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PROJECT-SPECIFIC ADDENDUM

TO THE

QUALITY ASSURANCE MANUAL

FOR THE INSTALLATION OF

GEOSYNTHETIC LINING SYSTEMS

Prepared for

33628

Trail Ridge Landfill, Inc.
Post Office Box 6987
Jacksonville, Florida 32236

Prepared by

GeoSyntec Consultants
1200 South Federal Highway
Suite 204
Boynton Beach, Florida 33435

GeoSyntec Consultants Project No. FQ2030

3 January 1992

England-Thims & Miller, Inc.
Consulting & Design Engineers
3131 St. Johns Bluff Road So. Jacksonville, FL 32216
904-642-8990

PRINCIPALS
James E. England, P.E., President
Robert E. Thims, V.Pres., Sec.
Douglas C. Miller, P.E., V. Pres.
N. Hugh Mathews, P.E., V. Pres.

January 7, 1992

Ms. Mary Nogas, P.E.
Florida Department of Environmental Regulation
7825 Baymeadows Way, Suite B-200
Jacksonville, Florida 32256-7577

Reference: Trail Ridge Landfill "Plan A"
FDER Permit No. SC16-184444
ET&M No. E91-156 (Permit File)

Dear Mrs. Nogas:

Pursuant to Specific Conditions No. 2 (a) through (g) of the referenced permit, please find the following:

Permit Condition 2(a), (b), (e), (d), (f) and (g):
1. Quality Assurance Manual for the Installation of Geosynthetic Lining Systems

Permit Condition 2(d)
2. Construction Materials Testing Program

Should you have any questions, please do not hesitate to call.

Sincerely,

ENGLAND, THIMS & MILLER, INC.

Douglas C. Miller, P.E.

Attachments: 4 copies each

cc: Harvey Bush
Luke DeBock
Scott Kelly

Soils Quality Assurance Consultant
Construction Materials Testing Program

Trail Ridge Landfill

I. Landfill Components

A. Subgrade Material (A-3 sand)

1. Location- to be tested in place

2. Standard- 95 percent Modified Proctor (ASTM D1557) maximum dry density @ ±2 percent optimum moisture;
Testing by Drive Cylinder (ASTM D2937); Nuclear (ASTM D2922) or Sand Cone (ASTM D1556) Methods

3. Frequency- one test per 10,000 square foot of finished subgrade, including same frequency for each 12-inch lift of fill

B. Subbase Material (clayey sand/sandy clay)

1. Location- to be sampled and thickness measured in place;
permeability tested in laboratory

2. Standard- Coefficient of Permeability less than $1x10^{-5}$ cm/sec
Thickness greater than 6 inches at each location
Permeability testing by Falling Head Method (ASTM D5084)

3. Frequency- one test per 10,000 square feet

C. Synthetic Components (Claymax/Geonet/Geotextile)
Testing by Liner Quality Assurance Consultant

D. Protective Sand Cover (A-3 sand)

1. Location- material to be prequalified by permeability testing at the borrow location
Truck tickets utilized for chain of custody to site
Thickness to be verified by as built survey

2. Standard- Coefficient of Permeability greater than $1x10^{-3}$ cm/sec at a density of 100 percent Modified Proctor
Thickness greater than 24 inches at each location
Permeability testing by Constant Head Method (ASTM D2434)

3. Frequency- Coefficient of Permeability testing on going as necessary to support fill borrow operation with minimum of one test per 500 cubic yards

4. Miscellaneous- The material shall be placed loose and spread on top of the liner system to a minimum depth of 24 inches. No equipment shall come in direct contact with liner. Low ground pressure equipment shall be used for the placement and spreading of the sand cover. Temporary haul roads and access roads over the liner for the delivery of material shall include a minimum of 36 inches of sand cover depth. These temporary facilities shall be removed during the finish grading of the sand cover.
Compatibility of protective sand cover grain size with geotextile to be determined prior to initial placement.

Soils Quality Assurance Consultant
Construction Materials Testing Program

Trail Ridge Landfill

I. Landfill Components -Continued-

E. Anchor Trench Material (sandy clay/clay)

1. Location- to be sampled in place; permeability testing in laboratory

2. Standard- Coefficient of Permeability less than $1x10^{-7}$ cm/sec
   Permeability testing by Falling Head Method (ASTM D5084)

3. Frequency- one testing location per 100 linear feet of trench

F. Leachate Trench Aggregate

1. Location- Sampled on site during placement
   Gradation determined in laboratory

2. Standard- Gradation meets No. 3 coarse aggregate (ASTM D448) and is non-calcareous
   Testing by Sieve Analysis (ASTM C136)

3. Frequency- One test per sump plus one test per 500 linear feet of trench with minimum of one testing location per trench

G. Retaining Wall Concrete

1. Location- Sampled (ASTM C172) on-site during placement
   Slump/temperature measured on-site
   Compressive strength measured in laboratory

2. Standard- Slump (ASTM C143) less than 4 inches
   Temperature less than 96 degrees
   Compressive Strength (ASTM C39) at least 4000 psi

3. Frequency- one set of four cylinders per 50 cubic yards or each day's pour whichever is less.

II. Roadway/Pavement Materials

A. Subgrade (existing or fill materials)

1. Location- tested in place; LBR prequalified in laboratory

2. Standard- 98 percent of Modified Proctor maximum dry density.
   Testing by Drive Cylinder (ASTM D2937), Nuclear (ASTM D2922) or Sand Cone (ASTM D1556) Methods
   LBR equal to 40 or greater

3. Frequency- One test per 100 linear feet of roadway, including same frequency for each 12 inch lift of fill

II. Roadway/Pavement Materials -Continued-

B. Base Course (Limerock)

1. Location- Density/thickness tested in place; LBR prequalified in laboratory

2. Standard- 98 percent of Modified Proctor maximum dry density
   Testing by Nuclear (ASTM D2922) or Sand Cone (ASTM D1556) Methods
   LBR equal to 75 or greater

3. Frequency- One test per 100 lineal feet of roadway

C. Surface Course (Type S1 Asphalt)

1. Location- Thickness measured in-place; Material sampled in-place

2. Standard- Minimum specified thickness with ¼ inch tolerance

3. Frequency- One testing location per 200 linear feet of roadway

III. Utility Trench Material (Backfill)

1. Location- Tested in-place

2. Standard- 95 percent of Modified Proctor maximum dry density. Note upper 12 inches of backfill in areas of pavement must meet Roadway Subgrade criteria
   Testing by Drive Cylinder (ASTM D2937), Nuclear (ASTM D2922) or Sand Cone (ASTM D1556) Methods

3. Frequency- One test per lift per 100 feet of trench

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1. TERMS OF REFERENCE

In accordance with the Florida Department of Environmental Regulation (FDER) Permit Number SC16-184444 Permit, GeoSyntec Consultants has prepared the following Site-Specific Addendum to the Geosynthetic Lining System Quality Assurance Manual for the Trail Ridge Landfill, Inc. This addendum was prepared by Mr. Daniel A. Schauer, P.G., Regional Manager, Field Services, and reviewed by Dr. J.P. Giroud, Senior Principal, both of GeoSyntec Consultants. This addendum was prepared at the request of Mr. Clarke M. Lundell, P.E. of Waste Management of North America (WMNA), Southeast Region.

2. BACKGROUND

A copy of the Specific Conditions section, paragraph 2 of the FDER Permit, is provided in Attachment A. According to this document, the Trail Ridge Landfill, Inc. "shall submit a revised Quality Control/Quality Assurance Plan for installing the Class I area synthetic liner system, after selection of the synthetic liner manufacturer, and prior to its installation." As indicated in Section 3, the liner manufacturer has been selected. To comply with the FDER requirement, GeoSyntec Consultants has prepared the following Project-Specific Addendum to WMNA Quality Assurance Manual for the Installation of Geosynthetic Lining Systems (QAM), dated June 1990. A copy of the WMNA QAM is presented in Attachment B. The WMNA QAM dated June 1990 supersedes the WMNA QAM dated July 1986, previously submitted to FDER.

Section 1.0 of the WMNA QAM states that "Project-specific addenda shall be used to provide for additions, deletions, and changes necessary to the QAM used for a particular project." Accordingly, this report is titled "Project-Specific Addendum to the Quality Assurance Manual for the Installation of Geosynthetic Lining Systems". Additional addenda may be necessary during construction. Copies of these addenda will be immediately forwarded to FDER as required.

3. PARTIES INVOLVED

The following parties and their respective roles in design and construction of the Class I geosynthetic lining systems are as follows:

- Trail Ridge Landfill, Inc. - Owner/Project Manager
- England-Thims & Miller, Inc. - Designer
- National Seal Company (NSC) - Liner Manufacturer/Geosynthetics Installer
- GeoSyntec Consultants - Geosynthetics Quality Assurance Consultant and Laboratory

4. SPECIFIC CONDITION ITEMS

The specific condition items listed on page 5 of the Permit, as shown in Attachment A, are individually addressed below. Most responses refer to the WMNA's QAM dated June 1990, which can be found in Appendix B. The QAM in Appendix B (i.e., the June 1990 QAM) is more comprehensive than the QAM dated 1986, which was previously submitted to FDER. As a result, detailed answers to some of the specific condition items addressed below can be found in the June 1990 QAM in Appendix B.

Item a: **Retention of a registered professional engineer for independent quality assurance.**

Response. *In accordance with Section 1.2.5 of the June 1990 QAM, WMNA has retained GeoSyntec Consultants of Boynton Beach, Florida, as Geosynthetic Quality Assurance Consultant for Phase I and II of this project. Implementation of the on-site quality assurance program will be provided by GeoSyntec Consultants' Engineer of Record, registered in the State of Florida.*

* * *

Item b: **Minimum qualifications of the quality assurance engineer and supporting quality assurance personnel.**

Response. *The minimum qualifications are addressed in Section 1.2.5.3 of the June 1990 QAM. The qualifications of GeoSyntec Consultants quality assurance personnel designated for this project will meet or exceed the requirements of the June 1990 QAM.*

* * *

Item c: **Sampling activities, size and locations, frequency of testing, acceptance and rejection criteria, and plans for implementing corrective measures that may be necessary.**

Response. *The June 1990 QAM is complete and comprehensive in addressing the topics listed in item c for each geosynthetic type to be used at the Trail Ridge Landfill site:*

- *For the geomembranes:*
    - *sampling procedures, Section 4.8.3*
    - *sample size, Section 4.8.4*
    - *sample location and frequency, Section 4.8.2*

  - *frequency of testing, and acceptance and rejection criteria, Section 4.8.6*
  - *plans for implementing corrective measures, Section 4.8.7 and Section 4.9.*

- *For the geotextiles:*

  - *sampling procedures, Section 5.3.1*
  - *sample size, Section 5.3.1*
  - *sample location and frequency, Section 5.3.1*
  - *frequency of testing, and acceptance and rejection criteria, Section 5.3.2*
  - *plans for implementing corrective measures, Section 5.6.*

- *For the geonets:*

  - *sampling procedures, Section 6.3.1*
  - *sample size, Section 6.3.1*
  - *sample location and frequency, Section 6.3.1*
  - *frequency of testing, and acceptance and rejection criteria, Section 6.3.2*
  - *plans for implementing corrective measures, Section 6.6.*

* * *

Item d: Procedure for testing the density of the compacted subbase at least once per acre.

Response. *The June 1990 QAM does not specifically address geotechnical testing and quality control/quality assurance of the subbase soils. This item will be addressed under separate cover by Trail Ridge Landfill Inc.'s Soils Quality Assurance Consultant, Law Engineering of Jacksonville, Florida.*

* * *

Item e: Procedures for testing the permeability of the Claymax at least once per 40,000 square feet.

Response. *GeoSyntec Consultants' Geotechnical Engineering Laboratory located in Norcross, Georgia will conduct the permeability testing of the Claymax rolls designated for the site. The Claymax will be tested at a maximum frequency of one test per 40,000 ft^2 (3700 m^2). The permeability test procedure will be conducted in accordance with the American Society for Testing and Materials (ASTM) standard test method D5084, "Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeater". A copy of ASTM D5084 is shown in Attachment C.*

* * *

Item f: The synthetic liner manufacturer's and installer's specific recommendations for acceptability of the soil portion ("subgrade" for the synthetic liner) and the Claymax portion of the liner system. The Permittee shall ensure that the installation contractor of the synthetic portion submits his certification of acceptance of the subgrade to the Department immediately upon its execution.

Response. *NSC's recommendations for soil subgrade surface acceptability are described in NSC's Construction Quality Control Manual, Section 3.1, Earth Work. A copy of Section 3.1 is shown in Attachment D. Installation recommendations for the Claymax are presented in Attachment E. The geosynthetics installer will submit daily Certificates of Completion of Soil Subgrade Surface to Trail Ridge Landfill Inc. The certificates will identify the specific location of the subgrade surface lined that day. The certificates will also be acknowledged by signature of the geosynthetic quality assurance consultant. Trail Ridge Landfill Inc. will be responsible for submitting the completed certificates to the FDER upon their* *execution. A copy of the Certificate of Completion of Soil Subgrade Surface is shown in Appendix C of the QAM.*

* * *

Item g: **The synthetic liner manufacturer's specifications and recommendations for installing and testing the specific liner selected and demonstrating that it meets or exceeds NSF Standard 54. Quality Assurance Reports shall be submitted to the Department with the Certification of Completion. Installation of the synthetic liner for the leachate holding basin shall be performed in accordance with the Department approved Construction Quality Assurance Plan and shall meet the liner manufacturer's recommended installation procedures, pursuant to FAC Rule 17-701.050(4)(c).**

Response. *NSC's technical data sheet showing the physical properties and applicable test methods for 60 mil (1.5 mm) thick high density polyethylene (HDPE) geomembrane is presented in Attachment F. The data sheet states that "All properties meet or exceed NSF Standard 54 specifications for HDPE." GeoSyntec Consultants has verified that the property values listed in the data sheet do meet or exceed the NSF Standard 54 specifications for HDPE. NSC's Construction Quality Control Manual Sections 1 through 5 describing liner installation recommendations are presented in Attachment G. The geosynthetic quality assurance consultant shall submit the Certification of Completion with the Final Quality Assurance Report. The Certification will be provided for only those specific working areas for which quality assurance activities were monitored and documented. A copy of the Certification of Completion is shown in Appendix C of the QAM. The geosynthetic installer will be required to perform the installation of the leachate holding basin liner system in accordance with the QAM and recommended installation procedures.*

* * *

5. REVISIONS AND DELETIONS

5.1 Revisions

Revisions to the June 1990 QAM are as follows:

- Page 32, Section 4.6.6.2 8, second sentence:

  "Under cold weather conditions, new trial seams shall be conducted if the ambient temperature drops by more than 5°F from the initial trial seam test conditions."

  Change 5°F to 10°F.

- Page 38, Section 4.9.3, second sentence:

  "Repairs of this type shall be approved by the Geosynthetic QAE and shall not exceed 50 ft (15 m) in length."

  Change 50 ft (15 m) to 100 ft (30 m).

- Page 54-58, Section 7.0 **Geogrids**:

  Because geogrids are not included in the Trail Ridge Landfill design this section will not apply.

5.2 Deletions

Deletions to the June 1990 QAM are as follows:

- Section 4.2, Page 22:

  Delete the entire item 9, i.e., everything from **"A characterization of"** to **"this QAM."**

- Page 43, Section 5.3, item 10f:

  Delete "**thickness**".

- Page 44, Section 5.3, item 6:

  Delete "**thickness**".

ATTACHMENT A

FDER PERMIT SPECIAL CONDITIONS

Florida Department of Environmental Regulation
Northeast District • Suite B200, 7825 Baymeadows Way • Jacksonville, Florida 32256-7577
Lawton Chiles, Governor
Carol M. Browner, Secretary

PERMITTEE:

Trail Ridge Landfill, Inc.
Post Office Box 6987
Jacksonville, Florida 32236

I.D. Number: GMS3116P03090
Permit/Cert Number: SC16-184444
Date of Issue: 12-24-91
Expiration Date: 12-24-96
County: Duval
Lat/Long: 30°14'00"N/82°02'30"W
Section/Township/Range: 18, 19, 20, 21/3S/23E
Project: Trail Ridge "Plan A" Landfill

This permit is issued under the provisions of Chapters 373 and 403, Florida Statutes and Florida Administrative Code Chapters 17-3, 17-4, and 17-701. The above-named Permittee is hereby authorized to perform the work or operate the facility shown on the application and approved drawing(s), plans, and other documents attached hereto or on file with the department and made a part hereof and specifically described as follows:

To construct and operate the Trail Ridge "Plan A" Landfill, with a total site area of 1288± acres of which 148± acres will be used for disposal of Class I wastes and 28 acres will be used for disposal of Class III wastes. The leachate containment system is a double liner system as spelled out in Florida Administrative Code Rule 17-701.050(5)(d)1.b., with the addition of 0.25 inches of Claymax below the bottom liner. The primary and secondary leachate collection systems will consist of synthetic geodrains and a two (2)-foot protective soil layer will lie above the primary drain.

The facility design includes wetland mitigation and a surface water management system. A groundwater monitoring system is also included.

The Trail Ridge Landfill entrance is located on the west side of U.S. Highway 301 approximately one mile north of Maxville in Duval County.

This permit is issued in accordance with the application received July 27, 1990 and additional information provided on September 12 and October 10 and 11, 1990, and includes Department File Nos. 184444, 184445, and 184447.

Administration 448-4300
Air 448-4310
Waste Management 448-4320
Water Facilities 448-4330
Water Management 448-4340
FAX 448-4366

PERMITTEE:

Trail Ridge Landfill, Inc.

I.D. Number: GMS3116P03090
Permit/Cert Number: SC16-184444
Date of Issue: 12-24-91
Expiration Date: 12-24-96

SPECIFIC CONDITIONS (CONT'D):

2. The Permittee shall submit to the Department for approval a revised Quality Control/Quality Assurance Plan for installing the Class I area synthetic liner system, after selection of the synthetic liner manufacturer, and prior to its installation. The plan shall include the following:

   a. Retention of a registered professional engineer for independent quality assurance.

   b. Minimum qualifications of the Construction Quality Assurance engineer and supporting Quality Assurance personnel.

   c. Sampling activities, size and locations, frequency of testing, acceptance and rejection criteria, and plans for implementing corrective measures that may be necessary.

   d. Procedure for testing the density of the compacted clay subbase at least once per acre.

   e. Procedures for testing the permeability of the Claymax at least once per 40,000 square feet.

   f. The synthetic liner manufacturer's and installer's specific recommendations for acceptability of the soil portion ("subgrade" for the synthetic liner) and the Claymax portion of the liner system. The Permittee shall ensure that the installation contractor of the synthetic portion submits his certification of acceptance of the subgrade to the Department immediately upon its execution.

   g. The synthetic liner manufacturer's specifications and recommendations for installing and testing the specific liner selected and demonstrating that it meets or exceeds NSF Standard 54. Quality Assurance Reports shall be submitted to the Department with the Certification of Completion. Installation of the synthetic liner for the leachate holding basin shall be performed in accordance with the Department approved Construction Quality Assurance Plan and shall meet the liner manufacturer's recommended installation procedures, pursuant to FAC Rule 17-701.050(4)(c).

3. The Permittee shall establish financial assurance for closure and long-term care. Proof that the financial assurance mechanism is funded in accordance with FAC Rule 17-701.076 shall be submitted to the Department sixty (60) days prior to the acceptance of any solid waste at the facility [17-701.076(2)]. All submittals in response to this specific condition shall be submitted to: Financial Coordinator, Solid Waste Section, Department of Environmental Regulation, 2600 Blair Stone Road, Tallahassee, Florida 32399-2400.

ATTACHMENT B

WMNA QUALITY ASSURANCE MANUAL
JUNE 1990

QUALITY ASSURANCE MANUAL
FOR THE INSTALLATION OF
GEOSYNTHETIC LINING SYSTEMS

June 15, 1990

QUALITY ASSURANCE MANUAL FOR THE INSTALLATION OF GEOSYNTHETIC LINING SYSTEMS

QUALITY ASSURANCE MANUAL
FOR THE INSTALLATION OF
GEOSYNTHETIC LINING SYSTEMS

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APPENDICES

1.0 GENERAL

1.1 SCOPE

This Quality Assurance Manual (QAM) addresses the quality assurance of the installation of geosynthetic materials used by Waste Management of North America, Inc. (WMNA) in its land disposal, surface impoundment, and other waste containment facilities. This manual is one component of the overall Quality Assurance Plan (QAP) developed for each project. Extreme care and detailed documentation are required in the production and installation of all geosynthetic materials used in waste containment applications.

This manual addresses quality assurance, not quality control. In the context of this manual, **quality assurance** refers to means and actions employed to assure conformity of the geosynthetic system production and installation with the project-specific Quality Assurance Plan (QAP), drawings, specifications, and contractual and regulatory requirements. Quality assurance is provided by a party independent from production and installation. **Quality control** refers only to those actions taken to ensure that materials and workmanship meet the requirements of the plans and specifications. Quality control is provided by the manufacturers and installers of the various components of the geosynthetic system.

A project-specific QAP is required for each project. At a minimum, the QAP shall consist of the following:

1. Applicable QAMs.

2. Project-Specific Addenda to the above QAMs. (Project-specific addenda shall be used to provide for additions, deletions, and changes necessary to the QAM(s) used for a particular project.)

3. Project-Specific Plans and Specifications.

The scope of this QAM applies to manufacturing, shipment, handling, and installation of geosynthetics. This QAM does not address design guidelines, installation specifications, or selection of geosynthetic materials. It also does not address the quality assurance of soils, except in cases where soil placement may have an influence on the geosynthetics. The quality assurance of soil components of landfill lining systems is addressed in the WMNA "Quality Assurance Manual for the Installation of Soil Components of Lining Systems".

This QAM was developed consistent with EPA guidance including "Construction Quality Assurance for Hazardous Waste Landfill Disposal Facilities," EPA/530-SW-86-031, October 1986, and regulations governing CQA requirements listed in 40 CFR 264.

1.2 PARTIES

The parties discussed in this section are associated with the ownership, design, manufacture, transportation, installation, and quality assurance of the geosynthetic system. The definitions, qualifications, and responsibilities of these parties are outlined in the following subsections.

1.2.1 Project Manager

1.2.1.1 Definitions

The Project Manager is the official representative of WMNA; in this manual, the term Project Manager shall apply equally to "Construction Coordinator", i.e., the individual responsible for coordinating construction and quality assurance activities for the project.

1.2.1.2 Responsibilities

The Project Manager is responsible for all construction quality assurance activities. The Project Manager is responsible for the organization and implementation of the QAP for the project as outlined in Section 1.1 of this manual.

The Project Manager shall serve as communications coordinator for the project, initiating the resolution, pre-construction, and construction meetings outlined in Section 1.3. As communications coordinator , the Project Manager shall serve as a liaison between all parties involved in the project to insure that communications are maintained.

The Project Manger shall also be responsible for proper resolution of all quality assurance issues that arise during construction.

1.2.1.3 Qualifications

The selection of the Project Manager is the direct responsibility of WMNA. Qualifications for this position include familiarity with the following:

1. Applicable QAMs.

2. General geosynthetic lining techniques.

3. All applicable regulatory requirements.

4. Company policies and procedures for project management.

1.2.2 Designer

1.2.2.1 Definitions

The Designer is the individual and/or firm responsible for the preparation of the design, including plans and project-specific specifications for the geosynthetic lining system.

1.2.2.2 Responsibilities

The Designer is responsible for performing the engineering design and preparing the associated drawings and specifications for the geosynthetic lining system. The Designer is responsible for approving all design and specification changes and making design clarifications necessitated during construction of the geosynthetic lining system. The Designer may attend the resolution and pre-construction meetings outlined in Section 1.3 of this manual upon the request of the Project Manager.

1.2.2.3 Qualifications

The Designer shall be a qualified engineer, certified or licensed as required by regulation. The Designer shall be familiar with geosynthetics (including detailed geosynthetic design methods and procedures) and applicable regulatory requirements.

1.2.2.4 Submittals

The Designer shall submit the project design drawings and specifications to the Project Manager. The Designer shall submit completed design clarification forms to the Project Manager in a timely manner upon request.

1.2.3 Manufacturer

1.2.3.1 Definitions

The Manufacturer is the firm responsible for production of any of the various geosynthetic liner system components outlined in this QAM.

1.2.3.2 Responsibilities

Each Manufacturer is responsible for the production of its geosynthetic product. In addition, each Manufacturer is responsible for the condition of the geosynthetic until the material is accepted by the Project Manager upon delivery. Each Manufacturer shall produce a consistent product meeting the project specifications. Each Manufacturer shall provide quality control documentation for its product as specified in this QAM.

1.2.3.3 Qualifications

Each Manufacturer shall be pre-qualified by WMNA. Each Manufacturer shall provide sufficient production capacity and qualified personnel to meet the demands of the project. Each Manufacturer shall have an internal quality control program for its product that meets the requirements presented in this QAM.

1.2.3.4 Submittals

Pre-qualification: A Manufacturer shall meet the following requirements and submit the following information to be considered for pre-qualification:

1. Corporate background and information

2. Manufacturing capabilities:

   a. Information on plant size, equipment, personnel, number of shifts per day, and capacity per shift.
   b. Daily production quantity available for WMNA facilities.
   c. A list of material properties including certified test results, to which are attached geosynthetic samples.
   d. A list of at least 15 completed landfill or surface impoundment facilities totalling a minimum of 15,000,000 ft^2 (1,500,000 m^2), for which the Manufacturer has manufactured a geosynthetic. For each facility, the following information shall be provided:

      (1) Name and purpose of facility, its location and date of installation.
      (2) Name of owner, project manager, designer, fabricator (if any) and installer.
      (3) Type of geosynthetic, surface area of geosynthetic manufactured.
      (4) Available information on the performance of the lining system and the facility.

3. The Manufacturer's quality control manual, including a description of the quality control laboratory facilities.

4. The origin (supplier's name and production plant) and identification (brand name and number) of resin used to manufacture the product.

5. A fingerprint of the Manufacturer's geosynthetic product (for polyethylene-based geosynthetics) in accordance with fingerprinting protocol listed in Appendix B of this QAM.

Pre-installation: Prior to the installation of any geosynthetic material, a Manufacturer must submit to the Project Manager all quality control documentation required by the appropriate section of this QAM. This documentation shall be reviewed by the

Geosynthetic Quality Assurance Consultant as outlined in Section 1.2.5 of this QAM before installation can begin.

1.2.4 Installer

1.2.4.1 Definitions

The Installer is the firm responsible for installation of the geosynthetics. The Installer may be affiliated with the Manufacturer.

The Superintendent is responsible for the Installer's field crew. The Superintendent shall represent the Installer at all site meetings and shall be responsible for acting as the Installer's spokesman on the project.

The Master Seamer shall be the most experienced seamer of the Installer's field crew. The Master Seamer shall provide direct supervision over less experienced seamers.

1.2.4.2 Responsibilities

The Installer shall be responsible for field handling, storing, deploying, seaming, temporary restraining and all other aspects of the geosynthetics installation. The Installer may also be responsible for transportation of these materials to the site and for anchor systems, if required by the project specifications. The Installer shall be responsible for submittal of the documentation listed in Section 1.2.4.4.

