slopes. To facilitate the vegetation growth, it is general practice for no compaction on the top 6-inch top soil layer. Should there be a minimum compaction requirement for the bottom 18-inch soil layer to prevent subsidence, local slope failure, and soil erosion? Please clarify.*

   This 24-inch thick layer is tracked-in similar to the 18-inch thick vegetative soil layer that will be placed above the geosynthetics. Given this level of compaction and a suitable stand of grass, we do not anticipate any issues with subsidence, localized slope failure, or erosion on the proposed 4H:1V slopes. Additionally, to facilitate deeper root penetration and to provide better drought resistance, it is best not to overly compact soil below the upper 6 inches.

   ii. *(Paragraph B.2) The earthen material used in the VSL is specified in this paragraph having the maximum grain size less than 3 inches. Would the selected grain size of earthen material be based on the criteria concluded from the filter design (see Comment 5) and the recommendations for geomembrane protection from geosynthetic manufacturers? Please clarify.*

   The 3 inch maximum size is expected only in very limited quantity. From our experience, the drainage geocomposite will be more than adequate to protect the GCL or geomembrane from damage from isolated particles of this size. Regarding grain size and filter design, please see the response to Comment 6 below.

6. *(Section 02712, Drainage Composite) Please address the following concerns:*

   I. *Please provide a filter design calculation to ensure that the selected geotextile with AOS equivalent to U.S. sieve # 70 (in Table 1) can properly function as filter material preventing the DGC from clogging by fines in the overlying VSL.*

Attached is a calculation using typical grain size curves for soils at the site. The calculation verifies that a geotextile with an AOS of No. 70 or greater should perform acceptably as a filter.

ii. *Please provide design calculations to demonstrate that the specified DGC has a sufficient transmissivity, consideration of the long-term performance, which is able to safely convey the surface water in the designed storm event to the drainage system.*

The attached calculations demonstrate that the specified drainage geocomposite would have a factor of safety of over 2, and is, thus, adequate for the proposed application.

iii. *(Table 1, Note 2) Would the laboratory measured transmissivity be determined under a simulated condition for 100-hour duration, rather than 24-hour? Please clarify.*

A 100-hour duration is more appropriate for higher normal load situations such as for a leachate collection system. In our experience, 24 hours is more than sufficient to see any reductions that may occur in transmissivity under a low normal load (in this case 1,000 psf as specified/approximately 200 psf in service).

iv. *(Table 1, Note 3) Would the GCL be saturated prior to conducting the laboratory testing on interface shear strength between geocomposite and GCL? Please clarify.*

Yes. The last line in Table 1 of Section 02776, GCL, states the GCL is in a "Hydrated" or "Saturated" condition when measuring interface shear strength.

v. *(Paragraph D.3 - Installation, on page 02712-4) Please provide specifications to protect the in-place geomembrane or GCL during the course of deploying DGC from vehicle, equipment, tool, and unexpected long-duration exposure.*

Paragraph D.4 of both the GCL and Geomembrane specifications address the placement of overlying materials. Additionally, Paragraph D.3.j of the GCL specification, states that the GCL shall be covered or otherwise protected from hydration due to rainfall.

vi. *(Paragraph D.6 – Cover Placement, on page 02712-6) Provide the specification of (a) the maximum ground pressure of the equipment and buffer material thickness above DGC, if equipment is allowed to directly operate on top of DGC to placing VSL material; and (b) the maximum duration that in-placed DGC can be exposed without placing any permanent cover material and the actions to be taken if this specified duration is passed.*

Section 02258, Vegetative Soil Layer, has been revised to address covering of geosynthetics. Additionally, Section 02712 Paragraph D.6 has been revised to address exposure concerns. Please find attached revised Sections 02558 and 02712.

7. *(Section 02776, Geosynthetic Clay Liner) Please address the following concerns:*

I. *Specify the GCL Installer's qualification as described in Section 7.2 of the CQA Plan.*

In that a GCL does not require any seaming (other than overlapping) we are not requiring any special qualifications for the installer on this project.

ii. *(Paragraph C.1.e – Installation Procedures and Drawings, on page 02776-4) Would the Contractor be required to submit CQA Engineer a conceptual plan for placement of the GCL panels over the area of installation for review and approval? Please clarify.*

No. Installation drawings showing panel layouts are not typically required for GCL installation. Although a panel layout is required for the installation of a geomembrane, it is typically only of minimal value in planning the work.

iii. *(Paragraphs B, on page 02776-3) The Paragraph B shall specify the material properties of the granular sodium bentonite applied between all overlapped seams described in the Paragraph D.3.g. and repairs in the Paragraph D.3.i.*

Paragraph B.3 has been revised to include requirements for granular sodium bentonite. Please find attached revised Section 02776.

iv. *(Paragraph D.3.a, on page 02776-5) Because the GCL will directly contact the subgrade – 12-inch-thick intermediate soil cover, this sub-paragraph needs to specify the maximum soil grain size in the finished subgrade to prevent void fraction and/or puncture damage on GCL from the certain sizes of rock or gravel or other material.*

Paragraph D.3.a has been revised to clarify grain size. Please find attached revised Section 02776.

v. *(Paragraph D.3.a, on page 02776-5) Please specify the subgrade certification requirement prior to placing GCL layer according to Rule .1624(b)(9)(C)(i).*

Paragraph D.3.b has been added (following paragraphs renumbered) to clarify certification requirements. Please find attached revised Section 02776.

vi. *(Paragraph D.3.i, on page 02776-6) What method or practice is there to ensure the patched area will not be removed or displaced while placing the cover material? Should dry granular sodium bentonite be applied around the damage area prior to placing the patch? Please clarify.*

The placement of the overlying drainage geocomposite will be observed by CQA personnel, thus, minimizing the potential for unobserved movement of the patch. It would also be acceptable to place the patch below the existing GCL; thus, letting the larger GCL panel ballast the patch. Paragraph D.3.i (now D.3.j) has been modified to state that granular bentonite is to be placed between all patches and the undamaged GCL. Please find attached revised Section 02776.

vii. *(Table1) Please specify the confine pressure (consideration of low normal loading condition for the cover system) and hydration condition which are simulating the field condition for the hydraulic conductivity on the GCL according to Rule 1624(b)(9)(A)(ii).*

The hydraulic conductivity of GCL is tested in accordance with ASTM D 5887, which is the industry standard test method. This test method requires hydrated samples and uses an effective confining stress of 5 psi (720 psf). Based on discussion with Mr. J.P. Kline, P.E., Geosynthetics Laboratory Manager at Geotechnics, using a lower pressure would likely cause problems with proper sealing around the edges of the sample.

8. (Section 02778, LLDPE Geomembrane(LLDPE-GM)) Please address the following concerns:

i. (Paragraph D.3, on page 02778-7) Because the LLDPE-GM will directly contact the subgrade – 12-inch-thick intermediate soil cover, this sub-paragraph specify the maximum size of grain (rock, gravel, other material) is ½ inches. Please provide a calculation to demonstrate this maximum grain size will not create puncture damage on the 30-mil LLDPE-GM.

Typical industry calculations for protection of geomembranes are based on higher load applications (i.e. landfill or reservoir liners) and, thus, are not directly applicable to a final cover system. The ½-inch maximum size as specified is based on industry practice. Additionally, in that the subgrade is specified to be smooth (i.e. smooth drum rolled) prior to installation of the geomembrane, it is highly unlikely that there will be an isolated ½ -inch rock that is not embedded into the subgrade, where it would be of minimal concern.

ii. (Paragraph D.5, on page 02778-9) What provisions are there to avoid "fish-mouths" or wrinkles while seaming and to fix or correct the problem? Please clarify.

Paragraph D.5.n (prior numbering adjusted) has been added to clarify that excessive wrinkles along geomembrane seams shall be minimized and that fish-mouths (where wrinkled seam is un-bonded) or large wrinkles shall be cut and the seam re-constructed with a flat overlap. Cuts shall be repaired by patching (following D.7.a.(1). Please find attached revised Section 02778.

iii. (Paragraph D.6, on page 02778-10) Will the anchor trenches be constructed for installing the LLDPE-GM? There is no trench layout or trench detail showing on the Drawings (Sheet No. 5/Drawing No. S4 and Sheet No. 6/Drawing No. D1) indicate. Please clarify.

There are no anchor trenches proposed for this project. This is a general statement in the specifications and would cover the case if an anchor trench were added during construction.

<u>Attachment C– CQA Plan</u>

9. (Section 5.0 Geomembrane CQA) Are the specified air pressure test requirements for 30-mil LLDPE in Table 5.2 consistent with the specifications in ASTM D 5820 which states the pressure ranges from 25 psi to 30 psi? Please clarify.

ASTM D 5820 does not specify a specific pressure to use referring instead to "the pressure

appropriate for the geomembrane type". The 15 psi was originally selected for 30 mil LLDPE geomembranes based on industry practice. However, based on a review of current information, RSG has revised the minimum test pressure to 25 psi. Please find attached revised CQA Section 5.0.

10. (Section 5.4.6.3 Geomembrane CQA Laboratory Destructive Testing) Please specify the LLDPE-GM samples for laboratory testing will only be conducted after the samples from the same batch collected for field destructive seam testing have passed the shear strength criteria stated in Table 3 of Section 02778 in Attachment B.

Shear strength testing is typically conducted on representative samples to determine if the proposed materials are suitable and so as to not hold up the production-run of material for the project. Thus, interface shear strength testing typically is done first.

Attachment D – Operations Manual

11. Please address the requirement stated in the Rule .0542(j)(8).

This requirement related to waste removal has been addressed through the addition of a statement at the end of Section 2.5.2. Please see the attached revised Operations Manual (Title page through Section 3.0).

12. (Section 1.4 Signage) Please add the requirement stated in the Rule .0542(j)(6) to this section. The 18 February 2010 Facility Compliance Audit Report indicated the C&DLF does not in compliance with the rule requirement.

This requirement related to unacceptable wastes has been addressed through the addition of a statement at the end of Section 1.4. Please see the attached revised Operations Manual (Title page through Section 3.0). Note that the County has added a sign with this information since the February audit.

13. (Section 2.5) Please address the requirement stated in the Rule .0542(g)(3). The 18 February 2010 Facility Compliance Audit Report indicated the C&DLF does not in compliance with the rule requirement.

This requirement related to windblown waste has been addressed through the addition of a statement near the end of Section 2.5.2 (second to last paragraph). Please see the attached revised Operations Manual (Title page through Section 3.0).

14. (Section 2.5.5.1) The Rule .0542(f)(1) requires the working face to be cover when the waste exceeds one-half acres, and this period cover requirement stated in this section is incorrect. Please make necessary correction.

Section 2.5.5.1 has been corrected accordingly.

15. *(Section 3.4) Please identify the gas probes (total number of probes and identification numbers) that will be sampled quarterly. There are nine (9) landfill gas probes (GM-1, GM-2, GM-2B, GM-2R, GM-3, GM-4, GM-4R, GM-5, and GM-5B) shown on Drawing No. FIG. 1. Will theses ten probes be sampled quarterly?*

Yes, these probes are sampled quarterly. Section 3.4.1 has been revised to include a listing of these probes.

Attachment F – Closure and Post-Closure Plan

16. *(Table 3.1) The cost for CQA is incorrect. However, after consulting the closure cost estimates for other landfill facilities in the State of North Carolina, the reviewer thinks the unit cost for CQA of $6,000 will be a reasonable cost. Please increase the unit cost from 5,000 to $6,000.*

The CQA cost will vary significantly based chiefly on type of cover and size of area to be closed. The total for this line item was already based on $6,000 per acre (i.e. the unit cost should have been updated previously). Thus, no change in the total closure cost was made.). Please see the attached revised Section 3.0 of the Closure and Post-Closure Plan.

Figures

17. *(Drawing No. S4/Sheet No. 5) Please double check the drawing detail references and correct the typographic errors shown below:*

I *Down pipe detail is shown on 1/EC1 (Sheet No. 7), not on 2/EC1.*

This correction has been made. Please find attached revised Drawing S4.

ii *Filter berm detail is shown on 3/EC1 (Sheet No. 7), not on 2/EC3.*

This correction has been made. Please find attached revised Drawing S4.

Please contact me at your earliest convenience with any questions or comments which you may have on this submittal or any further questions or comments you may have on this application.

Sincerely,
Richardson Smith Gardner & Associates, Inc.

Pieter K. Scheer, P.E.
Principal, Project Manager
pieter@rsgengineers.com

Attachments: NC DWM Letter - March 16, 2010
Calculation Replacement Pages (Pages 7 & 8 of 9)
Filter Geotextile Analysis
Final Cover Drainage Layer Analysis
Revised Specifications:
- Section 02258 (Vegetative Soil Layer)
- Section 02712 (Drainage Geocomposite)
- Section 02776 (GCL)
- Section 02778 (LLDPE Geomembrane)

Revised CQA Section 5.0 (Geomembrane)
Revised Operations Manual (Through Section 3.0)
Revised Closure and Post-Closure Plan Section 3.0 (Cost Analysis)
Revised Drawing S4

cc: Larry Garriss, Halifax County

North Carolina Department of Environment and Natural Resources
Division of Waste Management

Beverly Eaves Perdue
Governor

Dexter R. Matthews
Director

Dee Freeman
Secretary

Solid Waste Section

March 16, 2010

Mr. Larry Garriss, Solid Waste Director
Halifax County Department of Public Utilities
P.O. Box 70
Halifax, North Carolina 27839

Re: Additional Comments on Permit Application of Halifax County Construction and Demolition Debris Landfill (C&DLF), Area 1 Continued Operations (the Permit Application)
Halifax County, North Carolina
Permit No. 42-04, Document ID No. (Doc ID) 9907

Dear Mr. Garriss:

On February 5, 2010, Solid Waste Section of the Division of Waste Management (DWM) received the written responses to the DWM's comment dated October 2, 2009. Richardson Smith Gardner and Associates (RSG), on behalf of Halifax County, prepared and submitted the responses (DIN 9562) which have been incorporated to the revised Permit Application. The Solid Waste Section has preformed a review of the above-referenced documentations and requests for additional information below:

Attachment A – Facility and Engineering Plan

1. (Section 3.0 Landfill Capacity) On October 3, 2002 G.N. Richardson &Associated on behalf of the Halifax County submitted a permit extension request letter and attached figures. The Drawing S2 & S3 shown the C&DLF incremental fill sequences No. 1 through No.7 and indicated that the fill operations would be terminated at the elevation contours up to 346 feet above mean sea level (AMSL). The Solid Waste Section approved this permit extension request on December 30, 2002. The Facility Plan of this 2008 Permit Application proposes that the final fill operations will be terminated at the elevation contours up to 358 feet AMSL which results in the C&DLF containing the total gross capacity of 131,267 cubic yards. Could you please describe the volume of the approved total gross capacity of the C&DLF in October 3, 2002 permit application to demonstrate if the variance of total gross capacity results in a "substantial amendment" in accordance with NCGS 130A-294(b1)(1)?

2. (Section 5.1 Final Cover System) Since the geosynthetic material will function as a moisture barrier, will the proposed 18-inch thick vegetative support layer provide a sufficient soil depth supporting health growth of vegetation during the lengthy draught experienced in recent years in the State of North Carolina? Please clarify.

3. (Appendix A – 1.0 Landfill Volume Study) The data of net waste capacity for remaining Area 1 presented in Sheet 3 of 9 (33,886 cy/23,720 ton) is inconsistent with that in Sheet 7 of 9 (34,975 cy/24,483 tons). The remaining service life for Area 1 is not consistent, either. Please clarify and make necessary corrections.

Attachment B – Technical Specifications

4. Please provide specification for constructing 12-inch-thick intermediate soil cover.

5. (Section 02258, Vegetative Soil Layer(VSL)) Please address the following concerns:
    i. The alternative soil cover system proposes to construct a 24-inch thick VSL on the 4 (horizontal) to 1 (vertical) side slopes. To facilitate the vegetation growth, it is general practice for no compaction on the top 6-inch top soil layer. Should there be a minimum compaction requirement for the bottom 18-inch soil layer to prevent subsidence, local slope failure, and soil erosion? Please clarify.
    ii. (Paragraph B.2) The earthen material used in the VSL is specified in this paragraph having the maximum grain size less than 3 inches. Would the selected grain size of earthen material be based on the criteria concluded from the filter design (see Comment 5) and the recommendations for geomembrane protection from geosynthetic manufacturers? Please clarify.

6. (Section 02712, Drainage Composite) Please address the following concerns:
    i. Please provide a filter design calculation to ensure that the selected geotextile with AOS equivalent to U.S sieve # 70^{+} (in Table 1) can properly function as filter material preventing the DGC from clogging by fines in the overlying VSL.
    ii. Please provide design calculations to demonstrate that the specified DGC has a sufficient transmissivity, consideration of the long-term performance, which is able to safely convey the surface water in the designed storm event to the drainage system.
    iii. (Table 1, Note 2) Would the laboratory measured transmissivity be determined under a simulated condition for 100-hour duration, rather than 24-hour? Please clarify.
    iv. (Table 1, Note 3) Would the GCL be saturated prior to conducting the laboratory testing on interface shear strength between geocomposite and GCL? Please clarify.
    v. (Paragraph D.3 - Installation, on page 02712-4) Please provide specifications to protect the in-placed geomembrane or GCL during the course of deploying DGC from vehicle, equipment, tool, and unexpected long-duration exposure.
    vi. (Paragraph D.6 – Cover Placement, on page 02712-6) Provide the specification of (a) the maximum ground pressure of the equipment and buffer material thickness above DGC, if equipment is allowed to directly operate on top of DGC to placing VSL material; and (b) the maximum duration that in-placed DGC can be exposed without placing any permanent cover material and the actions to be taken if this specified duration is passed.

7. (Section 02776, Geosynthetic Clay Liner) Please address the following concerns:
    i. Specify the GCL Installer's qualification as described in Section 7.2 of the CQA Plan.
    ii. (Paragraph C.1.e – Installation Procedures and Drawings, on page 02776-4) Would the Contractor be required to submit CQA Engineer a conceptual plan for placement of the GCL panels over the area of installation for a review and approval? Please clarify.
    iii. (Paragraphs B, on page 02776-3) The Paragraphs B shall specify the material properties of the granular sodium bentonite applied between all overlapped seams described in the Paragraph D.3.g. and repairmen in the Paragraph D.3.i.
    iv. (Paragraph D.3.a, on page 02776-5) Because the GCL will directly contact the subgrade – 12-inch-thick intermediate soil cover, this sub-paragraph needs to specify the maximum soil grain size in the finished subgrade to prevent void fraction and/or puncture damage on GCL from the certain sizes of rock or gravel or other material.
    v. (Paragraph D.3.a, on page 02776-5) Please specify the subgrade certification requirement prior to placing GCL layer according to Rule .1624(b)(90(C)(i).

vi. (Paragraph D.3.i, on page 02776-6) What method or practice is there to ensure the patched area will not be removed or displaced while placing the cover material? Should dry granular sodium bentonite be applied around the damage area prior to placing the patch? Please clarify.

vii. (Table1) Please specify the confine pressure (consideration of low normal loading condition for the cover system) and hydration condition which are simulating the field condition for the hydraulic conductivity on the GCL according to Rule 1624(b)(9)(A)(ii).

8. (Section 02778, LLDPE Geomembrane(LLDPE-GM)) Please address the following concerns:
   i. (Paragraph D.3, on page 02778-7) Because the LLDPE-GM will directly contact the subgrade – 12-inch-thick intermediate soil cover, this sub-paragraph specify the maximum size of grain (rock, gravel, other material) is ½ inches. Please provide a calculation to demonstrate this maximum grain size will not create puncture damage on the 30-mil LLDPE-GM.
   ii. (Paragraph D.5, on page 02778-9) What provisions are there to avoid "fish-mouths" or wrinkles while seaming and to fix or correct the problem? Please clarify.
   iii. (Paragraph D.6, on page 02778-10) Will the anchor trenches be constructed for installing the LLDPE-GM? There is no trench layout or trench detail showing on the Drawings (Sheet No. 5/Drawing No. S4 and Sheet No. 6/Drawing No. D1) indicate. Please clarify.

Attachment C– CQA Plan

9. (Section 5.0 Geomembrane CQA) Are the specified air pressure test requirements for 30-mil LLDPE in Table 5.2 consistent with the specifications in ASTM D 5820 which states the pressure ranges from 25 psi to 30 psi? Please clarify.

10. (Section 5.4.6.3 Geomembrane CQA Laboratory Destructive Testing) Please specify the LLDPE-GM samples for laboratory testing will only be conducted after the samples from the same batch collected for field destructive seam testing have passed the shear strength criteria stated in Table 3 of Section 02778 in Attachment B.

Attachment D – Operations Manual

11. Please address the requirement stated in the Rule .0542(j)(8).

12. (Section 1.4 Signage) Please add the requirement stated in the Rule .0542(j)(6) to this section. The 18 February 2010 Facility Compliance Audit Report indicated the C&DLF does not in compliance with the rule requirement.

13. (Section 2.5) Please address the requirement stated in the Rule .0542(g)(3). The 18 February 2010 Facility Compliance Audit Report indicated the C&DLF does not in compliance with the rule requirement.

14. (Section 2.5.5.1) The Rule .0542(f)(1) requires the working face to be cover when the waste exceeds one-half acres, and this period cover requirement stated in this section is incorrect. Please make necessary correction.

15. (Section 3.4) Please identify the gas probes (total number of probes and identification numbers) that will be sampled quarterly. There are nine (9) landfill gas probes (GM-1, GM-2, GM-2B, GM-2R, GM-3, GM-4, GM-4R, GM-5, and GM-5B) shown on Drawing No. FIG. 1. Will theses ten probes be sampled quarterly?

Attachment F – Closure and Post-Closure Plan

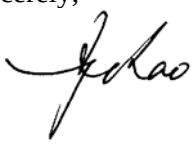
16. (Table 3.1) The cost for CQA is incorrect. However, after consulting the closure cost estimates for other landfill facilities in the State of North Carolina, the reviewer thinks the unit cost for CQA of $6,000 will be a reasonable cost. Please increase the unit cost from 5,000 to $6,000.

Figures

6. (Drawing No. S4/Sheet No. 5) Please double check the drawing detail references and correct the typographic errors shown below:
    i Down pipe detail is shown on 1/EC1 (Sheet No. 7), not on 2/EC1.
    ii Filter berm detail is shown on 3/EC1 (Sheet No. 7), not on 2/EC3.

Please submit the written responses to the comments. If the responses will be incorporated into the Permit Application, please submit a hard copy and an electronic copy of the revised portions of the Permit Application. The Solid Waste Section appreciates your efforts and cooperation in this matter. If you have any questions, please contact me at (919) 508- 8507.

Sincerely,



Ming-Tai Chao, P.E.
Environmental Engineer II
Permitting Branch, Solid Waste Section

cc:
Pieter K. Scheer, P.E., RSG
Donna Wilson, DWM
Dennis Shackelford, DWM
Central Files
Ed Mussler, Permitting Branch Supervisor
Zinith Barbee, DWM
Mary Whaley, DWM

RICHARDSON SMITH GARDNER & ASSOCIATES
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SHEET: 7/9
JOB #: HALIFAX-08-1
DATE: 1/29/10
BY: PKS
CHKD BY:

Halifax County C&D Landfill
Capacity Evaluation - Summary

Landfill Unit	Area (Acres)	Gross Capacity (CY)	Net (Waste) Capacity (See Note 1)		Life Expectancy (Years) (See Note 2)
			(CY)	(Tons)	
C&D Landfill Units					
Area 1 (Filled)	6.5	67,399	60,659	51,616	-----
Area 1 (Remaining)	-----	63,868	33,886	23,720	4.3
Area 2 - Phase 1	3.3	73,129	65,816	39,490	5.3
Area 2 - Phase 2	2.4	90,571	74,980	44,988	6.0
Area 2 - Phase 3	-----	102,568	74,016	44,410	5.9
Total (C&D)	12.2	397,535	309,357	204,224	21.5

Notes:
1. Net capacity is based on an assumed 10% periodic cover soil ratio and waste density of 0.7 tons/cy (Area 1) and 0.6 tons/cy (Area 2).
2. Area 1 life expectancy is based on an assumed average disposal rate of 5,500 tons/year and is projected from May 1, 2008.
3. Area 2 life expectancy is based on an assumed average disposal rate of 7,500 tons/year.

Halifax County Solid Waste Dept.
Volume Report 5/1/2008
9/2/2008

version	date	time	surfBase	surfCompare	volCut	volFill	volNet
1	9/2/2008	15-57-38	TOPO 0902	SURVEY_050108	8,058.73	40,879.14	32,820.41
1	9/2/2008	15-57-38	SURVEY_050108	AREA_1 FCVR	917.54	64,785.69	63,868.15 ←

3/9

Objective To determine the maximum geotextile apparent opening size (AOS) to provide proper retention to protect drainage media from piping and clogging from adjacent soil. Additionally, to determine the minimum required geotextile permittivity to provide proper drainage from the adjacent soil. Geotextile filtration properties must be selected based on the up-gradient soil gradation and plasticity and site specific hydraulic conditions.

References

Bhatia, S.K. and Huang, Q. (1995), "Geotextile Filters for Internally Stable/Unstable Soils", *Geosynthetics International*, Vol. 2, No. 3, pp. 537-565.

Koerner, Robert M. (1999), Designing with Geosynthetics, 4th Ed., Prentice-Hall Inc., Englewood Cliffs, NJ, pp. 84-91.

Mirafi - Geotextile Filter Design, Application, and Product Selection Guide, Ten Cate Nicolon Corp. (www.mirafi.com).

Richardson, G.N., Giroud, J-P., and Zhao, A. (2000), Design of Lateral Drainage Systems for Landfills, Tenax Corp., Baltimore.

Assumption The design criteria given assume that the soil is "set" in intimate contact with the geotextile.

Background From Richardson et. al.:

For the purposes of filtration design, soils can be characterized as stable or unstable. Stable soils perform an internal filtration process that limits migration of fines within the soil. Typically, these soil types include well-graded soils. Unstable soils are those which cannot perform self-filtration (i.e. they have the potential to pipe internally). They may include gap-graded, broad-graded, and other highly erodible soils. In gap-graded soils, there exists a coarse and fine fraction, but very little medium fraction. If there is an insufficient quantity of soil particles in the medium fraction, fine soil particles pipe through the coarse fraction. In broad-graded soils, the gradation is distributed over a very wide range of particle sizes such that fine soil tends to pipe through coarser particles.

Analysis

1. **Define Application and Function of Geotextile:**

   Define the application and function of the geotextile (i.e. where the geotextile is to be used and whether retention or permeability is the key function of the material) and also the confining stress (i.e. high - leachate collection system; low - final cover system) and flow conditions (i.e. steady-state - landfill drains; dynamic - shoreline protection).

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2. Evaluate Soils Information:

For representative soils, evaluate grain size and plasticity information. From the grain size curves determine the coefficients of uniformity and curvature as follows:

$$C_u = \frac{d_{60}}{d_{10}}$$

$$C_c = \frac{d_{30}^{\,2}}{\left(d_{10} \times d_{60}\right)}$$

where: C_u = coefficient of uniformity (quantifies the distribution of particle sizes)
C_c = coefficient of curvature (identifies internal soil stability)
d_x = the diameter at which x percent of the soil is finer

For $C_u \leq 4$, the soil is uniformly-graded; for $4 < C_u \leq 20$, the soil is well-graded; and for $C_u > 20$, the soil is broad-graded. Uniformly-graded and broad-graded soils require careful analysis. Gap-graded soils which have a coarse and fine fraction, but limited medium fraction are of particular concern and should be avoided. Gap-graded soils are readily identified by the appearance of the grain size curve. For $1 \leq C_c \leq 3$, the soil should be internally stable (Bhatia and Huang state that soils having $C_c \leq 7$ are internally stable.).

Additionally, in general, particles do not move within soils having a plasticity index (PI) greater than 15% so there is no clogging potential (Richardson et. al.).

3. Selection of Soil Retention Requirements (Maximum AOS):

To determine the maximum AOS, use the method given in Koerner/Mirafi (after Luettich) and the method given in Bhatia and Huang. For the AOS determined by either method, the following shows the relationship between opening size and the corresponding U.S. sieve number (with typical non-woven geotextile information as shown).

Opening Size (mm)	U.S. Sieve
0.150	100 (most 8 to 16 oz/sy non-wovens)
0.180	80
0.212	70 (most 4 to 6 oz/sy non-wovens)
0.250	60
0.300	50
0.425	40
0.600	30

- Luettich Method:

For steady-state conditions, use the chart below.

- Bhatia and Huang Method:

Bhatia and Huang developed the following retention criteria:

For $n \geq 60\%$: $O_{95} < d_{85}\left(2.71 - 0.36C_c\right)$ $\quad C_c \leq 7$

$O_{95} < d_{85}\left(0.65 - 0.05C_c\right)$ $\quad C_c > 7$

For $n < 60\%$: $O_{95} < d_{85}$

where: O_{95} = apparent opening size
n = geotextile porosity (%) (for non-woven geotextiles this value is typically 70 to 90%)

4. Determine Geotextile Permittivity Requirements:

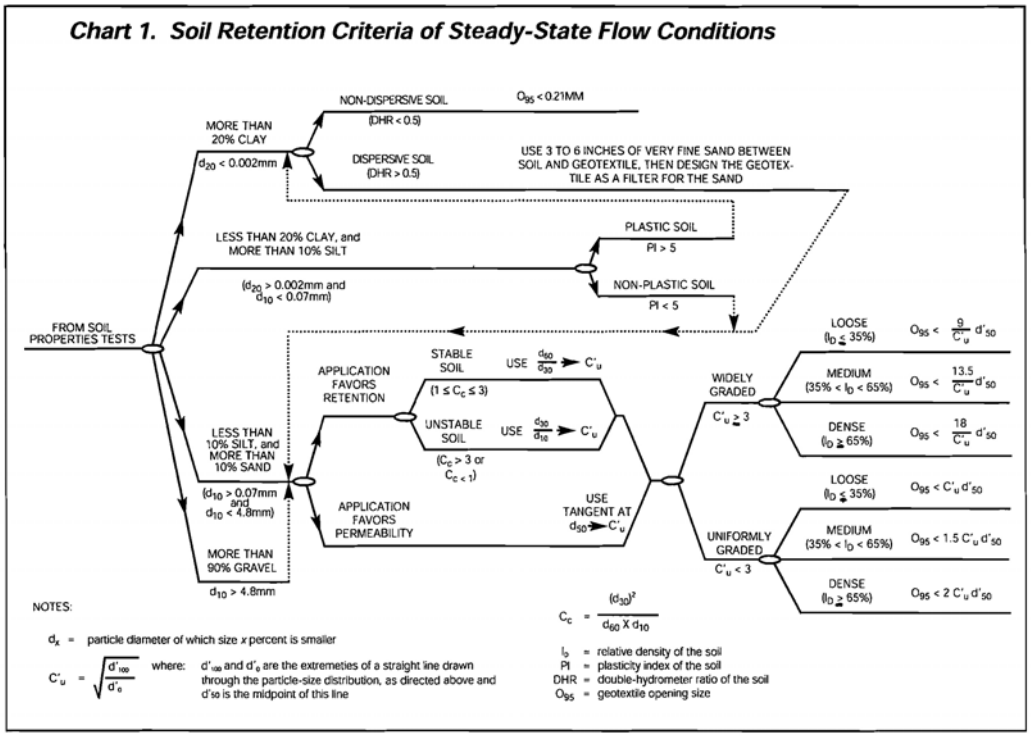
Determine the geotextile permittivity requirements:

$$\Psi = \frac{k_g}{t_g} \qquad (\text{sec}^{-1})$$

where: Ψ = minimum required geotextile permittivity (sec^{-1})
k_g = minimum allowable geotextile permeability (cm/sec)
$k_g \geq i_S k_S$
t_g = geotextile thickness under design load (cm)
i_S = hydraulic gradient (use 1.5 for landfills)
k_S = permeability of retained soil (cm/sec).

5. Other Considerations:

Other things to consider in the design of a filter geotextile include anti-clogging requirements and survivability/durability requirements. For anti-clogging, it is generally best to use the largest AOS that satisfies the retention criteria. For non-woven geotextiles used in landfill applications, an AOS of 0.21 mm (No. 70 sieve) is typically the largest AOS that is available. For survivability/durability concerns, generally an adequately UV stabilized geotextile made from polypropylene or polyester with an AASHTO M288 Strength Class of 2 is suitable for use in subsurface drainage applications.



Ref: Mirafi (After Luettich)

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SHEET: 5/5
JOB #: HALIFAX-08-1
DATE: 10/8/10
BY: PKS
CHKD BY:

Halifax County C&D Landfill - Area 1 Final Cover
Filter Geotextile Analysis (Final Cover System)

Application: Final Cover Drainage Geocomposite
Primary Function: Retention
Relative Confining Stress: Low
Flow Conditions: Steady-State

	Soil Evaluated				
	B-4	B-9			
Soil Description:	Red/Orange Fine Sandy Clayey Silt	Tan Brown Sandy Silt			
Soil Type:	SM/ML	ML			
Particle Size (mm) d_{85}:	2.100	1.600			
d_{60}:	1.200	0.160			
d_{50}:	1.000	0.050			
d_{30}:	0.360	0.010			
d_{20}:	0.150	0.005			
d_{10}:	0.009	0.003			
PI:	14	6			
C_u:	133.33	61.54			
	Use Caution - Soil is Broad Graded!	Use Caution - Soil is Broad Graded!			
C_c	12.00	0.24			
Luettich Method:*	-----	-----			
Soil Dispersion (When Applicable):	Is Soil Dispersive? (Y/N)	Is Soil Dispersive? (Y/N)			
	N	N			
Recommended Maximum AOS (mm) (When Applicable):	**0.210** **No. 70 Sieve**	**0.210** **No. 70 Sieve**			
Internal Soil Stability (When Applicable):	NA	NA			
Particle Size (mm) for Determining C'_u d'_{100}:					
d'_{50}:					
d'_0:					
C'_u (When Applicable):					
Soil Relative Density (I_D) (Loose (L), Medium (M), Dense (D) (When Applicable):					
Recommended Maximum AOS (mm) (When Applicable):					
Bhatia & Huang Method:	-----	-----			
Internal Soil Stability:	Soil is Unstable.	Soil is Stable.			
Geotextile Porosity (%):	80	80			
Recommended Max. AOS (mm):	**0.105** **Check Available Geotextiles.**	**4.198** **No. 30 Sieve**			
Required Geotextile Properties:	-----	-----			
Hydraulic Gradient (i_g):	1.5	1.5			
Estimated Soil Permeability (k_s) (cm/sec):	1.0E-04	1.0E-04			
Min. Allowable Geotextile Permeability (k_g) (cm/sec):	1.5E-04	1.5E-04			
Geotextile Thickness (t_g) (cm):	0.25	0.25			
Min. Required Geotextile Permittivity (Ψ) (sec^{-1}):	**0.0006**	**0.0006**			

***Note: Spreadsheet assumes retention application in using the Luettich Method.**

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Objective To evaluate the required transmissivity for the drainage geocomposite placed in the final cover system.

Reference Richardson, G.N., Giroud, J-P., and Zhao, A. (2000), Design of Lateral Drainage Systems for Landfills, Tenax Corp., Baltimore.

Analysis

Step 1:

Determine the required transmissivity (θ_{reqd}) of the drainage geocomposite based on the following equation:

$$\theta_{reqd} = \frac{RF_{dc} q_n L i}{\sin\beta} = \frac{RF_{dc} q_n L \cos\beta}{\sin\beta} = \frac{RF_{dc} q_n L}{\tan\beta}$$ (Richardson et. al. Eq. 4-6 Mod.)

where:
- θ_{reqd} = required transmissivity ($m^3/m/sec$)
- RF_{dc} = drainage geocomposite reduction factor (See Note 1)
- q_n = fluid input rate/impingement rate (m/s) (See Note 2)
- L = flow length/drain spacing (horizontally projected) (m)
- β = slope angle of final cover (degrees).