1.2.4.3 Qualifications

The Installer shall be pre-qualified and approved by WMNA. The Installer shall be able to provide qualified personnel to meet the demands of the project. At a minimum, the Installer shall provide a Superintendent and a Master Seamer as described below.

The Superintendent must be qualified based on previously demonstrated experience, management ability, and authority. The Superintendent, unless otherwise approved by the Project Manager, shall have previously managed, at a minimum, two installation projects which entailed the installation of at least a total of 1,000,000 ft^2 (100,000 m^2) of polyethylene geomembrane.

For geomembrane installation all personnel performing seaming operations shall be qualified by experience or by successfully passing seaming tests. The Master Seamer shall have experience seaming a minimum of 1,000,000 ft^2 (100,000 m^2) of polyethylene geomembrane using the same type of seaming apparatus to be used at the site.

1.2.4.4 Submittals

Pre-qualification: To be considered for pre-qualification, the Installer shall submit the following information:

1. Corporate background and information

2. Description of installation capabilities:
   a. Information on equipment (numbers and types), and personnel (number of superintendents, number of crews).
   b. Average daily production anticipated.
   c. Samples of field geomembrane seams and a list of minimum values for geomembrane seam properties.

3. A list of at least ten completed facilities, totalling a minimum of 2,000,000 ft^2 (200,000 m^2) for which the Installer has installed geosynthetics. For each installation, the following information shall be provided:
   a. Name and purpose of facility, its location, and date of installation.
   b. Name of owner, project manager, designer, manufacturer, fabricator (if any), and name of contact at the facility who can discuss the project .
   c. Name and qualifications of the Superintendent(s) of the Installer's crew(s).
   d. Type of geosynthetic, and surface area installed.
   e. Type of seaming and type of seaming apparatus used.
   f. Duration of installation.
   g. Available information on the performance of the lining system and the facility.

4. The Installer's quality control manual.

5. A copy of a letter of recommendation supplied by the geomembrane manufacturer.

Pre-installation: Prior to commencement of the installation, the Installer must submit to the Project Manager:

1. Resume of the Superintendent to be assigned to this project, including dates and duration of employment.
2. Resume of the Master Seamer to be assigned to this project, including dates and duration of employment.
3. A panel layout drawing showing the installation layout identifying field seams as well as any variance or additional details which deviate from the engineering drawings. The layout shall be adequate for use as a construction plan and shall include dimensions, details, etc.
4. Installation schedule.
5. A list of personnel performing field seaming operations along with pertinent experience information.

6. All geosynthetic quality control certificates as required by this QAM (unless submitted directly to the Project Manager by the Manufacturer).
7. Certification that extrudate to be used is comprised of the same resin as the geomembrane to be used.

This documentation shall be reviewed by the Geosynthetic Quality Assurance Consultant, as outlined in Section 1.2.5 of this QAM, before installation of the geosynthetic can begin.

Installation: During the installation, the Installer shall be responsible for the submission of:

1. Quality control documentation recorded during installation.
2. Subgrade surface acceptance certificates for each area to be covered by the lining system, signed by the Installer.

Completion: Upon completion of the installation, the Installer shall submit:

1. The warranty obtained from the Manufacturer.
2. The installation warranty.

1.2.5 Geosynthetic Quality Assurance Consultant

1.2.5.1 Definitions

The Geosynthetic Quality Assurance Consultant (QAC) is a firm independent from the Project Manager, Manufacturer(s), and Installer that shall be responsible for observing and documenting activities related to the quality assurance of the production and installation of the geosynthetic system on behalf of WMNA.

In this QAM the term Geosynthetic Quality Assurance Engineer (QAE) shall be used to designate the engineer (working for the Geosynthetic QAC) in charge of the quality assurance work. In some cases the duties of the Geosynthetic QAE described below may be shared by two individuals: a Geosynthetic Quality Assurance Managing Engineer located at the headquarters of the Geosynthetic QAC, and a Geosynthetic Quality Assurance Resident Engineer located at the site. The personnel of the Geosynthetic QAC also include Geosynthetic Quality Assurance Monitors who are located at the site for construction observation and documentation.

1.2.5.2 Responsibilities

The Geosynthetic QAC is responsible for observing and documenting activities related to the quality assurance of the production and installation of the geosynthetic system. The Geosynthetic QAC is responsible for implementation of the project QAP prepared by the Project Manager and management of the Geosynthetic Quality Assurance Laboratory. The

Geosynthetic QAC is also responsible for issuing a final certification report, sealed by a registered professional engineer, as outlined in Section 2.0 of this QAM.

The specific duties of the Geosynthetic QAC personnel are as follows:

1. The Geosynthetic QAE:

   a. Reviews all design drawings and specifications.
   b. Reviews other site-specific documentation, including proposed layouts, and manufacturer's and installer's literature.
   c. Develops a site-specific addendum for quality assurance of geosynthetics (if necessary) with the assistance of the Project Manager.
   d. Administers the geosynthetic portions of the QAP, e.g., assigns and manages all geosynthetic quality assurance personnel, reviews all field reports, and provides engineering review of all quality assurance related issues.
   e. Reviews all changes to design drawings and specifications as issued by the Designer.
   f. Acts as the on-site (resident) representative of the Geosynthetic QAC.
   g. Familiarizes all Geosynthetic Quality Assurance Monitors with the site and the project QAP.
   h. Attends all quality assurance related meetings, e.g., resolution, pre-construction, daily, weekly.
   i. Reviews all Manufacturer and Installer certifications and documentation and makes appropriate recommendations.
   j. Reviews the Installer's personnel qualifications for conformance with those qualifications pre-approved for work on site.
   k. Manages the preparation of the as-built drawing(s)
   l. Reviews the calibration certification of the on-site tensiometer, if applicable
   m. Reviews all Geosynthetic Quality Assurance Monitor's daily reports, logs and photographs.
   n. Notes any on site activities that could result in damage to the geosynthetics.
   o. Reports to the Project Manager, and logs in the daily report, any relevant observations reported by the Geosynthetic Quality Assurance Monitors.
   p. Prepares his own daily report.
   q. Prepares a daily summary of the quantities of geosynthetics installed that day.
   r. Prepares the weekly summary of geosynthetic quality assurance activities.
   s. Oversees the marking, packaging and shipping of all laboratory test samples.
   t. Reviews the results of laboratory testing and makes appropriate recommendations.
   u. Designates a Geosynthetic Quality Assurance Monitor to represent the QAE whenever he is absent from the site while operations are ongoing.
   v. Reports any unapproved deviations from the QAP to the Project Manager.
   w. Prepares the final certification report.

2. The Geosynthetic Quality Assurance Monitor:

   a. Monitors, logs, photographs and/or documents all geosynthetic installation operations. Photographs shall be taken routinely and in critical areas of the installation sequence. These duties shall be assigned by the Geosynthetic QAE.

   b. Monitors the following operations for all geosynthetics:

      (1) Material delivery
      (2) Unloading and on-site transport and storage
      (3) Sampling for conformance testing
      (4) Deployment operations
      (5) Joining and/or seaming operations
      (6) Condition of panels as placed
      (7) Visual inspection by walkover
      (8) Repair operations

   c. Monitors and documents the geomembrane seaming operations, including:

      (1) Trial seams
      (2) Seam preparation
      (3) Seaming
      (4) Nondestructive seam testing
      (5) Sampling for destructive seam testing
      (6) Field tensiometer testing
      (7) Laboratory sample marking
      (8) Repair operations

   d. Documents any on-site activities that could result in damage to the geosynthetics. Any problems noted shall be reported as soon as possible to the Geosynthetic QAE.

1.2.5.3 Qualifications

The Geosynthetic QAC shall be pre-qualified by WMNA. The Geosynthetic QAC shall be experienced in quality assurance of geosynthetics with emphasis on polyethylene geomembranes. The Geosynthetic QAC shall be experienced in the preparation of quality assurance documentation including: quality assurance forms, reports, certifications, and manuals.

The Geosynthetic Quality Assurance Managing Engineer shall hold a B.S., M.S. or Ph.D. engineering degree and be registered as a Professional Engineer. He shall also comply with the experience requirements listed in the previous paragraph. The Geosynthetic Quality Assurance Resident Engineer shall be specifically experienced in the installation of geosynthetics and shall be trained and certified by the Geosynthetic QAC in the duties of a Geosynthetic QAE.

Geosynthetic Quality Assurance Monitors shall be quality assurance personnel who have been specifically trained in the quality assurance of geosynthetics. At a minimum, one of every four monitors (or at least one monitor per project) shall have a minimum of 1,000,000 ft^2 (100,000 m^2) field experience in polyethylene geomembrane quality assurance.

1.2.5.4 Submittals

<u>Pre-qualification:</u> To be considered for pre-qualification, the Geosynthetic QAC must provide the following information:

1. Corporate background and information.

2. Quality assurance capabilities:
   a. A summary of the firm's experience with geosynthetics.
   b. A summary of the firm's experience in quality assurance, including installation quality assurance of geosynthetics.
   c. A summary of quality assurance documentation and methods used by the firm, including sample quality assurance forms, reports, certifications, and manuals prepared by the firm.
   d. Resumes of key personnel.

<u>Pre-installation:</u> Prior to beginning work on a project, the Geosynthetic QAC must provide the Project Manager with the following information:

1. Resumes of personnel to be involved in the project including Geosynthetic QAE, and Geosynthetic Quality Assurance Monitors.
2. Proof of professional engineering registration for the engineer to be designated as the Geosynthetic QAE, as well as proof of B.S., M.S., or Ph.D. engineering degree.
3. Proof of the required quality assurance experience of all of the quality assurance personnel with emphasis on polyethylene geomembranes.

<u>1.2.6 Geosynthetic Quality Assurance Laboratory</u>

1.2.6.1. Definitions

The Geosynthetic Quality Assurance Laboratory (QAL) is a firm, independent from the Project Manager, Manufacturer(s), and Installer, responsible for conducting tests on samples of geosynthetics taken from the site.

1.2.6.2 Responsibilities

The Geosynthetic QAL shall be responsible for conducting the appropriate laboratory tests as directed by the Geosynthetic QAE. The test procedures shall be done in accordance with the test methods outlined in this QAM and/or the project QAP. The Geosynthetic QAL shall be responsible for providing test results as outlined in Section 1.2.6.4.

1.2.6.3 Qualifications

The Geosynthetic QAL shall have experience in testing geosynthetics and be familiar with American Society for Testing and Materials (ASTM), Federal Test Method Standard (FTMS), National Sanitation Foundation (NSF), and other applicable test standards. The Geosynthetic QAL shall be capable of providing verbal results of destructive seam tests within 24 hours of receipt of test samples and shall maintain that standard throughout the installation. The Geosynthetic QAL shall be approved by WMNA.

On-site laboratory facilities may be used by the Geosynthetic QAL, provided they are appropriately equipped and approved by the Geosynthetic QAC and the Project Manager.

1.2.6.4 Submittals

The Geosynthetic QAL shall submit all destructive seam test results to the Geosynthetic QAE in written form within 48 hours of receipt of test samples unless otherwise specified by the Project Manager. Geomembrane destructive test results shall typically be provided verbally to the Geosynthetic QAE within 24 hours of receipt of test samples. Written test results shall be in an easily readable format and include references to the standard test methods used.

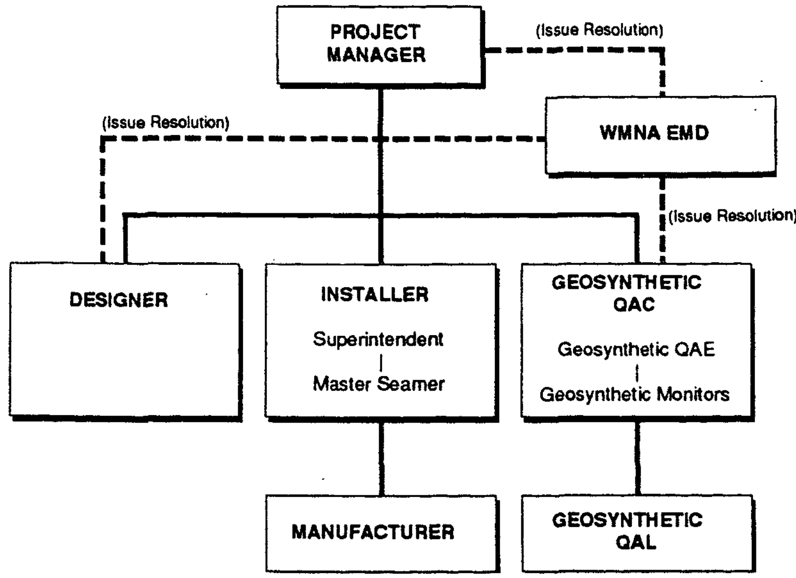
1.3 COMMUNICATION

To guarantee a high degree of quality during installation and assure a final product that meets all project specifications, clear, open channels of communication are essential. This section discusses appropriate lines of communication and describes all necessary meetings.

1.3.1 Lines of Communication

The typical lines of communication necessary during a project are illustrated in Exhibit 1-1. The Geosynthetic QAE shall be capable of direct communication with the Project Manager at all times. Access to WMNA Environmental Management Department (EMD) personnel is also available for issue resolution if necessary.

Exhibit 1-1
LINES OF COMMUNICATION



1.3.2 Resolution Meeting

Following permit approval and the completion of the construction drawings and specifications for the project, a resolution meeting may be held. If a resolution meeting is required, it is recommended that the meeting be held prior to bidding the construction work and include all parties then involved, typically including the Project Manager, Designer, Geosynthetic QAE, and a WMNA EMD representative. If necessary, this meeting can be held in conjunction with the pre-construction meeting.

The purpose of this meeting is to establish lines of communication, review construction drawings and specifications for completeness and clarity, begin planning for coordination of tasks, anticipate any problems which might cause difficulties and delays in construction, and complete the QAP. All aspects of the design shall be reviewed during this meeting so that clarification and/or design changes may be made before the construction work is bid. In addition, the guidelines regarding quality assurance testing and problem resolution must be known and accepted by all.

A recommended agenda for the resolution meeting is presented in Exhibit 1-2. The meeting shall be documented by a person designated at the beginning of the meeting, and minutes shall be transmitted to all parties.

1.3.3 Pre-Construction Meeting

A pre-construction meeting shall be held at the site prior to beginning geosynthetic deployment. Typically, the meeting shall be attended by the Project Manager, Designer, Installer, Geosynthetic QAE, and a WMNA EMD representative.

Specific topics considered for this meeting include review of the project QAP for any problems or additions. In addition, the responsibilities of each party should be reviewed and understood clearly. A recommended agenda with specific topics for the pre-construction meeting is presented in Exhibit 1-3. The meeting shall be documented by a person designated at the beginning of the meeting, and minutes shall be transmitted to all parties.

1.3.4 Progress Meetings

A weekly progress meeting shall be held between the Geosynthetic QAE, Installer's Superintendent, Project Manager, and any other concerned parties. This meeting shall discuss current progress, planned activities for the next week, issues requiring resolution, and any new business or revisions to the work. The Geosynthetic QAE shall log any problems, decisions, or questions arising at this meeting in his weekly report. If any matter remains unresolved at the end of this meeting, the Project Manager shall be responsible for the resolution of the matter and the communication of the decision to the appropriate parties.

Exhibit 1-2
RESOLUTION MEETING AGENDA

1. Introductions

    A. Assign Minute Taker

    B. Identify Parties

        1. Project Manager
        2. Designer
        3. Geosynthetic Quality Assurance Consultant
        4. WMNA EMD representative
        5. Others

2. Distribution of Documents

    A. Design and Construction Drawings
    B. Specifications
    C. Construction Quality Assurance (CQA) Manuals
    D. Permit Documents

3. Review Construction Drawings and Specifications

    A. Tour Project Site

4. Complete Quality Assurance Plan (QAP)

    A. Project-specific Addendum to Quality Assurance Manual(s) (QAM(s))
    B. Project-specific Addendum to specifications

5. Contract Administration and Construction Issues

6. Define Lines of Communication

7. Project Deliverables

8. Schedule

Exhibit 1-3
PRE-CONSTRUCTION MEETING AGENDA

1. Introductions

   A. Assign Minute Taker

   B. Identify Parties

      1. Project Manager
      2. Installer
      3. Geosynthetic Quality Assurance Consultant
      4. Surveyor
      5. Designer
      6. Geosynthetic Quality Assurance Laboratory
      7. WMNA EMD Representative

2. Distribution of Documents

   A. Design and Construction Drawings and Specifications
   B. Geosynthetic Panel Layout
   C. Project QAP

3. Lines of Communication

   A. Lines of Communication
   B. Reporting Methods
   C. Progress Meetings
   D. Procedures for Approving Design Clarifications and Changes During Construction

4. Tour Project Site

5. Site Requirements

   A. Safety Rules
   B. Site Rules
   C. Work Schedule
   D. Storage of Materials
   E. Available Facilities

Exhibit 1-3 Continued
PRE-CONSTRUCTION MEETING AGENDA

5. Construction Issues

   A. Scope of Work
   B. Review Design
      1. Design and Construction Drawings and Specifications
      2. Geosynthetic Panel Layout
   C. Construction Procedures
      1. Proposed Construction Sequencing
      2. Equipment
   D. Construction Schedule
   E. Procedures for Preparing and Approving Change Orders

6. Construction Quality Assurance Plan

   A. Soils
   B. Geosynthetics
   C. Structural Systems (e.g., risers, piping, etc.)

7. Project Deliverables

   A. Responsibilities
      1. Designer
      2. Installer
      3. Geosynthetic Quality Assurance Consultant
      4. Geosynthetic Quality Assurance Laboratory
      5. Project Manager
   B. Distribution of Deliverables
   C. Approval Procedures

2.0 DOCUMENTATION

An effective QAP depends largely on identification of all construction activities that shall be monitored, and on assigning responsibilities for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The Geosynthetic QAC shall document that all requirements in the geosynthetic portions of the project QAP have been addressed and satisfied.

The Geosynthetic QAC shall provide the Project Manager with signed descriptive remarks, data sheets, and checklists to verify that all monitoring activities have been carried out. The Geosynthetic QAC shall also maintain at the job site a complete file of all documents which comprise the QAP, including plans and specifications, this QAM, checklists, test procedures, daily logs, and other pertinent documents.

2.1 DAILY REPORTS

Each Geosynthetic Quality Assurance Monitor shall complete a daily report and/or logs on prescribed forms, outlining all monitoring activities for that day. The precise areas, panel numbers, seams completed and approved, and measures taken to protect unfinished areas overnight shall be identified. Failed seams or other panel areas requiring remedial action shall be identified with regard to nature of action, required repair, and precise location. Repairs completed must also be identified. Any problems or concerns with regard to operations on site should also be noted. This report must be completed at the end of each monitor's shift, prior to leaving the site, and submitted to the Geosynthetic QAC.

The Geosynthetic QAE shall review the daily reports submitted by the Geosynthetic Quality Assurance Monitors, and incorporate a summary of their reports into the Geosynthetic QAE's daily report. Any matters requiring action by the Project Manager shall be identified. The report shall include a summary of the quantities of all geosynthetics installed that day. This report must be completed daily, summarizing the previous day's activities, and a copy submitted to the Project Manager at the beginning of the work day following the report date.

2.2 DESTRUCTIVE TESTING REPORTS

The destructive test reports from all sources shall be collated by the Geosynthetic QAC. This includes field tests, Installer's laboratory tests (if performed), and Geosynthetic QAL tests. A summary list of test samples pass/fail results shall be prepared by the Geosynthetic QAC on an ongoing basis, and submitted with the weekly progress reports.

2.3 PROGRESS REPORTS

Progress reports shall be prepared by the Geosynthetic QAE and submitted to the Project Manager. These reports shall be submitted every week, starting the first Friday of geosynthetics deployment on site. This report shall include: an overview of progress to date; an outline of any changes made to the plans, drawings, or specifications; any problems or deficiencies in installation at the site, and an outline of any action taken to remedy the situation(s); a summary of weather conditions; and a brief description of activities anticipated for the next reporting period.

All Geosynthetic QAE daily reports for the period should be appended to each progress report.

2.4 AS-BUILT DRAWINGS

As-built drawings shall be prepared by the Geosynthetic QAC. The as-built drawings shall include, at a minimum, the following information for geomembranes:

1. Dimensions of all geomembrane field panels.
2. Location, as accurate as possible, of each panel relative to the site survey grid (furnished by the Project Manager).
3. Identification of all seams and panels with appropriate numbers or identification codes (see Section 4.5.1).
4. Location of all patches and repairs.
5. Location of all destructive testing samples.

The as-built drawings shall illustrate each layer of geomembrane, and, if necessary, another drawing shall identify problems or unusual conditions of the geotextile or geonet layers. In addition, applicable cross-sections shall show layouts of geonets, geotextiles or geogrids in sump areas or any other areas which are unusual or differ from the design drawings.

2.5 FINAL CERTIFICATION REPORT

A final certification report shall be submitted upon completion of the work. This report shall summarize the activities of the project, and document all aspects of the quality assurance program performed.

The final certification report shall include, at a minimum, the following information:

1. Parties and personnel involved with the project
2. Scope of work
3. Outline of project
4. Quality assurance methods
5. Test results (conformance, destructive and non-destructive, including laboratory tests)
6. Certification, sealed and signed by a registered professional engineer
7. As-built drawings, sealed and signed by a registered professional engineer

The Geosynthetic QAC shall certify in the report that the installation has proceeded in accordance with the project QAP except as noted to the Project Manager. A recommended outline for the final certification report is given in Exhibit 2-1.

Exhibit 2-1

FINAL CONSTRUCTION QUALITY ASSURANCE CERTIFICATION REPORT
GENERAL OUTLINE

1. Introduction
   - Purpose
   - Scope
   - Unit Description

2. Project Specifications
   - Scope
   - Design Changes

3. Quality Assurance Plan
   - Scope
   - Project-Specific Addenda

4. Quality Assurance Work Performed
   - Weather Constraints
   - Conformance Testing
   - Visual Monitoring
   - Nondestructive Testing
   - Destructive Testing
   - Repairs

5. Summary and Conclusions

6. Project Certification

7. Appendices
   - Geosynthetic and/or Soils QAC Personnel
   - Contractor Personnel
   - Quality Assurance Plan (QAP) and Specification Modifications
   - Design Change Forms
   - Earthwork Testing Records (if required)
   - Conformance Testing Records
   - Manufacturer Quality Control Records
   - Quality Assurance Reports
   - Subgrade Acceptance Certificates
   - Panel Placement Records
   - Non-Destructive Seam Testing Records
   - Destructive Seam Testing Records
   - Repairs
   - As-Built Drawings

3.0 LINING SYSTEM ACCEPTANCE

Upon written recommendation by the Geosynthetic QAC, the Project Manager shall consider accepting the geosynthetic lining system. The conditions of acceptance are described below. The Installer and Manufacturer(s) will retain all ownership and responsibility for the geosynthetics in the lining system until acceptance by WMNA. At WMNA's discretion, the geosynthetic lining system may be accepted in sections or at points of substantial completion (see Appendix C).

The geosynthetic lining system will be accepted by WMNA when:

1. The installation of the lining system, or section thereof, is finished.
2. Verification of the adequacy of all seams and repairs, including associated testing, is completed.
3. All documentation of installation is completed.
4. The Geosynthetic QAC is able to recommend acceptance.

The Geosynthetic QAC shall certify that installation has proceeded in accordance with the geosynthetic portions of the project QAP except as noted to the Project Manager. This certification shall be provided in the final certification report as outlined in Section 2.5.

4.0 GEOMEMBRANES

4.1 MANUFACTURING PLANT INSPECTION

WMNA will conduct an annual inspection of the Manufacturer's plant. In addition, the Project Manager, or his designated representative, may visit the manufacturing plant for a project-specific inspection if deemed necessary. If possible, the project-specific inspection shall be prior to or during the manufacturing of the geomembrane rolls for that particular project. The purpose of the plant inspection is to review the manufacturing process and quality control procedures.

The manufacturing plant inspection shall include:

1. Verification that properties guaranteed by the Manufacturer meet all WMNA and/or project specifications.
2. Verification that the measurement of properties by the Manufacturer is properly documented and test methods used are acceptable.
3. Spot inspection of the rolls and verification that they are free of imperfections or any sign of contamination by foreign matter.
4. Review of handling, storage, and transportation procedures, and verification that these procedures will not damage the geomembrane.
5. Verification that roll packages have a label indicating the name of the manufacturer, type of geomembrane, thickness, roll number, and roll dimensions.
6. Verification that extrusion rods and/or beads are produced from the same base resin type as the geomembrane.

A report describing the inspection shall be retained by WMNA for annual inspections and by the Project Manager for project-specific inspections.

4.2 QUALITY CONTROL DOCUMENTATION

Prior to the installation of any geomembrane material, the Manufacturer or Installer shall provide the Project Manager with the following information:

1. The origin (resin supplier's name and resin production plant), identification (brand name and number), and production date of the resin.
2. Copies of the quality control certificates issued by the resin supplier.
3. Reports on tests conducted by the Manufacturer to verify that the quality of the resin used to manufacture the geomembrane meets the WMNA specifications (see Appendix A).
4. Reports on quality control tests conducted by the Manufacturer to verify that the geomembrane manufactured for the project meets the project specifications.
5. A statement indicating that the amount of reclaimed polymer added to the resin during manufacturing was done with appropriate cleanliness and does not exceed 2% by weight.

6. A list of the materials which comprise the geomembrane, expressed in the following categories as percent by weight: polyethylene, carbon black, other additives.
7. A specification for the geomembrane which includes all properties contained in the WMNA specifications (see Appendix A) measured using the appropriate test methods.
8. Written certification that minimum values given in the specification are guaranteed by the Manufacturer.
9. A characterization of the geomembrane based on the results of fingerprinting tests listed in Appendix B of this QAM.
10. Quality control certificates, signed by a responsible party employed by the Manufacturer. Each quality control certificate shall include roll identification numbers, sampling procedures, and results of quality control tests. At a minimum, results shall be given for:

    a. Density
    b. Carbon black content
    c. Carbon black dispersion
    d. Thickness
    e. Tensile properties
    f. Tear resistance

    These quality control tests shall be performed in accordance with the test methods specified in the WMNA specifications (see Appendix A), for every 40,000 ft^2 (4,000 m^2) of geomembrane produced.

The Manufacturer shall identify all rolls of geomembranes with the following:

1. Manufacturer's name
2. Product identification
3. Thickness
4. Roll number
5. Roll dimensions

The Geosynthetic QAE shall review these documents and shall report any discrepancies with the above requirements to the Project Manager. The Geosynthetic QAE shall verify that:

1. Property values certified by the Manufacturer meet all of its guaranteed specifications.
2. Measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.
3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.
4. Rolls are appropriately labeled.
5. Certified minimum properties meet the WMNA specifications (see Appendix A).

4.3 CONFORMANCE TESTING

Upon delivery of the rolls of geomembrane, the Geosynthetic QAC shall ensure that conformance test samples are obtained for the geomembrane. These samples shall then be forwarded to the Geosynthetic QAL for testing to ensure conformance to the WMNA specifications (see Appendix A).