Notes:

1. Based on the recommendations of Richardson, Giroud, & Zhao, use $RF_{dc} = 6$ for steeper slopes where veneer stability is key (i.e. 5H:1V or steeper). Lesser reduction factors are appropriate where there are shallow slopes.

2. Typically the impingement into the drainage geocomposite is determined by the **lessor** of:

   a. Permeability of the overlying vegetative soil layer(k_{veg}) or
   b. Design rainfall.

   Per Richardson,Giroud, & Zhao, use $q_n = k_{veg}$ except in arid/semi-arid areas.

Step 2:

Determine the required transmissivity test parameters:

- Normal Stress (cover thickness x unit weight of cover soil) and
- Hydraulic Gradient (equals slope of cover system).

FCS DRAIN LAYER.WPD

Step 3:

Calculate the required total flow capacity (Q) of the drain based on the following equation:

$$Q = q_n A$$

where:
- Q = flow capacity (cfs)
- q_n = impingement (ft/s)
- A = total area served by the drain (= L x DL) (ft^2)
- DL = length of drain between outlet locations (ft).

Step 4:

After finding Q for each drain, the designer shall select the appropriate type and size of drain.

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SHEET: 3/3
JOB #: HALIFAX-08-1
DATE: 10/8/10
BY: PKS
CHKD BY:

Halifax County C&D Landfill - Area 1 Closure
Final Cover Drainage Layer Analysis

Input Parameters:

Side Slope Angle (β):	5.7	degrees	(10%)
Impingement (q_n):	0.0001	cm/sec	(= Permeability of Vegetative Soil Layer) (Conservative)
Drain Spacing (L):	100	ft	(= Horizontally Projected Distance Up & Down Slope)
Reduction Factors for Drainage Geocomposite:			(Per Richardson, Giroud, & Zhao Recommendations)
$RF_{intrusion}$:	1.1		
RF_{creep}:	1.2		
$RF_{chemical\ clogging}$:	1.1		
$RF_{biological\ clogging}$:	1.3		
Overall Factor of Safety:	1.5		
Reduction Factor for Drainage Geocomposite in Final Cover (RF_{dc}):	2.6		
Drain Length (DL):	200	ft	(= Distance Across Slope at Toe)
Final Cover: Thickness:	1.5	ft	
Unit Weight:	110	pcf	

Note: Spreadsheet Converts Units as Required.

Transmissivity Requirements:

Determine Minimum Transmissivity:

θ_{min} = 8.0E-04 $m^3/m/sec$ = 3.9 gpm/ft

Determine Transmissivity Test Parameters:

Min. Normal Stress = 165.0 psf

Hydraulic Gradient = 0.10

Determine Required Drain Capacity:

Calculate Required Total Flow Capacity:

Q = 0.07 cfs *Based on 200 foot spacing between outlets.

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SECTION 02258

VEGETATIVE SOIL LAYER

Vegetative Soil Layer (VSL): The Vegetative Soil Layer (VSL) is placed in the final cover system in order to support permanent vegetative cover.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of the VSL (including topsoil) for the landfill cover, including borrowing, hauling, spreading, and final grading and all necessary and incidental items as detailed or required to complete the VSL, all in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

Work	Section
Drainage Geocomposite	02712
LLDPE Geomembrane	02778
Revegetation	02930
CQA Manual	Attached

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) are hereby made a part of these Specifications.

ASTM D 2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System).

4. Quality Assurance:

Quality Assurance during placement of Vegetative Soil Layer will be provided by the Owner as described in the accompanying Project CQA Manual.

B. MATERIALS

Soil that meets all of the following requirements shall be classified as select soil fill for use in construction of the VSL.

1. Soil shall be classified according to the Unified Soil Classification System (USCS) as SC, SM, ML, or CL (ASTM D 2487). Alternatives to these requirements must be approved in advance by the Engineer.

2. Select soil fill materials shall be reasonably free of gypsum, ferrous, and/or calcareous concretions and nodules, refuse, roots, or other deleterious substances.

3. Continuous and repeated visual inspection of the materials being used will be performed by the Contractor to ensure proper soils are being used. In addition, the CQA Engineer shall make frequent inspections of the placement operations and materials, and will consult with the Engineer.

4. The VSL shall be uniform, smooth, and free of debris, rock, plant materials, and other foreign material larger than 3 inches in diameter. The material should contain no sharp edges. This material must be capable of supporting growth of vegetative cover.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Before approval is given to proceed, the Contractor shall submit descriptive information on placement equipment to be used in construction of the VSL.

2. Survey Results:

After completion of a segment of VSL, survey results shall be submitted for review prior to VSL acceptance.

D. CONSTRUCTION

1. The VSL is placed directly over geosynthetics and/or piping; thus, extreme caution shall be exercised by the Contractor to prevent damage to these materials.

2. All placement and compaction of VSL shall be performed only when the CQA Engineer is informed by the Contractor of intent to perform such work.

3. VSL shall be placed over geosynthetics only after areas have been released by the Geosynthetics Installer and the CQA Engineer. VSL shall be placed as specified below:

a. The VSL, including topsoil, shall be placed and spread using low ground pressure (6 psi or less) tracked equipment. The CQA Engineer shall approve the equipment used to place the VSL.

b. Tracked equipment used to place and spread VSL shall operate on at least 1 foot of material overlying geosynthetics and/or piping. Sharp turning of tracked equipment on the VSL will not be permitted.

c. On slopes of 6H:1V or steeper, VSL shall be placed and spread from the bottom up unless otherwise approved by the Engineer. No material shall be dumped down a slope.

d. VSL shall be placed and compacted to the lines and grades shown on the Contract Drawings with the exception that a 0.15 foot overbuild at Contractor's expense is allowed. The Contractor will perform all surveys necessary to establish and verify lines and grades for all VSL.

e. VSL shall be compacted by tracking the final lift with tracked equipment.

4. The VSL shall be spread in a manner that minimizes development of wrinkles or tension in the underlying geosynthetics. Any portion of the underlying geosynthetics that develops excessive wrinkles or crimp or is otherwise damaged shall be repaired by the Geosynthetics Installer at no expense to the Owner.

a. VSL shall not be placed when conditions are warm enough to produce excessive wrinkles in the underlying geosynthetics. Likewise, VSL shall not be placed when conditions are cold enough to produce tension in the underlying geosynthetics.

b. If during spreading, excessive wrinkles develop, the Contractor shall adjust placement and spreading methods, or cease until the underlying geosynthetics cool and wrinkles decrease in size.

c. Wrinkles that exceed approximately 6 inches in height and cannot be eliminated by amended placement and spreading methods or underlying geosynthetics that become crimped shall be cut and repaired by the Geosynthetics Installer in a method approved by the Engineer.

5. Stockpiling of VSL on the final cover shall be subject to advance approval by the Engineer. Any hauling equipment (dump trucks, etc.) operating over geosynthetics shall have a minimum of 3 feet of separation between the vehicle wheels and the underlying geosynthetics.

6. The CQA Engineer may require removal of VSL and/or other underlying layers at the Contractor's sole expense to allow examination of the underlying geosynthetics and/or piping. Any damage to underlying layers or excessive

wrinkling or crimping during placement of the VSL shall be repaired in accordance with the applicable section of these Specifications at the Contractor's sole expense.

7. After the specified thickness has been achieved and verified, the Contractor shall proceed immediately with seeding.

8. Surveying:

After completion of a segment of VSL, the VSL shall be surveyed on 100 foot centers and at slope breaks (including all tops and toes of slope, points of grade change, etc.) to ensure:

a. The specified thickness has been achieved. A hand auger or similar method may be used to check for thickness at each location.

b. The top of the VSL slopes at grades specified on the Contract Drawings; and

c. VSL placed more than 0.15 feet beyond the limits of the lines and grades as shown on the Contract Drawings will not be accepted and must be removed at the Contractor's sole expense if required by the Engineer.

This work shall be performed at the Contractor’s cost by a registered surveyor.

END OF SECTION

SECTION 02712

DRAINAGE GEOCOMPOSITE

Drainage Geocomposite (DGC): The Drainage Geocomposite (DGC) consists of a geonet drainage core and heat-bonded nonwoven geotextile. The purpose of the DGC is to rapidly transmit flow to collection piping.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of DGC, including all necessary and incidental items, in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

Work	Section
Vegetative Soil Layer	02258
LLDPE Geomembrane	02778
Geosynthetic Clay Liner	02776
CQA Manual	Attached

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) and the Geosynthetic Research Institute (GRI) are hereby made a part of these specifications.

ASTM D 413	Standard Test Methods for Rubber Property - Adhesion to Flexible Substrate.
ASTM D 1505	Standard Test Method for Density of Plastics by the Density-Gradient Technique.
ASTM D 1603	Standard Test Method for Carbon Black in Olefin Plastics.
ASTM D 4218	Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds By the Muffle-Furnace Technique.

ASTM D 4355	Standard Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus).
ASTM D 4491	Standard Test Methods for Water Permeability of Geotextiles by Permittivity.
ASTM D 4632	Standard Test Method for Grab Breaking Load and Elongation of Geotextiles.
ASTM D 4716	Standard Test Method for Constant Head Hydraulic Transmissivity (In-Plane Flow) of Geotextiles and Geotextile Related Products.
ASTM D 4751	Standard Test Method for Determining Apparent Opening Size of a Geotextile.
ASTM D 4833	Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.
ASTM D 5199	Standard Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes.
ASTM D 5261	Standard Test Method for Measuring Mass per Unit Area of Geotextiles.
ASTM D 5321	Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method.
ASTM D 6243	Standard Test Method for Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by the Direct Shear Method.
GRI GC7	Determination of Adhesion and Bond Strength of Geocomposites.

4. Quality Control:

The Contractor shall perform Quality Control tests in accordance with Table 3 of this section.

5. Quality Assurance:

Quality Assurance during installation of DGC will be provided by the Owner as described in the accompanying Project CQA Manual.

B. MATERIALS

1. General:

The materials supplied under these Specifications shall consist of new, first-quality products designed and manufactured specifically for the purpose of this work, which shall have been satisfactorily demonstrated, by prior use, to be suitable and durable for such purposes.

Labels on each roll of DGC shall identify the length, width, lot and roll numbers, and name of Manufacturer.

2. The geonet drainage core shall be manufactured by extruding polyethylene strands to form a three dimensional structure to provide planer water flow.

3. A nonwoven needlepunched geotextile, consisting of polyester or polypropylene and manufactured in a manner approved by the Engineer, shall be heat-bonded to the geonet drainage core. Roll edges shall have a maximum unbonded length of 6 inches, unless otherwise approved by the Engineer. Heat bonding shall be performed by the Manufacturer prior to shipping to the site.

4. The geonet drainage core shall contain UV inhibitors to prevent ultraviolet light degradation.

5. Final Cover Drainage Geocomposite:

Final Cover DGC shall have a nonwoven geotextile heat-bonded to both sides of the geonet drainage core. Physical properties of the DGC shall be as shown in Table 1 of this section.

C. SUBMITTALS

Prior to DGC installation, the Contractor shall submit the following to the CQA Engineer:

1. Mill Certificate and Sample: Prior to shipping to the site, the Contractor shall submit a mill certificate or affidavit signed by a legally authorized official of the Manufacturer for the DGC attesting that the DGC meets the physical and manufacturing requirements stated in these Specifications. The Contractor shall also submit a sample of the DGC to be used. The sample shall be labeled with the product name and be accompanied by the Manufacturer's specifications.

2. Shipping, Handling, and Storage Instructions: The Manufacturer's plan for shipping, handling, and storage shall be submitted for review.

3. Seaming Procedures:

Submit proposed seaming procedures including proposed method and equipment.

4. Quality Control Certificates: For DGC delivered to the site, quality control certificates, signed by the Manufacturer's quality assurance manager shall be provided which represent every roll of DGC. Each certification shall have the roll identification number(s), test methods, frequency, and test results. At a minimum, the test results and frequency of testing shall be as shown in Table 2 of this section.

5. Contractor Quality Control Test Results: The Contractor shall provide the results of required testing.

6. Furnish copies of delivery tickets or other approved receipts as evidence for materials received that will be incorporated into the construction.

D. CONSTRUCTION

1. Shipping, Handling, and Storage:

All DGC shall be shipped, handled, and stored in strict accordance with the Manufacturer's recommendations.

2. Failing CQA Material Control Tests:

DGC that is rejected upon testing shall be removed from the project site and replaced at Contractor's cost. Sampling and quality assurance testing of DGC supplied as replacement for rejected material shall be performed by the CQA Engineer at Contractor's cost.

3. Installation:

a. The DGC shall be placed only on Geomembrane that has been approved by the Geomembrane Installer and accepted by the CQA Engineer. The Contractor shall remove debris, including sediment to the degree possible, from the Geomembrane prior to placement of the DGC.

b. DGC shall be placed to the lines and grades shown on the Contract Drawings. At the time of installation, the DGC shall be rejected, if it has defects, rips, holes, flaws, evidence of deterioration, or other damage. Isolated areas of up to 1 square yard where the geotextile has become delaminated from the geonet drainage core may be allowed by the CQA Engineer as long as there appears to be a good bond between the geotextile and the geonet in surrounding areas. Rolls where the geotextile

appears to be easily delaminated from the geonet such as by foot or ATV traffic shall be rejected.

c. Orientation: If the DGC transmits flow in a predominant direction (typically along the roll length), then the DGC shall be installed with the predominant flow direction laid approximately perpendicular to contour lines (i.e. in the direction of the slope) or as specified by the Engineer. Otherwise, DGC shall be installed with the machine direction (along the roll length) generally in the direction of flow or as specified by the Engineer.

d. The DGC shall be placed smooth and free of excessive wrinkles.

e. The Contractor shall provide temporary anchorage of the DGC at the top of perimeter and interior berms during installation as necessary to prevent movement during construction. Such anchorage may include sandbags and the like, as approved by the CQA Engineer. Permanent bonding to the Geomembrane shall be prohibited.

4. Seams:

a. All seams constructed on slopes of 6H:1V or steeper or within 10 feet of the toe of a slope of 6H:1V or steeper shall be vertical seams, except where slope lengths exceed standard roll lengths and elsewhere as approved in advance by the Engineer. Where allowed by the Engineer, end seams on slopes of 6H:1V or steeper shall be staggered a minimum of 5 feet between adjacent rolls.

b. Geonet Drainage Core: The geonet drainage core shall be laid with a 3 inch minimum overlap seam along roll edges and a 6 inch minimum overlap seam along roll ends and shall be secured using plastic ties. Ties shall be placed every 5 feet along roll edges; every 12 inches along roll ends; and every 6 inches in the anchor trench.

c. Geotextile Component(s): Where applicable, the bottom geotextile of the DGC shall be overlapped with the same of the adjacent rolls. The top geotextile of the DGC shall be continuously sewn or heat bonded to the same of the adjacent rolls with methods approved by the Engineer.

(1) Seams to be sewn shall be sewn using a Type 401 stitch. One or two rows of stitching may be used. Each row of stitching shall consist of 4 to 7 stitches per inch. The minimum distance from the geotextile edge to the stitch line nearest to that edge (seam allowance) shall be 1.5 inches if a Type SSa (prayer or flat) seam is used. The minimum seam allowance for all other seam types shall be 1.0 inches.

(2) Seams to be heat bonded shall be bonded using hot plate, hot knife, ultrasonic, or other approved devices.

5. Repairs:

Any DGC that is torn, crushed, punctured, or otherwise damaged shall be repaired or replaced, as directed by the CQA Engineer, by the Contractor at no additional cost to the Owner. The repair shall consist of a patch of the same type of material, placed over the damaged area and shall overlap the existing material a minimum of 12 inches from any point of the damage. The patch shall be connected to the geonet drainage core of the damaged material using plastic cable ties at a 6 inch spacing and the upper geotextile of the patch shall be spot sewn or heat bonded to the upper geotextile of the damaged material. A geotextile patch, spot sewn or heat bonded to the damaged material, may be used where damage is to only that portion of the DGC.

6. Cover Placement:

a. DGC shall be covered in a timely manner to limit potential UV damage. Unless otherwise approved by the Engineer, covering shall occur within 30 days of installation. Extension of this time may be considered by the Engineer based on weather conditions (i.e. prolonged cloud cover during 30 day period) or technical information provided by the Manufacturer that would justify an extension.

(1) The CQA Engineer may conduct sampling and testing of any DGC exposed for a period longer than allowed to verify the material properties. The cost associated with this testing and the subsequent repair(s) shall be bourne solely by the Contractor regardless of the test results. In no case will the maximum length of exposure be greater than 60 days without verification of material properties.

b. Placement of materials over DGC shall be performed in a manner as to ensure that DGC and the underlying geosynthetics are not damaged; minimal slippage of DGC on the underlying geosynthetics occurs; no excess tensile stresses occur in the DGC; and that no portion of the DGC develops excessive wrinkles or crimp. Wrinkles that exceed approximately 6 inches in height and cannot be eliminated by amended placement and covering methods or DGC that becomes crimped shall be cut and repaired by the Geosynthetics Installer in a method approved by the Engineer.

TABLE 1: REQUIRED DRAINAGE GEOCOMPOSITE PROPERTIES

PROPERTY	TEST METHOD	UNITS	VALUE
Geonet:			
Thickness	ASTM D 5199	inches	0.25 (See Note 1)
Density	ASTM D 1505	g/cm^3	0.94
Carbon Black Content	ASTM D 1603/D 4218	%	2-3
Geotextile:			
Mass per Unit Area (Unit Wt.)	ASTM D 5261	oz/yd^2	6
Tensile Properties:	ASTM D 4632		
Grab Strength		lbs	160
Grab Elongation		%	$\geq$ 50
Puncture Resistance	ASTM D 4833	lbs	55
Apparent Opening Size (AOS)	ASTM D 4751	U.S. Sieve	70+
Permittivity	ASTM D 4491	sec^{-1}	1.0
Ultraviolet Resistance (500 hrs)	ASTM D 4355	%	70
Geocomposite:			
Ply Adhesion	ASTM D 413/ GRI GC7	lb/inch	2.0 Typ. 1.0 Min. Avg.
Transmissivity: (Final Cover)	ASTM D 4716	$m^3/m/sec$	8.0×10^{-4} (See Note 2)
Interface Shear Strength (Peak)[3, 4] (Final Cover)	ASTM D 5321 ASTM D 6243 (GCL)	psf	55 psf (Load = 200 psf)

Notes:

1. A thicker geonet may be required depending on transmissivity requirements.
2. Final Cover:
   Conduct test for transmissivity at a normal compressive load of 1,000 psf and at a hydraulic gradient of 0.10 after a seating period of at least 24 hours. Boundary

conditions are soil (sand) interface on the upper geotextile and textured LLDPE geomembrane (or GCL) against the lower geotextile.

3. DGC shall have adequate adhesion against adjacent materials under low normal loads to achieve the successful installation of overlying components without slippage.
4. The specified interface shear strength requirement is based on a finished slope no steeper than 6H:1V. Steeper slopes will require evaluation by the Engineer.

TABLE 2: REQUIRED MANUFACTURER QUALITY CONTROL TESTS

PROPERTY	TEST METHOD	MINIMUM TEST FREQUENCY
Geonet:		
Thickness	ASTM D 5199	50,000 ft^2
Density	ASTM D 1505	50,000 ft^2
Carbon Black Content	ASTM D 1603/D 4218	50,000 ft^2
Geotextile:		
Mass Per Unit Area	ASTM D 5261	200,000 ft^2
Tensile Properties	ASTM D 4632	200,000 ft^2
Puncture Resistance	ASTM D 4833	200,000 ft^2
Apparent Opening Size (AOS)	ASTM D 4751	600,000 ft^2
Permittivity	ASTM D 4491	600,000 ft^2
UV Resistance	ASTM D 4355	600,000 ft^2
Geocomposite:		
Ply Adhesion	ASTM D 413/ GRI GC7	100,000 ft^2
Transmissivity[1]	ASTM D 4716	100,000 ft^2 (See Note 2)

Notes:

1. Conduct transmissivity tests in accordance with the criteria given in Table 1.
2. The required Manufacturer's quality control testing for transmissivity may be reduced to one test per resin lot or one test per 500,000 ft^2 (whichever provides

the larger number of tests) if the minimum measured transmissivity is at least 50% greater than specified.

TABLE 3: REQUIRED CONTRACTOR QUALITY CONTROL TESTS

PROPERTY	TEST METHOD	MINIMUM TEST FREQUENCY
Interface Shear Strength	ASTM D 5321 ASTM D 6243 (GCL)	(See Note 1)

Notes:

1. Test each interface to be used on this project using representative samples of materials to be supplied under normal loads indicated and using test parameters as specified by the Engineer. For this project, interfaces to be tested are:

   A. Textured LLDPE-GM (30 mil) or GCL against existing cover soils (intermediate cover);
   B. Drainage Geocomposite against textured LLDPE-GM (30 mil) or GCL; and
   C. Vegetative Soil Layer against Drainage Geocomposite.

   If there are material differences in the surface of any of the geosynthetic materials from one side to the other, then all possible combinations of interfaces shall be tested. This testing shall be performed at Contractor cost by an independent GAI accredited laboratory and submitted to the Engineer for review prior to shipping. Upon review of test results, the Engineer may allow exceptions to the above criteria.

   For tests involving textured geomembranes, the laboratory shall also report the asperity height (GRI GM12) for the material samples used in the actual direct shear tests.

END OF SECTION

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SECTION 02776

GEOSYNTHETIC CLAY LINER (GCL)

Geosynthetic Clay Liner (GCL): The GCL serves as the primary hydraulic barrier within the final cover system.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of GCL in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

Work	Section
Drainage Geocomposite	02712
CQA Manual	Attached

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) are hereby made a part of these specifications.

ASTM D 5887	Standard Test Method for Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter.
ASTM D 5890	Standard Test Method for Swell Index of Clay Mineral Component of Geosynthetic Clay Liners.
ASTM D 5891	Standard Test Method for Fluid Loss of Clay Component of Geosynthetic Clay Liners.
ASTM D 5993	Standard Test Method for Measuring Mass per Unit of Geosynthetic Clay Liners.

ASTM D 6243	Standard Test Method for Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by the Direct Shear Method.
ASTM D 6496	Standard Test Method for Determining Average Bonding Peel Strength Between the Top and Bottom Layers of Needle-Punched Geosynthetic Clay Liners.
ASTM D 6768	Standard Test Method for Tensile Strength of Geosynthetic Clay Liners.

4. Quality Control:

The Contractor shall perform Quality Control tests in accordance with Table 3 of this section.

5. Quality Assurance:

Quality Assurance during installation of GCL will be provided by the Owner as described in the accompanying Project CQA Manual.

6. Manufacturer Qualifications:

The GCL shall be furnished by a Manufacturer that has previously produced a minimum of 10,000,000 square feet of the material for use in similar projects.

7. Warranties:

a. General: Should a defect occur, which is covered under warranty, the Warrantor shall bear all costs for repair and/or relocation and replacement of the GCL.

b. Workmanship: The Contractor shall furnish the Owner a warranty from the GCL Installer which warrants their workmanship to be free of defects on a prorata basis for five (5) years after the final acceptance of the Work. This warranty shall include but not be limited to overlapped seams, anchor trenches, attachments to appurtenances, and penetration seals, as applicable.

c. Manufacturer's Warranty: The Contractor shall furnish the Owner a warranty from the GCL Manufacturer for the materials used. The material warranty shall be for defects or failures related to manufacture on a prorata basis for five (5) years after date of shipment.

B. MATERIALS

1. General:

The GCL shall consist of bentonite encased, top and bottom, with 6 oz./square yard non-woven geotextiles needle-punched together for reinforcement. GCL with a lighter non-woven geotextile or a woven geotextile on one side may be considered by the Engineer as long as all other criteria are met. Needle-punched GCL shall be essentially free of broken needles and fragments of needles that would negatively effect the performance of the final product. The materials supplied under these Specifications shall be first quality products designed and manufactured specifically for the purposes of this work.

The GCL shall be supplied in rolls which have a minimum width of 14 feet. The roll length shall be maximized to provide the largest manageable sheet for the fewest overlaps. Labels on the roll shall identify the length, width, lot and roll numbers, name of Manufacturer, proper direction of unrolling, and minimum recommended overlap.

2. Needle Detection and Removal Procedures:

The GCL Manufacturer shall use continuous needle detection and removal devices (e.g. metal detectors and magnets) in the manufacture of needle-punched GCL.

3. Physical Properties:

Physical properties of GCL shall be as shown in Table 1 of this section. Granular sodium bentonite used for overlaps and repairs shall have the same properties as the bentonite used in the GCL.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Pre-Installation Requirements:

Prior to GCL installation, the Contractor shall submit the following:

a. Mill Certificate and Sample: Prior to shipping to the site, the Contractor shall submit a mill certificate or affidavit signed by a legally authorized official of the Manufacturer for the GCL attesting that the GCL meets the physical and manufacturing requirements stated in these Specifications including needle detection and removal procedures. The Contractor shall also submit a sample of the GCL to be used. The sample shall be labeled with the product name and be accompanied by the Manufacturer's specifications.

b. Qualifications:

(1) Submit list of equipment and personnel proposed for the Project. Include equipment type and quantities. Include personnel experience on similar projects.

(2) Submit resume and references of Installation Supervisor to be assigned to the Project, including data and duration of employment and pertinent experience information.

c. Shipping, Handling, and Storage Instructions: The Manufacturer's recommendations for shipping, handling, and storage shall be submitted for review.

d. Delivery Date: Submit notification of the scheduled delivery date for the materials.

e. Installation Procedures and Drawings:

Submit installation procedures and (shop) drawings for carrying out the work. Procedures addressed by the Contractor shall include but not be limited to material installation, repair, and protection to be provided in the event of rain. Submit drawings showing typical details including pipe penetrations (if applicable). Following review, these procedures and drawings will be used for installation of the GCL. Any deviations from these procedures and drawings must be approved by the Engineer and CQA Engineer.

f. Quality Control Certificates: For GCL delivered to the site, quality control certificates, signed by the Manufacturer's quality assurance manager shall be provided which represent every roll of GCL. Each certificate shall have the roll identification number(s), test methods, frequency, and test results. At a minimum, the test results and frequency of testing shall be as shown in Table 2 of this section. Each certificate shall also include a certification that each roll of GCL has been continually checked by the Manufacturer for needles and that any needles detected have been removed.

g. Contractor Quality Control Test Results: The Contractor shall provide the results of required testing.

h. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into the construction.

2. Post-Installation Requirements:

Upon completion of GCL installation the Contractor shall submit the following:

a. A certificate stating that the GCL has been installed in accordance with the Drawings, Specifications, and the Manufacturer's recommendations.

b. Completed Manufacturer's and Workmanship Warranties.

Finalization of payment for GCL installation shall not be made until the above submittals have been reviewed by the CQA Engineer.

D. CONSTRUCTION

1. Shipping , Handling, and Storage:

The GCL shall be shipped, handled, and stored in strict accordance with the Manufacturer's recommendations.

2. Failing CQA Material Control Tests:

GCL that is rejected upon testing shall be removed from the project site and replaced at Contractor's cost. Sampling and CQA testing of GCL supplied as replacement for rejected material shall be performed by the CQA Engineer at Contractor's cost.

3. Installation of GCL:

a. The surface of the subgrade shall be smooth, uniform, free from sudden changes in grade (such as vehicular ruts), rocks or stones greater than ½ inch in size, standing water, debris, and deleterious materials.

b. Before an individual panel of GCL is installed; the Contractor and Installer shall verify in writing and submit to the CQA Engineer:

(1) Lines and grades are in conformance with the Drawings and Specifications.

(2) The surface area to be lined has been rolled and compacted, free of irregularities and abrupt changes in grade.

c. GCL shall be placed to the lines and grades shown on the Contract Drawings. At the time of installation, GCL shall be rejected by the CQA Engineer if it has defects, rips, holes, flaws, evidence of deterioration, or other damage.

d. The GCL shall not be placed during precipitation. Any material that becomes hydrated shall be removed and replaced at Contractor expense.

e. The GCL shall be placed smooth and free of excessive wrinkles.

f. Where horizontal seams are required on sloped surfaces, the panels shall be placed such that the "upstream" panel forms the upper panel and overlaps the "downstream" panel in order to minimize infiltration potential. All seams constructed on slopes of 6H:1V or steeper shall be vertical seams, except where slope lengths exceed standard roll lengths and elsewhere as approved in advance by the Engineer.

g. All vertical panels placed on slopes of 6H:1V or steeper shall extend a minimum of 5 feet beyond the grade break with a slope flatter than 6H:1V.

h. The GCL shall be laid with a 6 inch minimum overlap seam along roll edges and a 12 inch minimum overlap seam along roll ends. Granular sodium bentonite shall be added between all overlapped seams at a rate of approximately 0.25 lbs/linear foot. As an alternative to the addition of bentonite along roll edges, GCL with slits cut in one of the geotextiles may be used if approved in advance by the Engineer.

i. GCL shall be temporarily secured in a manner approved by the CQA Engineer prior to placement of overlying materials.

j. Any GCL that is torn, punctured, or otherwise damaged shall be repaired or replaced as directed by the CQA Engineer, by the Contractor at no additional cost to the Owner. The repair shall consist of a patch of GCL placed over (or alternatively under) the damaged areas and shall overlap the existing GCL a minimum of 12 inches from any point of the damage. Granular sodium bentonite shall be added around the perimeter of the damaged area and between the patch and the GCL at a rate of approximately 0.25 lbs/linear foot. Small tears or punctures may be repaired by the addition of granular sodium bentonite alone where approved by the CQA Engineer.

k. GCL shall be covered with the overlying materials or otherwise protected from hydration due to rainfall (i.e. temporary tarps, scrap geomembrane, etc.) within 24 hours of GCL placement, or sooner if rain is imminent.

l. <u>Penetrations:</u> All penetrations of GCL shall be made in accordance with the Contract Drawings and/or as directed by the Engineer.

4. Cover Placement:

Placement of materials over GCL shall be performed in a manner as to ensure that GCL and the underlying geosynthetics are not damaged; minimal slippage of GCL on the underlying geosynthetics occurs; no excess tensile stresses occur in the GCL; and that no portion of the GCL develops excessive wrinkles or crimp. Wrinkles that exceed approximately 6 inches in height and cannot be eliminated by amended placement and covering methods or GCL that becomes crimped shall be cut and repaired by the Geosynthetics Installer in a method approved by the Engineer.

TABLE 1: REQUIRED GCL PROPERTIES

PROPERTY	TEST METHOD	UNITS	VALUE
Clay:			
Bentonite Swell Index	ASTM D 5890	ml/2g	24
Bentonite Fluid Loss	ASTM D 5891	ml	$\leq$ 18
GCL:			
Bentonite Content	ASTM D 5993	psf	0.75 (@ 0% moisture)
Tensile Strength	ASTM D 6768	lbs/in	30
Peel Strength	ASTM D 6496	lbs/in	5.3 Min. Avg.
Hydraulic Conductivity	ASTM D 5887	cm/sec	$\leq 5 \times 10^{-9}$
Internal Shear Strength[1] (Hydrated) (Peak)	ASTM D 6243	psf	500
Interface Shear Strength (Hydrated) (Peak)[2, 3]	ASTM D 6243	psf	55 psf (Load = 200 psf)

Notes:

1. Peak value measured at a normal load of 200 psf after a minimum 24 hour hydration period.
2. GCL shall have adequate adhesion against adjacent materials under low normal loads to achieve the successful installation of overlying components without slippage.

3. The specified interface shear strength requirement is based on a finished slope no steeper than 6H:1V. Steeper slopes will require evaluation by the Engineer.

TABLE 2: REQUIRED MANUFACTURER QUALITY CONTROL TESTS

PROPERTY	TEST METHOD	MINIMUM TEST FREQUENCY
Clay:		
Bentonite Swell Index	ASTM D 5890	50 tons
Bentonite Fluid Loss	ASTM D 5891	50 tons
GCL:		
Bentonite Content	ASTM D 5993	5,000 yd^2
Tensile Strength	ASTM D 6768	25,000 yd^2
Peel Strength[1]	ASTM D 6496	5,000 yd^2
Hydraulic Conductivity	ASTM D 5887	30,000 yd^2
Internal Shear Strength[2] (Hydrated)	ASTM D 6243	Periodic

Notes:

1. Conduct peel strength tests in accordance with the criteria given in Table 1.
2. Conduct shear strength tests in accordance with the criteria given in Table 1.

TABLE 3: REQUIRED CONTRACTOR QUALITY CONTROL TESTS

PROPERTY	TEST METHOD	MINIMUM TEST FREQUENCY
Interface Shear Strength	ASTM D 6243	(See Note 1)

Notes:

1. Test each interface to be used on this project using representative samples of materials to be supplied under normal loads indicated and using test parameters as specified by the Engineer. For this project, interfaces to be tested are:

   A. Textured LLDPE-GM (30 mil) or GCL against existing cover soils (intermediate cover);
   B. Drainage Geocomposite against textured LLDPE-GM (30 mil) or GCL; and
   C. Vegetative Soil Layer against Drainage Geocomposite.

   If there are material differences in the surface of any of the geosynthetic materials from one side to the other, then all possible combinations of interfaces shall be tested. This testing shall be performed at Contractor cost by an independent GAI accredited laboratory and submitted to the Engineer for review prior to shipping. Upon review of test results, the Engineer may allow exceptions to the above criteria.

   For tests involving textured geomembranes, the laboratory shall also report the asperity height (GRI GM12) for the material samples used in the actual direct shear tests.

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SECTION 02778

LLDPE GEOMEMBRANE

LLDPE Geomembrane (LLDPE-GM): The LLDPE Geomembrane serves as the primary hydraulic barrier in the final cover system.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of LLDPE-GM including all necessary and incidental items as detailed or required to complete the installation in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

Work	Section
Vegetative Soil Layer	02258
Drainage Geocomposite	02712
CQA Manual	Attached

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) and the Geosynthetic Research Institute (GRI) are hereby made a part of these Specifications.

ASTM D 792	Standard Test Method for Density and Specific Gravity (Relative Density) of Plastics by Displacement.
ASTM D 1004	Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting.
ASTM D 1505	Standard Test Method for Density of Plastics by the Density-Gradient Technique.
ASTM D 1603	Standard Test Method for Carbon Black in Olefin Plastics.

ASTM D 5199	Standard Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes.
ASTM D 5321	Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method.
ASTM D 5596	Standard Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics.
ASTM D 5820	Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes.
ASTM D 5994	Standard Test Method for Measuring Core Thickness of Textured Geomembrane.
ASTM D 6392	Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods.
ASTM D 6693	Standard Test Method for Determining Tensile Properties of Nonreinforced Flexible Polyethylene and Nonreinforced Polypropylene Geomembranes.
GRI GM9	Cold Weather Seaming of Geomembranes.
GRI GM12	Asperity Measurement of Textured Geomembranes Using a Depth Gage.
GRI GM17	Standard Specification for Test Properties, Testing Frequency and Recommended Warranty for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes.
GRI GM19	Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes.

4. Quality Control:

   a. The Contractor shall perform Quality Control tests in accordance with Table 2 of this section.

   b. The Geomembrane Installer shall follow the procedures and requirements described in the accompanying Project CQA Manual during installation of LLDPE-GM including performing and documenting trial seams, nondestructive and destructive Quality Control tests, and repairs.

5. Quality Assurance:

Quality Assurance during installation of LLDPE-GM will be provided by the Owner as described in the accompanying Project CQA Manual.

6. Manufacturers Qualifications:

The Manufacturer shall have previously demonstrated his ability to produce the required LLDPE-GM by having successfully manufactured a minimum of 5,000,000 ft^2 of LLDPE-GM for hydraulic containment purposes.

7. Installer Qualifications:

a. Installation of the LLDPE-GM shall be performed by an Installer that has installed a minimum of 5,000,000 ft^2 of LLDPE-GM (or similar material) within the past five (5) years in similar landfill installations.

b. All Installation Supervisors assigned to the Project shall have previously managed the installation of at least 2,000,000 ft^2 of LLDPE-GM (or similar material) using the same techniques to be used on site.

c. All seaming equipment operators shall have demonstrated performance on previous geomembrane installations and/or documented training.