If the Project Manager desires, the Geosynthetic QAC can perform the conformance test sampling at the manufacturing plant. This may be advantageous in expediting the installation process for very large projects.

The following conformance tests shall be conducted:

1. Density
2. Carbon black content
3. Carbon black dispersion
4. Thickness
5. Tensile characteristics

These conformance tests shall be performed in accordance with the test methods specified in the WMNA specifications (see Appendix A).

<u>4.3.1 Sampling Procedures</u>

The rolls to be sampled shall be selected by the Geosynthetic QAC. Samples shall be taken across the entire width of the roll and shall not include the first 3 ft (1 m). Unless otherwise specified, samples shall be 3 ft (1 m) long by the roll width. The Geosynthetic QAC shall mark the machine direction on the samples with an arrow.

A lot shall be defined as a group of consecutively numbered rolls from the same manufacturing line. Alternatively, a lot may be designated by the Geosynthetic QAC based on a review of all roll information including quality control documentation and manufacturing records.

Unless otherwise specified, samples shall be taken at a rate of one per lot, not to exceed one conformance test per 100,000 ft^2 (10,000 m^2) of geomembrane.

<u>4.3.2 Test Results</u>

All conformance test results shall be reviewed and accepted or rejected by the Geosynthetic QAE prior to the deployment of the geomembrane.

The Geosynthetic QAE shall examine all results from laboratory conformance testing and shall report any nonconformance to the Project Manager. The Geosynthetic QAE shall be responsible for checking that all test results meet or exceed the property values listed in the project specifications.

If the Manufacturer has reason to believe that failing tests may be the result of the Geosynthetic QAL incorrectly conducting the tests, the Manufacturer may request that the sample in question be retested by the Geosynthetic QAL with a technical representative of the Manufacturer present during the testing. This retesting shall be done at the expense of the Manufacturer. Alternatively, the Manufacturer may have the sample retested at two different WMNA approved Geosynthetic QALs at the expense of the Manufacturer. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original Geosynthetic QAL's test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the Project Manager.

If a test result is in nonconformance, all material from the lot represented by the failing test should be considered out of specification and rejected. Alternatively, at the option of the Project Manager, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting specification (note that this procedure is valid only when all rolls in the lot are consecutively produced and numbered from one manufacturing line). To isolate the out of specification material, additional samples must be taken from rolls that have roll numbers immediately adjacent to the roll that was sampled and failed. If both additional tests pass, the roll that represents the initial failed test and the roll manufactured immediately after that roll (next larger roll number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that bracket a greater number of rolls within the lot.

4.4 SUBGRADE PREPARATION

4.4.1 Surface Preparation

The earthwork contractor shall be responsible for preparing the supporting soil for geomembrane placement. The Project Manager shall coordinate the work of the earthwork contractor and the Installer so that the requirements of the specifications and the project QAP are met.

Before the geomembrane installation begins, the Geosynthetic QAC shall verify that:

1. A qualified land surveyor has verified all lines and grades.
2. A qualified geotechnical engineer has verified that the supporting soil meets the density specified in the project specifications.
3. The surface to be lined has been rolled, compacted, or handworked so as to be free of irregularities, protrusions, loose soil, and abrupt changes in grade.
4. The surface of the supporting soil does not contain stones which may be damaging to the geomembrane.
5. There is no area excessively softened by high water content.

6. There is no area where the surface of the soil contains desiccation cracks with dimensions exceeding those allowed by the project specifications.

The Installer shall certify in writing that the surface on which the geomembrane will be installed is acceptable. A certificate of acceptance (see Appendix C) shall be given by the Installer to the Geosynthetic QAC prior to commencement of geomembrane deployment in the area under consideration. The Project Manager shall be given a copy of this certificate by the Geosynthetic QAC.

After the supporting soil has been accepted by the Installer, it is the Installer's responsibility to indicate to the Project Manager any change in the supporting soil condition that may require repair work. The Project Manager may consult with the Geosynthetic QAC regarding the need for repairs. If the Geosynthetic QAC concurs with Installer, the Project Manager shall ensure that the supporting soil is repaired.

At any time before or during the geomembrane installation, the Geosynthetic QAC shall indicate to the Project Manager any locations which may not be adequately prepared for the geomembrane.

4.4.2 Anchor Trench

The Geosynthetic QAC shall verify that the anchor trench has been constructed according to the design drawings and specifications.

If the anchor trench is excavated in a clay material susceptible to desiccation, the amount of trench open at any time should be minimized. The Geosynthetic QAC shall inform the Project Manager of any signs of significant desiccation associated with the anchor trench construction.

Slightly rounded corners shall be provided in the trench so as to avoid sharp bends in the geomembrane. Excessive amounts of loose soil shall not be allowed to underlie the geomembrane in the anchor trench.

The anchor trench shall be adequately drained to prevent ponding or softening of the adjacent soils while the trench is open. The anchor trench shall be backfilled and compacted as outlined in the project specifications.

Care shall be taken when backfilling the trenches to prevent any damage to the geosynthetics. The Geosynthetic QAC shall observe the backfilling operation and advise the Project Manager of any problems. Any problems shall be documented by the Geosynthetic QAC in his daily report.

4.5 GEOMEMBRANE DEPLOYMENT

4.5.1 Panel Nomenclature

A field panel is defined as a unit of geomembrane which is to be seamed in the field, i.e., a field panel is a roll or a portion of roll cut in the field.

It shall be the responsibility of the Geosynthetic QAC to ensure that each field panel is given an identification code (number or letter-number) consistent with the layout plan. This identification code shall be agreed upon by the Project Manager, Installer and Geosynthetic QAC. This field panel identification code shall be as simple and logical as possible. In general, it is not appropriate to identify panels using roll numbers since roll numbers established in the manufacturing plant are usually cumbersome and are not related to location in the field. The Geosynthetic QAC shall establish a table or chart showing correspondence between roll numbers and field panel identification codes. The field panel identification code shall be used for all quality assurance records.

The Geosynthetic QAC shall verify that field panels are installed at the locations indicated on the Installer's layout plan, as approved by the Project Manager.

4.5.2 Panel Deployment Procedure

The Geosynthetic QAC shall review the panel deployment progress of the Installer (keeping in mind issues relating to wind, rain, clay liner desiccation, and other site-specific conditions) and advise the Project Manager on its compliance with the approved panel layout drawing and its suitability to the actual field conditions. Once approved, only the Project Manager can authorize changes to the panel deployment procedure. The Geosynthetic QAC shall verify that the condition of the supporting soil does not change detrimentally during installation.

The Geosynthetic QAC shall record the identification code, location, and date of installation of each field panel.

4.5.3 Deployment Weather Conditions

Geomembrane deployment shall not proceed at an ambient temperature below 32°F (0°C) or above 104°F (40°C) unless otherwise authorized, in writing, by the Project Manager. Geomembrane placement shall not be performed during any precipitation, in the presence of excessive moisture (e.g., fog, dew), in an area of ponded water, or in the presence of excessive winds. Geomembrane deployment shall not be undertaken if weather conditions will preclude material seaming following deployment.

The Geosynthetic QAC shall verify that the above conditions are fulfilled. Ambient temperature shall be measured by the Geosynthetic QAC in the area in which the panels are to be deployed. The Geosynthetic QAC shall inform the Project Manager of any weather related problems which may not allow geomembrane placement to proceed.

4.5.4 Method of Deployment

Before the geomembrane is handled on site, the Geosynthetic QAC shall verify that handling equipment to be used on the site is adequate and does not pose risk of damage to the geomembrane. During handling, the Geosynthetic QAC shall observe and verify that the Installer's personnel handle the geomembrane with care.

The Geosynthetic QAC shall verify the following:

1. Any equipment used does not damage the geomembrane by handling, trafficking, excessive heat, leakage of hydrocarbons, or other means.
2. The prepared surface underlying the geomembrane has not deteriorated since previous acceptance, and is still acceptable immediately prior to geomembrane placement.
3. Any geosynthetic elements immediately underlying the geomembrane are clean and free of debris.
4. All personnel do not smoke or wear damaging shoes while working on the geomembrane, or engage in other activities which could damage the geomembrane.
5. The method used to unroll the panels does not cause excessive scratches or crimps in the geomembrane and does not damage the supporting soil.
6. The method used to place the panels minimized wrinkles (especially differential wrinkles between adjacent panels).
7. Adequate temporary loading and/or anchoring (e.g., sand bags, tires), not likely to damage the geomembrane, has been placed to prevent uplift by wind. In case of high winds, continuous loading, e.g., by sand bags, is recommended along edges of panels to the minimize risk of wind flow under the panels.
8. Direct contact with the geomembrane is minimized, and the geomembrane is protected by geotextiles, extra geomembrane, or other suitable materials, in areas where excessive traffic may be expected.

The Geosynthetic QAC shall inform the Project Manager if the above conditions are not fulfilled.

4.5.5 Damage and Defects

Upon delivery to the site, the Geosynthetic QAC shall conduct a surface observation of all rolls for defects and for damage. This inspection shall be conducted without unrolling rolls unless defects or damages are found or suspected. The Geosynthetic QAC shall advise the Project Manager, in writing, of any rolls or portions of rolls which should be rejected and removed from the site because they have severe flaws, and/or minor repairable flaws.

The Geosynthetic QAC shall inspect each panel, after placement and prior to seaming, for damage and/or defects. The Geosynthetic QAC shall advise the Project Manager which panels, or portions of panels, should be rejected, repaired, or accepted. Damaged panels, or portions of damaged panels, which have been rejected shall be marked and their removal from the work area recorded by the Geosynthetic QAC. Repairs shall be made using procedures described in Section 4.9.

4.5.6 Writing on the Liner

To avoid confusion, the Installer and the Geosynthetic QAC shall each use different colored markers that are readily visible for writing on the geomembrane. The markers used must be semi-permanent and compatible with the geomembrane. The Installer shall use a white marker to write on the geomembrane. The Geosynthetic QAC shall use a yellow marker.

4.6 FIELD SEAMING

4.6.1 Seam Layout

Before installation begins, the Installer must provide the Project Manager and the Geosynthetic QAC with a panel layout drawing, i.e., a drawing of the facility to be lined showing all expected seams. The Geosynthetic QAE shall review the panel layout drawing and verify that it is consistent with accepted state-of-practice. No panels may be seamed without the written approval of the panel layout drawing by the Project Manager. In addition, panels not specifically shown on the panel layout drawing may not be used without the Project Manager's prior approval.

In general, seams should be oriented parallel to the line of maximum slope, i.e., oriented along, not across, the slope. In corners and odd-shaped geometric locations, the number of seams should be minimized. No horizontal seam should be less than 5 ft (1.5 m) from the toe of the slope, or areas of potential stress concentrations, unless otherwise authorized by the Project Manager.

A seam numbering system compatible with the panel numbering system shall be used by the Geosynthetic QAC.

4.6.2 Accepted Seaming Methods

Approved processes for field seaming are extrusion welding and fusion welding. Proposed alternate processes shall be documented and submitted by the Installer to the Project Manager for approval. Only apparatus which have been specifically approved by make and model shall be used. The Project Manager shall submit all documentation regarding seaming methods to be used to the Geosynthetic QAC for review.

4.6.2.1 Extrusion Process

The Geosynthetic QAC shall log ambient, seaming apparatus, and geomembrane surface temperatures at appropriate intervals and report any noncompliances to the Project Manager.

The Geosynthetic QAC shall verify that:

1. The Installer maintains on-site the number of spare operable seaming apparatus decided upon at the pre-construction meeting.
2. Equipment used for seaming is not likely to damage the geomembrane.
3. Prior to beginning a seam, the extruder is purged until all heat-degraded extrudate has been removed from the barrel.
4. Clean and dry welding rods or extrudate pellets are used.
5. The electric generator is placed on a smooth base such that no damage occurs to the geomembrane.
6. Grinding shall be completed no more than 1 hour prior to seaming.
7. A smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage.
8. The geomembrane is protected from damage in heavily trafficked areas.
9. Exposed grinding marks adjacent to an extrusion weld shall be minimized. In no instance shall exposed grinding marks extend more than 1/4" from the seamed area.
10. In general, the geomembrane panels are aligned to have a nominal overlap of 3 in (75 mm) for extrusion welding. In any event, the final overlap shall be sufficient to allow peel tests to be performed on the seam.
11. No solvent or adhesive is used unless the product is approved in writing by the Project Manager prior to use (samples shall be submitted to the Project Manager for testing and evaluation).
12. The procedure used to temporarily bond adjacent panels together does not damage the geomembrane; in particular, the temperature of hot air at the nozzle of any temporary welding apparatus is controlled such that the geomembrane is not damaged or degraded.

4.6.2.2 Fusion Process

The Geosynthetic QAC shall log ambient, seaming apparatus, and geomembrane surface temperatures at appropriate intervals and report any noncompliances to the Project Manager.

The Geosynthetic QAC shall also verify that:

1. The Installer maintains on-site the number of spare operable seaming apparatus decided upon at the pre-construction meeting.
2. Equipment used for seaming is not likely to damage the geomembrane.
3. For cross seams, the edge of the cross seam is ground to an incline prior to welding.

4. The electric generator is placed on a smooth base such that no damage occurs to the geomembrane.
5. A smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage.
6. The geomembrane is protected from damage in heavily trafficked areas.
7. A movable protective layer is used as required by the Installer directly below each overlap of geomembrane that is to be seamed to prevent buildup of moisture between the sheets and prevent debris from collecting around the pressure rollers.
8. In general, the geomembrane panels are aligned to have a nominal overlap of 5 in (125 mm) for fusion welding. In any event, the final overlap shall be sufficient to allow peel tests to be performed on the seam.
9. No solvent or adhesive is used unless the product is approved in writing by the Project Manager prior to use (samples shall be submitted to the Project Manager for testing and evaluation).

4.6.3 Seam Preparation

The Geosynthetic QAC shall verify that prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris or foreign material of any kind. If seam overlap grinding is required, the Geosynthetic QAC must ensure that the process is completed according to the Manufacturer's instructions within one hour of the seaming operation, and in a way that does not damage the geomembrane. The Geosynthetic QAC shall also verify that seams are aligned with the fewest possible number of wrinkles and "fishmouths".

4.6.4 Trial Seams

Trial seams shall be made on fragment pieces of geomembrane liner to verify that conditions are adequate for production seaming. Such trial seams shall be made at the beginning of each seaming period, and at least once each five hours, for each production seaming apparatus used that day. Each seamer shall make at least one trial seam each day. Trial seams shall be made under the same conditions as actual seams.

The trial seam sample shall be at least 5 ft (1.0 m) long by 1 ft (0.3 m) wide (after seaming) with the seam centered lengthwise. Seam overlap shall be as indicated in Section 4.6.2.

Two specimens shall be cut from the sample with a 1 in (25 mm) wide die. The specimens shall be cut by the Installer at locations selected randomly along the trial seam sample by the Geosynthetic QAC. The specimens shall be tested in peel using a field tensiometer. The tensiometer shall be capable of maintaining a constant jaw separation rate of two inches per minute. They should not fail in the seam as described in Section 4.8.5. If a specimen fails, the entire operation shall be repeated. If the additional specimen fails, the seaming apparatus and seamer shall not be accepted and shall not be used for seaming until the deficiencies are corrected and two consecutive successful trial welds are achieved. The Geosynthetic QAC shall observe all trial seam procedures.

The remainder of the successful trial seam sample shall be cut into three pieces, one to be retained in the Project Manager's archives, one to be given to the Installer, and one to be retained by the Geosynthetic QAC for possible laboratory testing. Each portion of the sample shall be assigned a number and marked accordingly by the Geosynthetic QAC, who shall also log the date, hour, ambient temperature, number of seaming unit, name of seamer, and pass or fail description.

If agreed upon between the Project Manager and the Geosynthetic QAE, and documented by the Geosynthetic QAE in his daily report, the remaining portion of the trial seam sample can be subjected to destructive testing as indicated in Section 4.8.6. If a trial seam sample fails a test conducted by the Geosynthetic QAL, then a destructive seam test sample shall be taken from each of the seams completed by the seamer during the shift related to the considered trial seam. These samples shall be forwarded to the Geosynthetic QAL and, if they fail the tests, the procedure indicated in Section 4.8.7 shall apply. The conditions of this paragraph shall be considered satisfied for a given seam if a destructive seam test sample has already been taken.

4.6.5 General Seaming Procedures

During general seaming, the Geosynthetic QAC shall be cognizant of the following:

1. For fusion welding, it may be necessary to place a movable protective layer of plastic directly below each overlap of geomembrane that is to be seamed. This is to prevent any moisture buildup between the sheets to be welded and prevent debris from collecting around the pressure rollers.
2. If required, a firm substrate shall be provided by using a flat board, a conveyor belt, or similar hard surface directly under the seam overlap to achieve proper support.
3. Fishmouths or wrinkles at the seam overlaps shall be cut along the ridge of the wrinkle in order to achieve a flat overlap. The cut fishmouths or wrinkles shall be seamed and any portion where the overlap is inadequate shall then be patched with an oval or round patch of the same geomembrane extending a minimum of 6 in (150 mm) beyond the cut in all directions.
4. If seaming operations are carried out at night, adequate illumination shall be provided.
5. Seaming shall extend to the outside edge of panels placed in the anchor trench.
6. All cross seam tees should be extrusion welded to a minimum distance of 4 in on each side of the tee.
7. No field seaming shall take place without the Master Seamer being present.

The Geosynthetic QAC shall verify that the above seaming procedures (or any other procedures agreed upon and indicated in the project QAP) are followed, and shall inform the Project Manager of any nonconformance.

4.6.6 Seaming Weather Conditions

4.6.6.1 Normal Weather Conditions

The normal required weather conditions for seaming are as follows:

1. Ambient temperature between 32°F (0°C) and 104°F (40°C).
2. Dry conditions, i.e. no precipitation or other excessive moisture, such as fog or dew.
3. No excessive winds.

The Geosynthetic QAE shall verify that these weather conditions are fulfilled and notify the Project Manager in writing if they are not. Ambient temperature shall be measured by the Geosynthetic QAC in the area in which the panels are to be placed. The Project Manager will then decide if the installation is to be stopped or special procedures used.

4.6.6.2 Cold Weather Conditions

To ensure a quality installation, if seaming is conducted when the ambient temperature is below 32°F (0°C), the following conditions must be met:

1. Geomembrane surface temperatures shall be determined by the Geosynthetic QAC at intervals of at least once per 100 foot of seam length to determine if preheating is required. For extrusion welding, preheating is required if the surface temperature of the geomembrane is below 32°F (0°C).
2. Preheating may be waived by the Project Manager based on a recommendation from the Geosynthetic QAE, if the Installer demonstrates to the Geosynthetic QAE's satisfaction that welds of equivalent quality may be obtained without preheating at the expected temperature of installation.
3. If preheating is required, the Geosynthetic QAC shall inspect all areas of geomembrane that have been preheated by a hot air device prior to seaming, to ensure that they have not been overheated.
4. Care shall be taken to confirm that the surface temperatures are not lowered below the minimum surface temperatures specified for welding due to winds or other adverse conditions. It may be necessary to provide wind protection for the seam area.
5. All preheating devices shall be approved prior to use by the Project Manager.
6. Additional destructive tests (as described in Section 4.8) shall be taken at an interval between 500 feet and 250 feet of seam length, at the discretion of the Geosynthetic QAE.
7. Sheet grinding may be performed before preheating, if applicable.
8. Trial seaming, as described in Section 4.6.4, shall be conducted under the same ambient temperature and preheating conditions as the actual seams. Under cold weather conditions, new trial seams shall be conducted if the ambient temperature drops by more than 5°F from the initial trial seam test conditions.

4.6.6.3 Warm Weather Conditions

At ambient temperatures above 104°F, no seaming of the geomembrane shall be permitted unless the Installer can demonstrate to the satisfaction of the Project Manager that geomembrane seam quality is not compromised.

Trial seaming, as described in Section 4.6.4, shall be conducted under the same ambient temperature conditions as the actual seams.

At the option of the Geosynthetic QAC, additional destructive tests (as described in Section 4.8) may be required for any suspect areas.

4.7 NONDESTRUCTIVE SEAM TESTING

4.7.1 Concept

The Installer shall nondestructively test all field seams over their full length using a vacuum test unit, air pressure test (for double fusion seams only), or other approved method. Vacuum testing and air pressure testing are described in Sections 4.7.2 and 4.7.3 respectively. The purpose of nondestructive tests is to check the continuity of seams. It does not provide quantitative information on seam strength. Nondestructive testing shall be carried out as the seaming work progresses, not at the completion of all field seaming.

For all seams, the Geosynthetic QAC shall:

1. Observe nondestructive testing procedures.
2. Record location, data, test unit number, name of tester, and outcome of all testing.
3. Inform the Installer and Project Manager of any required repairs.

Any seams that cannot be nondestructively tested shall be cap-stripped with the same geomembrane. The cap-stripping operations shall be observed by the Geosynthetic QAC and Installer for uniformity and completeness.

4.7.2 Vacuum Testing

The following procedures are applicable to vacuum testing.

1. The equipment shall consist of the following:

   a. A vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, a porthole or valve assembly, and a vacuum gauge.
   b. A pump assembly equipped with a pressure controller and pipe connections.
   c. A rubber pressure/vacuum hose with fittings and connections.

d. A soapy solution.
e. A bucket and wide paint brush, or other means of applying the soapy solution.

2. The following procedures shall be followed:

   a. Energize the vacuum pump and reduce the tank pressure to approximately 5 psi (10 in of Hg) (35 kPa) gauge.
   b. Wet a strip of geomembrane approximately 12 in x 48 in (0.3 m x 1.2 m) with the soapy solution.
   c. Place the box over the wetted area.
   d. Close the bleed valve and open the vacuum valve.
   e. Ensure that a leak-tight seal is created.
   f. For a period of not less than 10 seconds, apply vacuum and examine the geomembrane through the viewing window for the presence of soap bubbles.
   g. If no bubble appears after 10 seconds, close the vacuum valve and open the bleed valve, move the box over the next adjoining area with a minimum 3 in (75 mm) overlap, and repeat the process.
   h. All areas where soap bubbles appear shall be marked and repaired in accordance with Section 4.9.3.

4.7.3 Air Pressure Testing

The following procedures are applicable to double fusion welding which produces a double seam with an enclosed space.

1. The equipment shall consist of the following:
   a. An air pump (manual or motor driven), equipped with pressure gauge capable of generating and sustaining a pressure between 25 and 30 psi (160 and 200 kPa) and mounted on a cushion to protect the geomembrane.
   b. A rubber hose with fittings and connections.
   c. A sharp hollow needle, or other approved pressure feed device.

2. The following procedures shall be followed:

   a. Seal both ends of the seam to be tested.
   b. Insert needle or other approved pressure feed device into the air channel created by the fusion weld.
   c. Insert a protective cushion between the air pump and the geomembrane.
   d. Energize the air pump to a pressure between 25 and 30 psi (160 and 200 kPa), close valve, allow 2 minutes for pressure to stabilize, and sustain pressure for at least 5 minutes.
   e. If loss of pressure exceeds 4 psi (30 kPa) or does not stabilize, locate faulty area and repair in accordance with Section 4.9.3.

f. Cut opposite end of tested seam area once testing is completed to verify continuity of the air channel. If air does not escape, locate blockage and retest unpressurized area. Seal the cut end of the air channel.
g. Remove needle or other approved pressure feed device and seal.

4.7.4 Test Failure Procedures

The Installer shall complete any required repairs in accordance with Section 4.9. For repairs, the Geosynthetic QAC shall:

1. Observe the repair and testing of the repair.
2. Mark on the geomembrane that the repair has been made.
3. Document the repair procedures and test results.

4.8 DESTRUCTIVE SEAM TESTING

4.8.1 Concept

Destructive seam tests shall be performed at selected locations. The purpose of these tests is to evaluate seam strength. Seam strength testing shall be done as the seaming work progresses, not at the completion of all field seaming.

4.8.2 Location and Frequency

The Geosynthetic QAC shall select locations where seam samples will be cut out for laboratory testing. Those locations shall be established as follows:

1. A minimum frequency of one test location per 500 ft (150 m) of seam length performed by each welder. This minimum frequency is to be determined as an average taken throughout the entire facility.
2. Test locations shall be determined during seaming at the Geosynthetic QAC's discretion. Selection of such locations may be prompted by suspicion of overheating, contamination, offset welds, or any other potential cause of imperfect welding.

The Installer shall not be informed in advance of the locations where the seam samples will be taken.

4.8.3 Sampling Procedures

Samples shall be cut by the Installer at locations chosen by the Geosynthetic QAC as the seaming progresses so that laboratory test results are available before the geomembrane is covered by another material. The Geosynthetic QAC shall:

1. Observe sample cutting.
2. Assign a number to each sample, and mark it accordingly.

3. Record sample location on layout drawing.
4. Record reason for taking the sample at this location (e.g., statistical routine, suspicious feature of the geomembrane).

All holes in the geomembrane resulting from destructive seam sampling shall be immediately repaired in accordance with repair procedures described in Section 4.9.3. The continuity of the new seams in the repaired area shall be tested according to Section 4.7.2.

4.8.4 Sample Dimensions

At a given sampling location, two types of samples shall be taken by the Installer. First, two samples for field testing should be taken. Each of these samples shall be cut with a 1 in (25 mm) wide die, with the seam centered parallel to the width. The distance between these two samples shall be 42 in (1.1 m). If both samples pass the field test described in Section 4.8.5, a sample for laboratory testing shall be taken.

The sample for laboratory testing shall be located between the samples for field testing. The sample for laboratory testing shall be 12 in (0.3 m) wide by 42 in (1.1 m) long with the seam centered lengthwise. The sample shall be cut into three parts and distributed as follows:

1. One portion to the Installer for optional laboratory testing, 12 in x 12 in. (0.3 m x 0.3 m)
2. One portion for Geosynthetic QAL testing, 12 in x 18 in (0.3 m x 0.5 m) and
3. One portion to the Project Manager for archive storage, 12 in x 12 in (0.3 m x 0.3 m).

Final determination of the sample sizes shall be made at the pre-construction meeting.

4.8.5 Field Testing

The two 1 in (25 mm) wide strips mentioned in Section 4.8.4 and Section 4.6.4 shall be tested in the field using a tensiometer for peel and shall not fail according to the criteria in Table A-2, Appendix A. The tensiometer shall be capable of maintaining a constant jaw separation rate of two inches per minute. If the test passes in accordance with this section, the sample qualifies for testing in the laboratory. If it fails, the seam should be repaired in accordance with Section 4.8.7. Final judgement regarding seam acceptability, based on the failure criteria, rests with the Geosynthetic QAE.

The Geosynthetic QAC shall witness all field tests and mark all samples and portions with their number. The Geosynthetic QAC shall also log the date and time, ambient temperature, number of seaming unit, name of seamer, welding apparatus temperatures and pressures, and pass or fail description, and attach a copy to each sample portion.

4.8.6 Laboratory Testing

Destructive test samples shall be packaged and shipped, if necessary, under the responsibility of the Geosynthetic QAC in a manner which will not damage the test sample. The Project Manager will be responsible for storing the archive samples. Test samples shall be tested by the Geosynthetic QAL.