8. Warranties:

a. General: Should a defect occur, which is covered under warranty, the Warrantor shall bear all costs for repair and/or relocation and replacement of the LLDPE-GM.

b. Workmanship: The Contractor shall furnish the Owner a warranty from the Installer of the LLDPE-GM which warrants their workmanship to be free of defects on a prorata basis for five (5) years after the final acceptance of the Work. This warranty shall include but not be limited to all field seams, anchor trenches, attachments to appurtenances, and penetration seals, as applicable.

c. Manufacturer's Warranty: The Contractor shall furnish the Owner a warranty from the LLDPE-GM Manufacturer for the materials used. The material warranty shall be for defects or failures related to manufacture on a prorata basis for five (5) years after the date of shipment.

B. MATERIALS

1. General:

The materials supplied under these Specifications shall consist of new, first-quality products designed and manufactured specifically for the purpose of this work, which shall have been satisfactorily demonstrated, by prior use, to be suitable and durable for such purposes. The LLDPE-GM and LLDPE-GM Manufacturer shall be approved by the Engineer.

The LLDPE-GM shall be supplied in rolls which shall have a minimum width of 22 feet. The roll length shall be maximized to provide the largest manageable sheet for the fewest seams. Labels on the roll shall identify the thickness, length, width, lot and roll numbers, and name of Manufacturer.

2. LLDPE-GM Materials:

a. Textured LLDPE-GM shall be 30 mils thick. Resin and sheet properties of LLDPE-GM shall meet or exceed the requirements of GRI GM17 and Table 1 of this section.

b. Materials classified as Very Flexible Polyethylene (VFPE) which otherwise meet the requirements of this section are also acceptable.

3. Extrusion Resin/Typical Extrudate:

Extrusion resin/typical extrudate used for extrusion seaming of LLDPE-GM shall be linear low density polyethylene (LLDPE). Physical properties shall be the same as the LLDPE-GM sheet. The extrudate's additives shall be thoroughly dispersed throughout the rod or bead. The extrudate shall be free of contamination by moisture or foreign matter and shall be recommended for use with the associated sheet material.

4. Texturing:

Textured LLDPE-GM, where required, shall be fabricated using coextrusion or impingement methods. Texturing shall not be created by lamination, structuring, or embossing. Texturing applied to LLDPE-GM using impingement methods shall be bonded securely to the parent LLDPE-GM. All texturing shall be uniform in appearance and coverage on the finished sheet. Textured LLDPE-GM shall be textured on both sides of the sheet.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Pre-Installation Requirements:

Prior to LLDPE-GM installation, the Contractor shall submit the following:

a. Mill Certificate and Sample: Prior to shipping to the site, the Contractor shall submit a mill certificate or affidavit signed by a legally authorized official of the Manufacturer for the LLDPE-GM attesting that the LLDPE-GM meets the physical and manufacturing requirements stated in these Specifications. The Contractor shall also submit a sample of the LLDPE-GM to be used. The sample shall be labeled with the product name and be accompanied by the Manufacturer's specifications.

b. Qualifications:

(1) Submit list of equipment and personnel proposed for the Project. Include equipment type and quantities. Include personnel experience on similar projects.

(2) Submit resume and references of Installation Supervisor to be assigned to the Project, including data and duration of employment and pertinent experience information.

(3) Submit resumes and references of installation personnel who will perform seaming operations, including dates and durations of employment and pertinent experience information.

c. Shipping, Handling, and Storage Instructions: The Manufacturer's plan for shipping, handling, and storage shall be submitted for review.

d. Delivery Date: Submit notification of the scheduled delivery dates for the materials.

e. Installation Procedures and Drawings:

Submit installation procedures and (shop) drawings for carrying out the work.

(1) Installation procedures to be addressed shall include but not be limited to material installation, repair, and protection to be provided in the event of rain or strong winds.

(2) Shop drawings shall have LLDPE-GM sheet layout with proposed size, number, position, and sequence of placing all panels, and indicating the location of all field seams. Shop drawings shall also show complete details and/or methods for anchoring the LLDPE-

GM, making field seams, and making seals around pipes and structures penetrating the LLDPE-GM (if applicable).

Following review, these procedures and drawings shall be used for installation of the LLDPE-GM. Any deviations from these procedures and drawings must be approved by the Engineer and CQA Engineer.

f. Quality Control Certificates: For LLDPE-GM delivered to the site, quality control certificates, signed by the Manufacturer's quality assurance manager shall be provided which represent every roll of LLDPE-GM. Each certificate shall have the roll identification number(s), test methods, frequency, and test results. At a minimum, the test results and frequency of testing shall meet or exceed the requirements of GRI GM17.

g. Contractor Quality Control Test Results: The Contractor shall provide the results of required testing.

h. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into the construction.

2. Post-Installation Requirements:

Upon completion of the LLDPE-GM installation, the Contractor shall submit the following:

a. Certificate stating that the LLDPE-GM has been installed in accordance with the Drawings, Specifications, and the Manufacturer's recommendations.

b. Completed Manufacturer's and workmanship warranties.

c. Record Information: Record information shall include but not be limited to:

(1) CQC Documentation: Includes trial seam logs, panel placement logs, panel seaming logs, non-destructive seam testing report forms, field destructive seam testing report forms, and repair logs.

(2) As-Built Drawing: Includes the requirements listed in Paragraph D.8 (Surveying) of this Specification.

Finalization of payment for LLDPE-GM installation shall not be made until the above submittals have been reviewed by the CQA Engineer.

D. CONSTRUCTION

1. Shipping, Handling, and Storage:

The LLDPE-GM shall be shipped, handled, and stored in strict accordance with the Manufacturer's recommendations.

2. Failing CQA Material Control Tests:

LLDPE-GM that is rejected upon testing shall be removed from the project site and replaced at Contractor's cost. Sampling and CQA testing of LLDPE-GM supplied as replacement for rejected material shall be performed by the CQA Engineer at Contractor's cost.

3. Subgrade Preparation:

a. The surface of the subgrade shall be smooth, uniform, free from sudden changes in grade (such as vehicular ruts), rocks or stones greater than ½ inch in size, debris, and deleterious materials. During actual placing and seaming of the LLDPE-GM, the subgrade shall be kept free of all standing water. If the subgrade below the LLDPE-GM becomes excessively wet and unstable as determined by the CQA Engineer, it shall be dried and recompacted, and replaced if needed.

b. Before an individual panel of LLDPE-GM is installed; the Contractor and Installer shall verify in writing and submit to the CQA Engineer:

(1) Lines and grades are in conformance with the Drawings and Specifications.

(2) The surface area to be lined has been rolled and compacted, free of irregularities and abrupt changes in grade.

4. LLDPE-GM Placement:

a. Weather Conditions:

LLDPE-GM placement shall not proceed at an ambient temperature below 32° F or above 100° F unless otherwise authorized, in writing, by the Engineer. Installation of LLDPE-GM at temperatures below 32° F, if authorized by the Engineer, shall follow GRI GM9. LLDPE-GM placement shall not be performed during precipitation, excessive moisture, in an area of ponded water, or in excessive winds. Any portion of LLDPE-GM or subgrade damaged due to weather conditions shall be repaired at the Contractor's cost.

b. Method of Placement:

(1) Each panel of the LLDPE-GM shall be installed in accordance with the approved shop drawings prepared by the Contractor. The layout shall be designed to keep field seaming of the LLDPE-GM to a minimum and consistent with proper methods of LLDPE-GM installation.

(2) Panels shall be oriented perpendicular to the line of the slope crest (i.e., down and not across slope).

(3) The LLDPE-GM shall be placed smooth and free of excessive wrinkles.

(4) LLDPE-GM rolls shall be placed using proper spreader and rolling bars with cloth slings. If a sheet must be displaced a distance greater than its width, a slip sheet shall be used.

(5) The CQA Engineer shall inspect each panel, after placement and prior to seaming, for damage and/or defects. Defective or damaged panels shall be replaced or repaired, as approved by the CQA Engineer and as described in this section.

(6) The Installer shall avoid dragging the LLDPE-GM on rough soil subgrades.

(7) All LLDPE-GM shall be anchored as shown on the Contract Drawings and consistent with Manufacturer's recommendations.

(8) Personnel working on the LLDPE-GM shall not smoke, wear damaging shoes, or involve themselves in any activity that may damage the LLDPE-GM, in the opinion of the CQA Engineer.

(9) The LLDPE-GM shall be properly weighted to avoid uplift due to wind.

(10) Vehicular traffic across the LLDPE-GM shall not be allowed, except that four-wheel (or greater) all-terrain vehicles (ATVs) with low ground pressure may be allowed if approved in advance by the Engineer. The Contractor shall submit proposed equipment and procedures for use of ATVs to the CQA Engineer as part of his submittals. If ATVs are allowed by the Engineer, each ATV shall be operated such that no sudden stops, starts, or turns are made.

(11) All damage shall be recorded and located on the record drawings.

(12) The LLDPE-GM shall be kept free of debris, unnecessary tools, and materials. In general, the LLDPE-GM area shall remain neat in appearance.

c. Pipe Penetrations:

All pipe penetrations through the LLDPE-GM shall be as shown in the Contract Drawings. Alternative penetration details may be approved by the Engineer and CQA Engineer.

5. Field Seams:

a. Individual panels of LLDPE-GM shall be laid out and overlapped by a minimum of 4 inches prior to seaming. The area to be seamed shall be cleaned and prepared in accordance with the Manufacturer's recommendations.

b. Dual or single track hot wedge methods shall be used for straight seams.

c. Extrusion fillet methods shall be used to seam cross seam tees, patches, repairs, and penetration boots. All extrudate shall be free of dirt, dry, and protected from damage. To limit overgrinding, the amount of grinding exposed after an extrusion seam is completed shall be less than ¼ inch.

d. The seaming equipment used shall be capable of continuously monitoring and controlling the temperatures in the zone of contact where the machine is actually fusing the LLDPE-GM so as to ensure that changes in environmental conditions will not affect the integrity of the seam.

e. All seams shall have a seam number that corresponds with the panel layout numbers. The numbering system shall be used in the development of the record drawings. Seam numbers shall be derived from the combination of the two panel numbers that are to be seamed together.

f. Where horizontal seams are required on sloped surfaces, the panels shall be placed such that the "upstream" panel forms the upper panel and overlaps the "downstream" panel in order to minimize infiltration potential. All seams constructed on slopes of 6H:1V or steeper shall be vertical seams, except where slope lengths exceed standard roll lengths and elsewhere as approved in advance by the Engineer. Where approved, end seams on slopes of 6H:1V or steeper shall be staggered a minimum of 5 feet and shall be made at an angle of approximately 45 degrees.

g. All panels placed on slopes of 6H:1V or steeper shall extend a minimum of 5 feet beyond the grade break with a slope flatter than 6H:1V.

h. All seams shall extend to the full extent of the anchor trench (where applicable).

i. Unless otherwise approved by the Engineer, all "T" seams (i.e., the result of three panels placed together) shall be staggered a minimum of 3 feet along either seam and shall be covered with a patch.

j. No junctions of four or more panels shall be allowed unless approved by the Engineer.

k. If extrusion seaming equipment is stopped for longer than one minute, it shall be purged to remove heat-degraded extrudate. All purged extrudate shall be placed on a sacrificial sheet and disposed of.

l. To prevent moisture buildup during seaming, it may be necessary to place a movable protective layer of plastic directly below each overlap of LLDPE-GM that is to be seamed.

m. If required, a firm substrate shall be provided by using a flat board or similar hard surface directly under the seam overlap to achieve proper support.

n. Excessive wrinkles along geomembrane seams shall be minimized. Fish-mouths or large wrinkles shall be cut along the ridge of the wrinkle to allow a flat overlap, which shall be re-seamed. All cuts shall be repaired with a patch.

o. All seams (including repairs) shall meet or exceed the requirements of GRI GM19 and Table 3 of this section.

p. No overlying material shall be placed over the LLDPE-GM until approved by the CQA Engineer.

6. Anchor Trench:

a. The anchor trench shall be constructed as shown on the Contract Drawings and as specified herein. The anchor trench shall be maintained by the Contractor.

b. Slightly rounded corners shall be provided in the trench to avoid sharp bends in the LLDPE-GM.

c. The anchor trench shall be adequately drained to prevent water ponding and softening to adjacent soils. The anchor trench shall be backfilled with controlled fill material and compacted to 90% standard Proctor dry density (ASTM D 698).

d. If the anchor trench is located in a clay susceptible to desiccation, the amount of trench open at any time shall be limited to one day of LLDPE-GM installation capacity.

7. Repair Procedures:

a. Any portion of the LLDPE-GM exhibiting signs of defect or failing a nondestructive or a destructive test, shall be repaired by the Geomembrane Installer. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure shall be made by the CQA Engineer. The procedures available include:

(1) Patching - Apply a new piece of LLDPE-GM sheet over, and at least 6-inches beyond the limits of a defect. The patch shall be extrusion seamed to the underlying LLDPE-GM. This method should be used to repair holes, tears, destructive test locations, undispersed raw materials, contamination by foreign matter, dents, pinholes, and pressure test holes.

(2) Capping - Apply a new strip of LLDPE-GM along the length of a delineated faulty seam. The cap strip shall extend at least 6-inches beyond the limit of the seam and the edges shall be extrusion seamed to the underlying LLDPE-GM. This method should be used to repair lengths of extrusion or hot wedge seams.

(3) Replacement - The faulty seam is removed and replaced.

b. In addition, the following provisions shall be satisfied:

(1) Surfaces of the LLDPE-GM which are to be repaired shall be abraded no more than one hour prior to the repair;

(2) All surfaces must be clean and dry at the time of the repair;

(3) All seaming equipment used in repairing procedures must be approved;

(4) The repair procedures, materials, and techniques shall be approved in advance of the specific repair by the CQA Engineer;

(5) Extrusion seaming of flaps of dual track hot wedge seams is not acceptable. A patch or cap strip shall be used; and

(6) Patches or caps shall extend at least 6-inches beyond the edge of the defect, and all patch corners shall be rounded.

8. Surveying:

a. After completion of a segment of LLDPE-GM, the Contractor shall survey LLDPE-GM to obtain the following information:

(1) Location and numbering of all panels/seams.

(2) Location of all repairs/patches;

(3) Location of all destructive test locations; and

(4) Location of all pipe penetrations and other appurtenances (if applicable).

b. No overlying materials shall be placed before survey information is obtained.

c. The Contractor shall provide the CQA Engineer with updated survey information when requested by the CQA Engineer to verify that the required information is being obtained.

9. Cover Placement:

Placement of materials over LLDPE-GM shall be performed in a manner as to ensure that LLDPE-GM and the underlying geosynthetics are not damaged; minimal slippage of LLDPE-GM on the underlying geosynthetics occurs; no excess tensile stresses occur in the LLDPE-GM; and that no portion of the LLDPE-GM develops excessive wrinkles or crimp. Wrinkles that exceed approximately 6 inches in height and cannot be eliminated by amended placement and covering methods or LLDPE-GM that becomes crimped shall be cut and repaired by the Geosynthetics Installer in a method approved by the Engineer.

TABLE 1: REQUIRED LLDPE-GM PROPERTIES

PROPERTY	TEST METHOD	UNITS	VALUE
Interface Shear Strength (Peak)[1, 2, 3]	ASTM D 5321	psf	55 psf (Load = 200 psf)

Notes:

1. Textured LLDPE-GM shall have adequate adhesion against adjacent materials under low normal loads to achieve the successful installation of overlying components without slippage.
2. Note that the required values for textured LLDPE-GM may require an aggressively textured sheet.
3. The specified interface shear strength requirement is based on a finished slope no steeper than 6H:1V. Steeper slopes will require evaluation by the Engineer.

TABLE 2: REQUIRED CONTRACTOR QUALITY CONTROL TESTS

PROPERTY	TEST METHOD	MINIMUM TEST FREQUENCY
Interface Shear Strength	ASTM D 5321	(See Note 1)

Notes:

1. Test each interface to be used on this project using representative samples of materials to be supplied under normal loads indicated and using test parameters as specified by the Engineer. For this project, interfaces to be tested are:

   A. Textured LLDPE-GM (30 mil) or GCL against existing cover soils (intermediate cover);
   B. Drainage Geocomposite against textured LLDPE-GM (30 mil) or GCL; and
   C. Vegetative Soil Layer against Drainage Geocomposite.

   If there are material differences in the surface of any of the geosynthetic materials from one side to the other, then all possible combinations of interfaces shall be tested. This testing shall be performed at Contractor cost by an independent GAI accredited laboratory and submitted to the Engineer for review

prior to shipping. Upon review of test results, the Engineer may allow exceptions to the above criteria.

For tests involving textured geomembranes, the laboratory shall also report the asperity height (GRI GM12) for the material samples used in the actual direct shear tests.

TABLE 3: REQUIRED SEAM STRENGTH PROPERTIES

PROPERTY	TEST METHOD	VALUE	
		Hot Wedge Seams	**Extrusion Fillet Seams**
30 mil			
Shear Strength[1]	ASTM D 6392	45 lbs/inch	
Shear Elongation at Break[2]		50%	
Peel Strength[1]		38 lbs/inch	34 lbs/inch
Peel Separation (Incursion)		≤ 25%	
Locus-of-Break		See Note 3	

Notes:

1. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values.
2. Omit elongation measurements when performing field tests.
3. Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D 6392 (in this regard, SIP is an acceptable break code):

   Hot Wedge: AD and AD-BRK with > 25% Separation
   Extrusion Fillet: AD1, AD2, and AD-WLD (unless strength is achieved).

END OF SECTION

SECTION 5.0
GEOMEMBRANE CQA

5.1 INTRODUCTION

This section of the CQA Manual addresses the geomembrane component of the final cover system and outlines the CQA program to be implemented with regard to manufacturer and installer approval, material approval, subgrade approval, field and laboratory control and record tests, repairs, and resolution of problems.

5.2 GEOMEMBRANE MANUFACTURER AND INSTALLER APPROVAL

The Contractor shall submit the qualifications of the Geomembrane Manufacturer and the Geomembrane Installer, as described in the specifications, to the CQA Engineer for approval.