Testing shall include "Seam Strength" and "Peel Adhesion". These terms are defined in the specifications. The minimum acceptable values to be obtained in these tests are indicated in the WMNA specifications (see Appendix A). At least 5 specimens shall be tested in each shear and peel. Specimens shall be selected alternately by test from the samples (i.e., peel, shear, peel, shear...). A passing test shall meet the minimum acceptable values in at least 4 of the 5 specimens tested for each method.

The Geosynthetic QAL shall provide verbal test results no more than 24 hours after they receive the samples. The Geosynthetic QAE shall review laboratory test results as soon as they become available, and make appropriate recommendations to the Project Manager.

4.8.7 Destructive Test Failure Procedures

The following procedures shall apply whenever a sample fails a destructive test, whether that test is conducted by the Geosynthetic QAL, or by field tensiometer. The Installer has two options:

1. The Installer can repair the seam between any two passing test locations.
2. The Installer can trace the welding path to an intermediate location (at 10 ft (3 m) minimum from the point of the failed test in each direction) and take a sample with a 1 in (25 mm) wide die for an additional field test at each location. If these additional samples pass the test, then full laboratory samples are taken. If these laboratory samples pass the tests, then the seam is repaired between these locations. If either sample fails, then the process is repeated to establish the zone in which the seam should be repaired.

All acceptable repaired seams shall be bound by two locations from which samples passing laboratory destructive tests have been taken. Passing laboratory destructive tests of trial seam samples taken as indicated in Section 4.6.4 may be used as a boundary for the failing seam. In cases exceeding 150 ft (50 m) of repaired seam, a sample taken from the zone in which the seam has been repaired must pass destructive testing. Repairs shall be made in accordance with Section 4.9.

The Geosynthetic QAC shall document all actions taken in conjunction with destructive test failures.

4.9 DEFECTS AND REPAIRS

4.9.1 Identification

All seams and non-seam areas of the geomembrane shall be examined by the Geosynthetic QAC for identification of defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter. Because light reflected by the geomembrane helps to detect defects, the surface of the geomembrane shall be clean at the time of examination. The geomembrane surface shall be cleaned by the Installer if the amount of dust or mud inhibits examination.

4.9.2 Evaluation

Each suspect location both in seam and non-seam areas shall be nondestructively tested using the methods described in Section 4.7 as appropriate. Each location which fails the nondestructive testing shall be marked by the Geosynthetic QAC and repaired by the Installer. Work shall not proceed with any materials which will cover locations which have been repaired until appropriate nondestructive and laboratory test results with passing values are available.

4.9.3 Repair Procedures

Any portion of the geomembrane exhibiting a flaw, or failing a destructive or nondestructive test, shall be repaired. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure shall be agreed upon between the Project Manager, Installer, and Geosynthetic QAE.

1. The repair procedures available include:

   a. Patching, used to repair large holes, tears, undispersed raw materials, and contamination by foreign matter.
   b. Spot welding or seaming, used to repair small tears, pinholes, or other minor, localized flaws.
   c. Capping, used to repair large lengths of failed seams.
   d. Extrusion welding the flap, used to repair areas of inadequate fusion seams, which have an exposed edge. Repairs of this type shall be approved by the Geosynthetic QAE and shall not exceed 50 ft (15 m) in length.
   e. Removing bad seam and replacing with a strip of new material welded into place.

2. For any repair method, the following provisions shall be satisfied:

   a. Surfaces of the geomembrane which are to be repaired using extrusion methods shall be abraded no more than one hour prior to the repair.
   b. All surfaces shall be clean and dry at the time of the repair.

c. All seaming equipment used in repairing procedures shall meet the requirements of the project QAP.
d. Patches or caps shall extend at least 6 in (150 mm) beyond the edge of the defect, and all corners of patches shall be rounded with a radius of approximately 3 in (75 mm).

4.9.4 Repair Verification

Each repair shall be numbered and logged. Each repair shall be nondestructively tested using the methods described in Section 4.7 as appropriate. Repairs which pass the nondestructive test shall be taken as an indication of an adequate repair. Repairs more than 150 ft long may be of sufficient extent to require destructive test sampling, at the discretion of the Geosynthetic QAE. Failed tests indicate that the repair shall be redone and retested until a passing test results. The Geosynthetic QAC shall observe all nondestructive testing of repairs and shall record the number of each repair, date, and test outcome.

4.9.5 Large Wrinkles

When seaming of the geomembrane is completed, and prior to placing overlying materials, the Geosynthetic QAE shall indicate to the Project Manager which wrinkles should be cut and reseamed by the Installer. The number of wrinkles to be repaired should be kept to an absolute minimum. Therefore, wrinkles should be located during the coldest part of the installation process, while keeping in mind the forecasted weather to which the uncovered geomembrane may be exposed. Wrinkles are considered to be large when the geomembrane can be folded over on to itself. This is generally the case for a wrinkle that extends 12 in. from the subgrade. Seams produced while repairing wrinkles shall be tested as outlined above.

When placing overlying material on the geomembrane, every effort must be made to minimize wrinkle development. If possible, cover should be placed during the coolest weather available. In addition, small wrinkles should be isolated and covered as quickly as possible to prevent their growth. The placement of cover materials shall be observed by the Geosynthetic QAC to ensure that wrinkle formation is minimized.

4.10 GEOMEMBRANE PROTECTION

The quality assurance procedures indicated in this Section are intended only to assure that the installation of adjacent materials does not damage the geomembrane. The quality assurance of the adjacent materials themselves should be covered in separate sections of the project QAP as necessary.

4.10.1 Soils

A copy of the specifications prepared by the Designer for placement of soils shall be given to the Geosynthetic QAE by the Project Manager. The Geosynthetic QAE shall verify that these specifications are consistent with the state-of-practice such as:

1. Placement of soils on the geomembrane shall not proceed at an ambient temperature below 32°F (0°C) nor above 104°F (40°C) unless otherwise specified.
2. Placement of soil on the geomembrane should be done during the coolest part of the day to minimize the development of wrinkles in the geomembrane.
3. A geotextile or other cushion approved by the Designer is generally required between aggregate and the geomembrane.
4. Equipment used for placing soil shall not be driven directly on the geomembrane.
5. A minimum thickness of 1 ft (0.3 m) of soil is specified between a light dozer (ground pressure of 5 psi (35 kPa) or lighter) and the geomembrane.
6. In any areas traversed by any vehicles other than low ground pressure vehicles approved by the Project Manager, the soil layer shall have a minimum thickness of 3 ft (0.9 m). This requirement may be waived if provisions are made to protect the geomembrane through an engineered design. Drivers shall proceed with caution when on the overlying soil and prevent spinning of tires or sharp turns.

The Geosynthetic QAC shall measure soil thickness and verify that the required thicknesses are present. The Geosynthetic QAC must also verify that final thicknesses are consistent with the design and verify that placement of the soil is done in such a manner that geomembrane damage is unlikely. The Geosynthetic QAE shall inform the Project Manager if the above conditions are not fulfilled.

4.10.2 Concrete

A copy of the specifications prepared by the Designer for placement of concrete shall be given by the Project Manager to the Geosynthetic QAC. The Geosynthetic QAC shall verify that these specifications are consistent with the state-of-practice, including the use of geosynthetic layers between concrete and geomembrane. The Geosynthetic QAC shall verify that geosynthetic layers are placed between the concrete and the geomembrane according to design specifications. The Geosynthetic QAC will also verify that construction methods used are not likely to damage the geomembrane.

4.10.3 Sumps and Appurtenances

A copy of the plans and specifications prepared by the Designer for sumps and appurtenances shall be given by the Project Manager to the Geosynthetic QAC. The Geosynthetic QAC shall review these plans and verify that:

1. Installation of the geomembrane in sump and appurtenant areas, and connection of geomembrane to sumps and appurtenances have been made according to specifications.

2. Extreme care is taken while welding around appurtenances since neither non-destructive nor destructive testing may be feasible in these areas.
3. The geomembrane has not been visibly damaged while making connections to sumps and appurtenances.

The Geosynthetic QAC shall inform the Project Manager in writing if the above conditions are not fulfilled.

5.0 GEOTEXTILES

5.1 MANUFACTURING PLANT INSPECTION

WMNA will conduct a periodic inspection of the Manufacturer's plant. In addition, the Project Manager, or his designated representative, may visit the manufacturing plant for a project-specific inspection if deemed necessary. If possible, the project-specific inspection shall be prior to or during the manufacturing of the geotextile rolls for that particular project. The purpose of the plant inspection is to review the manufacturing process and quality control procedures.

The manufacturing plant inspection shall include:

1. Verification that properties guaranteed by the Manufacturer meet all WMNA and/or project specifications.
2. Verification that the measurement of properties by the Manufacturer is properly documented and test methods used are acceptable.
3. Spot inspection of the rolls and verification that they are free of imperfections or any sign of contamination by foreign matter.
4. Review of packaging, handling, storage, and transportation procedures and verification that these procedures will not damage the geotextile.
5. Verification that roll packages have a label indicating the name of the manufacturer, type of geotextile, roll number, and roll dimensions.
6. Verification that the geotextiles are inspected continuously for the presence of needles using a metal detector.

A report describing the inspection will be retained by WMNA for periodic inspections and by the Project Manager for project-specific inspections.

5.2 QUALITY CONTROL DOCUMENTATION

Prior to the installation of any geotextile, the Manufacturer or Installer shall provide the Project Manager with the following information:

1. The origin (resin supplier's name and resin production plant) and identification (brand name and number) of the resin used to manufacture the geotextile.
2. Copies of the quality control certificates issued by the resin supplier.
3. Reports on tests conducted by the Manufacturer to verify that the quality of the resin used to manufacture the geotextile meets the Manufacturer's resin specifications.
4. Reports on quality control tests conducted by the Manufacturer to verify that the geotextile manufactured for the project meets the project specifications.
5. A statement indicating that the reclaimed polymer added to the resin during manufacturing was done with appropriate cleanliness.
6. A list of the materials which comprise the geotextile, expressed in the following categories as percent by weight: base polymer, carbon black, other additives.

7. A specification for the geotextile which includes all properties contained in the project specifications measured using the appropriate test methods.
8. Written certification that minimum average roll values given in the specification are guaranteed by the Manufacturer.
9. For non-woven geotextiles, written certification that the Manufacturer has continuously inspected the geotextile for the presence of needles and found the geotextile to be needle free.
10. Quality control certificates, signed by a responsible party employed by the Manufacturer. The quality control certificates shall include roll identification numbers, sampling procedures and results of quality control tests. At a minimum, results shall be given for:

    a. Mass per unit area
    b. Grab strength
    c. Trapezoidal tear strength
    d. Burst strength
    e. Puncture strength
    f. Thickness

    Quality control tests shall be performed in accordance with the test methods specified in the project specifications for at least every 100,000 ft^2 (10,000 m^2) of geotextile produced.

The Manufacturer shall identify all rolls of geotextiles with the following:

1. Manufacturer's name
2. Product identification
3. Roll number
4. Roll dimensions

The Geosynthetic QAE shall review these documents and shall report any discrepancies with the above requirements to the Project Manager. The Geosynthetic QAE shall verify that:

1. Property values certified by the Manufacturer meet all of its guaranteed specifications.
2. Measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.
3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.
4. Roll packages are appropriately labeled.
5. Certified minimum average roll properties meet the project specifications.

5.3 CONFORMANCE TESTING

Upon delivery of the rolls of geotextiles, the Geosynthetic QAC shall ensure that conformance test samples are obtained for the geotextile. These samples shall then be forwarded to the Geosynthetic QAL for testing to ensure conformance to ensure conformance to the project specifications.

At a minimum, the following conformance tests shall generally be performed on geotextiles:

1. Mass per unit area
2. Grab strength
3. Trapezoidal tear strength
4. Burst strength
5. Puncture strength
6. Thickness

These conformance tests shall be performed in accordance with the test methods specified in the project specifications. Other conformance tests may be required by the project specifications.

5.3.1 Sampling Procedures

The rolls to be sampled shall be selected by the Geosynthetic QAC. Samples shall be taken across the entire width of the roll and shall not include the first complete revolution of fabric on the roll. Samples shall not be taken from any portion of a roll which has been subjected to excess pressure or stretching. Unless otherwise specified, samples shall be 3 ft (1 m) long by the roll width. The Geosynthetic QAC shall mark the machine direction on the samples with an arrow. All lots of material and the particular test sample that represents each lot should be defined before the samples are taken.

A lot shall be defined as a group of consecutively numbered rolls from the same manufacturing line. Alternatively, a lot may be designated by the Geosynthetic QAC based on a review of all roll information including quality control documentation and manufacturing records.

Unless otherwise specified, samples shall be taken at a rate of one per lot, not to exceed one conformance test per 100,000 ft^2 (10,000 m^2) of geotextile.

5.3.2 Test Results

All conformance test results shall be reviewed and accepted or rejected by the Geosynthetic QAE prior to the deployment of the geotextile.

The Geosynthetic QAE shall examine all results from laboratory conformance testing and shall report any nonconformance to the Project Manager. The Geosynthetic QAE shall be responsible for checking that all test results meet or exceed the property values listed in the project specifications.

If the Manufacturer has reason to believe that failing tests may be the result of the Geosynthetic QAL incorrectly conducting the tests, the Manufacturer may request that the sample in question be retested by the Geosynthetic QAL with a technical representative of the Manufacturer present during the testing. This retesting shall be done at the expense of the Manufacturer. Alternatively, the Manufacturer may have the sample retested at two different WMNA approved Geosynthetic QALs at the expense of the Manufacturer. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original Geosynthetic QAL's test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the Project Manager.

If a test result is in nonconformance, all material from the lot represented by the failing test should be considered out of specification and rejected. Alternatively, at the option of the Project Manager, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting specification (note that this procedure is valid only when all rolls in the lot are consecutively produced and numbered from one manufacturing line). To isolate the out of specification material, additional samples must be taken from rolls that have roll numbers immediately adjacent to the roll that was sampled and failed. If both additional tests pass, the roll that represents the initial failed test and the roll manufactured immediately after that roll (next larger roll number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that bracket a greater number of rolls within the lot.

5.4 GEOTEXTILE DEPLOYMENT

During shipment and storage, the geotextile shall be protected from ultraviolet light exposure, precipitation or other inundation, mud, dirt, dust, puncture, cutting, or any other damaging or deleterious conditions. Geotextile rolls shall be shipped and stored in relatively opaque and watertight wrappings. Wrappings shall be removed shortly before deployment.

The Geosynthetic QAC shall observe rolls upon delivery at the site and any deviation from the above requirements shall be reported to the Project Manager.

The Installer shall handle all geotextiles in such a manner as to ensure they are not damaged in any way, and the following shall be complied with:

1. On slopes, the geotextiles shall be securely anchored and then rolled down the slope in such a manner as to continually keep the geotextile sheet in tension.
2. In the presence of wind, all geotextiles shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during deployment and shall remain until replaced with cover material.

3. Geotextiles shall be cut using a geotextile cutter (hook blade) only. If in place, special care shall be taken to protect other materials from damage which could be caused by the cutting of the geotextiles.
4. The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the geotextile.
5. During placement of geotextiles, care shall be taken not to entrap, in or beneath the geotextile, stones, excessive dust, or moisture that could damage the geomembrane, cause clogging of drains or filters, or hamper subsequent seaming.
6. A visual examination of the geotextile shall be carried out over the entire surface, after installation, to ensure that no potentially harmful foreign objects, such as needles, are present.

The Geosynthetic QAC shall note any noncompliance and report it to the Project Manager.

5.5 SEAMING PROCEDURES

On slopes steeper than 10 (horizontal):1 (vertical), all geotextiles shall be continuously sewn (i.e., spot sewing is not allowed). Geotextiles shall be overlapped a minimum of 3 in (75 mm) prior to seaming. In general, no horizontal seams shall be allowed on side slopes (i.e. seams shall be along, not across, the slope), except as part of a patch.

On bottoms and slopes shallower than 10 (horizontal):1 (vertical), geotextiles shall be seamed as indicated above (preferred), or thermally bonded with the written approval of the Project Manager.

The Installer shall pay particular attention at seams to ensure that no earth cover material could be inadvertently inserted beneath the geotextile.

Any sewing shall be done using polymeric thread with chemical and ultraviolet light resistance properties equal to or exceeding those of the geotextile. Sewing shall be done using machinery and stitch types specified in the project specifications or as approved in writing by the Project Manager and the Geosynthetic QAE.

5.6 DEFECTS AND REPAIRS

Any holes or tears in the geotextile shall be repaired as follows:

On slopes, a patch made from the same geotextile shall be sewn into place in accordance with the project specifications. Should any tear exceed 10% of the width of the roll, that roll shall be removed from the slope and replaced.

Care shall be taken to remove any soil or other material which may have penetrated the torn geotextile.

The Geosynthetic QAC shall observe any repair and report any noncompliance with the above requirements in writing to the Project Manager.

5.7 GEOTEXTILE PROTECTION

All soil materials located on top of a geotextile shall be deployed in such a manner as to ensure:

1. The geotextile and underlying lining materials are not damaged.
2. Minimal slippage of the geotextile on underlying layers occurs.
3. No excess tensile stresses occur in the geotextile.

Unless otherwise specified by the Designer, all lifts of soil material shall be in conformance with the guidelines given in Section 4.10.1.

Any noncompliance shall be noted by the Geosynthetic QAC and reported to the Project Manager.

If portions of the geotextile are exposed, the Geosynthetic QAC may periodically place two (or more, at his discretion) marks on the geotextile 10 ft (3 m) apart along the slope and measure the elongation of the geotextile during the placement of soil. This data shall be reported to the Project Manager.

6.0 GEONETS

6.1 MANUFACTURING PLANT INSPECTION

WMNA will conduct a periodic inspection of the manufacturer's plant. In addition, the Project Manager, or his designated representative may visit the manufacturing plant for a project-specific inspection if deemed necessary. If possible, the project-specific inspection shall be prior to or during the manufacturing of the geonet rolls for that particular project. The purpose of the inspection is to review the manufacturing process and quality control procedures.

The manufacturing plant inspection shall include:

1. Verification that properties guaranteed by the Manufacturer meet all WMNA and/or project specifications.
2. Verification that the measurement of properties by the Manufacturer is properly documented and test methods used are acceptable.
3. Spot inspection of the rolls and verification that they are free of imperfections or any sign of contamination by foreign matter.
4. Review of packaging, handling, storage, and transportation procedures and verification that these procedures will not damage the geonet.
5. Verification that roll packages have a label indicating the name of the manufacturer, type of geonet, roll number, and roll dimensions.

A report describing the inspection will be retained by WMNA for periodic inspections and by the Project Manager for project-specific inspections.

6.2 QUALITY CONTROL DOCUMENTATION

Prior to the installation of any geonet, the Manufacturer or Installer shall provide the Project Manager with the following information:

1. The origin (resin supplier's name and resin production plant), identification (brand name and number), and production date of the resin.
2. Copies of the quality control certificates issued by the resin supplier.
3. Reports on tests conducted by the Manufacturer to verify that the quality of the resin used to manufacture the geonet meets the WMNA specifications (see Appendix A).
4. Reports on quality control tests conducted by the Manufacturer to verify that the geonet manufactured for the project meets the project specifications.
5. A statement indicating that the amount of reclaimed polymer added to the resin during manufacturing was done with appropriate cleanliness and does not exceed 2% by weight.
6. A list of the materials which comprise the geonet, expressed in the following categories as percent by weight: polyethylene, carbon black, other additives.
7. A specification for the geonet which includes all properties contained in the WMNA specifications (see Appendix A) measured using the appropriate test methods.

8. Written certification that minimum values given in the specification are guaranteed by the Manufacturer.
9. Quality control certificates, signed by a responsible party employed by the Manufacturer. The quality control certificates shall include roll identification numbers, sampling procedures and results of quality control tests. At a minimum, results shall be given for:

   a. Density
   b. Mass per unit area
   c. Thickness
   d. Carbon black content

   Quality control tests shall be performed in accordance with the test methods specified in the WMNA specifications (see Appendix A), for every 40,000 ft^2 (4,000 m^2) of geonet produced.

The Manufacturer shall identify all rolls of geonets with the following:

1. Manufacturer's name
2. Product identification
3. Roll number
5. Roll dimensions

The Geosynthetic QAE shall review these documents and shall report any discrepancies with the above requirements to the Project Manager. The Geosynthetic QAE shall verify that:

1. Property values certified by the Manufacturer meet all of its guaranteed specifications.
2. Measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.
3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.
4. Roll packages are appropriately labeled.
5. Certified minimum properties meet the WMNA specifications (see Appendix A).

6.3 CONFORMANCE TESTING

Upon delivery of the rolls of geonet, the Geosynthetic QAC shall ensure that conformance test samples are obtained for the geonet. These samples shall then be forwarded to the Geosynthetic QAL for testing to ensure conformance to the WMNA specifications (see Appendix A).

At a minimum, the following tests shall be performed:

1. Density
2. Mass per unit area
3. Thickness

These conformance tests shall be performed in accordance with the test methods specified in the WMNA specifications (see Appendix A). Other conformance tests may be required by the project specifications.

6.3.1 Sampling Procedures

The rolls to be sampled shall be selected by the Geosynthetic QAC. Samples shall be taken across the entire width of the roll and shall not include the first 3 ft (1 m). Unless otherwise specified, samples shall be 3 ft (1 m) long by the roll width. The Geosynthetic QAC shall mark the machine direction on the samples with an arrow.

A lot shall be defined as a group of consecutively numbered rolls from the same manufacturing line. Alternatively, a lot may be designated by the Geosynthetic QAC based on a review of all roll information including quality control documentation and manufacturing records.

Unless otherwise specified, samples shall be taken at a rate of one per lot, not to exceed one conformance test per 100,000 ft^2 (10,000 m^2) of geonet.

6.3.2 Test Results

All conformance test results shall be reviewed and accepted or rejected by the Geosynthetic QAE prior to the deployment of the geonet.

The Geosynthetic QAE shall examine all results from laboratory conformance testing and shall report any nonconformance to the Project Manager. The Geosynthetic QAE shall be responsible for checking that all test results meet or exceed the property values listed in the project specifications.

If the Manufacturer has reason to believe that failing tests may be the result of the Geosynthetic QAL incorrectly conducting the tests, the Manufacturer may request that the sample in question be retested by the Geosynthetic QAL with a technical representative of the Manufacturer present during the testing. This retesting shall be done at the expense of the Manufacturer. Alternatively, the Manufacturer may have the sample retested at two different WMNA approved Geosynthetic QALs at the expense of the Manufacturer. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original Geosynthetic QAL's test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the Project Manager.

If a test result is in nonconformance, all material from the lot represented by the failing test should be considered out of specification and rejected. Alternatively, at the option of the Project Manager, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting specification (note that this procedure is valid only when all rolls in the lot are consecutively produced and numbered from one manufacturing line). To isolate the out of specification material, additional samples must be taken from rolls that have roll numbers immediately adjacent to the roll that was sampled and failed. If both additional tests pass, the roll that represents the initial failed test and the roll manufactured immediately after that roll (next larger roll number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that bracket a greater number of rolls within the lot.

6.4 GEONET DEPLOYMENT

The Geosynthetic QAC shall examine rolls upon delivery and any deviation from the above requirements shall be reported to the Project Manager.

Geonet cleanliness is essential to its performance. Therefore, the geonet rolls should be protected against dust and dirt during shipment and storage.

The Geosynthetic QAC shall verify that the geonet is free of dirt and dust prior to installation. The Geosynthetic QAC shall report the outcome of this verification to the Project Manager, and if the geonet is judged dirty or dusty, it shall be washed by the Installer prior to installation. Washing operations shall be observed by the Geosynthetic QAC and improper washing operations shall be reported to the Project Manager.

The Installer shall handle all geonet in such a manner as to ensure that it is not damaged in any way, and the following shall be complied with:

1. On slopes, the geonet shall be secured and rolled down the slope in such a manner as to continually keep the geonet sheet in tension. If necessary, the geonet shall be positioned by hand after being unrolled to minimize wrinkles.

2. In the presence of wind, all geonet shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during deployment and shall remain until replaced with cover material.

3. Unless otherwise specified, geonet shall not be welded to geomembrane.

4. Geonet shall only be cut using scissors or other cutting tools approved by the Project Manager that will not damage the underlying geosynthetics. Care shall be taken not to leave tools in the geonet.

5. The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the geonet.

6. During placement of geonet, care shall be taken not to entrap in the geonet dirt or excessive dust that could cause clogging of the drainage system, and/or stones that could damage the adjacent geomembrane. If dirt or excessive dust is entrapped in the geonet, it should be hosed clean prior to placement of the next material on top of it. In this regard, care shall be taken with the handling of sandbags, to prevent rupture or damage of the sandbag.

The Geosynthetic QAC shall note any noncompliance and report it to the Project Manager.

6.5 SEAMS AND OVERLAPS

Adjacent geonet shall be joined according to construction drawings and specifications. At a minimum, the following requirements shall be met:

1. Adjacent rolls shall be overlapped by at least 4 in (100 mm).
2. Overlaps shall be secured by tying.
3. Tying can be achieved by plastic fasteners or polymer braid. Tying devices shall be white or yellow for easy inspection. Metallic devices are not allowed.
4. Tying shall be every 5 ft (1.5 m) along the slope, every 6 in (0.15 m) in the anchor trench, and every 6 in (0.15 m) along end-to-end seams on the base of the landfill.
5. In general, no horizontal seams shall be allowed on side slopes.
6. In the corners of the side slopes of rectangular landfills, where overlaps between perpendicular geonet strips are required, an extra layer of geonet shall be unrolled along the slope, on top of the previously installed geonet, from top to bottom of the slope.
7. When more than one layer of geonet is installed, joints shall be staggered.

The Geosynthetic QAC shall note any noncompliance and report it to the Project Manager.

When several layers of geonet are stacked, care shall be taken to prevent strands of one layer from penetrating the channels of the next layer, thereby significantly reducing the transmissivity. This cannot happen if stacked geonet are placed in the same direction. A stacked geonet shall never be laid in perpendicular directions to the underlying geonet (unless otherwise specified by the Designer).

6.6 DEFECTS AND REPAIRS

Any holes or tears in the geonet shall be repaired by placing a patch extending 1 ft (0.3 m) beyond the edges of the hole or tear. The patch shall be secured to the original geonet by tying every 6 in (0.15 m). Tying devices shall be as indicated in Section 6.5. If the hole or tear width across the roll is more than 50% of the width of the roll, the damaged area shall be repaired as follows:

1. On the base of the landfill, the damaged area shall be cut out and the two portions of the geonet shall be joined as indicated in Section 6.5.
2. On sideslopes, the damaged geonet shall be removed and replaced.

The Geosynthetic QAC shall observe any repair and report any noncompliance with the above requirements in writing to the Project Manager.

6.7 GEONET PROTECTION

Soil should never be placed in direct contact with geonet. Soil materials near the geonet shall be placed in such a manner as to ensure:

1. The geonet and underlying lining materials are not damaged.
2. Minimal slippage of the geonet on underlying layers occurs.
3. No excess tensile stresses occur in the geonet.

Unless otherwise specified by the Designer, all lifts of soil material shall be in conformance with the guidelines given in Section 4.10.1.