5.3 GEOMEMBRANE MATERIAL APPROVAL

5.3.1 Geomembrane Product Data

The CQA Engineer will review the Contractor's submittals for conformance with the project specifications.

5.3.2 Shipment And Storage

During shipment and storage, all geomembrane will be protected as required by the project specifications. The CQA Engineer will observe rolls upon delivery at the site.

5.3.3 Quality Control Certificates

Upon delivery, the CQA Engineer will:

- verify that the Manufacturer's quality control certificates have been provided at the specified frequency and that each certificate identified the rolls or sheets related to it; and

- review the Manufacturer's quality control certificates and verify that the certified properties meet the project technical specifications.

5.3.4 Material Control Tests

Samples for material control tests, as shown on **Table 5.1**, will be obtained by the CQA Engineer at the indicated frequencies upon delivery of the geomembrane. Alternatively, samples may be randomly obtained at the manufacturing site by the CQA Engineer or representatives of the Geosynthetics CQA Laboratory.

Unless otherwise specified, samples will be 3 feet long by the roll or sheet width. The

CQA Engineer will mark the machine direction on the samples with an arrow.

All material control tests will be performed by the Geosynthetics CQA Laboratory.

All control test results must be available at the site prior to the deployment of all geomembrane. The CQA Engineer will examine all results from laboratory conformance testing.

5.3.4.1 Material Control Test Failure

The following procedure will apply whenever a sample fails a material control test:

A. The Geomembrane Installer will replace the roll or sheet of geomembrane that is in nonconformance with the project specifications with a roll or sheet that meets project specifications.

B. The Geomembrane Installer will remove conformance samples for testing by the Geosynthetics CQA Laboratory from the closest numerical roll or sheet on both sides of the failed roll or sheet. These two samples must both conform to project specifications. If either of these samples fail, then the next numerical roll or sheet will be tested until a passing roll or sheet is found. This additional conformance testing will be at the expense of the Geomembrane Installer. If either of the two closest rolls or sheets fail, the Engineer will dictate the frequency of additional testing.

The CQA Engineer will document actions taken in conjunction with material control test failures.

5.4 GEOMEMBRANE INSTALLATION

5.4.1 Handling

The Geosynthetic Installer will handle all geomembrane in such a manner as required by the project specifications.

5.4.2 Earthwork

5.4.2.1 Surface Preparation

The Geomembrane Installer will certify in writing that the surface on which the geomembrane will be installed meets line and grade, and the surface preparation requirements of the project specifications. The certificate of acceptance will be given to the CQA Engineer prior to commencement of geomembrane installation in the area under consideration. The CQA Engineer will give a copy of this certificate to the Engineer.

To ensure a timely covering of the subgrade surface, the Engineer may allow subgrade acceptance in areas as small as one acre. After the supporting soil has been accepted by the Geomembrane Installer, it will be the Geomembrane Installer's responsibility to indicate to the Engineer and CQA Engineer any change in the supporting soil condition that may require repair work. If the CQA Engineer concurs with the Geomembrane Installer, then the Engineer will ensure that the supporting soil is repaired.

5.4.2.2 Anchorage System

The CQA Engineer will verify that anchor trenches have been constructed and backfilled according to project specifications and design drawings.

5.4.3 Geomembrane Placement

5.4.3.1 Field Panel Identification

The CQA Engineer will document that the Geomembrane Installer labels each field panel with an "identification code" (number or letter-number consistent with the layout plan) agreed upon by the Geomembrane Installer and CQA Engineer at the Geosynthetics CQA Meeting (see **Section 1.7.2**).

The Geomembrane Installer will establish a table or chart showing correspondence between roll or sheet numbers and field panel identification codes. This documentation shall be submitted to the CQA Engineer weekly for review and verification. The field panel identification code will be used for all quality control and quality assurance records.

5.4.3.2 Field Panel Placement

5.4.3.2.1 Location: The CQA Engineer will verify that field panels are installed at the location indicated in the Geomembrane Installer's layout plan, as approved or modified in **Section 5.4.3.1**.

5.4.3.2.2 Installation Schedule: The CQA Engineer will evaluate every change in the schedule proposed by the Geomembrane Installer and advise the Engineer on the acceptability of that change.

The CQA Engineer will record the identification code, location, and date of installation of each field panel.

5.4.3.2.3 Placement of Geomembrane: The CQA Engineer will verify that project specification related restrictions on placement of geomembrane are fulfilled. Additionally, the

CQA Engineer will verify that the supporting soil has not been damaged by weather conditions.

5.4.3.2.4 Damage: The CQA Engineer will visually observe each panel, after placement and prior to seaming, for damage. The CQA Engineer will advise the Engineer which panels, or portion of panels, should be rejected, repaired, or accepted. Damaged panels or portions of damaged panels which have been rejected will be marked and their removal from the work area recorded by the CQA Engineer. Repairs will be made according to procedures described in this section.

As a minimum, the CQA Engineer will document that:

- the panel is placed in such a manner that it is unlikely to be damaged; and
- any tears, punctures, holes, thin spots, etc. are either marked by the Geomembrane Installer for repair or the panel is rejected.

5.4.4 Field Seaming

5.4.4.1 Seam Layout

The Geomembrane Installer will provide the CQA Engineer with a seam layout drawing, i.e., a drawing of the area to be lined showing all expected seams. The CQA Engineer and Engineer will review the seam layout drawing and verify that it is consistent with the accepted state of practice and this CQA Manual.

A seam numbering system compatible with the panel numbering system will be agreed upon at the Geosynthetics CQA Meeting (see **Section 1.7.2**). An on-going written record of the seams and repair areas shall be maintained by the Geomembrane Installer with weekly review by the CQA Engineer.

5.4.4.2 Requirements of Personnel

The Geomembrane Installer will provide the CQA Engineer with a list of proposed seaming personnel and their experience records. This document will be reviewed by the CQA Engineer for compliance with project specifications.

5.4.4.3 Seaming Equipment and Products

Field seaming processes must comply with project specifications. Proposed alternate processes will be documented and submitted to the Engineer and CQA

Engineer for their approval. Only seaming apparatus which have been specifically approved by make and model will be used. The CQA Engineer will submit all documentation to the Engineer for his concurrence.

5.4.5 Field Seam Control Tests

5.4.5.1 Trial Seams

A. Prior to production seaming, after four (4) hours of continuous seaming, and/or when significant changes in geomembrane or ambient temperature occurs, the Geomembrane Installer shall perform trial seams to verify that seaming conditions and procedures are adequate. Trial seams shall be performed by each operator of extrusion welders and by the primary operator of each wedge welder using seaming equipment to be used in production seaming.

B. Trial seams shall be made on appropriate sized pieces of identical or equivalent geomembrane material.

C. Hot wedge trial seams shall be approximately 72" x 12" with the seam centered lengthwise. Extrusion fillet trial seams shall be approximately 36" x 12" with the seam centered lengthwise. A minimum of four coupons shall be tested in peel and shear (two each) (ASTM D 6392) by the Geomembrane Installer using a field tensiometer. All coupons shall meet the minimum seam strength requirements as shown in the project specifications.

D. Each trial seam shall be assigned a number and the test results recorded in the appropriate log by the Geomembrane Installer. The CQA Engineer will observe all trial seams and compile all trial seam logs.

5.4.6 Field Seam Record Tests

5.4.6.1 Nondestructive Seam Continuity Testing

The Geomembrane Installer shall test and document all seams continuously over their full length using one of the following nondestructive seam tests. This testing shall be performed simultaneously with geomembrane deployment as the work progresses and not at the completion of all field seaming.

A. Vacuum Testing shall conform to ASTM D 5641 requirements.

B. Air Pressure Testing (for double seam with an enclosed space) shall conform to ASTM D 5820 requirements and the requirements listed in **Table 5.2**.

The CQA Engineer will observe the nondestructive testing on a full time basis to ensure conformance with this CQA Manual and the project specifications.

5.4.6.2 Field Destructive Seam Testing

A. The Geomembrane Installer shall obtain 12" x 30" (or longer as needed) samples of field seams with the seam centered lengthwise, suitable for testing, at an average frequency of one sample per 500 linear feet of seam. The sample shall be cut into two equal-length pieces, one for field destructive seam testing by the Geosynthetics Installer and one given to the CQA Engineer as an archive sample. The date, time, equipment, seam number, and seaming parameters will be marked on each sample and recorded by the CQA Engineer.

B. The Geomembrane Installer shall perform and document field destructive seam testing using a field tensiometer which has been calibrated within the prior 6 months (calibration information shall be provided to the CQA Engineer). A minimum of three (3) coupons each will be tested in peel and shear (ASTM D 6392). Coupons shall meet the minimum seam strength requirements as shown in the project specifications.

C. The CQA Engineer or the Owner may require additional random samples to be taken for testing in areas which visually appear defective and not in accordance with the project requirements.

D. All holes in the geomembrane resulting from destructive seam sampling shall be immediately repaired in accordance with repair procedures described in this manual.

5.4.6.3 Geosynthetics CQA Laboratory Destructive Testing

A. The Geomembrane Installer shall obtain 12" x 30" (or longer as needed) samples of field seams with the seam centered lengthwise, suitable for testing, at an average frequency of one sample per day to confirm field destructive seam tests. The sample shall be cut into two equal-length pieces, both to be given to the CQA Engineer for laboratory destructive seam testing and as an archive sample. The date, time, equipment, seam number, and seaming parameters will be marked on each sample and recorded by the CQA Engineer.

B. Laboratory destructive test samples will be packaged and shipped to the Geosynthetics CQA Laboratory by the CQA Engineer in a manner that will not damage the test sample.

C. A minimum of five (5) coupons each will be tested in peel and shear (ASTM D 6392) by the Geosynthetics CQA Laboratory. Coupons shall

meet the minimum seam strength requirements as shown in the project specifications.

D. All geomembrane destructive test samples that fail to meet project specifications will be saved and sent to the CQA Engineer for observation.

E. The CQA Engineer will review laboratory test results as soon as they become available.

5.4.6.4 Field Seam Record Test Failure

For noncomplying tests, the CQA Engineer will:

- observe continuity testing of the repaired areas performed by the Geomembrane Installer;
- confirm the record location, date, test unit number, name of tester, and compile the record of testing provided by the Geomembrane Installer;
- provide a walk-through inspection of all impacted seam areas and verify that the areas have been tested in accordance with the CQA Manual and project specifications; and
- verify that the Geomembrane Installer has marked repair areas with the appropriate color-coded marking pencil.

5.4.6.5 Defining Extent of Field Seam Record Test Failure

All defective seam test failures must be bounded by acceptable destructive tests. The CQA Engineer will document repair actions taken in conjunction with all seam test failures.

5.4.7 Repairs & Verification

5.4.7.1 Repair Procedures

A. All repair procedures shall be in accordance with the project specifications. The CQA Engineer will observe all repair procedures.

B. All surfaces shall be clean and dry at the time of the repair.

C. After an extrusion seam is made, no more than ¼ inch of abrasion shall be visible beyond the weld.

5.4.7.2 Repair Verification

A. Each repair shall be numbered and logged by the Geomembrane Installer.

B. Each repair shall be non-destructively tested by the Geomembrane Installer using the methods described above. Repairs which pass non-destructive testing shall be taken as an indication of an adequate repair.

C. Repairs more than 150 feet long may be of sufficient length to require destructive test sampling, at the discretion of the CQA Engineer. A failed test indicates that the repair shall be redone and retested until passing test results are achieved.

5.5 LINER SYSTEM ACCEPTANCE

The geomembrane component of the liner system will be accepted by the Owner when:

- the installation is finished;
- verification of the adequacy of all seams and repairs, including associated testing, is complete;
- CQA Engineer provides the Engineer with a final copy of the nondestructive test documentation, repair information, and as-built drawings, as submitted by the Geomembrane Installer;
- CQA Engineer provides the Engineer with a certification, submitted by the Geomembrane Installer that the geomembrane was installed in accordance with the Geomembrane Manufacturer's recommendations as well as the project drawings and project specifications; and
- all documentation of the installation is completed including the CQA Engineer's final report.

5.6 MATERIALS IN CONTACT WITH GEOMEMBRANES

The quality assurance procedures indicated in this subsection are only intended to assure that the installation of these materials does not damage the geomembrane. All reasonable measures to protect the geomembrane and provide additional quality assurance procedures are necessary to assure that systems built with these materials will be constructed to ensure proper performance.

5.6.1 Soils

Prior to placement, the CQA Engineer will visually confirm that all soil materials to be placed against the geomembrane comply with project specifications. The Geomembrane Installer will provide the CQA Engineer a written surface acceptance certificate in accordance with **Section 5.4.2**. All soil materials shall be placed and compacted in accordance with project specifications.

5.6.2 Sumps and Appurtenances

The CQA Engineer will verify that:

- installation of the geomembrane in appurtenance areas, and connection of the geomembrane to appurtenances have been made according to the project specifications;
- extreme care is taken while seaming around appurtenances since neither nondestructive nor destructive testing may be feasible in these areas; and
- the geomembrane or appurtenances have not been visibly damaged while making connections to appurtenances.

5.7 DEFICIENCIES

The CQA Engineer will immediately determine the extent and nature of all defects and deficiencies and report them to the Owner and Engineer. All defects and deficiencies will be documented by the CQA Engineer. The Contractor shall correct defects and deficiencies to the satisfaction of the CQA Engineer. The CQA Engineer will observe all retests on repaired defects.

TABLE 5.1: CQA TESTING PROGRAM FOR GEOMEMBRANE MATERIAL APPROVAL

PROPERTY	TEST METHOD	TEST FREQUENCY
Thickness	ASTM D 5199/D 5994	100,000 ft^2 or 1 per Lot[1]
Density	ASTM D 1505/D 792	100,000 ft^2 or 1 per Lot[1]
Carbon Black Content	ASTM D 1603	100,000 ft^2 or 1 per Lot[1]
Carbon Black Dispersion	ASTM D 5596	100,000 ft^2 or 1 per Lot[1]
Tensile Properties:	ASTM D 6693 (Type IV)	
Tensile Strength at Yield		100,000 ft^2 or 1 per Lot[1]
Tensile Strength at Break		100,000 ft^2 or 1 per Lot[1]
Elongation at Yield		100,000 ft^2 or 1 per Lot[1]
Elongation at Break		100,000 ft^2 or 1 per Lot[1]
Tear Resistance	ASTM D 1004	100,000 ft^2 or 1 per Lot[1]

Notes:

1. Whichever provides the larger number of tests.

TABLE 5.2 AIR PRESSURE TEST REQUIREMENTS

MATERIAL	MIN. PRESSURE (PSI)	MAX. PRESSURE DROP (PSI) AFTER 5 MINUTES
30 Mil LLDPE	25	3

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Operations Manual

Halifax County Landfill Facility
Halifax County, North Carolina

Prepared for:

Halifax County Department of Public Utilities
Halifax, North Carolina

June 2008
Revised: December 2010

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HALIFAX COUNTY LANDFILL FACILITY

OPERATIONS MANUAL

TABLE OF CONTENTS

Table of Contents (Continued)

SECTION 1.0
GENERAL FACILITY OPERATIONS

1.1 OVERVIEW

This Operations Manual was prepared for operations of the Halifax County Landfill facility (Permit No. 42-04) located near Littleton. This document discusses the operation of the following landfill units and other solid waste management activities:

- Area 1 C&D Landfill Unit (vertical expansion over closed unlined MSW unit);
- Area 2 C&D Landfill Unit (Proposed);
- Ash Monofill;
- Animal Waste Disposal Area;
- Wood Waste Processing Area;
- White Goods Handling Area;
- Used Tire Storage Area; and
- Used Pesticide Container Storage Area.

Refer to **Figure 1** for the location of existing and proposed landfill units and other solid waste management activities.

The information contained herein was prepared to provide landfill personnel with a clear understanding of how the Design Engineer assumed that the completed facility would be operated. While deviations from the operations outlined here may be acceptable, they should be reviewed and approved by the Design Engineer. Please refer to the appropriate permit application for a detailed discussion and calculations for the individual components of each landfill unit, including phasing plans.

1.2 CONTACT INFORMATION

All correspondence and questions concerning the operation of the Halifax County Landfill should be directed to the appropriate County and State personnel listed below. For fire or police emergencies dial 911.

1.2.1 Halifax County

Halifax County Department of Public Utilities
26 N. King Street (Public Works Bldg.)
P.O. Box 70
Halifax, NC 27839
Phone: (252) 583-1451
Fax: (252) 593-5014
Contact: Gwen Matthews, Interim Director

Halifax County Landfill
921 Liles Road
Littleton, NC 27850
Phone: (252) 586-7516
Fax: (252) 586-2685
Contact: Larry Garriss, Solid Waste Director

1.2.2 North Carolina Department of Environment and Natural Resources

North Carolina DENR - Raleigh Central Office (RCO)
401 Oberlin Road
Raleigh, NC 27605
Phone: (919) 508-8400
Fax: (919) 715-3605

North Carolina DENR - Wilmington Regional Office (WRO)
127 Cardinal Drive Extension
Wilmington, NC 28405
Phone: (910) 796-7215
Fax: (910) 350-2004

North Carolina DENR - Raleigh Regional Office (RRO)
3800 Barrett Drive
Raleigh, NC 27609
Phone: (919) 571-4700
Fax: (919) 571-4718

Division of Waste Management (DWM) - Solid Waste Section:

Field Operations Branch Head:	Mark Poindexter (RCO)
Eastern Regional Supervisor:	John Crowder (WRO)
Waste Management Specialist:	Mary Whaley (RCO)

Division of Land Resources - Land Quality Section:

Regional Engineer:	John Holley, P.E. (RRO)

1.3 ACCESS CONTROL

Limiting access to the landfill facility is important for the following reasons:

- Unauthorized and illegal dumping of waste materials is prevented.
- Trespassing, and injury resulting therefrom, is discouraged.
- The risk of vandalism is greatly reduced.

Access to active areas of the landfill will be controlled by a combination of fences and natural

barriers, and strictly enforced operating hours. A landfill attendant will be on duty at all times when the facility is open for public use to enforce access restrictions (see also **Section 1.9**).