Any noncompliance shall be noted by the Geosynthetic QAC and reported to the Project Manager.

7.0 GEOGRIDS

7.1 MANUFACTURING PLANT INSPECTION

WMNA will conduct a periodic inspection of the manufacturer's plant. In addition, the Project Manager, or his designated representative may visit the manufacturing plant for a project-specific inspection if deemed necessary. If possible, the project-specific inspection shall be prior to or during the manufacturing of the geogrid rolls for that particular project. The purpose of this inspection shall be to review the manufacturing process and quality control procedures.

The manufacturing plant inspection shall include:

1. Verification that properties guaranteed by the Manufacturer meet all WMNA and/or project specifications.
2. Verification that the measurement of properties by the Manufacturer is properly documented and test methods used are acceptable.
3. Spot inspection of the rolls and verification that they are free of imperfections or any sign of contamination by foreign matter.
4. Review of packaging, handling, storage, and transportation procedures and verification that these procedures will not damage the geogrid.
5. Verification that roll packages have a label indicating the name of the manufacturer, type of geogrid, roll number, and roll dimensions.

A report describing the inspection will be retained by WMNA for periodic inspections and by the Project Manager for project-specific inspections.

7.2 QUALITY CONTROL DOCUMENTATION

Prior to the installation of any geogrid, the Manufacturer or Installer shall provide the Project Manager with the following information:

1. The origin (resin supplier's name and resin production plant), identification (brand name and number), and production date of the resin.
2. Copies of the quality control certificates issued by the resin supplier.
3. Reports on tests conducted by the Manufacturer to verify that the quality of the resin used to manufacture the geogrid meets the WMNA specifications (see Appendix A).
4. Reports on quality control tests conducted by the Manufacturer to verify that the geogrid manufactured for the project meets the project specifications.
5. A statement indicating that the amount of reclaimed polymer added to the resin during manufacturing was done with appropriate cleanliness and does not exceed 2% by weight.
6. A list of the materials which comprise the geogrid, expressed in the following categories as percent by weight: polyethylene, carbon black, other additives.
7. A specification for the geogrid which includes all properties contained in the project specifications measured using the appropriate test methods.

8. Written certification that minimum values given in the specification are guaranteed by the Manufacturer.
9. Quality control certificates, signed by a responsible party employed by the Manufacturer. The quality control certificate shall include roll identification numbers, sampling procedures, and results of quality control tests. At a minimum, results shall be given for:

   a. Mass per unit area
   b. Measurement of spacing between strands
   c. Wide strip tensile strength
   d. Node strength

   Quality control tests shall be performed in accordance with the test methods specified in the project specifications, for every 40,000 ft^2 (4,000 m^2) of geogrid produced.

The Manufacturer shall identify all rolls of geogrids with the following:

1. Manufacturer's name
2. Product identification
3. Roll number
5. Roll dimensions

The Geosynthetic QAE shall review these documents and shall report any discrepancies with the above requirements to the Project Manager. The Geosynthetic QAE shall verify that:

1. Property values certified by the Manufacturer meet all of its guaranteed specifications.
2. Measurement of properties by the Manufacturer are properly documented and that the test methods used are acceptable.
3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.
4. Roll packages are appropriately labeled.
5. Certified minimum properties meet the project specifications.

7.3 CONFORMANCE TESTING

Upon delivery of the rolls of geogrid, the Geosynthetic QAC shall ensure that conformance test samples are obtained for the geogrid. These samples shall then be forwarded to the Geosynthetic QAL for testing to ensure conformance to the project specifications.

At a minimum, the following conformance tests shall be performed on geogrid:

1. Mass per unit area
2. Measurement of spacing between strands
3. Wide strip tensile strength

4. Node strength

These conformance tests shall be performed in accordance with the test methods specified in the project specifications. Other conformance tests may be required by the project specifications.

7.3.1 Sampling Procedures

A lot shall be defined as a group of consecutively numbered rolls from the same manufacturing line. Alternatively, a lot may be designated by the Geosynthetic QAC based on a review of all roll information including quality control documentation and manufacturing records.

Unless otherwise specified, samples shall be taken at a rate of one per lot, not to exceed one conformance test per 100,000 ft^2 (10,000 m^2) of geogrid.

7.3.2 Test Results

All conformance test results must be reviewed and accepted or rejected by the Geosynthetic QAE prior to the deployment of the geogrid.

The Geosynthetic QAE shall examine all results from laboratory conformance testing and shall report any nonconformance to the Project Manager. The Geosynthetic QAC shall be responsible for checking that all test results meet or exceed the minimum property values listed in project specifications.

If the Manufacturer has reason to believe that failing tests may be the result of the Geosynthetic QAL incorrectly conducting the tests, the Manufacturer may request that the sample in question be retested by the Geosynthetic QAL with a technical representative of the Manufacturer present during the testing. This retesting shall be done at the expense of the Manufacturer. Alternatively, the Manufacturer may have the sample retested at two different WMNA approved Geosynthetic QALs at the expense of the Manufacturer. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original Geosynthetic QAL's test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the Project Manager.

If a test result is in nonconformance, all material from the lot represented by the failing test shall be considered out of specification and rejected. Alternatively, at the option of the Project Manager, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting specification (note that this procedure is valid only when all rolls in the lot are consecutively produced and numbered from one manufacturing line). To isolate the out of specification material, additional samples must be taken from rolls that have roll numbers immediately adjacent to the roll that was sampled and failed. If both additional tests pass, the roll that represents the initial failed test and the roll manufactured immediately after that roll (next larger roll number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that bracket a greater number of rolls within the lot.

7.4 GEOGRID DEPLOYMENT

The Installer shall handle all geogrid in such a manner as to ensure it is not damaged in any way, and the following shall be complied with:

1. On slopes, the geogrid shall be secured and rolled down the slope in such a manner as to continually keep the geogrid in tension.

2. In the presence of wind, all geogrids shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during deployment and shall remain until replaced with cover material.

3. Geogrid shall be cut using scissors only. If in place, special care shall be taken to protect other materials from damage which could be caused by the cutting of the geogrid.

4. The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the geogrid.

The Geosynthetic QAC shall note any noncompliance and report it to the Project Manager.

7.5 SEAMS AND OVERLAPS

The geogrid, where used, shall be placed in continuous pieces downslope. No lateral joining is required. Edge to edge placement shall be sufficient.

Where geogrid is joined end to end, a splice approved by the manufacturer shall be used. The splice shall not have any metallic components.

7.6 REPAIRS

Any damaged roll of geogrid shall be discarded. No repairs shall be allowed.

7.7 SOIL MATERIALS PLACEMENT

All soil materials located on top of a geogrid shall be deployed in such a manner as to ensure:

1. The geogrid and underlying materials are not damaged.
2. Minimal slippage of the geogrid on underlying layers occurs.

Unless otherwise specified by the Designer, all lifts of soil material shall be in conformance with the guidelines given in Section 4.10.1.

Any noncompliance shall be noted by the Geosynthetic QAC and reported to the Project Manager.

APPENDIX A

WMNA SPECIFICATIONS FOR HDPE GEOSYNTHETICS

June 15, 1990

TABLE A-1
HDPE GEOMEMBRANE PROPERTIES

PROPERTY	QUALIFIER	UNIT	SPECIFIED VALUE				ALL THICKNESSES	TEST METHOD
Thickness	minimum avg	mils	40	60	80	100		
Thickness	minimum	mils	36	54	72	90		ASTM D751*
Density (geomembrane)	minimum	g/cc	-------- 0.940 --------					ASTM D1505 or ASTM D792
Melt Index (resin)	range	g/10 min	------- 0.1 - 1.1 ------					ASTM D1238 (Condition 190/216)
Tensile Properties: (each direction)								ASTM D638*
1. Yield strength	minimum	lb/in	88	132	176	220	2200 psi	
2. Break strength	minimum	lb/in	152	228	304	380	3800 psi	
3. Elongation at yield	minimum	%	---------- 12 ---------					
4. Elongation at break	minimum	%	--------- 600 ---------					
Tear Strength	minimum	lb	28	42	56	70	700 lb/in	ASTM D1004 Die C
Puncture Resistance	minimum	lb	72	108	144	180	1800 lb/in	ASTM D4833
Low Temperature	maximum	deg. C	--------- (-60) ---------					ASTM D746
Carbon Black Content	range	%	-------- 2.0 to 3.0 -------					ASTM D1603
Carbon Black Dispersion	rating	N/A	------ A-1 or A-2 -------					ASTM D3015
Dimensional Stability (each direction)	max. change	%	---------- 2.0 ----------					ASTM D1204*
Environmental Stress Crack	minimum	hours	---------- 2000 ----------					ASTM D1693*

TABLE A-2
HDPE SEAM PROPERTIES

PROPERTY	QUALIFIER	UNIT	SPECIFIED VALUE				ALL THICKNESSES	TEST METHOD
Thickness	minimum avg.	mils	40	60	80	100		
Bonded Seam Strength	minimum	lb/in	88	132	176	220	2200 psi	ASTM D4437*
Peel Adhesion:								
Fusion	minimum	lb/in	60	90	120	150	1500 psi	ASTM D4437*
Extrusion	minimum	lb/in	52	78	104	130	1300 psi	ASTM D4437*

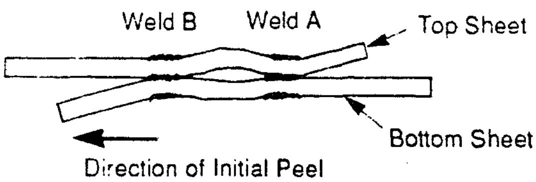
NOTE:
* Test methods as modified on the following page

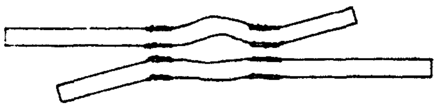
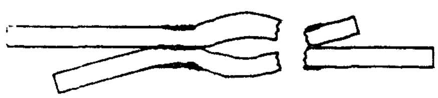
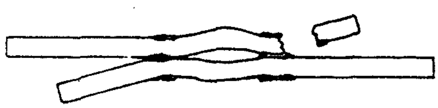
NOTES FOR TABLE A-1

PROPERTY	TEST METHOD	MODIFICATIONS
Thickness	ASTM D751	Measure thickness at one foot intervals across the width of the roll (perpendicular to the machine direction) and report average, standard deviation, and lowest individual readings.
Tensile Properties	ASTM D638	Type IV Die. ASTM D638 test specimen shall be used. The grip separation shall be 2.5 inches. This test does not require the use of extensometers. The rate of grip separation will be 2 inches per minute. A gauge length of 1.3 inches for yield values, and 2.5 inches for break values shall be used to calculate elongation from grip movement.
Dimensional Stability	ASTM D1204	100°C for 15 minutes
Environmental Stress Crack	ASTM D1693	Use Condition "B" (50°C) with the exception of the following modifications: 1. Use an aqueous solution containing 10% igepal by volume. 2. The final product shall be tested as produced, regardless of thickness. 3. The notch depth shall be as stated in condition B, 0.30 to 0.40 mm (0.012 to 0.015 in), for all sheet thicknesses. 4. Cut five (5) specimens with the length parallel to the machine direction (MD) and five (5) with the length parallel to the transverse direction (TD). 5. The failure time shall be the time in hours to the first specimen failure.
Bonded Seam Strength and Peel Adhesion	ASTM D4437	For shear tests, the sheet shall yield before failure of the seam. For peel adhesion, seam separation shall not extend more than 10% into the seam. For either test, testing shall be discontinued when the sample has visually yielded. Sample failure shall conform to a passing configuration as outlined in Figure A-1.

FIGURE A-1

Schematic of Untested Specimen



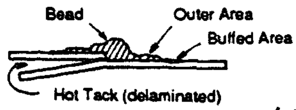
Types of Break	Locus-of-Break Code	Break Description	Classification[a]
	AD	Adhesion failure.	Non-FTB
	BRK	Break in sheeting. Break can be in either top or bottom sheet.	FTB
	SE1	Break at outer edge of seam. Break can be in either top or bottom sheet.	FTB
	SE2	Break at inner edge of seam through both sheets.	FTB
	AD-BRK	Break in first seam after some adhesion failure. Break can be in either the top or bottom sheet.	FTB

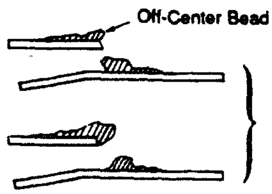
[a] FTB = Film - Tear Bond

NOT TO SCALE

After EPA/600/2-88/052
Lining of Waste Containment and Other Surface Impoundment Facilities

Schematic of Untested Specimen



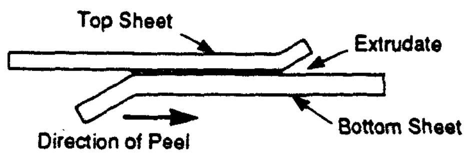
Types of Breaks	Locus-of-Break Code	Break Description	Classification[a]
	AD1	Failure in adhesion. Specimens may also delaminate under the bead and break through the thin extruded material in the outer area.	Non-FTB
	AD2	Failure in adhesion.	Non-FTB
	AD-WLD	Break through the fillet. Breaks through the fillet range from breaks starting at the edge of the top sheet to breaks through the fillet after some adhesion failure between the fillet and the bottom sheet.	Non-FTB[b]
	SE1	Break at seam edge in the bottom sheet. Specimens may break anywhere from the bead/outer area edge to the outer area/buffed area edge. (Applicable to shear only).	FTB
	SE2	Break at seam edge in the top sheet. Specimens may break anywhere from bead/outer area edge to the outer area/buffed area edge.	FTB
	SE3	Break at seam edge in the bottom sheet. (Applicable to peel only).	FTB
	BRK1	Break in the bottom sheeting. A "B" in parentheses following the code means the specimen broke in the buffed area. (Applicable to shear only).	FTB
	BRK2	Break in the top sheeting. A "B" in parentheses following the code means the specimen broke in the buffed area.	FTB
	AD-BRK	Break in the bottom sheeting after some adhesion failure between the fillet and the bottom sheet. (Applicable to peel only).	FTB
	HT	Break at the edge of the hot tack for specimens which could not be delaminated in the hot tack.	No Test

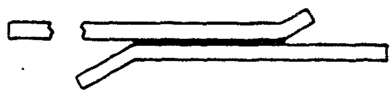
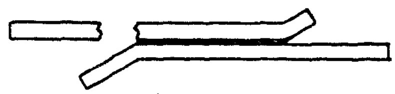
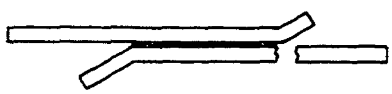
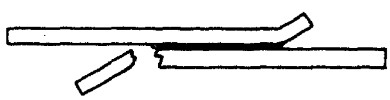
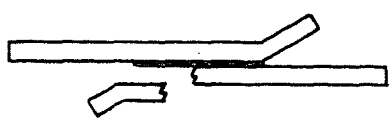
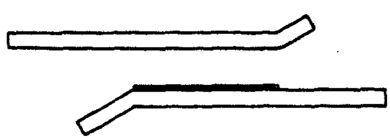
[a] FTB = Film - Tear Bond.

[b] Acceptance of AD-WLD breaks may depend on whether test values meet a minimum specification value and not on classification as a FTB or non-FTB break.

FIGURE A-1 (cont.)

Schematic of Untested Specimen



Location of Break	Locus-of-Break Code	Break Description	Classification[a]
	BRK	Break in sheeting outside weld area. Break can be in either the top or bottom sheet	FTB
	SE1	Break in top sheet at seam edge.	FTB
	SE2	Break in bottom sheeting at seam edge	FTB
	SE3	Break in bottom sheeting at seam edge. (Applicable to peel only).	FTB
	AD-BRK	Break in sheeting after some adhesion failure between extrudate and surface of the sheeting. Break can be in either the top or bottom sheet.	FTB
	AD	Failure in adhesion between the extrudate and the sheeting surface.	Non-FTB

[a] FTB = Film - Tear Bond

After EPA/600/2-88/052
Lining of Waste Containment and Other Surface Impoundment Facilities

TABLE A-3
HDPE GEONET PROPERTIES

PROPERTY	QUALIFIER	UNIT	VALUE	TEST METHOD
Polyethylene Content	minimum	%	95	———
Resin Density	minimum	g/cc	0.935	ASTM D1505
Carbon Black Content	range	%	2.0 – 3.0	ASTM D1603
Melt Index	maximum	g/10 min	1.0	ASTM D1238 (Condition 190/216)
Thickness	minimum	mils	200	ASTM D1777
Weight per Sq Ft	minimum	lb/ft^2	0.16	ASTM D3776 (option C)
Tensile Strength	minimum	lb/in	40	ASTM D1682[1]
Transmissivity	minimum	m^2/sec	1×10^{-3}	ASTM D4716[2]

1. Test method modified as follows:
   a) Use 4 in x 8 in specimens.
   b) Use test rate of 8 in/min.
   c) Continue test until first strand separates completely.
   d) Report averages of 5 tests in each direction (machine and cross).

2. Gradient = 1.0, Confining Pressure = 15,000 psf, Measured between two steel plates one hour after application of confining pressure.

APPENDIX B

FINGERPRINTING PROTOCOL FOR HDPE GEOSYNTHETICS

June 15, 1990

Fingerprinting Protocol for High Density Polyethylene Geosynthetics

The following tests must be performed by the Manufacturer of any HDPE geosynthetic for identification of the Manufacturer's product:

Parameter	Method
Density	ASTM D792 or ASTM D1505
Melt Flow Ratio	ASTM D1238
Percent Volatiles	ASTM D3030
Percent extractables with methyl ethyl ketone (MEK) and N-hexane	ASTM D3421
Structural comparison of extractables	Infrared (IR) Spectrophotometry
Composition Carbon black Ash Polymer Decomposition temperature Temperature at maximum rate of weight loss	Thermal Gravimetric Analysis (TGA)
Crystallinity Melting range and point at endotherm maximum	Differential Scanning Calorimetry (DSC)

The results of the above tests should be submitted to WMNA for pre-qualification of each product. Once the product is approved by WMNA, the manufacturer shall supply all WMNA projects with material made using the same HDPE resin type (within the resin Manufacturer's specifications) and manufacturing process as that of the material identified by the Manufacturer's product fingerprint. Any change in resin or manufacturing process must be approved by WMNA, based on a new fingerprint of the proposed material.

June 15, 1990

APPENDIX C

EXAMPLES OF GEOSYNTHETIC QUALITY ASSURANCE DOCUMENTATION

June 15, 1990

PANEL PLACEMENT FORM

PROJECT:	QUALITY ASSURANCE MONITOR:	MATERIAL DESCRIPTION:

DATE/ TIME	PANEL NUMBER	ROLL NUMBER	PANEL LENGTH	PANEL WIDTH	PANEL LOCATION	PANEL CONDITION- VISUAL INSPECTION	COMMENTS

TRIAL WELD INFORMATION FORM

PROJECT:	QUALITY ASSURANCE MONITOR:	MATERIAL DESCRIPTION:

DATE/ TIME	WEATHER/ WINDS	AMBIENT TEMP.	SEAMER INITIALS	MACHINE NUMBER	EXTRUSION WELDS		FUSION WELDS			PEEL VALUES (LBS/INCH)	PASS/ FAIL	COMMENTS
					BARREL TEMP. SET/PYRO	PREHEAT TEMP. SET/PYRO	WEDGE TEMP. SET/PYRO	MEASURED SPEED (FT/MIN)	WHEEL TENSION SETTING			

PANEL SEAMING CHECKLIST

PROJECT:	QUALITY ASSURANCE MONITOR:	MATERIAL DESCRIPTION:

DATE/ TIME	WEATHER/ WINDS	AMBIENT TEMP.	SEAMER INITIALS	MACHINE NUMBER	SEAM TYPE	SEAM NUMBER	PANEL NUMBERS	SEAM LENGTH	TEMP. SETTING	MACHINE SPEED	COMMENTS

NON-DESTRUCTIVE SEAM TEST LOG

PROJECT:	QUALITY ASSURANCE MONITOR:	MATERIAL DESCRIPTION:

DATE/ TIME	SEAM NUMBER	TESTER INITIALS	AIR TESTING					PASS/ FAIL	VACUUM BOX PASS/FAIL	COMMENTS
			PRESSURE (PSI)			TIME				
			START	END	DROP	START	END			

DESTRUCTIVE SEAM TEST LOG

PROJECT:	QUALITY ASSURANCE MONITOR:	MATERIAL DESCRIPTION:

DATE/ TIME	SAMPLE I.D.	SEAM NUMBER	TENS. NUMBER	OPERATOR INITIALS	FIELD TENSIOMETER PEEL VALUES (LBS/INCH)			PASS/ FAIL	DATE TO LAB PKG. SLIP NO.	LAB PASS/ FAIL	COMMENTS

CERTIFICATE OF COMPLETION

Type: Partial___ Substantial___ Final___

Project Name: ____

Site Name: ____

Date: ____

Description of Work Certified: ____________________________

I hereby certify that the above identified work has been inspected and that it has been properly installed. I further certify that all required testing has been completed and the results have been deemed acceptable by the Geosynthetic QAE. The work is suitable for its intended use.

GEOSYNTHETIC QAE

Signature: ____________________ Date: ________

Name (print): ____________________

Title: ____________________

Representing: ____________________

INSTALLER'S Representative

Signature: ____________________ Date: ________

Name (print): ____________________

Title: ____________________

Representing: ____________________

WMNA Representative

Signature: ____________________ Date: ________

Name (print): ____________________

Title: ____________________

Representing: ____________________

June 15, 1990

CERTIFICATE OF COMPLETION

OF SOIL SUBGRADE SURFACE

Date: ____________

Project Name: ______________________________

Site Name: ______________________________

Location of Subgrade Surface to be Lined: ______________________________

____

____

I hereby certify that the above area is suitable for the installation of geosynthetics, and that I shall be responsible for its integrity and suitability in accordance with the specifications from this date to completion of the installation.

INSTALLER'S REPRESENTATIVE

Name (print): ______________________ Date: ____________

Title: ______________________________

Representing: ______________________________

Signature: ______________________________

Acknowledged by:

GEOSYNTHETIC QUALITY ASSURANCE CONSULTANT

Name (print): ______________________ Date: ____________

Title: ______________________________

Representing: ______________________________

Signature: ______________________________

ATTACHMENT C

ASTM TEST METHOD D 5084

Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter[1]

This standard is issued under the fixed designation D 5084; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers laboratory measurement of the hydraulic conductivity (also referred to as *coefficient of permeability*) of water-saturated porous materials with a flexible wall permeameter.

1.2 This test method may be utilized with undisturbed or compacted specimens that have a hydraulic conductivity less than or equal to 1×10^{-5} m/s (1×10^{-3} cm/s).

1.3 The hydraulic conductivity of materials with hydraulic conductivities greater than 1×10^{-5} m/s may be determined by Test Method D 2434.

1.4 The values stated in SI units are to be regarded as the standard, unless other units are specifically given. By tradition in U.S. practice, hydraulic conductivity is reported in centimetres per second, although the common SI units for hydraulic conductivity are metres per second.

1.5 *This standard does not purport to address the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]

D 698 Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (305-mm) Drop[2]

D 1557 Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 10-lb (4.54-kg) Rammer and 18-in. (457-mm) Drop[2]

D 1587 Practice of Thin-Walled Tube Sampling of Soils[2]

D 2113 Practice for Diamond Core Drilling for Site Investigation[2]

D 2216 Method for Laboratory Determination of Water (Moisture) Content in Soil, Rock, and Soil-Aggregate Mixtures[2]

D 2434 Test Method for Permeability of Granular Soils (Constant Head)[2]

D 4220 Practices for Preserving and Transporting Soil Samples[2]

D 4753 Specification for Evaluating, Selecting and Specifying Balances and Scales for Use in Soil and Rock Testing[2]

D 4767 Test Method for Consolidated-Undrained Triaxial Compression[2]

E 145 Specification for Gravity-Convection and Forced-Ventilation Ovens[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *hydraulic conductivity, k*—the rate of discharge of water under laminar flow conditions through a unit cross-sectional area of a porous medium under a unit hydraulic gradient and standard temperature conditions (20°C).

DISCUSSION—The term *coefficient of permeability* is often used instead of *hydraulic conductivity*, but *hydraulic conductivity* is used exclusively in this test method. A more complete discussion of the terminology associated with Darcy's law is given in the literature.[4]

3.1.2 *pore volume of flow*—the cumulative quantity of flow into a test specimen divided by the volume of voids in the specimen.

3.1.3 For definitions of other terms used in this test method, see Terminology D 653.

4. Significance and Use

4.1 This test method applies to one-dimensional, laminar flow of water within porous materials such as soil and rock.

4.2 The hydraulic conductivity of porous materials generally decreases with an increasing amount of air in the pores of the material. This test method applies to water-saturated porous materials containing virtually no air.

4.3 This test method applies to permeation of porous materials with water. Permeation with other liquids, such as chemical wastes, can be accomplished using procedures similar to those described in this test method. However, this test method is only intended to be used when water is the permeant liquid.

4.4 It is assumed that Darcy's law is valid and that the hydraulic conductivity is essentially unaffected by hydraulic gradient. The validity of Darcy's law may be evaluated by measuring the hydraulic conductivity of the specimen at three hydraulic gradients; if all measured values are similar (within about 25 %), then Darcy's law may be taken as valid. However, when the hydraulic gradient acting on a test

[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.04 on Hydrologic Properties of Soil and Rocks.

Current edition approved June 29, 1990. Published October 1990.

[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 04.02.

[4] Olson, R. E., and Daniel, D. E., "Measurement of the Hydraulic Conductivity of Fine-Grained Soils," *Symposium on Permeability and Groundwater Contaminant Transport*, *ASTM STP 746*, ASTM, 1981, pp. 18–64.

specimen is changed, the state of stress will also change, and, if the specimen is compressible, the volume of the specimen will change. Thus, some change in hydraulic conductivity may occur when the hydraulic gradient is altered, even in cases where Darcy's law is valid.

4.5 This test method provides a means for determining hydraulic conductivity at a controlled level of effective stress. Hydraulic conductivity varies with varying void ratio, which in turn changes when the effective stress changes. If the void ratio is changed, the hydraulic conductivity of the test specimen will likely change. To determine the relationship between hydraulic conductivity and void ratio, the hydraulic conductivity test would have to be repeated at different effective stresses.

4.6 The correlation between results obtained with this test method and the hydraulic conductivities of in-place field materials has not been fully investigated. Experience has sometimes shown that flow patterns in small test specimens do not necessarily follow the same patterns on large field scales and that hydraulic conductivities measured on small test specimens are not necessarily the same as larger-scale values. Therefore, the results should be applied to field situations with caution and by qualified personnel.

5. Apparatus

5.1 *Hydraulic System*—Constant head (Method A), falling head (Methods B and C), or constant rate of flow (Method D) systems may be utilized provided they meet the criteria outlined as follows:

5.1.1 *Constant Head*—The system must be capable of maintaining constant hydraulic pressures to within ±5 % and shall include means to measure the hydraulic pressures to within the prescribed tolerance. In addition, the head loss across the test specimen must be held constant to within ±5 % and shall be measured with the same accuracy or better. Pressures shall be measured by a pressure gage, electronic pressure transducer, or any other device of suitable accuracy.