1.3.1 Physical Restraints

The site will be accessed by the existing entrance on Liles Road. Scales and a scale house and office are provided at the entrance. All waste will have been weighed prior to being placed in the landfill. The entrance has a gate which will be securely locked during non-operating hours.

1.3.2 Security

Frequent inspections of gates and fences will be performed by landfill personnel. The County will arrange for a random security patrol of the main gate to further discourage trespassing. Evidence of trespassing, vandalism, or illegal operation will be reported to the County Solid Waste Director.

1.4 SIGNAGE

A prominent sign(s) containing the information required by the DWM will be placed at the landfill entrance. This sign(s) will provide information on operating hours, operating procedures, and acceptable wastes. Additional signage will be provided as necessary within the landfill complex to distinctly distinguish the roadway to the active landfill unit(s). Service and maintenance roads for use by operations personnel will be clearly marked and barriers (e.g., traffic cones, barrels, etc.) will be provided as required.

Specific to the C&D landfill unit, a sign will be posted which states that liquid, hazardous, and municipal solid wastes are excluded from disposal in the C&D landfill unit.

1.5 COMMUNICATIONS

Two way radio communication will be maintained between the active landfill unit(s) and the landfill scale house and office. The scale house and office have telephones in case of emergency and for the conduct of day-to-day business. Emergency telephone numbers are displayed in the scale house and office.

1.6 FIRE AND SAFETY

1.6.1 Fire Control

Although no open burning of waste is allowed at the facility, the possibility of fire within the landfill or a piece of equipment must be anticipated in the daily operation of the landfill. A combination of factory installed fire suppression systems and/or portable fire extinguishers will be operational on all heavy pieces of equipment at all times. For larger or more serious outbreaks, the local fire department will respond.

Fires within the landfill will be limited by the use of daily and intermediate cover as a fire break and control of "hot" loads entering the landfill. Landfill personnel at the scale house will turn away all trucks containing waste that is suspected to be hot. If a hot load is placed on the working face, then the load will be spread as thin as possible and daily cover soil will be immediately placed on the waste to extinguish the fire.

In general, fires that break out close to the surface of the disposal area should be excavated and smothered with cover material. Deep fires should be smothered out by placing moist soil on the surface and by constructing soil barriers around the fire. Where the smothering technique fails, the burning material must be excavated and smothered or quenched with water once the burning material is brought to the surface. Water is usually not effective unless it can be directly applied to the burning material.

The County will verbally notify the DWM (see **Section 1.2.2**) within 24 hours of discovery of a fire within any landfill disposal area. In addition, written documentation describing the fire, the actions carried out to extinguish the fire, and a strategy for preventing future occurrences will be provided to the DWM within 15 days following any such occurrence.

1.6.2 Safety

All aspects of the operation of the landfill facility were developed with the health and safety of the landfill's operating staff, customers, and neighbors in mind. Prior to commencement of operations in the new landfill phase/area, a member of the landfill operating staff will be designated site safety officer. This individual, together with the facility's management will modify the site safety and emergency response program to remain consistent with National Solid Waste Management Association and Occupational Safety and Health Administration (OSHA) guidance.

Safety equipment provided includes equipment rollover protective cabs, seat belts, audible reverse warning devices, hard hats, safety shoes, and first aid kits. Landfill personnel will be encouraged to complete the American Red Cross Basic First Aid Course. Other safety requirements as designated by the County will also be implemented.

1.7 SEVERE WEATHER CONDITIONS

Unusual weather conditions can directly affect the operation of the landfill facility. Some of these weather conditions and recommended operational responses are as follows.

1.7.1 Ice Storms

An ice storm can make access to the landfill dangerous, prevent movement or placement of daily cover, and, thus, may require closure of the landfill until the ice is removed or has melted.

1.7.2 Heavy Rains

Exposed soil surfaces can create a muddy situation in some portions of the landfill during rainy periods. The control of drainage and use of crushed stone on unpaved roads should provide all-weather access for the site and promote drainage away from critical areas. In areas where the aggregate surface is washed away or otherwise damaged, new aggregate should be used for repair.

Intense rains can affect newly constructed drainage structures such as swales, diversions, cover soils, and vegetation. After such a rain event, inspection by landfill personnel will be initiated and corrective measures taken to repair any damage found before the next rainfall.

1.7.3 Electrical Storms

The open area of a landfill is susceptible to the hazards of an electrical storm. If necessary, landfilling activities will be temporarily suspended during such an event. To guarantee the safety of all field personnel, refuge will be taken in the on-site buildings or in rubber-tired vehicles.

1.7.4 Windy Conditions

Landfill operations during a particularly windy period may require that the working face be temporarily shifted to a more sheltered area. Periodic cover will be placed as required.

1.7.5 Violent Storms

In the event of hurricane, tornado, or severe winter storm warning issued by the National Weather Service, landfill operations may be temporarily suspended until the warning is lifted. Daily cover will be placed on exposed waste and buildings and equipment will be properly secured.

1.8 EQUIPMENT REQUIREMENTS

The County will maintain on-site equipment required to perform the necessary landfill activities. Periodic maintenance of all landfilling equipment, and minor and major repair work will be performed at designated maintenance zones outside of the landfill.

1.9 PERSONNEL REQUIREMENTS

At least one member of the landfill supervisory staff will be certified as a Manager of Landfill Operations (MOLO) by the Solid Waste Association of North America (SWANA). Each landfill employee will go through an annual training course (led by supervisory staff) and is certified by SWANA as Landfill Operations personnel. As part of this training, personnel learn to recognize loads which may contain prohibited wastes.

At least one trained individual will be on duty at the site while the facility is open for public use and at all times during active waste management operations to ensure compliance with operational requirements.

1.10 UTILITIES

Electrical power, water, telephone, and restrooms will be provided at the landfill scale house and/or office.

1.11 RECORD KEEPING PROGRAM

The County will maintain the following records in an operating record at the landfill:

A. Current permit(s);
B. Inspection reports;
C. Audit and compliance records;
D. Annual landfill reports;
E. Waste inspection records (see **Section 2.4**);
F. Daily tonnage records - including source of generation;
G. Waste determination records;
H. Quantity, location of disposal, generator, and special handling procedures for all special wastes disposed of at the site;
I. List of generators and haulers that have attempted to dispose of restricted wastes;
J. Employee training procedures and records of training completed;
K. All ground water monitoring and surface water quality information (See the current **Water Quality Monitoring Plan**) including:
    1. Monitoring well construction records;
    2. Sampling dates and results;
    3. Statistical analyses; and
    4. Results of inspections, repairs, etc.
L. Gas monitoring results and remediation measures as required (see **Section 3.4.2**);
M. All closure and post-closure information, where applicable, including:
    1. Notification of intent to close;
    2. Testing;
    3. Certification; and
    4. Recording.
N. Cost estimates or financial assurance documentation.
O. A notation of the date and time of cover placement.

The operating record will be kept up to date by the Solid Waste Director or his designee. It will be presented upon request to the DWM for inspection. A copy of this Operations Manual will be kept at the landfill and will be available for use at all times.

SECTION 2.0
WASTE HANDLING OPERATIONS

2.1 OVERVIEW

This section describes the required waste handling operations for the Halifax County Landfill facility. In addition to the C&D and ash waste disposed of at this facility, the County also handles white goods, used tires, and used pesticide containers. These materials are stored at the landfill facility until there are sufficient quantities for pick up by various recycling contractors. The County also operates an animal waste disposal area and a wood waste processing area.

2.2 ACCEPTABLE WASTES

2.2.1 C&D Landfill Units

Only the following wastes generated within the approved service area may be disposed of in the C&D landfill unit (Note list is in accordance with existing permit):

- Land Clearing and Inert Debris Landfill: as defined in 15A NCAC 13B.0101(54) means a facility for the disposal of land-clearing waste, concrete, brick, concrete block, uncontaminated soil, gravel and rock, untreated and unpainted wood, and yard trash.
- Land Clearing Waste: as defined in 15A NCAC 13B.0101(53) means solid waste which is generated solely from land-clearing activities, limited to stumps, trees, limbs, brush, grass, and other naturally occurring vegetative material.
- Asphalt: in accordance with NCGS 130A-294(m).
- Construction and Demolition Debris: as defined in NCGS 130A-290(a)(4) means solid waste resulting solely from construction, remodeling, repair, or demolition operations on pavement, buildings, or other structures, but does not include inert debris, land-clearing debris, or yard debris.
- Industrial solid waste that is generated by mobile or modular home manufacturers and asphalt shingle manufacturers in Halifax County. The waste must be separated at the manufacturing site to exclude municipal solid waste, hazardous waste, and other waste prohibited from disposal in a Construction and Demolition Landfill.
- Other Wastes as Approved by the Solid Waste Section of the Division of Waste Management.

In addition, the special wastes (asbestos only) described in **Section 2.5.4** may also be disposed of in the C&D landfill units.

2.2.2 Ash Monofill

Only coal combustion by-products (residuals including fly ash, bottom ash, boiler slag, and flue gas desulfurization residue produced by coal fired electrical or steam generation units) generated within the approved service area may be disposed of in the ash monofill.

2.2.3 Wood Waste Processing Area

Clean wood waste including pallets, lumber scraps, and yard waste is accepted for processing within the facility's wood waste processing area (see **Section 2.6**).

2.3 PROHIBITED WASTES

2.3.1 C&D Landfill Units

Only wastes, as defined in **Section 2.2.1** above may be accepted for disposal in the C&D landfill unit. No other wastes may be accepted.

2.3.2 Ash Monofill

Only wastes, as defined in **Section 2.2.2** above may be accepted for disposal in the ash monofill. No other wastes may be accepted.

2.3.3 Wood Waste Processing Area

Only clean wood waste as defined in **Section 2.2.3** above may be accepted. No other wastes may be accepted. Unacceptable wastes found in this area, if not otherwise prohibited, are disposed of within the active C&D landfill unit.

2.4 WASTE SCREENING PROGRAMS

In order to assure that prohibited wastes are not entering the landfill facility, screening programs have been implemented at the landfill. Waste received at both the scale house entrance and waste taken to the working face is inspected by trained personnel. These individuals have been trained to spot indications of suspicious wastes, including: hazardous placarding or markings, liquids, powders or dusts, sludges, bright or unusual colors, drums or commercial size containers, and "chemical" odors. Screening programs for visual and olfactory characteristics of prohibited wastes are an ongoing part of the landfill operation.

2.4.1 Waste Receiving and Inspection

All vehicles must stop at the scale house located at the entrance of the facility and visitors are required to sign-in. All waste transportation vehicles are weighed and the content of the load assessed. The scale attendant(s) requests from the driver of the vehicle a description of the waste it is carrying to ensure that unacceptable waste is not allowed into the landfill. The attendant(s) then visually checks the vehicle as it crosses the scale. Signs informing users of the acceptable and unacceptable types of waste are posted at the scale house. Once passing the scales, the vehicles are routed to the appropriate landfill unit or other area (white goods handling area, etc.) as appropriate.

Vehicles are randomly selected for screening on a regular basis a minimum of three times per quarter (i.e. three months). However, if something looks suspicious is spotted in any

waste load, that load is inspected further.

Vehicles selected for inspection are directed to an area of intermediate cover adjacent to the working face where the vehicle will be unloaded. Waste is carefully spread using suitable equipment. An attendant trained to identify wastes that are unacceptable at the landfill inspects the waste discharged at the screening site. If unacceptable waste is found, including wastes generated from outside of the service area, the load will be isolated and secured by berming off the area. For unacceptable wastes that are non-hazardous, the Solid Waste Director will then notify officials of the DWM (see **Section 1.2.2**) within 24 hours of attempted disposal of any waste the landfill is not permitted to receive in order to determine the proper course of action. For unacceptable wastes that are hazardous, the Hazardous Waste Contingency Plan outlined in **Section 2.4.2** will be followed. The hauler is responsible for removing unacceptable waste from the landfill property.

If no unacceptable waste is found, the load will be pushed to the working face and incorporated into the daily waste cell. All random waste inspections will be documented by landfill staff using the waste screening form provided in **Appendix A**.

In addition to random waste screening described above, waste unloaded on the active face will be inspected by the equipment operators, trained to spot unacceptable wastes, before and during spreading and compaction. Any suspicious looking waste is reported immediately to the designated primary inspector for further evaluation.

2.4.2 Hazardous Waste Contingency Plan

In the event that identifiable hazardous waste or waste of questionable character is detected at the landfill, appropriate equipment, protective gear, personnel, and materials as necessary will be employed to isolate the wastes. The DWM will be notified immediately (see **Section 1.2.2**) that an attempt was made to dispose of hazardous waste at the landfill. If the vehicle attempting disposal of such waste is known, all attempts will be made to prevent that vehicle from leaving the site or, if the vehicle has left the site, immediate notice will be served on the owner of the vehicle that hazardous waste, for which they have responsibility, has been disposed of at the landfill.

The County will assist the DWM as necessary and appropriate in the removal and disposition of the hazardous waste and in the prosecution of responsible parties. If needed, the hazardous waste will be covered with either on-site soils or other tarping material until such time when an appropriate method can be implemented to properly handle the waste. The cost of the removal and disposing of the hazardous waste will be charged to the owner of the vehicle involved. Any vehicle owner or operator who knowingly dumps hazardous waste in the landfill may be barred from using the landfill.

Should an incident where hazardous waste is found at the landfill occur, the event will be documented by landfill staff using the waste screening form provided in **Appendix A**.

Records of information gathered as part of the waste screening programs will be maintained at the landfill site during its active life and as long as required by the County and the DWM.

2.5 WASTE DISPOSAL

2.5.1 Access

Traffic will be clearly directed to the appropriate active access road. The location of access roads during waste placement will be determined by operations personnel in order to reflect waste placement strategy. Additionally, access will be maintained for site monitoring locations.

2.5.2 General Procedures

For each active landfill unit, waste transportation vehicles will arrive at the working face at random intervals. There may be a number of vehicles unloading waste at the same time, while other vehicles are waiting. In order to maintain control over the unloading of waste, a certain number of vehicles will be allowed on the working face at a time. The actual number will be determined by the truck spotter. This procedure will be used in order to minimize the potential of unloading unacceptable waste and to control disposal activity. Operations at the working face will be conducted in a manner which will encourage the efficient movement of transportation vehicles to and from the working face, and to expedite the unloading of waste.

The approach to the working face will be maintained such that two or more vehicles may safely unload side by side. A vehicle turn-around area large enough to enable vehicles to arrive and turn around safely with reasonable speed will be provided adjacent to the unloading area. The vehicles will back to a vacant area near the working face to unload. Upon completion of the unloading operation, the transportation vehicles will immediately leave the working face area. Personnel will direct traffic necessary to expedite safe movement of vehicles.

Waste unloading at the landfill will be controlled to prevent disposal in locations other than those specified by site management. Such control will also be used to confine the working face to a minimum width, yet allow safe and efficient operations. The width and length of the working face will be maintained as small as practical in order to maintain the appearance of the site, control windblown waste, and minimize the amount of cover required each day. Normally, only one working face will be active on any given day, with all deposited waste in other areas covered by either periodic, intermediate, or final cover, as appropriate.

The procedures for placement and compaction of C&D waste include: unloading of vehicles, spreading of waste into 2 foot lifts, and compaction on relatively flat slopes (i.e. 5H:1V max.) using a landfill compactor and a minimum number of three full passes. For the ash monofill, the ash is spread and tracked in with a bulldozer.

The use of portable signs with directional arrows and portable traffic barricades will facilitate the unloading of wastes to the designated disposal locations. These signs and barricades will be placed along the access route to the working face of the landfill or other designated areas which may be established.

Appropriate methods such as wind screens and/or diking adjacent to the working face will be used as required to control windblown waste. All windblown waste will be collected and disposed of by landfill staff at the end of each working day.

The removal of solid waste from any landfill unit is prohibited unless an appropriate recycling plan has been approved by the DWM. Regardless, the general public is prohibited from any waste removal activities from any landfill unit.

2.5.3 Ash Monofill

The following are items unique to the ash monofill in that this unit includes a geomembrane liner.

2.5.3.1 Placement of Initial Lift

During ash placement, the geomembrane liner is most vulnerable during the placement of the first lift of ash. The first lift should be a minimum of two (2) to four (4) feet thick and be carefully spread using a bulldozer. A spotter should be used during placement of the first lift of ash to ensure that no stretching or wrinkling of the geomembrane is occurring.

In the event that the landfill staff identifies any damage to any part of the geomembrane liner, they should immediately initiate its repair. Additionally, they should document the damage and the repair as a part of the operating record.

2.5.3.2 Equipment Operations Within the Landfill

Both the facility's operational vehicles and waste transportation vehicles must be restricted as follows within the ash monofill:

- Equipment operation directly on the protective cover will be limited to rubber-tired vehicles having a maximum ground contact, i.e., tire pressure, of less than 32 psi.
- A minimum vertical separation of 3 feet will be maintained between the geomembrane liner and all ash transportation vehicles.
- A minimum vertical separation of 2 feet will be maintained between the geomembrane liner and bulldozers used in placement of the ash.

The operation of vehicles within those portions of the ash monofill not actively receiving waste should be restricted to activities associated with erosion and sedimentation control.

2.5.4 Special Waste Management

2.5.4.1 Asbestos Management (C&D Landfill Units)

The County may dispose of asbestos within the C&D landfill units. Asbestos will only be accepted if it has been processed and packaged in accordance with State and Federal (40 CFR 61) regulations. Asbestos will arrive at the site in vehicles that contain only the asbestos waste and only after advance notification by the generator.

Once the hauler brings the asbestos to the landfill, the hauler will be directed to the designated asbestos disposal area by operations personnel. The designated disposal area will be prepared by operations personnel by leveling a small area using a dozer or loader. Prior to disposal, the landfill operators will stockpile cover soil near the designated asbestos disposal area. The volume of soil stockpiled will be sufficient to cover the waste and to provide any berms, etc. to maintain temporary separation from other landfill traffic.