5.1.2 *Falling Head*—The system shall allow for measurement of the applied head loss, thus hydraulic gradient, to within 5 % or better at any time. In addition, the ratio of initial head loss divided by final head loss over an interval of time shall be measured such that this computed ratio is accurate to within ±5 %. The head loss shall be measured with a pressure gage, electronic pressure transducer, engineer's scale, graduated pipette, or any other device of suitable accuracy. Falling head tests may be performed with either a constant tailwater elevation (Method B) or a rising tailwater elevation (Method C).

5.1.3 *Constant Rate of Flow*—The system must be capable of maintaining a constant rate of flow through the specimen to within 5 % or better. Flow measurement shall be by calibrated syringe, graduated pipette, or other device of suitable accuracy. The head loss across the specimen shall be measured to an accuracy of 5 % or better using an electronic pressure transducer or other device of suitable accuracy. More information on testing with a constant rate of flow is given in the literature.[5]

5.1.4 *System De-airing*—The hydraulic system shall be designed to facilitate rapid and complete removal of free air bubbles from flow lines.

5.1.5 *Back Pressure System*—The hydraulic system shall have the capability to apply back pressure to the specimen to facilitate saturation. The system shall be capable of maintaining the applied back pressure throughout the duration of hydraulic conductivity measurements. The back pressure system shall be capable of applying, controlling, and measuring the back pressure to 5 % or better of the applied pressure. The back pressure may be provided by a compressed gas supply, a deadweight acting on a piston, or any other method capable of applying and controlling the back pressure to the tolerance prescribed in this paragraph.

NOTE 1—Application of gas pressure directly to a fluid will dissolve gas in the fluid. A variety of techniques are available to minimize dissolution of gas in the back pressure fluid, including separation of gas and liquid phases with a bladder and frequent replacement of the liquid with de-aired water.

5.2 *Flow Measurement System*—Both inflow and outflow volumes shall be measured unless the lack of leakage, continuity of flow, and cessation of consolidation or swelling can be verified by other means. Flow volumes shall be measured by a graduated accumulator, graduated pipette, vertical standpipe in conjunction with an electronic pressure transducer, or other volume-measuring device of suitable accuracy.

5.2.1 *Flow Accuracy*—Required accuracy for the quantity of flow measured over an interval of time is 5 % or better.

5.2.2 *De-airing and Compliance of the System*—The flow-measurement system shall contain a minimum of dead space and be capable of complete and rapid de-airing. Compliance of the system in response to changes in pressure shall be minimized by using a stiff flow measurement system. Rigid tubing, such as metallic or rigid thermoplastic tubing, shall be used.

5.2.3 *Head Losses*—Head losses in the tubes, valves, porous end pieces, and filter paper may lead to error. To guard against such errors, the permeameter shall be assembled with no specimen inside and then the hydraulic system filled. If a constant or falling head test is to be used, the hydraulic pressures or heads that will be used in testing a specimen shall be applied, and the rate of flow measured with an accuracy of 5 % or better. This rate of flow shall be at least ten times greater than the rate of flow that is measured when a specimen is placed inside the permeameter and the same hydraulic pressures or heads are applied. If a constant rate of flow test is to be used, the rate of flow to be used in testing a specimen shall be supplied to the permeameter and the head loss measured. The head loss without a specimen shall be less than 0.1 times the head loss when a specimen is present.

5.3 *Permeameter Cell Pressure System*—The system for pressurizing the permeameter cell shall be capable of applying and controlling the cell pressure to within 5 % of the applied pressure. However, the effective stress on the test specimen (which is the difference between the cell pressure and the pore water pressure) shall be maintained to the desired value with an accuracy of 10 % or better. The device for pressurizing the cell may consist of a reservoir connected to the permeameter cell and partially filled with de-aired

[5] Olson, H. W., Morin, R. H., and Nichols, R. W., "Flow Pump Applications in Triaxial Testing," *Symposium on Advanced Triaxial Testing of Soil and Rock, ASTM STP 977*, ASTM, 1988, pp. 68–81.

water, with the upper part of the reservoir connected to a compressed gas supply or other source of pressure (see Note 2). The gas pressure shall be controlled by a pressure regulator and measured by a pressure gage, electronic pressure transducer, or any other device capable of measuring to the prescribed tolerance. A hydraulic system pressurized by deadweight acting on a piston or any other pressure device capable of applying and controlling the permeameter cell pressure to the tolerance prescribed in this paragraph may be used.

NOTE 2—De-aired water is commonly used for the cell fluid to minimize potential for diffusion of air through the membrane into the specimen. Other fluids, such as oils, which have low gas solubilities are also acceptable, provided they do not react with components of the permeameter. Also, use of a long (approximately 5 to 7 m) tube connecting the pressurized cell liquid to the cell helps to delay the appearance of air in the cell fluid and to reduce the flux of dissolved air into the cell.

5.4 *Permeameter Cell*—An apparatus shall be provided in which the specimen and porous end pieces, enclosed by a membrane sealed to the cap and base, are subjected to controlled fluid pressures. A schematic diagram of a typical cell is shown in Fig. 1.

5.4.1 The permeameter cell may allow for observation of changes in height of the specimen, either by observation through the cell wall using a cathetometer or other instrument, or by monitoring of either a loading piston or an extensometer extending through the top plate of the cell bearing on the top cap and attached to a dial indicator or other measuring device. The piston or extensometer should pass through a bushing and seal incorporated into the top plate and shall be loaded with sufficient force to compensate for the cell pressure acting over the cross-sectional area of the piston where it passes through the seal. If deformations are measured, the deformation indicator shall be a dial indicator or cathetometer graduated to 0.3 mm (0.01 in.) or better and having an adequate travel range. Any other measuring device meeting these requirements is acceptable.

5.4.2 In order to facilitate gas removal, and thus saturation of the hydraulic system, four drainage lines leading to the specimen, two each to the base and top cap, are recommended. The drainage lines shall be controlled by no-volume-change valves, such as ball valves, and shall be designed to minimize dead space in the lines.

5.5 *Top Cap and Base*—An impermeable, rigid top cap and base shall be used to support the specimen and provide for transmission of permeant liquid to and from the specimen. The diameter or width of the top cap and base shall be equal to the diameter or width of the specimen ±5 %. The base shall prevent leakage, lateral motion, or tilting, and the top cap shall be designed to receive the piston or extensometer, if used, such that the piston-to-top cap contact area is concentric with the cap. The surface of the base and top cap that contacts the membrane to form a seal shall be smooth and free of scratches.

5.6 *Flexible Membranes*—The flexible membrane used to encase the specimen shall provide reliable protection against leakage. The membrane shall be carefully inspected prior to use and if any flaws or pinholes are evident, the membrane shall be discarded. To minimize restrain to the specimen, the diameter or width of the unstretched membrane shall be

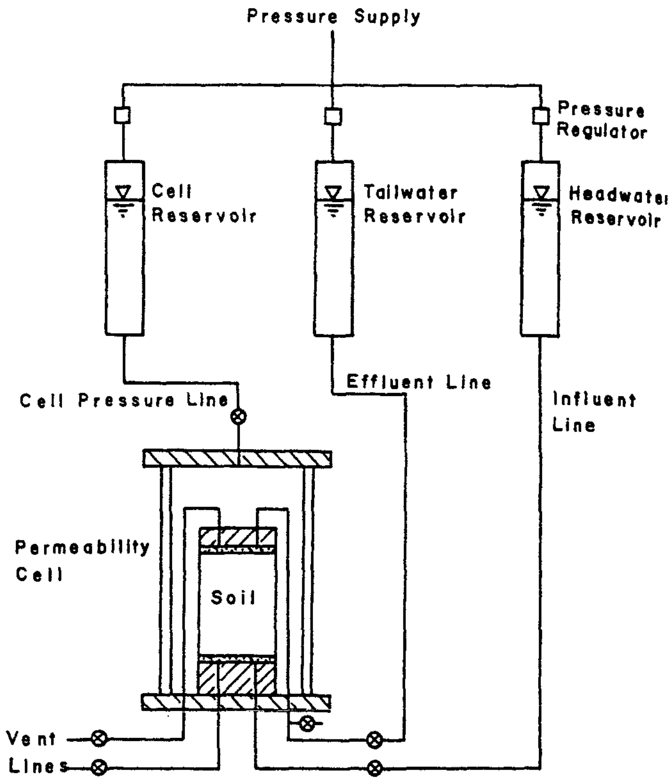


FIG. 1 Permeameter Cell

between 90 and 95 % of that of the specimen. The membrane shall be sealed to the specimen base and cap with rubber O-rings for which the unstressed, inside diameter or width is less than 90 % of the diameter or width of the base and cap, or by any other method that will produce an adequate seal.

NOTE 3—Membranes may be tested for flaws by placing them around a form sealed at both ends with rubber O-rings, subjecting them to a small air pressure on the inside, and then dipping them into water. If air bubbles come up from any point on the membrane, or if any visible flaws are observed, the membrane shall be discarded.

5.7 *Porous End Pieces*—The porous end pieces shall be of silicon carbide, aluminum oxide, or other material that is not attacked by the specimen or permeant liquid. The end pieces shall have plane and smooth surfaces and be free of cracks, chips, and nonuniformities. They shall be checked regularly to ensure that they are not clogged.

5.7.1 The porous end pieces shall be the same diameter or width (±5 %) as the specimen, and the thickness shall be sufficient to prevent breaking.

5.7.2 The hydraulic conductivity of the porous end pieces shall be significantly greater than that of the specimen to be tested. The requirements outlined in 5.2.3 ensure this.

5.8 *Filter Paper*—If necessary to prevent intrusion of material into the pores of the porous end pieces, one or more sheets of filter paper shall be placed between the top and bottom porous end pieces and the specimen. The paper shall have a negligibly small hydraulic impedance. The requirements outlined in 5.2.3 ensure that the impedance is small.

5.9 *Equipment for Compacting a Specimen*—Equipment (including compactor and mold) suitable for the method of compaction specified by the requester shall be used.

5.10 *Sample Extruder*—When the material being tested is a soil core, the soil core shall usually be removed from the sampler with an extruder. The sample extruder shall be capable of extruding the soil core from the sampling tube in the same direction of travel in which the sample entered the tube and with minimum disturbance of the sample. If the soil core is not extruded vertically, care should be taken to avoid bending stresses on the core due to gravity. Conditions at the time of sample extrusion may dictate the direction of removal, but the principal concern is to keep the degree of disturbance minimal.

5.11 *Trimming Equipment*—Specific equipment for trimming the specimen to the desired dimensions will vary depending on quality and characteristics of the sample; however, the following items listed may be used: lathe, wire saw with a wire about 0.3 mm (0.01 in.) in diameter, spatulas, knives, steel rasp for very hard clay specimens, cradle or split mold for trimming specimen ends, and steel straight edge for final trimming of specimen ends.

5.12 *Devices for Measuring the Dimensions of the Specimen*—Devices used to measure the dimensions of the specimen shall be capable of measuring to the nearest 0.3 mm (0.01 in.) or better and shall be constructed such that their use will not disturb the specimen.

5.13 *Balances*—The balance shall be suitable for determining the mass of the specimen and shall be selected as discussed in Specification D 4753. The mass of specimens less than 100 g shall be determined to the nearest 0.01 g. The mass of specimens 100 g or larger shall be determined to the nearest 0.1 g. The mass of specimens >1000 g shall be determined to the nearest 1.0 g.

5.14 *Equipment for Mounting the Specimen*—Equipment for mounting the specimen in the permeameter cell shall include a membrane stretcher or cylinder, and ring for expanding and placing O-rings on the base and top cap to seal the membrane.

5.15 *Vacuum Pump*—To assist with de-airing of permeameter system and saturation of specimens.

5.16 *Temperature Maintaining Device*—The temperature of the permeameter, test specimen, and reservoir of permeant liquid shall not vary more than ±3°C (±5.7°F). Normally, this is accomplished by performing the test in a room with a relatively constant temperature. If such a room is not available, the apparatus shall be placed in a water bath, insulated chamber, or other device that maintains a temperature within the tolerance specified in 5.16. The temperature shall be periodically measured and recorded.

5.17 *Water Content Containers*—The containers shall be in accordance with Method D 2216.

5.18 *Drying Oven*—The oven shall be in accordance with Specification E 145.

6. Reagents

6.1 *Permeant Water:*

6.1.1 The permeant water is the liquid used to permeate the test specimen and is also the liquid used in backpressuring the specimen.

6.1.2 The type of permeant water should be specified by the requestor. If no specification is made, tap water shall be used for the permeant liquid. The type of water utilized shall be indicated in the report.

NOTE 4—Chemical interactions between a permeant liquid and the porous material may lead to variations in hydraulic conductivity. Distilled water can significantly lower the hydraulic conductivity of clayey soils (see the literature).[4] For this reason, distilled water is not usually recommended as a permeant liquid. A permeant liquid used by some is 0.005 N $CaSO_4$, which can be obtained for example, by dissolving 6.8 g of nonhydrated, reagent-grade $CaSO_4$ in 10 L of de-aired, distilled water. This $CaSO_4$ solution is thought to neither increase nor decrease significantly the hydraulic conductivity of clayey soils. In areas with extremely brackish tap water, the $CaSO_4$ solution is recommended.

6.1.3 *Deaired Water*—To aid in removing as much air from the test specimen as possible, deaired water shall be used. The water is usually deaired by boiling, by spraying a fine mist of water into an evacuated vessel attached to a vacuum source, or by forceful agitation of water in a container attached to a vacuum source. If boiling is used, care shall be taken not to evaporate an excessive amount of water, which can lead to a larger salt concentration in the permeant water than desired. To prevent dissolution of air back into the water, deaired water shall not be exposed to air for prolonged periods.

7. Test Specimens

7.1 *Size*—Specimens shall have a minimum diameter of 25 mm (1.0 in.) and a minimum height of 25 mm. The height and diameter of the specimen shall be measured to the nearest 0.3 mm (0.01 in.) or better. The length and diameter shall vary by no more than ±5 %. The surface of the test specimen may be uneven, but indentations must not be so deep that the length or diameter vary by more than ±5 %. The diameter and height of the specimen shall each be at least 6 times greater than the largest particle size within the specimen. If, after completion of a test, it is found based on visual observation that oversized particles are present, that information shall be indicated on the report.

NOTE 5—Most hydraulic conductivity tests are performed on cylindrical test specimens. It is possible to utilize special equipment for testing prismatic test specimens, in which case reference to "diameter" in 7.1 applies to the least width of the prismatic test specimen.

7.2 *Undisturbed Specimens*—Undisturbed test specimens shall be prepared from a representative portion of undisturbed samples secured in accordance with Practice D 1587 or Practice D 2113, and preserved and transported in accordance with requirements for Group C materials in Practice D 4220. Specimens obtained by tube sampling or coring may be tested without trimming except for cutting the end surfaces plane and perpendicular to the longitudinal axis of the specimen, provided soil characteristics are such that no significant disturbance results from sampling. Where the sampling operation has caused disturbance of the soil, the disturbed material shall be trimmed. Where removal of pebbles or crumbling resulting from trimming causes voids on the surface of the specimen that cause the length or diameter to vary by more than ±5 %, the voids shall be filled with remolded material obtained from the trimmings. The ends of the test specimen shall be cut and not troweled (troweling can seal off cracks, slickensides, or other secondary features that might conduct water flow). Specimens shall be trimmed, whenever possible, in an environment where changes in moisture content are minimized. A controlled high-humidity room is usually used for this purpose. The mass and dimensions of the test specimen shall be determined to the tolerances given in 5.12 and 5.13. The test specimen shall be mounted immediately in the permeameter. The water content of the trimmings shall be determined in accordance with Method D 2216.

7.3 *Laboratory-Compacted Specimens*—The material to be tested shall be prepared and compacted inside a mold in a manner specified by the requestor. If the specimen is placed and compacted in layers, the surface of each previously-compacted layer shall be lightly scarified (roughened) with a fork, ice pick, or other suitable object, unless the requester specifically states that scarification is not to be performed. Test Methods D 698 and D 1557 describe two methods of compaction, but any other method specified by the requestor may be used as long as the method is described in the report. Large clods of material should not be broken down prior to compaction unless it is known that they will be broken in field construction, as well, or the requestor specifically requests that the clod size be reduced. Neither hard clods nor individual particles of the material shall exceed $1/6$ of either the height or diameter of the specimen. After compaction, the test specimen shall be removed from the mold, the ends scarified, and the dimensions and weight determined within the tolerances given in 5.12 and 5.13. After the dimensions and mass are determined, the test specimen shall be immediately mounted in the permeameter. The water content of the trimmings shall be determined in accordance with Method D 2216.

7.4 *Other Preparation Methods*—Other methods of preparation of a test specimen are permitted if specifically requested. The method of specimen preparation shall be identified in the report.

7.5 After the height, diameter, mass, and water content of the test specimen have been determined, the dry unit weight shall be calculated. Also, the initial degree of saturation shall be estimated (this information may be used later in the backpressure stage).

8. Procedure

8.1 *Specimen Setup:*

8.1.1 Cut two filter paper sheets to approximately the same shape as the cross section of the test specimen. Soak the two porous end pieces and filter paper sheets, if used, in a container of permeant water.

8.1.2 Place the membrane on the membrane expander. Apply a thin coat of silicon high-vacuum grease to the sides of the end caps. Place one porous end piece on the base and place one filter paper sheet, if used, on the porous end piece, followed by the test specimen. Place the second filter paper sheet, if used, on top of the specimen followed by the second porous end piece and the top cap. Place the membrane around the specimen, and using the membrane expander or other suitable O-ring expander, place one or more O-rings to seal the membrane to the base and one or more additional O-rings to seal the membrane to the top cap.

8.1.3 Attach flow tubing to the top cap, if not already attached, assemble the permeameter cell, and fill it with de-aired water or other cell fluid. Attach the cell pressure reservoir to the permeameter cell line and the hydraulic system to the influent and effluent lines. Fill the cell pressure reservoir with deaired water, or other suitable liquid, and the hydraulic system with deaired permeant water. Apply a small

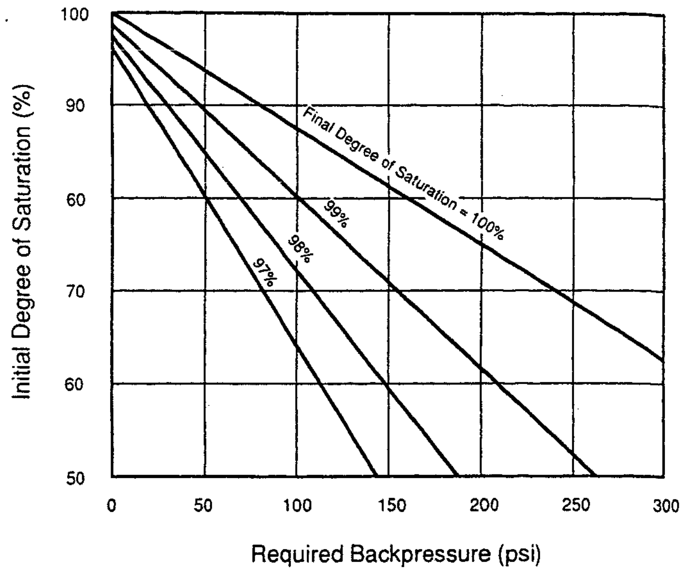


FIG. 2 Back Pressure to Attain Various Degrees of Saturation[6]

confining pressure of 7 to 35 kPa (1 to 5 psi) to the cell and apply a pressure less than the confining pressure to both the influent and effluent systems, and flush permeant water through the flow system. After all visible air has been removed from the flow lines, close the control valves. At no time during saturation of the system and specimen or hydraulic conductivity measurements shall the maximum applied effective stress be allowed to exceed that to which the specimen is to be consolidated.

8.2 *Specimen Soaking (Optional)*—To aid in saturation, specimens may be soaked under partial vacuum applied to the top of the specimen. Atmospheric pressure shall be applied to the specimen base through the influent lines, and the magnitude of the vacuum set to generate a hydraulic gradient across the sample less than that which will be used during hydraulic conductivity measurements.

NOTE 6—Soaking under vacuum is applicable when there are continuous air voids in the specimen. Soaking under vacuum is only recommended for test specimens with initial degrees of saturation below 70 %. The specimen may swell when exposed to water; the effective stress will tend to counteract the swelling. However, for materials that tend to swell, unless the applied effective stress is greater than or equal to the swell pressure, the specimen will swell.

8.3 *Backpressure Saturation*—To saturate the specimen, backpressuring is usually necessary. Figure 2 provides guidance on back pressure required to attain saturation.

NOTE 7—Figure 2 assumes that the water used for back pressure is deaired and that the only source for air to dissolve into the water is air from the test specimen. If air pressure is used to control the back pressure, pressurized air will dissolve into the water, thus reducing the capacity of the water used for back pressure to dissolve air located in the pores of the test specimen. The problem is minimized by using a long (>5 m) tube that is impermeable to air between the air-water interface and test specimen, by separating the back-pressure water from the air by a material or fluid that is relatively impermeable to air, by periodically replacing the back-pressure water with deaired water, or by other means.

[6] Lowe, J., and Johnson, T. C., "Use of Back Pressure to Increase Degree of Saturation of Triaxial Test Specimens," *Proceedings, ASCE Research Conference on Shear Strength of Cohesive Soils*, Boulder, CO, 1960.

8.3.1 Open the flow line valves and flush out of the system any free air bubbles using the procedure outlined in 8.1.3. If an electronic pressure transducer or other measuring device is to be used during the test to measure pore pressures or applied hydraulic gradient, it should be bled of any trapped air. Take and record an initial reading of specimen height, if being monitored.

8.3.2 Adjust the applied confining pressure to the value to be used during saturation of the sample. Apply backpressure by simultaneously increasing the cell pressure and the influent and effluent pressures in increments. The maximum value of an increment in backpressure shall be sufficiently low so that no point in the specimen is exposed to an effective stress in excess of that to which the specimen will be subsequently consolidated. At no time shall a head be applied so that the effective confining stress is <7 kPa (1 psi) because of the danger of separation of the membrane from the test specimen. Maintain each increment of pressure for a period of a few minutes to a few hours, depending upon the characteristics of the specimen. To assist in removal of trapped air, a small hydraulic gradient may be applied across the specimen to induce flow.

8.3.3 Saturation shall be verified with one of the three following techniques:

8.3.3.1 Saturation may be verified by measuring the *B* coefficient as described in Test Method D 4767 (see Note 8). The test specimen shall be considered to be adequately saturated if (*1*) the *B* value is ≥0.95, or (*2*) for relatively incompressible materials, for example, rock, if the *B* value remains unchanged with application of larger values of back pressure. The *B* value may be measured prior to or after completion of the consolidation phase (see 8.4). Accurate *B*-value determination can only be made if no gradient is acting on the specimen and all pore pressure induced by consolidation has dissipated.

NOTE 8—The *B* coefficient is defined for this type of test as the change in pore water pressure in the porous material divided by the change in confining pressure. Compressible materials that are fully saturated with water will have a *B* value of 1.0. Relatively incompressible, saturated materials have *B* values which are somewhat less than 1.0.

8.3.3.2 Saturation of the test specimen may be confirmed at the completion of the test by calculation of the final degree of saturation. The final degree of saturation shall be 100 ± 5 %. However, measurement of the *B* coefficient as described in 8.3.3.1 or use of some other technique (8.3.3.3) is strongly recommended because it is much better to confirm saturation prior to permeation than to wait until after the test to determine if the test was valid.

8.3.3.3 Other means for verifying saturation, such as measurement of the volume change of the specimen when the pore water pressure has been changed, can be used for verifying saturation provided data are available for similar materials to establish that the procedure used confirms saturation as required in 8.3.3.1 or 8.3.3.2.

8.4 *Consolidation*—The specimen shall be consolidated to the effective stress specified by the requestor. Consolidation may be accomplished in stages, if desired.

NOTE 9—The test specimen may be consolidated prior to application of backpressure. Also, the backpressure and consolidation phases may be completed concurrently if backpressures are applied sufficiently slowly to minimize potential for overconsolidation of the specimen.

8.4.1 Record the specimen height, if being monitored, prior to application of consolidation pressure and periodically during consolidation.

8.4.2 Increase the cell pressure to the level necessary to develop the desired effective stress, and begin consolidation. Drainage may be allowed from the base or top of the specimen, or simultaneously from both ends.

8.4.3 (Optional) Record outflow volumes to confirm that primary consolidation has been completed prior to initiation of the hydraulic conductivity test. Alternatively, measurements of the change in height of the test specimen can be used to confirm completion of consolidation.

NOTE 10—The procedure in 8.4.3 is optional because the requirements of 8.5 ensure that the test specimen is adequately consolidated during permeation because if it is not, inflow and outflow volumes will differ significantly. However, for accurate *B*-value determination, completion of consolidation should be confirmed (see 8.3.3.1). It is recommended that outflow volumes or height changes be recorded as a means for verifying the completion of consolidation prior to initialization of permeation. Also, measurements in the change in height of the test specimen, coupled with knowledge of the initial height, provide a means for checking the final height of the specimen.

8.5 *Permeation:*

8.5.1 *Hydraulic Gradient*—When possible, the hydraulic gradient used for hydraulic conductivity measurements should be similar to that expected to occur in the field. In general, hydraulic gradients from <1 to 5 cover most field conditions. However, the use of small hydraulic gradients can lead to very long testing times for materials having low hydraulic conductivity (less than about 1×10^{-6} cm/s). Somewhat larger hydraulic gradients are usually used in the laboratory to accelerate testing, but excessive gradients must be avoided because high seepage pressures may consolidate the material, material may be washed from the specimen, or fine particles may be washed downstream and plug the effluent end of the test specimen. These effects could increase or decrease hydraulic conductivity. If no gradient is specified by the requestor, the following guidelines may be followed:

Hydraulic Conductivity, cm/s	Recommended Maximum Hydraulic Gradient
1×10^{-3} to 1×10^{-4}	2
1×10^{-4} to 1×10^{-5}	5
1×10^{-5} to 1×10^{-6}	10
1×10^{-6} to 1×10^{-7}	20
less than 1×10^{-7}	30

NOTE 11—Seepage pressures associated with large hydraulic gradients can consolidate soft, compressible specimens and reduce their hydraulic conductivity. It may be necessary to use smaller hydraulic gradients (<10) for such specimens.

8.5.2 *Initialization*—Initiate permeation of the specimen by increasing the influent pressure (see 8.3.2). The effluent pressure shall not be decreased because air bubbles that were dissolved by the specimen water during backpressuring may come out of solution if the pressure is decreased. The back pressure shall be maintained throughout the permeation phase.

8.5.3 *Constant Head Test (Method A)*—Measure and record the required head loss across the test specimen to the tolerances stated in 5.1.1 and 5.2.3. The head loss across the specimen shall be kept constant ±5 %. Measure and record periodically the quantity of inflow as well as the quantity of outflow. Also measure and record any changes in height of the test specimen, if being monitored (see Note 11). Continue permeation until at least four values of hydraulic conductivity are obtained over an interval of time in which: (*1*) the ratio of outflow to inflow rate is between 0.75 and 1.25, and (*2*) the hydraulic conductivity is steady. The hydraulic conductivity shall be considered steady if four or more consecutive hydraulic conductivity determinations fall within ±25 % of the mean value for $k \geq 1 \times 10^{-10}$ m/s or within ±50 % for $k < 1 \times 10^{-10}$ m/s, and a plot of the hydraulic conductivity versus time shows no significant upward or downward trend.

8.5.4 *Falling-Head Tests (Methods B and C)*—Measure and record the required head loss across the test specimen to the tolerances stated in 5.1.2. For falling-head tests, at no time shall the applied head loss across the specimen be less than 75 % of the initial (maximum) head loss during each individual hydraulic conductivity determination (see Note 12). Periodically measure and record any changes in the height of the specimen, if being monitored. Continue permeation until at least four values of hydraulic conductivity are obtained over an interval of time in which: (*1*) the ratio of outflow to inflow rate is between 0.75 and 1.25, and (*2*) the hydraulic conductivity is steady (see 8.5.3).

NOTE 12—When the water pressure in a test specimen changes and the applied total stress is constant, the effective stress in the test specimen changes, which can cause volume changes that can invalidate the test results. The requirement that the head loss not decrease very much is intended to keep the effective stress from changing too much. For extremely soft, compressible test specimens, even more restrictive criteria might be needed. Also, when the initial and final head losses across the test specimen do not differ by much, great accuracy is needed to comply with the requirement of 5.1.2 that the ratio of initial to final head loss be determined with an accuracy of ±5 % or better. When the initial and final head loss over an interval of time do not differ very much, it may be possible to comply with the requirements for a constant head test (8.5.3) in which the head loss must not differ by more than ±5 % and to treat the test as a constant head test.

8.5.4.1 *Test with Constant Tailwater Level (Method B)*—If the water pressure at the downstream (tailwater) end of the test specimen is kept constant, periodically measure and record either the quantity of inflow or the level of water in the influent standpipe; measure and record the quantity of outflow from the test specimen.

8.5.4.2 *Test with Increasing Tailwater Level (Method C)*—If the water pressure at the downstream end of the test specimen rises during an interval of time, periodically measure and record either the quantity or inflow and outflow or the changes in water levels in the influent and effluent standpipes.

8.5.5 *Constant Rate of Flow Tests (Method D)*—Initiate permeation of the specimen by imposing a constant flow rate. Choose the flow rate so the hydraulic gradient does not exceed the value specified, or if none is specified, the value recommended in 8.5.1. Periodically measure the rate of inflow, the rate of outflow, and head loss across the test specimen to the tolerances given in 5.1.3. Also, measure and record any changes in specimen height, if being monitored. Continue permeation until at least four values of hydraulic conductivity are obtained over an interval of time in which (*1*) the ratio of inflow to outflow rates is between 0.75 and 1.25, and (*2*) hydraulic conductivity is steady (see 8.5.3).

8.6 *Final Dimensions of the Specimen*—After completion of permeation, reduce the applied confining, influent, and effluent pressures in a manner that does not generate significant volume change of the test specimen. Then carefully disassemble the permeater cell and remove the specimen. Measure and record the final height, diameter, and total mass of the specimen. Then determine the final water content of the specimen by the procedure of Method D 2216. Dimensions and mass of the test specimen shall be measured to the tolerances specified in 5.13 and 7.1.

NOTE 13—The specimen may swell after removal of back pressure as a result of air coming out of solution. A correction may be made for this effect, provided that changes in the length of the specimen are monitored during the test. The strain caused by dismantling the cell is computed from the length of the specimen before and after dismantling the cell. The same strain is assumed to have occurred in the diameter. The corrected diameter and actual length before the back pressure was removed are used to compute the volume of the test specimen prior to dismantling the cell. The volume prior to dismantling the cell is used to determine the final dry density and degree of saturation.

9. Calculation

9.1 *Constant Head and Constant Rate of Flow Tests (Methods A and D)*—Calculate the hydraulic conductivity, k, as follows:

$$k = QL/Ath \tag{1}$$

where:

k = hydraulic conductivity, m/s,
Q = quantity of flow, taken as the average of inflow and outflow, m^3,
L = length of specimen along path of flow, m,
A = cross-sectional area of specimen, m^2,
t = interval of time, s, over which the flow Q occurs, and
h = difference in hydraulic head across the specimen, m of water.

9.2 *Falling-Head Tests:*

9.2.1 *Constant Tailwater Pressure (Method B)*—Calculate the hydraulic conductivity, k, as follows:

$$k = \frac{aL}{At} \ln \left(\frac{h_1}{h_2}\right) \tag{2}$$

where:

a = cross-sectional area of the reservoir containing the influent liquid, m^2,
L = length of the specimen, m,
A = cross-sectional area of the specimen, m^2,
t = elapsed time between determination of h_1 and h_2, s,
h_1 = head loss across the specimen at time t_1, m, and
h_2 = head loss across the specimen at time t_2, m.

9.2.2 *Increasing Tailwater Pressure (Method C)*—Calculate the hydraulic conductivity, k, as follows:

$$k = \frac{a_{in}\, a_{out}\, L}{A\, t\, (a_{in} + a_{out})} \ln(h_1/h_2) \tag{3}$$

where:

a_{in} = cross-sectional area of the reservoir containing the influent liquid, m^2,
a_{out} = cross-sectional area of the reservoir containing the effluent liquid, m^2,
L = length of the specimen, m,
A = cross-sectional area of the specimen, m^2,
t = elapsed time between determination of h_1 and h_2, s,
h_1 = head loss across the specimen at time t, m, and
h_2 = head loss across the specimen at time t_2, m.

NOTE 14—For the case in which $a_{out} = a_{in} = a$, the equation for calculating k for a falling head test with a rising tailwater level is:

$$k = \frac{a\,L}{-2\,A\,t} \ln\left(\frac{h_1}{h_2}\right) \quad (4)$$

9.3 Correct the hydraulic conductivity to that for 20°C (68°F), k_{20}, by multiplying k by the ratio of the viscosity of water at test temperature to the viscosity of water at 20°C (68°F), R_T, from Table 1, as follows:

$$k_{20} = R_T k \quad (5)$$

10. Report

10.1 Report the following information:

10.1.1 Sample identifying information,

10.1.2 Any special selection and preparation process, such as removal of stones or other materials, or indication of their presence, if undisturbed specimen,

10.1.3 Descriptive information on method of compaction,

10.1.4 Initial dimensions of the specimen,

10.1.5 Initial water content and dry unit weight of the specimen,

10.1.6 Type of permeant liquid used,

10.1.7 Magnitude of total back pressure,

10.1.8 Maximum and minimum effective consolidation stress,

NOTE 15—The maximum effective stress exists at the effluent end of the test specimen and the minimum stress at the influent end.

10.1.9 Height of specimen after completion of consolidation, if monitored,

10.1.10 Range of hydraulic gradient used,

10.1.11 Final length, diameter, water content, dry unit weight, and degree of saturation of the test specimen,

10.1.12 Average hydraulic conductivity for the last four determinations of hydraulic conductivity (obtained as described in 8.5.3 to 8.5.5), reported with two significant figures, for example, 7.1×10^{-10} m/s, and reported in units of m/s (plus additional units, if requested or customary),

10.1.13 Graph or table of hydraulic conductivity versus time or pore volumes of flow is recommended.

TABLE 1 Correction Factor R_T for Viscosity of Water at Various Temperatures[A]

Temperature, °C	R_T	Temperature, °C	R_T
0	1.783	25	0.889
1	1.723	26	0.869
2	1.664	27	0.850
3	1.611	28	0.832
4	1.560	29	0.814
5	1.511	30	0.797
6	1.465	31	0.780
7	1.421	32	0.764
8	1.379	33	0.749
9	1.339	34	0.733
10	1.301	35	0.719
11	1.265	36	0.705
12	1.230	37	0.692
13	1.197	38	0.678
14	1.165	39	0.665
15	1.135	40	0.653
16	1.106	41	0.641
17	1.077	42	0.629
18	1.051	43	0.618
19	1.025	44	0.607
20	1.000	45	0.598
21	0.976	46	0.585
22	0.953	47	0.575
23	0.931	48	0.565
24	0.910	49	0.556

[A] $R_T = (-0.02452\ T + 1.495)$ where T is the degrees celsius.

11. Precision and Bias

11.1 *Precision*—Data are being evaluated to determine the precision of this test method. In addition, Subcommittee D18.04 on Hydrologic Properties of Soil and Rocks, is seeking pertinent data from users of this test method.

11.2 *Bias*—There is no accepted reference value for this test method, therefore, bias cannot be determined.

12. Keywords

12.1 coefficient of permeability; hydraulic barriers; hydraulic conductivity; liner; permeameter

ATTACHMENT D

NSC CONSTRUCTION QUALITY CONTROL MANUAL, SECTION 3.1

1. INTRODUCTION

1.1 This manual addresses the Quality Control Program developed and utilized by National Seal Company Installation Personnel to assure the quality of workmanship and the installation integrity of geomembranes and other geosynthetic products.

1.2 All geosynthetic components of lining systems will be addressed in this manual, including geomembranes, geotextiles, geonets, and bentonite mats. National Seal Company recognizes that careful and specific documentation of the installation is required to substantiate this Quality Control Program.

2. MATERIAL DELIVERY

2.1 A Third Party QA Representative should be present, whenever possible, to observe and assist in material delivery and unloading on site. The Third Party QA Representative is to note any materials received in a damaged state and note any material damaged during unloading. Upon mobilization to site, a NSC Representative shall:

- Verify the equipment used on site is adequate and does not risk damage to the geomembrane or other materials.
- Mark rolls or portions of rolls which appear damaged.
- Verify that storage of materials ensures adequate protection against dirt, theft, vandalism, and passage of vehicles.
- Ensure that rolls are properly labeled and that labeling corresponds with Quality Control documentation and Shipping Bills of Lading.
- Assist Third Party QA Representative, if present, with material sampling or record keeping.
- Complete roll numbers, date, bill of lading number, roll size, and any damage noted will be logged on the NSC Material Delivery Checklist. (See Appendix A).

3. GEOMEMBRANE INSTALLATION

3.1 Earth Work

3.1.1 The General and/or Earthwork Contractor shall be responsible for preparing and maintaining the subgrade in a condition suitable for installation of the liner unless specifically agreed otherwise.

3.1.2 In cases where no site specific earthwork quality control guidelines exist, the following general minimum guidelines shall be followed.

3.1.2.1 Surfaces to be lined shall be smooth and free of debris, roots, and angular or sharp rocks. All fill shall consist of well-graded material, free of organics, trash, clayballs, or other deleterious material that may cause damage to the geomembrane. The upper six inches (6") of the finished subgrade shall not contain stones or debris larger than one-half inch (1/2"). The subgrade shall be compacted in accordance with design specifications, but in no event less than is required to provide a firm, unyielding foundation sufficient to permit the movement of vehicles and welding equipment over the subgrade without causing rutting or other deleterious effects. The subgrade shall have no sudden sharp or abrupt changes in grade.

3.1.2.2 The Earthwork Contractor shall protect the subgrade from desiccation, flooding, and freezing. Protection, if required, may consist of a thin plastic protective cover (or other material as approved by the engineer) installed over the completed subgrade until such time as the placement of geomembrane liner begins. Subgrades found to have desiccation cracks greater than one-half inch (1/2") in width or depth, or which exhibit swelling, heaving, or other similar conditions shall be replaced or reworked by the General and/or Earthwork Contractor to remove these defects.

3.1.2.3 Surface Acceptance. Upon request, National Seal Company's Site Supervisor will provide the Owner's and/or Contractor's Representatives with a written acceptance of the surface to be lined. This acceptance will be limited to the amount of area that National Seal Company is capable of lining during a particular work shift. Direction and control of any subsequent repairs to the subgrade, including the subgrade surface, shall remain the responsibility of the Earthwork Contractor. An example of

National Seal Company's Subgrade Surface Acceptance Form is included in Appendix A.

3.2 Crest Anchorage System

3.2.1 The anchor trench shall be excavated by the General and/or the Earthwork Contractor to the lines and widths shown on the design drawings prior to geomembrane placement.

3.2.2 Anchor trenches excavated in clay soils susceptible to desiccation cracks should be excavated only the distance required for that days liner placement to minimize the potential of desiccation cracking of the clay soils.

3.2.3 Corners in the anchor trench shall be slightly rounded where the geomembrane adjoins the trench to minimize sharp bends in the geomembrane.

3.3 Preparation for Geomembrane Deployment

3.3.1 Panel Layout

Prior to commencement of liner deployment, layout drawings shall be produced to indicate the panel configuration and general location of field seams for the project.

3.3.2 Identification

Each panel used for the installation shall be given a numeric or alpha-numeric identifier. This panel identification number shall be related on the NSC Panel Placement Form to a manufacturing roll number that identifies the resin type, batch number, and date of manufacture.

3.4 Field Panel Placement

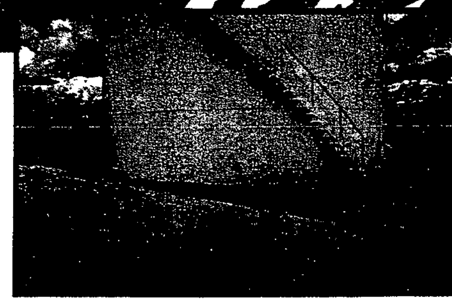
3.4.1 Weather Conditions

Geomembrane deployment will generally not be done during any precipitation, in the presence of excessive moisture (i.e fog, dew), in an area of standing water, or during high winds.

ATTACHMENT E

CLAYMAX INSTALLATION RECOMMENDATIONS

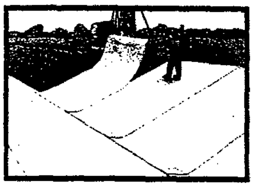
CLAYMAX®



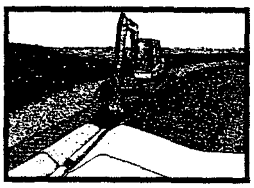
CLAYMAX® IS THE STATE-OF-THE-ART GEOCOMPOSITE LINER FOR THE WATER AND WASTE CONTAINMENT INDUSTRY. CLAYMAX® . . . THE IMPERMEABLE BARRIER OF BENTONITE CLAY IN CARPET FORM.

SITE PREPARATION: The pond, lagoon, tank farm enclosure or canal excavation depth should be determined to allow for a final addition of a minimum 6-8 inches of soil or aggregate cover material. The excavation should be well contoured with slopes that are at a maximum of three-to-one. Protrusions and rocks larger than 2 inches in diameter should be removed and the entire excavation should be compacted sufficiently to prevent ruts from installation vehicles. Compaction can be accomplished using either conventional rolling equipment or wheeled vehicles. Use of sheepsfoot rolling equipment is not recommended. A liner **locking trench (min. 18 inches deep)** must be provided at the top of all slopes.

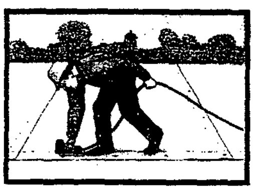
ORIENTATION: When installing CLAYMAX liner, **all seams on slopes must be perpendicular to the excavation bottom.** This method prevents seam displacement during the backfill procedure. It is also important that the first CLAYMAX liner roll and all succeeding rolls be pulled tight to smooth out creases.



ANCHORING: All CLAYMAX liner sheets should be anchored to pressure-treated wooden 2 x 4's (or equivalent) and locked into trenches at the top of all slopes, covered with fill and compacted to prevent slippage during installation. This trench should be at least 12 inches above the final contained liquid level and should be approximately **18 inches deep** and **18 inches back from the finished waterline.**



SEAMING: CLAYMAX liner seams are non-critical and self-seaming. CLAYMAX liner seams require a **simple 6-inch overlap** with long pins or nails every yard to allow for movement of CLAYMAX liner during ground subsidence. No adhesive or thermal welding is required. The hydrated bentonite will push through the woven polypropylene forming a monolithic seal with a permeability of no greater than 1×10^{-9} cm/sec.



REPAIRING: Irregular shapes, cuts or tears are **easily repaired** by covering the area with CLAYMAX liner to provide a 6-inch overlap on all sides. These repair pieces should be stapled or nailed in position until cover material has been placed.

COVERING: Cover material (minimum 6-8 inches of aggregate or backfill) should be applied as CLAYMAX liner sheets are placed to afford maximum protection. **Correctly installed, CLAYMAX liner is capable of supporting installation personnel and equipment.** Because it is not recommended for vehicles to operate directly on CLAYMAX liner without the support of a backfill, **cover material should always be pushed forward.** Cover material (other than aggregate) should be compacted after placement.

CLAYMAX® liner, the *state-of-the-art geocomposite,* can be used as a primary or secondary liner.

MATERIAL SPECIFICATIONS

Primary Backing (Typical Properties) — Polypropylene is nonbiodegradable and inert to most chemicals, acids and alkalis.

Color	Natural white
Filler Fiber	Nylon
Substrate	24 x 10 Delustered woven polypropylene, non-toxic, water permeable
Weight	4 oz. per square yard
Tensile Strength	78 lbs. per inch (minimum)
Grab Strength (ASTM D-1682)	Warp 95 lbs., Fill 70 lbs.
Mullen Burst Strength (ASTM D774)	250.25 lbs. per square inch
Puncture Strength (5/16" mandril ASTM D3787 MOD.)	249 lbs.
Melting Point	329° F
Elongation (ASTM D-1682)	Warp 15%, Fill 18%
Shrinkage—Hot Water	Nil
Shrinkage—Dry (20 min. @ 270°F)	2%

Cover Fabric	100% spunlace polyester; open weave allows for expansion of bentonite
Weight	1 oz. per square yard
Grab Strength	Warp 30 lbs., Fill 13.6 lbs.
Burst Strength	35 lbs. per square inch

Bentonite Sizing (Sodium Montmorillonite)	Specially graded, 6 mesh and 30 mesh granules
Mineralogical Composition	90% Montmorillonite (min.)

Adhesive	Water soluble, non-toxic
Storage	On dry ground, under roof or other protective covering

The manufacturer reserves the right to change product specifications and instructions/limitations without notice. Information contained herein supersedes previously printed material prior to 7/89.

ATTACHMENT F

NSC HDPE GEOMEMBRANE PHYSICAL PROPERTIES

NSC

HDPE GEOMEMBRANE

National Seal Company's High Density Polyethylene (HDPE) geomembranes are extruded using virgin, first-quality, high molecular weight, polyethylene resin and are manufactured specifically for the purpose of containment in hydraulic structures. The HDPE compound used in **NSC** geomembranes has been formulated to be chemically resistant, free of leachable additives and resistant to ultraviolet degradation.

60 MIL (1.5mm) PHYSICAL PROPERTIES

ALL PROPERTIES MEET OR EXCEED NSF STANDARD 54 SPECIFICATIONS FOR HDPE

PROPERTY	MINIMUM AVERAGE ROLL VALUES (unless otherwise indicated)			
	ENGLISH		METRIC	
	UNITS	VALUE	UNITS	VALUE
THICKNESS, ASTM D 751, NSF Mod., Nominal	mils	60.0	mm	1.50
Minimum Average	mils	60.0	mm	1.52
Lowest Individual Reading	mils	57.0	mm	1.45
DENSITY, ASTM D 1505			g/cm^3	0.940
MELT FLOW INDEX, ASTM D 1238, Cond. E, Max.			g/10 min	1.0
CARBON BLACK CONTENT, ASTM D 1603	percent	2.0 to 3.0	percent	2.0 TO 3.0
CARBON BLACK DISPERSION, ASTM D 3015	rating	A1 or A2	rating	A1 or A2
MINIMUM TENSILE PROPERTIES, ASTM D 638				
Stress at Yield	psi	2200	MPa	15.2
	ppi	132	N/cm	231
Stress at Break	psi	3800	MPa	26.2
	ppi	228	N/cm	399
Strain at Yield	percent	13	percent	13
nominal gage of 1.30" per NSF Mod.				
Strain at Break	percent	700	percent	700
nominal gage of 2.5" per NSF Mod.	percent	560	percent	560
TEAR RESISTANCE, ASTM D1004	ppi	700	N/cm	1230
	lbs	42	N	187
PUNCTURE RESISTANCE, FTMS 101, 2065	ppi	1300	N/cm	2280
	lbs	78	N	347
ESCR, ASTM D 1693, NSF Mod., Pass	hours	1500	hours	1500
DIMENSIONAL STABILITY, ASTM D1204, NSF Mod, Max.	percent	2.0	percent	2.0

NATIONAL SEAL SEAMING PROPERTIES

(All NSC seams will demonstrate a Film Tearing Bond in Peel and Shear)

SHEAR STRENGTH, ASTM D 4437, NSF Mod.	psi	2000	MPa	13.8
	ppi	120	N/cm	210
PEEL ADHESION, ASTM D 4437, NSF Mod.	psi	1500	MPa	10.3
(Hot wedge fusion weld)	ppi	90	N/cm	158
PEEL ADHESION, ASTM D 4437, NSF Mod.	psi	1300	MPa	8.97
(fillet extrusion weld)	ppi	78	N/cm	137

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NSC

NATIONAL SEAL COMPANY
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NSC

HDPE GEOMEMBRANE

60 MIL (1.5mm) CHARACTERISTICS

PROPERTY	MINIMUM AVERAGE ROLL VALUES (unless otherwise indicated)			
	ENGLISH		METRIC	
	UNITS	VALUE	UNITS	VALUE
MODULUS OF ELASTICITY, ASTM D 882	psi	80,000	MPa	552
HYDROSTATIC RESISTANCE, ASTM D 751 A	psi	450	MPa	3.10
COEF. LINEAR THERMAL EXPANSION, Nominal	/°F	$6.7x10^{-5}$	/° C	$1.2x10^{-4}$
BRITTLENESS TEMP, ASTM D 746 B, Pass	°F	-103	°C	-75
SOIL BURIAL RESISTANCE, NSF 54, Max. Change	percent	10	percent	10
OIT, 200° C, 1 atm 0_2, Al pan	minutes	100	sec	6,000
PUNCTURE RESISTANCE, ASTM D 4833	ppi	1800	N/cm	3150
	lbs	108	N	480
TENSILE IMPACT, ASTM D 1822	ft lbs/in²	238	kJ/m²	500
VOLATILE LOSS, ASTM D 1203A, Max.	percent	0.1	percent	0.1
OZONE RESISTANCE, ASTM D 1149, 168 hrs, 100 pphm		No Cracks		No Cracks
WATER ABSORPTION, ASTM D 570, 23° C	percent	0.1	percent	0.1
WATER VAPOR TRANSMISSION, ASTM E 96, Max.			g/hr m^2	0.005
PERMEABILITY, WATER, ASTM E 96, Max.			cm/sec Pa	$1.1x10^{-13}$

STANDARD ROLL DIMENSIONS*	TYPICAL ROLL VALUE			
WEIGHT	lbs	5,000	kg	2,270
WIDTH	ft	15.0	m	4.57
LENGTH	ft	1,110	m	338
AREA	ft²	16,650	M^2	1,547

*Values Are Approximate
Custom Roll Sizes And Half Size Rolls Are Available
Sheet is Rolled on 12" Diameter Cores

HD-60-0391C

NSC does not generally perform conformance testing for properties on this page.

NSC
NATIONAL SEAL COMPANY
1245 Corporate Blvd., Suite 300
Aurora, IL 60504
800/323-3820 708/898-1161

NSC

HDPE GEOMEMBRANE

60 MIL (1.5mm) CHARACTERISTICS

PROPERTY	MINIMUM AVERAGE ROLL VALUES (unless otherwise indicated)			
	ENGLISH		METRIC	
	UNITS	VALUE	UNITS	VALUE
MODULUS OF ELASTICITY, ASTM D 882	psi	80,000	MPa	552
HYDROSTATIC RESISTANCE, ASTM D 751 A	psi	450	MPa	3.10
COEF. LINEAR THERMAL EXPANSION, Nominal	/°F	6.7×10^{-5}	/° C	1.2×10^{-4}
BRITTLENESS TEMP, ASTM D 746 B, Pass	°F	-103	°C	-75
SOIL BURIAL RESISTANCE, NSF 54, Max. Change	percent	10	percent	10
OIT, 200° C, 1 atm O_2, Al pan	minutes	100	sec	6,000
PUNCTURE RESISTANCE, ASTM D 4833	ppi	1800	N/cm	3150
	lbs	108	N	480
TENSILE IMPACT, ASTM D 1822	ft lbs/in²	238	kJ/m²	500
VOLATILE LOSS, ASTM D 1203A, Max.	percent	0.1	percent	0.1
OZONE RESISTANCE, ASTM D 1149, 168 hrs, 100 pphm		No Cracks		No Cracks
WATER ABSORPTION, ASTM D 570, 23° C	percent	0.1	percent	0.1
WATER VAPOR TRANSMISSION, ASTM E 96, Max.			g/hr m²	0.005
PERMEABILITY, WATER, ASTM E 96, Max.			cm/sec Pa	1.1×10^{-13}

STANDARD ROLL DIMENSIONS*	TYPICAL ROLL VALUE			
WEIGHT	lbs	5,000	kg	2,270
WIDTH	ft	15.0	m	4.57
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ATTACHMENT G

NSC CONSTRUCTION QUALITY CONTROL MANUAL, SECTIONS 1-5

NSC

NATIONAL SEAL COMPANY

CONSTRUCTION
QUALITY CONTROL
MANUAL

NSC

INDEX

NSC

INDEX

NSC

INDEX

APPENDICES

1. INTRODUCTION

1.1 This manual addresses the Quality Control Program developed and utilized by National Seal Company Installation Personnel to assure the quality of workmanship and the installation integrity of geomembranes and other geosynthetic products.

1.2 All geosynthetic components of lining systems will be addressed in this manual, including geomembranes, geotextiles, geonets, and bentonite mats. National Seal Company recognizes that careful and specific documentation of the installation is required to substantiate this Quality Control Program.

2. MATERIAL DELIVERY

2.1 A Third Party QA Representative should be present, whenever possible, to observe and assist in material delivery and unloading on site. The Third Party QA Representative is to note any materials received in a damaged state and note any material damaged during unloading. Upon mobilization to site, a NSC Representative shall:

- Verify the equipment used on site is adequate and does not risk damage to the geomembrane or other materials.
- Mark rolls or portions of rolls which appear damaged.
- Verify that storage of materials ensures adequate protection against dirt, theft, vandalism, and passage of vehicles.
- Ensure that rolls are properly labeled and that labeling corresponds with Quality Control documentation and Shipping Bills of Lading.
- Assist Third Party QA Representative, if present, with material sampling or record keeping.
- Complete roll numbers, date, bill of lading number, roll size, and any damage noted will be logged on the NSC Material Delivery Checklist. (See Appendix A).

3. GEOMEMBRANE INSTALLATION

3.1 Earth Work

3.1.1 The General and/or Earthwork Contractor shall be responsible for preparing and maintaining the subgrade in a condition suitable for installation of the liner unless specifically agreed otherwise.

3.1.2 In cases where no site specific earthwork quality control guidelines exist, the following general minimum guidelines shall be followed.