Once placed in the prepared area, the asbestos waste will be covered with a minimum of 18 inches of cover soil placed in a single lift. The surface of the cover soil will be compacted and graded using a tracked dozer or loader. The landfill compactor will be prohibited from operating over asbestos disposal areas until at least 18 inches of cover are in-place.

The landfill staff will record the approximate location and elevation of the asbestos waste once cover is in-place. The Solid Waste Director will then review pertinent disposal and location information to assure compliance with regulatory requirements and enter the information into the Operating Record.

Once disposal and recording for asbestos waste is completed, the disposal area may be covered with waste. No excavation into designated asbestos disposal areas will be permitted.

2.5.4.2 Animal Carcasses (Animal Waste Disposal Area)

The disposal of animal carcasses within the animal waste disposal area will be handled as follows. The generator of the carcass(es) must call in advance to the landfill, and a determination will be made as to whether or not the carcass(es) will be accepted. If approved, the generator will deliver the carcass(es) at a predetermined time. An area for disposal will already have been prepared and the waste will be covered immediately with 3 feet of soil.

2.5.5 Periodic Cover

2.5.5.1 C&D Landfill Units

At the completion of waste placement each week, or sooner if the area of exposed waste exceeds one-half acre in size, a 6-inch layer of earthen material or other material as approved by the DWM will be placed over the exposed waste. This periodic cover is intended to control vectors, fire, odors, and blowing debris.

2.5.5.2 Ash Monofill

Due to the nature of the waste placed in this landfill unit, no periodic soil cover is required.

2.5.6 Intermediate Cover

2.5.6.1 C&D Landfill Units

A 12 inch layer of soil cover should be placed on all waste surfaces that have not received waste in 30 days but are below final elevation. This intermediate cover should be seeded immediately and graded such that all precipitation run-off is channeled to the surface water systems.

2.5.6.2 Ash Monofill

Unless suitable vegetation can be established on the surface of the ash a 12-inch layer of soil cover should be placed over the ash on all outer side slopes. This intermediate cover should be seeded immediately and graded such that all precipitation run-off is channeled to the surface water systems.

2.5.7 Height Monitoring

Periodically, the landfill staff will monitor landfill top and side slope elevations with a level. When such elevations approach design grades, the final top-of-waste grades will be staked to limit over-placement of waste.

2.6 WOOD WASTE PROCESSING AREA

A wood waste processing are is located to the east of the existing Area 1 C&D landfill unit (see **Figure 1**). The operation of the wood waste processing area is as follows:

Acceptable wood and yard wastes are stockpiled to an approximate height of 15 feet over an area of approximately 1 acre (approximate weight of 1,500 to 2,000 lbs.). At that time a contractor is brought in to grind the waste. Once the waste is ground and becomes mulch, it is either hauled off-site, used around the site, primarily for surface stabilization, or placed in windrows to be given to the public or otherwise used in the future.

2.7 WHITE GOODS HANDLING AREA

A white goods handling area is located to the east of the existing Area 1 C&D landfill unit (see **Figure 1**). The operation of the white goods handling area is as follows:

Within the white goods handling area, white goods and scrap metal are stockpiled up to about 10 feet high over an approximate 100 foot by 100 foot area. Once the stockpile reaches capacity (typically every 2 to 3 months), a recycler removes Freon and hauls the white goods and scrap metal off-site to be recycled.

2.8 USED TIRE STORAGE AREA

Used tires are collected at an area near the landfill scale house (see **Figure 1**) and placed in up to three tire trailers. Once one or more trailers are full, the trailer(s) are picked up by a recycling contractor.

2.9 USED PESTICIDE CONTAINER STORAGE AREA

A sheltered storage area is located near the landfill office/maintenance building (see **Figure 1**) for used pesticide containers from local agricultural sources. Once approximately 5,000 containers have been collected, a recycling contractor grinds the containers, bags the ground plastic, and transports the plastic for recycling.

SECTION 3.0
ENVIRONMENTAL MANAGEMENT

3.1 OVERVIEW

This section reviews the overall environmental management tasks required for the successful operation of the landfill facility.

3.2 SURFACE WATER CONTROL

As used herein, the definition of "surface water" is water which results from precipitation or site run-on that has not contacted the waste.

Proper control of surface water at the landfill will accomplish the following goals:

- Prevent the run-on of surface water into the landfill unit(s) or the active face(s);
- Prevent the run-off of surface water that has come into contact with the waste (i.e. leachate);
- Limit the erosion caused by surface waters; and
- Limit sediments carried off-site by surface waters.

Separate erosion and sedimentation control plans have been provided for the various landfill units. These plans describe both short and long term engineered features and practices for preventing erosion and controlling sedimentation at this site. The following is a brief discussion of some of these features and practices, focusing more on the landfill units.

3.2.1 Surface Water Run-On Control

The perimeter berms and/or perimeter channels around the landfill unit(s) are designed to prevent the run-on of surface water from adjacent land into the landfill. Additional structures such as diversion berms, channels, down pipes, etc. carry surface water away from the landfill units.

3.2.2 Erosion Control

The serviceability of the landfill relies heavily on soil berms, barrier layers, and agricultural layers that are readily eroded by flowing water. Erosion control provisions incorporated in the landfill include the following:

- The slope of the working face must be no steeper than 5H:1V where practical to limit erosion of the periodic cover.
- Intermediate cover that has been exposed for more than 30 days must be

seeded immediately and repaired when erosion features are identified.

- Drainage breaks (diversion berms, etc.) are provided on the final cover to limit the flow length of run-off.

- Water collected by each drainage break is routed to stormwater drainage channels or down pipes so that the run-off volume does not accumulate going down the slope.

- The vegetative soil layer placed over the final cover must be seeded immediately.

Additional erosion control measures have been taken within the drainage channels and at points of stormwater discharge. All final cover should be inspected regularly for erosion damage and promptly repaired.

3.2.3 Sedimentation Control

Stormwater run-off from the landfill unit(s) is conveyed to one of the on site sediment basins and/or traps. These basins and/or traps should be inspected regularly for sediment build-up or erosion damage. The basins and/or traps should be cleaned out when sediment fills the lower half of the basin.

3.3 WATER QUALITY MONITORING

The monitoring program and procedures outlined in the current Water Quality Monitoring Plan will be followed for the monitoring of site groundwater monitoring wells and surface water monitoring locations. The results of the water quality monitoring program will be placed in the facility operating record as described in **Section 1.11**.

3.4 LANDFILL GAS (LFG) MANAGEMENT - CLOSED MSW LANDFILL UNIT

Landfill gas (LFG) is produced from degradation of the municipal solid waste (MSW) placed within the closed MSW landfill unit. Due to the nature of the wastes placed within the C&D landfill unit and the ash monofill, no separate LFG management is not expected to be a concern.

3.4.1 Methane Monitoring Program

The County will implement a routine methane monitoring program to ensure that methane concentrations do not exceed 25 percent of the lower explosive limit (LEL) in facility structures, or 100 percent of the LEL at property boundaries. Gas monitoring wells will be sampled on a quarterly basis. Monitoring of facility structures is not required due to the distance and natural barriers between the structures and the closed MSW landfill.

Currently nine gas probes are monitored quarterly. These probes include: GM-1, GM-2,

GM-2B, GM-2R, GM-3, GM-4, GM-4R, GM-5, and GM-5B.

3.4.2 Record Keeping

Results of the methane monitoring program will be placed in the facility operating record as described in **Section 1.11**.

3.4.3 LFG Contingency Plan

In the event methane concentrations exceed allowable limits, the emergency response plan will be as follows:

Open Air Areas

1. For 100% LEL at distances less than 250 feet from structures:

    a. Recalibrate equipment and recheck reading.
    b. Immediately take all necessary steps to ensure protection of human health (i.e. remove sources of ignition and limit access to the area).
    c. Call Fire Department.
    d. Notify the DWM (see **Section 1.2.2**).
    e. Notify the Consulting Engineer.
    f. Note the current weather and ground moisture conditions.
    g. Within seven days of detection, place in the operating record the methane gas levels detected and a description of the steps taken to protect human health.
    h. Within 60 days of detection, implement a remediation plan for the methane gas releases, place a copy of the plan in the operating record, and notify the DWM that the plan has been implemented. The plan will describe the nature and extent of the problem and the proposed remedy.

2. For 100% LEL at distances greater than 250 feet from structures:

    a. Recalibrate equipment and recheck reading.
    b. Immediately take all necessary steps to ensure protection of human health (i.e. remove sources of ignition and limit access to the area).
    c. Notify the DWM.
    d. Notify the Consulting Engineer.
    e. Note the current weather and ground moisture conditions.

Structures

1. For structures with greater than 25% LEL:

    a. Recalibrate equipment and recheck reading.
    b. Immediately take all necessary steps to ensure protection of human health

as above - including immediate evacuation leaving all doors open.

c. Call Fire Department.
d. Notify the DWM.
e. Notify the Consulting Engineer.
f. Note the current weather and ground moisture conditions.
g. Within seven days of detection, place in the operating record the methane gas levels detected and a description of the steps taken to protect human health.
h. Within 60 days of detection, implement a remediation plan for the methane gas releases, place a copy of the plan in the operating record, and notify the DWM that the plan has been implemented. The plan will describe the nature and extent of the problem and the proposed remedy.

2. For structures with 0-25% LEL:

a. Recalibrate equipment and recheck reading.
b. Discuss with the Consulting Engineer.

3.5 VECTOR CONTROL

Due to the nature of the waste disposed of at this facility, vector control is not anticipated to be of concern. Note that the use of periodic cover in the C&D landfill unit will discourage animals from nesting in the waste.

3.6 ODOR CONTROL

Due to the nature of the waste disposed of at this facility, odor control is not anticipated to be of concern. However, if odor control becomes a problem, additional measures (such as additional cover over wastes such as drywall) will be taken to ensure odor control.

3.7 DUST CONTROL

Dust related to waste hauler traffic on the access roads will be minimized by using a water truck to limit dust on the gravel portion of the road. Dust generated by excavation of cover soil will be limited by watering the cut soil areas if accessible to the water truck. The source of water is from one of the site sediment basins.

3.8 LEACHATE SEEPS

Leachate seeps can occur due to a variety of circumstances. The goal in dealing with leachate seeps is to prevent seepage from leaving the limits of waste disposal areas and to minimize the potential for reoccurrence. If evidence of leachate seeps is observed, the County will take the following actions. Depending on the circumstances, various combinations of actions may be appropriate.

1. If leachate is observed outside of the limits of waste disposal areas, notify the

DWM (see **Section 1.2.2**).

2. Contain the flow of leachate using soil berms and/or excavation.
3. Excavate the area of seepage to attempt to allow flow into the underlying waste (i.e. break-up soil layers that may be causing the seep.).
4. For contained leachate that will not flow into underlying waste, a pump may be required to route the leachate to a tanker truck for proper disposal off-site.
5. The use of soil (particularly clay) to plug the seepage may be successful in the case where flows are minor.
6. Remove and dispose of impacted cover soils accordingly.
7. Repair landfill cover as necessary.

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SECTION 3.0
CLOSURE/POST-CLOSURE COST ANALYSIS

3.1 OVERVIEW

The purpose of this section is to provide a written estimate in current dollars of all activities and costs associated with all activities specified in the written closure and post-closure plans which have been developed for Area 1 of the Halifax County C&D Landfill.

3.2 ESTIMATED CLOSURE COSTS

Table 3.1 summarizes the estimated costs for complete closure of Area 1 (the current maximum area to be closed). This cost estimate is based on a third party providing the necessary services and includes labor in the unit prices given. The estimated closure costs will be reviewed and updated as required to reflect adjustments for inflation, rising costs of anticipated closure care, increased costs in construction or materials, or any other adjustments to the Closure Plan.

3.3 ESTIMATED POST-CLOSURE COSTS

Table 3.2 summarizes the estimated costs for the post-closure care maintenance activities. This cost estimate is based on a third party providing the necessary services and includes labor in the unit prices given. The estimated post-closure costs will be reviewed and updated as required to reflect adjustments for inflation, rising costs of anticipated post-closure care, or any other adjustments to the Post-Closure Plan.

3.4 FINANCIAL ASSURANCE MECHANISM

Halifax County intends to continue to use the Local Government Financial Test (15A NCAC 13B.1628(e)(1)(f)) to demonstrate financial assurance for this facility.

TABLE 3.1: CLOSURE COST ESTIMATE[1]

ITEM	QUANTITY[2]	UNITS	UNIT COST	ITEM COST (2010 $)
Surface Preparation	6.5	Acre	$2,000	$13,000
Landfill Gas Wells/Vents	6.5	Acre	$3,000	$19,500
30 mil Textured LLDPE Geomembrane or Geosynthetic Clay Liner (GCL) (1.1 Ac.)	47,900	SF	$0.50	$23,950
Drainage Geocomposite (1.1 Ac.)	47,900	SF	$0.50	$23,950
Vegetative Soil Layer (24")	21,000	CY	$4.00	$84,000
Erosion Control (Diversion Berms, Down Pipes, Drainage Channels, Etc.)	6.5	Acre	$5,000	$32,500
Revegetation	6.5	Acre	$1,500	$9,750
Surveying	6.5	Acre	$2,000	$13,000
			Subtotal:	$219,650
Bonds, Mobilization, & Insurance			(4% of Subtotal):	$8,786
			Subtotal:	$228,436
			Contingency (10%):	$22,844
			Construction Subtotal:	**$251,280**
Engineering	6.5	Acre	$2,000	$13,000
CQA	6.5	Acre	$6,000	$39,000
			TOTAL:	**$303,280**

Notes:

1. Assumes closure of 6.5 acres (Area 1).
2. Estimated quantities shown are in-place quantities.

TABLE 3.2: POST-CLOSURE COST ESTIMATE[1]

ITEM	QUANTITY	UNIT	UNIT COST	TOTAL (2010 $)
Site Inspection And Record Keeping	80	HR	$75	$6,000
Revegetation (10% Total Area)	2	Acre	$1,500	$3,000
Mowing (once per year)	24	Acre	$100	$2,400
Erosion Control	1	LS	$5,000	$5,000
Gates/Fences/Access	1	LS	$2,000	$2,000
Groundwater/Surface Water Monitoring & Reporting (12 Wells/2 Surface Water Points - Semi-Annual)	14	Each	$1,000	$28,000
Methane Monitoring & Reporting (Semi-Annual After Year 1)	2	Each	$2,500	$5,000
			Subtotal:	$51,400
			Contingency (10%):	$5,140
			ANNUAL TOTAL:	$56,540
			30-YEAR TOTAL:	$1,696,200

Notes:

1. Assumes total of 24 acres (Area 1 and closed unlined MSW landfill unit).

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WHITE GOODS HANDLING FACILITY

SEASONAL SPRING

UNNAMED TRIBUTARY

ANIMAL WASTE DISPOSAL AREA

BORROW AREA

PERMITTED FACILITY BOUNDARY

EXISTING ROCK DAM

APPROXIMATE WASTE BOUNDARY (TYP.)

BREWER'S CREEK

DRAINAGE CHANNEL NO. 1 (2 / EC1)

EXISTING ROCK DAM

CULVERT NO. 1 24"ø RCP (CLASS III)
(INV. IN=304/ INV. OUT=302)
ADD 6" RIP RAP (12" THICK) AROUND CULVERT INLET

4 / EC1 RIP RAP OUTLET PROTECTION (TYP.)

EXISTING 12"ø DOWN PIPE (RELOCATE INLET END)

3 / EC1 FILTER BERM (TYP.) 3

1 / EC1 DOWN PIPE NO. 2 (18" CPE-TYPE C) 3

SEDIMENT BASIN

CLOSED UNLINED MSW LANDFILL UNIT (12/31/97)

BB / X1

EXISTING C&D LANDFILL UNIT (AREA 1)

3 DOWN PIPE NO. 3 (1 / EC1) (18" CPE-TYPE C)

5 / D1 CAP DIVERSION BERM

1 / EC1 DOWN PIPE NO. 1 (18"ø CPE-TYPE C) (TIE OUTLET TO EXISTING CHANNEL)

BEAVER POND

EXISTING DRAINAGE CHANNEL

LANDFILL GAS WELL/VENT (TYP.) (2 / D1)

EXISTING 18"ø DOWN PIPE (ADD ADDITIONAL 18"ø CPE-TYPE C PIPE)

SEDIMENT BASIN NO. 2

SEDIMENT BASIN NO. 1

AA / X1

E 2350500
E 2350000
E 2349500
E 2349000
E 2348500
N 958500
N 958000
N 957500
N 957000
N 956500
N 956000
N 955500

LEGEND

- EXISTING 10' CONTOUR
- EXISTING 2' CONTOUR
- PROPOSED 10' CONTOUR
- PROPOSED 2' CONTOUR
- PROPERTY LINE
- APPROXIMATE EXISTING WASTE LIMITS
- CDB — CAP DIVERSION BERM
- DRAINAGE CHANNEL
- DOWN PIPE / CULVERT
- LANDFILL GAS WELL / VENT

REFERENCES

1. OVERALL SITE TOPOGRAPHY PROVIDED BY PIEDMONT AERIAL SERVICES BASED ON APRIL 1996 AERIAL PHOTOGRAPHY.
2. WASTE CONTOURS FROM SURVEY DATED SEPTEMBER 2002.
3. BORROW SITE CONTOURS FROM SURVEY BY BURR & ASSOCATES DATED SEPTEMBER 12, 2001.

0 100' 200' 300'

NO.	DATE	REVISION
3	12/10	EDITS PER DWM COMMENTS
2	1/10	EDITS PER DWM COMMENTS

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SEAL: 021088 PROFESSIONAL ENGINEER PIETER K. SCHOLTZ

PROJECT TITLE:
HALIFAX COUNTY
C&D LANDFILL - AREA 1
CONTINUED OPERATIONS
PERMIT DRAWINGS

DRAWING TITLE:
AREA 1 FINAL COVER
GRADING AND DRAINAGE PLAN

DESIGNED BY:	DRAWN BY:
P.K.S.	C.T.J.
CHECKED BY:	PROJECT NO.:
	HALIFAX 08-1
SCALE:	DATE:
AS SHOWN	JUNE 2008
FILE NAME	
HALI-D0110B	
SHEET NO.	DRAWING NO.
5	S4

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