3.1.2.1 Surfaces to be lined shall be smooth and free of debris, roots, and angular or sharp rocks. All fill shall consist of well-graded material, free of organics, trash, clayballs, or other deleterious material that may cause damage to the geomembrane. The upper six inches (6") of the finished subgrade shall not contain stones or debris larger than one-half inch (1/2"). The subgrade shall be compacted in accordance with design specifications, but in no event less than is required to provide a firm, unyielding foundation sufficient to permit the movement of vehicles and welding equipment over the subgrade without causing rutting or other deleterious effects. The subgrade shall have no sudden sharp or abrupt changes in grade.

3.1.2.2 The Earthwork Contractor shall protect the subgrade from desiccation, flooding, and freezing. Protection, if required, may consist of a thin plastic protective cover (or other material as approved by the engineer) installed over the completed subgrade until such time as the placement of geomembrane liner begins. Subgrades found to have desiccation cracks greater than one-half inch (1/2") in width or depth, or which exhibit swelling, heaving, or other similar conditions shall be replaced or reworked by the General and/or Earthwork Contractor to remove these defects.

3.1.2.3 Surface Acceptance. Upon request, National Seal Company's Site Supervisor will provide the Owner's and/or Contractor's Representatives with a written acceptance of the surface to be lined. This acceptance will be limited to the amount of area that National Seal Company is capable of lining during a particular work shift. Direction and control of any subsequent repairs to the subgrade, including the subgrade surface, shall remain the responsibility of the Earthwork Contractor. An example of

National Seal Company's Subgrade Surface Acceptance Form is included in Appendix A.

3.2 Crest Anchorage System

3.2.1 The anchor trench shall be excavated by the General and/or the Earthwork Contractor to the lines and widths shown on the design drawings prior to geomembrane placement.

3.2.2 Anchor trenches excavated in clay soils susceptible to desiccation cracks should be excavated only the distance required for that days liner placement to minimize the potential of desiccation cracking of the clay soils.

3.2.3 Corners in the anchor trench shall be slightly rounded where the geomembrane adjoins the trench to minimize sharp bends in the geomembrane.

3.3 Preparation for Geomembrane Deployment

3.3.1 Panel Layout

Prior to commencement of liner deployment, layout drawings shall be produced to indicate the panel configuration and general location of field seams for the project.

3.3.2 Identification

Each panel used for the installation shall be given a numeric or alpha-numeric identifier. This panel identification number shall be related on the NSC Panel Placement Form to a manufacturing roll number that identifies the resin type, batch number, and date of manufacture.

3.4 Field Panel Placement

3.4.1 Weather Conditions

Geomembrane deployment will generally not be done during any precipitation, in the presence of excessive moisture (i.e fog, dew), in an area of standing water, or during high winds.

3.4.2 Location

National Seal Company intends to install field panels as indicated on the layout drawing. If the panels are deployed in a location other than that indicated on the layout drawings, the revised location shall be noted in the field on a record "as-built" drawing which will be modified at the completion of the project to reflect actual panel locations. Record drawings will be maintained and submitted by NSC and/or the Third Party QA Representative as required by the project specification and contract documents.

3.4.3 Documentation of Panel Placement

Information relating to geomembrane panel placement including date, time, panel number, and panel dimensions will be maintained on the Panel Placement Form as presented in Appendix A.

3.4.3.1 If a portion of a roll is set aside to be used at another time, the roll number will be written on the remainder of the roll in several places.

3.4.4 Method of Deployment

3.4.4.1 The method and equipment used to deploy the panels must not damage the geomembrane or the supporting subgrade surface.

3.4.4.2 No personnel working on the geomembrane will wear shoes that can damage the geomembrane or engage in actions which could result in damage to the geomembrane.

3.4.4.3 Adequate temporary loading and/or anchoring, (i.e. sandbags, tires), which will not damage the geomembrane, will be placed to prevent uplift of the geomembrane by wind.

3.4.4.4 The geomembrane will be deployed in a manner to minimize wrinkles.

3.4.5 Any area of a panel seriously damaged (torn, twisted, or crimped) will be marked and repaired in accordance with Paragraph 5.3 of this document.

3.5 Geomembrane Field Seaming

3.5.1 General Requirements

3.5.1.1 Layout

In general, seams shall be oriented parallel to the slope, i.e., oriented along, not across the slope. Whenever possible, horizontal seams should be located on the base of the cell, not less than five (5') feet from the toe of the slope. Each seam made in the field shall be numbered and indicated on the record drawings. Seaming information to include seam number, welder ID, machine number, temperature setting, and weather conditions will be maintained on NSC Panel Seaming Form as presented in Appendix A.

3.5.1.2 Personnel

All personnel performing seaming operations shall be trained in the operation of the specific seaming equipment being used and will qualify by successfully welding a test seam as described in Paragraph 3.5.3. The project Foreman will provide direct supervision of the seaming operations.

3.5.1.3 Equipment

3.5.1.3.1 Fusion Welding

Fusion Welding consists of placing a heated wedge, mounted on a self propelled vehicular unit, between two (2) over-lapped sheets such that the surface of both sheets are heated above the poly-ethylene's melting point. After being heated by the wedge, the overlapped panels pass through a set of pre-set pressure wheels which compress the two (2) panels together to form the weld. The fusion welder is equipped with a device which continuously monitors the temperature of the wedge.

3.5.1.3.2 Extrusion Fillet Welding

Extrusion fillet welding consists of introducing a ribbon of molten resin along the edge of the overlap of the two (2) geomembrane sheets to be welded. A hot-air preheat and the addition of molten polymer causes some of the material of each sheet to be liquified resulting in a homogeneous bond between the molten weld bead and the surfaces of the overlapped sheets. The extrusion welder is equipped with gauges giving the temperature in the apparatus and a numerical setting for the pre-heating unit.

3.5.1.4 Weather Conditions

National Seal Company relies on the experience of the Project Superintendent and the results of test seams to determine whether seaming is restricted by weather conditions. Many factors, such as the geomembrane temperature, humidity, wind, precipitation, etc. , can effect the integrity of field seams and must be taken into account when deciding whether or not seaming should proceed. Test seams, as described in Paragraph 3.5.3, are required prior to daily production seaming to determine if the weather conditions will effect National Seal Company's ability to produce quality seams. Additional non-destructive and destructive testing of production seams substantiate the decision made by the Project Superintendent to seam on any given day.

3.5.2 Seam Preparation

3.5.2.1 Fusion Welding

3.5.2.1.1 Overlap the panels of Geomembrane approximately four (4") to six (6") inches prior to welding.

3.5.2.1.2 Clean the seam area prior to seaming to assure the area is clean and free of moisture, dust, dirt, or debris of any kind. No grinding is required for fusion welding.

3.5.2.1.3 Adjust the panels so that seams are aligned with the fewest possible number of wrinkles and "fishmouths".

3.5.2.1.4 A movable protective layer may be used, at the discretion of the National Seal Company Project Superintendent, directly below the overlap of geomembrane that is to be seamed to prevent build-up of dirt or moisture between the panels.

3.5.2.2 Extrusion Fillet Welding

3.5.2.2.1 Whenever possible, extrusion welded seams will be pre-beveled prior to heat-tacking into place.

3.5.2.2.2 Overlap the panels of geomembrane a minimum of three inches (3").

3.5.2.2.3 Using a hot-air device, temporarily bond the panels of geomembrane to be welded, taking care not to damage the geomembrane.

3.5.2.2.4 Clean the seam area prior to seaming to assure the area is clean and free of moisture, dust, dirt, and debris of any kind.

3.5.2.2.5 Grind seam overlap prior to welding within one (1) hour of the welding operation in a manner that does not damage the geomembrane. Grind marks should be covered with extrudate whenever possible. In all cases grinding should not extend more than one-quarter inch (1/4") past the edge of the area covered by the extrudate during welding.

3.5.2.2.6 Purge the extruder prior to beginning the seam to remove all heat-degraded extrudate from the barrel. The purged extrudate will be placed on scrap material so as to prevent contact with installed geomembrane.

3.5.2.2.7 Keep welding rod clean and dry.

3.5.3 Trial Welds

Trial welds shall be conducted by Welding Technicians prior to each seaming period, every five (5) hours, as weather conditions dictate, or as requested by NSC CQC personnel if welding problems are suspected. All trial welds will be conducted under the same conditions as will be encountered during actual seaming. Once qualified by a passing trial weld, Welding Technicians will not change parameters (temperature, speed, etc.) without performing another trial weld.

3.5.3.1 Trial Weld Length

The trial weld shall be made by joining two (2) pieces of geomembrane at least six inches (6") in width. Trial welds for fusion welds will be 15 feet long and extrusion weld trial seams will be a minimum of four feet (4') long.

3.5.3.2 Sample Procedure

3.5.3.2.1 Visually inspect the seam for squeeze out, footprint, pressure, and general appearance.

3.5.3.2.2 Cut three (3) one inch (1") wide specimens, one (1) from the middle of the seam and one foot (1') from each end of the test seam. Specimens shall be obtained using a one inch (1") die cutter. The specimens shall then be tested in peel using a field tensiometer.

3.5.3.2.3 In order for a trial weld to be considered acceptable, all three specimens must meet the following criteria:

1. Exhibit Film Tearing Bond (FTB).

2. Meet or exceed the minimum peel strength values listed in NSC's Material Specification Sheet. If any specimens are in non-conformance, the entire procedure shall be repeated. In the case of double track fusion welded seams, both welds must pass in order to be considered acceptable.

3.5.3.2.4 If repeat tests utilizing reasonable sets of welding parameters also fail, the seaming apparatus shall not be accepted and shall not be used for seaming until the deficiencies are corrected and a passing test seam is achieved.

3.5.3.3 Trial Weld Documentation

3.5.3.3.1 CQC Coordinator and/or Assistant will be present during peel testing and will record date, time, operator, machine number, ambient and operating temperatures, speed setting, peel values, and pass/fail designation.

3.5.3.3.2 All trial weld records shall be maintained on National Seal Company's Trial Weld Form as exhibited in Appendix A.

3.5.3.3.3 The National Seal Company CQC Coordinator will give final approval to proceed with welding after observing trial welds.

3.5.4 General Seaming Procedures

3.5.4.1 Seaming shall extend to the outside edge of panels to be placed in the anchor trench.

3.5.4.2 While welding a seam, monitor and maintain the proper overlap.

3.5.4.3 Inspect seam area to assure it is clean and free of moisture, dust, dirt and debris of any kind.

3.5.4.4 Welding Technicians will periodically check machine operating temperature and speed, and will mark this information on the geomembrane.

3.5.4.5 Align wrinkles at the seam overlap to allow welding through the wrinkle.

3.5.4.6 "Fishmouths" or wrinkles at seam overlaps, which cannot be welded through, shall be cut along the ridge in order to achieve a flat overlap. The cut "fishmouth" or wrinkle shall be heat-tacked flat and extruded or patched with an oval or round patch of the same geomembrane extending a minimum of three inches (3") beyond the cut in all directions.

3.5.4.7 All cross/butt seams between two (2) rows of seamed panels shall be welded during the coolest time of the day to allow for contraction of the geomembrane.

3.5.4.8 Prior to welding cross/butt seams, the top and bottom overlap of intersecting fusion welded seams will be trimmed six inches (6"). Intersecting extrusion fillet welded seams will be ground to flatten the extrusion bead prior to welding butt seams.

3.5.4.9 All "T" joints produced as a result of cross/butt seams shall be extrusion fillet welded. The overlap on each "leg" of the "T" joint will be trimmed back six inches (6"). Then grind three inches (3") minimum on each of the three (3) legs of the "T" and extrusion weld all of the area prepared by grinding.

3.5.4.10 Whenever possible, Welding Technicians will cut a one inch (1") peel specimen at the end of every seam. Prior to welding the next seam, the specimen will be tested for peel. The CQC Coordinator may request additional trial welds, based on observations of peel test specimens.

3.5.4.11 In the event non-complying seam test strips are encountered, the welding machine will be taken out of service until a passing trial weld is obtained, and additional peel specimens will be taken to localize the flaw.

3.5.4.12 Results of field seam test strips will be maintained in the destructive test column on the Panel Seaming Form as shown in Appendix A.

3.5.4.13 The CQC Coordinator may, after consulting with NSC's Site Superintendent, take destructive samples from any seam, if defects are suspected.

3.5.5 Seaming Documentation

3.5.5.1 All seaming operations will be documented by the CQC Coordinator or a designated Assistant. Welding Technicians will mark on the liner with Mean Streak permanent markers at the start of all seams information regarding date, time, Welding Technician ID, machine number, and machine operating temperature and speed. CQC Coordinator or Assistant will record date, time, seam number, Technician ID, machine ID, set temperature, speed, and weather conditions on the NSC Panel Seaming Form (See Appendix A).

3.5.5.2 Welding Technicians will periodically check operating temperature and speed and mark the information along the seam.

3.5.5.3 CQC Coordinator will make periodic checks on welding operations to verify overlap, cleanliness, etc.

4. Seam Testing - Geomembranes

4.1 Concept

The welded seam created by National Seal Company's fusion welding process is composed of a primary seam and a secondary track that creates an unwelded channel. The presence of an unwelded channel permits National Seal Company's fusion seams to be tested by inflating the sealed channel with air to a predetermined pressure and observing the stability of the pressurized channel over time.

National Seal Company performs non-destructive air-pressure testing in accordance with the following procedures, developed by NSC, and adopted by the Geosynthetic Research Institute as Test Method GM-6.

4.2 Air Pressure Testing

4.2.1 Equipment for Air Testing

4.2.1.1 An air pump (manual or motor driven) capable of generating and sustaining a pressure between 20 to 60 psi.

4.2.1.2 A rubber hose with fittings and connections.

4.2.1.3 A sharp hollow needle, or other approved pressure feed device with a pressure gauge capable of reading and sustaining a pressure between 0 and 60 psi.

4.2.2 Procedure for Air Testing

4.2.2.1 Seal both ends of the seam to be tested.

4.2.2.2 Insert needle or other approved pressure feed device into the sealed channel created by the fusion weld.

4.2.2.3 Inflate the test channel to a pressure of approximately 30 psi, and maintain the pressure within the range listed in the Initial Pressure Schedule. Close valve, observe and record the initial pressure.

INITIAL PRESSURE SCHEDULE *

MATERIAL (mils)	MINIMUM (psi)	MAXIMUM (psi)
40	24	30
60	27	35
80	30	35
100	30	35

*Initial pressure settings are recorded after an optional two (2) minute stabilization period. The purpose of this "relaxing period" is to permit the air temperature and pressure to stabilize. The initial pressure reading may be recorded once stabilization has taken place.

4.2.2.4 Observe and record the air pressure five (5) minutes after the initial pressure setting is recorded. If loss of pressure exceeds the following or if the pressure does not stabilize, locate the suspect area and repair in accordance with Section 4.2.3.

MAXIMUM PERMISSIBLE PRESSURE DIFFERENTIAL AFTER 5 MINUTES - HDPE

MATERIAL (MIL)	PRESSURE DIFF.
40	4 psi
60	3 psi
80	2 psi
100	2 psi

4.2.2.5 At the conclusion of all pressure tests, the end of the air-channel opposite the pressure gauge is cut. A decrease in gauge pressure must be observed or the air channel will be considered "blocked" and the test will have to be repeated from the point of blockage. If the point of blockage cannot be found, cut the air channel in the middle of the seam and treat each half as a separate test.

4.2.2.6 Remove the pressure feed needle and seal the resulting hole by extrusion welding.

4.2.3 In the event of a Non-Complying Air Pressure Test, the following procedure shall be followed:

4.2.3.1 Check seam end seals and retest seams.

4.2.3.2 If a seam will not maintain the specified pressure, the seam should be visually inspected to localize the flaw. If this method is unsuccessful, cut one inch (1") samples from each end of the seam.

4.2.3.3 Perform destructive peel tests on the samples using the field tensiometer.

4.2.3.4 If all samples pass destructive testing remove the overlap left by the wedge welder and vacuum test the entire length of seam in accordance with Paragraph 4.3.

4.2.3.4.1 If a leak is located by the vacuum test, repair by extrusion fillet welding. Test the repair by vacuum testing.

4.2.3.4.2 If no leak is discovered by vacuum testing, the seam will be considered to have passed non-destructive testing.

4.2.3.5 If one or more peel specimens are in non-compliance, additional samples will be taken in accordance with Paragraph 4.4.3.

4.2.3.5.1 When two (2) passing samples are located, the length of seam bounded by the two (2) passing test locations will be considered non-complying. The overlap left by the wedge welder will be heat tacked in place along the entire length of seam and the non-complying portion of seam will be extrusion fillet welded.

4.2.3.5.2 Test the entire length of the repaired seam by vacuum testing in accordance with Paragraph 4.3.

4.2.4 General Air Testing Procedures

4.2.4.1 The opposite end of the air channel will in all cases be pierced to assure that no blockages of the air channel have occurred.

4.2.4.2 Whenever possible, seams should be air-tested prior to completing butt seams to avoid having to cut into liner. All cuts through the liner as a result of testing will be repaired by extrusion welding.

4.2.4.3 All needle holes in air channels remaining after testing will be circled by testing crew and will be repaired with an extrusion bead.

4.2.5 Air Pressure Testing Documentation

All information regarding air-pressure testing, (date, initial time and pressure, final time and pressure, pass/fail designation, and Technicians initials) will be written at both ends of the seam, or portion of seam tested. All of the above information will also be logged by the CQC Coordinator on the NSC Non-Destructive Testing Form as exhibited in Appendix A.

4.3 Vacuum Testing

This test is used on extrusion welds, or when the geometry of a fusion weld makes air pressure testing impossible or impractical, or when attempting to locate the precise location of a defect believed to exist after air pressure testing.

4.3.1 Equipment for Vacuum Testing

4.3.1.1 Vacuum box assembly consisting of a rigid housing with a soft neoprene gasket attached to the bottom, a transparent viewing window, port hole or valve assembly, and a vacuum gauge.

4.3.1.2 Vacuum pump assembly equipped with a pressure controller and pipe connection.

4.3.1.3 A rubber pressure/vacuum hose with fittings and connections.

4.3.1.4 A bucket and means to apply a soapy solution.

4.3.1.5 A soapy solution.

4.3.2 Procedure for Vacuum Testing

4.3.2.1 Trim excess overlap from the seam, if any.

4.3.2.2 Turn on the vacuum pump to reduce the vacuum box to approximately 10 inches of mercury, i.e., 5 psi gauge.

4.3.2.3 Apply a generous amount of a strong solution of liquid detergent and water to the area to be tested.

4.3.2.4 Place the vacuum box over the area to be tested and apply sufficient downward pressure to "seat" the seal strip against the liner.

4.3.2.5 Close the bleed valve and open the vacuum valve.

4.3.2.6 Apply a minimum of 5 psi vacuum to the area as indicated by the gauge on the vacuum box.

4.3.2.7 Ensure that a leak tight seal is created.

4.3.2.8 For a period of approximately 10 to 15 seconds, examine the geomembrane through the viewing window for the presence of soap bubbles.

4.3.2.9 If no bubbles appear after 15 seconds, close the vacuum valve and open the bleed valve, move the box over the next adjoining area with a minimum three inch (3") overlap, and repeat the process.

4.3.3 Procedure for Non-Complying Test

4.3.3.1 Mark all areas where soap bubbles appear and repair the marked areas in accordance with Paragraph 5.3.

4.3.3.2 Retest repaired areas.

4.3.4 General Vacuum Testing Procedures

4.3.4.1 Vacuum box testing will be performed by qualified construction personnel with frequent supervision by the CQC Coordinator.

4.3.4.2 Overlap must be trimmed prior to vacuum boxing all seams.

4.3.4.3 Special attention shall be exercised when vacuum testing "T" seams or patch intersections with seams.

4.3.5 Vacuum Testing Documentation

4.3.5.1 Vacuum testing crew will use permanent markers to write on liner indicating tester's initials, date, and pass/fail designation on all areas tested.

4.3.5.2 Records of vacuum testing will be maintained by the CQC Coordinator or testing crew on the NSC Non-Destructive Testing Form or NSC Repair Report Form as exhibited in Appendix A.

4.4 Destructive Testing

4.4.1 Concept

The purpose of destructive testing is to determine and evaluate seam strength. These tests require direct sampling and thus subsequent patching. Therefore, destructive testing should be held to a minimum to reduce the amount of repairs to the geomembrane.

4.4.2 Procedure for Destructive Testing

4.4.2.1 Destructive test samples shall be marked and cut out randomly at a minimum average frequency of one (1) test location every 500 feet of seam length.

4.4.2.2 Location of destructive samples will be selected by CQC Coordinator (or the Third Party QA Representative), with samples cut by NSC Construction Personnel.

4.4.2.3 Destructive samples should be taken and tested as soon as possible after the seams are welded (the same day), in order to receive test results in a timely manner.

4.4.2.4 CQC Coordinator will observe all destructive testing and record date, time, seam number, location, and test results on the NSC Destructive Testing Form as contained in Appendix A.

4.4.2.5 All destructive test locations with pass/fail designation will be marked on liner with permanent Mean Streak markers.

4.4.2.6 Sample Size

4.4.2.6.1 The sample should be twelve inches (12") wide with a seam sixteen inches (16") long centered lengthwise in the sample. The sample may be increased in size to accommodate independent laboratory testing by the Owner, at the Owner's request, or by specific project specifications.

4.4.2.6.2 A one inch (1") specimen shall be cut from each end of the test seam for field testing.

4.4.2.6.3 The two (2) one inch (1") wide specimens shall be tested on a field tensiometer for peel strength. If either field specimen does not pass, it will be assumed the sample would also not pass laboratory destructive testing.

The procedure outlined in Paragraph 4.4.3 shall be followed to locate passing samples to send to the laboratory.

4.4.3 Procedure for Non-Complying Destructive Tests

4.4.3.1 Cut additional field samples for peel testing. In the case of a field production seam, the samples must lie approximately ten (10') feet in each direction from the location of the initial non-complying sample. Perform a field test for peel strength. If these field samples pass, then laboratory samples can be cut and forwarded to the laboratory for full testing.

4.4.3.1.1 If the laboratory samples pass, then reconstruct the seam between the two (2) passing sample locations according to procedures detailed in Section 5.3.

4.4.3.1.2 If either of the samples are still in non-compliance, then additional samples are taken in accordance with the above procedure until two (2) passing samples are found to establish the zone in which the seam should be reconstructed.

4.4.3.2 All passing seams must be bounded by two (2) locations from which samples passing laboratory destructive tests have been taken.

4.4.3.3 In cases of reconstructed seams exceeding 150 feet, a sample must be taken and pass destructive testing from within the zone in which the seam has been reconstructed.

4.4.3.4 All destructive seam samples shall be numbered and recorded on National Seal Company's Destructive Test Form as exhibited in Appendix A.

4.5 Laboratory Testing of Destructive Seam Samples

4.5.1 Destructive Seam Testing Laboratory

Seam destructive samples will be sent to National Seal Company's laboratory when required by a site specific quality control plan or in the event that third party laboratory destructive testing is not being performed.

4.5.2 Acceptance Criteria

Destructive samples will be tested for "Shear Strength" and "Peel Adhesion" (ASTM D4437 as modified by NSF). Five (5) specimens shall be tested for each test method. Four (4) out of the five (5) specimens must exhibit FTB (as defined by NSF Standard Number 54-1991) for each round of peel and shear testing. In addition, four (4) of the five (5) individual specimens and the average of the five (5) peel and shear tests must meet or exceed the strength requirements as listed in NSC's Material Specification Sheet in order for the seam to pass the destructive test.

5. Defects and Repairs

5.1 National Seal Company's CQC Coordinator and Project Superintendent shall conduct a detailed walk through and visually check all seams and non-seam areas of the geomembrane for defects, holes, blisters, and signs of damage during installation.

5.2 All other National Seal Company installation personnel shall, at all times, be on the lookout for any damaged areas. Damaged areas shall be marked and repaired.

5.3 Repair Procedures

Any portion of the geomembrane or geomembrane seam showing a flaw, or having a destructive or non-destructive test in non-compliance shall be repaired. Several procedures exist for repair and the decision as to the appropriate repair procedure shall be made by National Seal Company's Project Superintendent.

Procedures available for repair include the following:

5.3.1 Patching - used to repair large holes, tears, and destructive sample locations. All patches shall extend at least three inches (3") beyond the edges of the defect and all corners of patches shall be rounded.

5.3.2 Grinding and Welding - used to repair sections of extruded fillet seams.

5.3.3 Spot Welding or Seaming - used to repair small tears, pinholes, or other minor localized flaws.

5.3.4 Capping - used to repair lengths of extrusion or fusion welded seams.

5.3.5 Extruding the exposed overlap along the length of fusion welded seams.

5.3.6 Removal of a suspect seam and replacement with a strip of new material seamed into place.

5.4 Verification of Repairs

Every repair shall be non-destructively tested using the methods set out in Paragraph 4.4. Repairs which pass the non-destructive test shall be deemed acceptable. Repairs in excess of 150 feet require a destructive test. Non-destructive testing of repairs shall be logged on a National Seal Company Repair Report Form as exhibited in Appendix A. The repair location shall be recorded on the record drawing.

6. Geotextiles

6.1 Handling and Placement

All geotextiles shall be handled in a manner to ensure they are not damaged. The following special handling requirements shall be adhered to:

6.1.1 On slopes, the geotextiles shall be secured in the anchor trench and then rolled down the slope in such a manner as to continually keep the geotextile sheet in sufficient tension to preclude folds and wrinkles.

6.1.2 In the presence of wind, all geotextiles shall be weighted with sandbags or the equivalent.

6.1.3 Geotextiles shall be cut using an approved cutter. If the material is being cut in place, special care must be taken to protect other geosynthetic materials from damage.

6.1.4 Care shall be taken not to entrap stones or excessive dust that could damage the geomembrane, or generate clogging of drains or filters.

6.2 Seams and Overlaps

Geotextiles may be seamed by thermal bonding or by sewing. No horizontal seams shall be allowed on side slopes.

6.2.1 On slopes steeper than ten (10) horizontal to one (1) vertical, it is recommended that geotextiles be continuously sewn along the entire length of the seam. Geotextiles shall be overlapped a minimum of four (4") inches prior to sewing.

6.2.2 On bottoms and slopes shallower than ten (10) horizontal to one (1) vertical, geotextiles can be either sewn as indicated above or thermally bonded. If thermally bonded the geotextile shall be overlapped a minimum of eight inches (8") prior to seaming.

6.3 Repairs

Any holes or tears in the geotextile shall be repaired as follows:

6.3.1 On Slopes - A patch made from the same geotextile shall be seamed into place. Should any tear exceed 10% of the width of the roll, that roll shall be removed from the slope and replaced.

6.3.2 Horizontal Areas - A patch made from the same geotextile shall be spot-seamed in place with a minimum of twelve inches (12") overlap in all directions.

7. Geonets

7.1 Handling and Placement

The geonets shall be handled in such a manner as to ensure that the geonets are not damaged in any way.

7.1.1 On slopes, the geonets shall be secured in the anchor trench and then rolled down the slope in such a manner as to continually keep the geonet sheet in tension. If necessary, the geonet shall be positioned by hand after being unrolled to minimize wrinkles. Geonets can be placed in the horizontal direction (across the slope) in some special locations (e.g., at the toe of a slope, or where an extra layer of geonet is required).

Such locations shall be identified by the Design Engineer in the project drawings.